Module 7: Overview of 15 Non-Proprietary BMPs

Module 7 Objectives

After completing this module, you will be able to:

- Relate the important design specifications of the 15 non-proprietary BMP from the Virginia Stormwater BMP Clearinghouse with plan review requirements

Module 7 Content

7: Overview of 15-Non-Proprietary BMP Design Specifications from the Virginia Stormwater BMP Clearinghouse

7. Overview of 15 Non-Proprietary BMPs

This module presents a summary of the 15 approved non-proprietary post-construction BMPs from the Virginia BMP Clearinghouse Stormwater Design specifications. The practices highlighted (and associated design tables herein) are based on the approved design specifications (dated 2011). It should be noted that there may be edits to fix typos, correct figure references, and other changes to reflect the latest research into BMP performance in the future. The instructor may discern some of these changes; however, the exam questions will be based on the approved design specifications for these 15 non-proprietary BMPs as provided in this module and the adopted/published 2011 design specifications currently available on the BMP Clearinghouse (http://www.vwrrc.vt.edu/swc/).

Proprietary BMPs or manufactured treatment devices approved for use in Virginia can be viewed on the BMP Clearinghouse (http://www.vwrrc.vt.edu/swc/ProprietaryBMPs.html).

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 1

ROOFTOP (IMPERVIOUS SURFACE) DISCONNECTION

This strategy involves managing runoff close to its source by intercepting, infiltrating, filtering, treating or reusing it as it moves from the impervious surface to the drainage system. Two kinds of disconnection are allowed:

(1) Simple disconnection, whereby residential or small commercial rooftops and/or on-lot residential impervious surfaces are directed to pervious areas, and

(2) Disconnection leading to an alternate runoff reduction practice(s) adjacent to the roof or small residential impervious area (**Figures 1.1** & **1.2**). Alternate disconnection practices can use less space than simple disconnection and can enhance runoff reduction rates.

Applicable practices include:

- Soil compost-amended filter path (Spec 4)
- Infiltration by micro-infiltration practice (dry wells or French drains; Spec 8)
- Filtration by rain gardens or micro-bioretention (Spec 9)
- Storage and reuse with a cistern or other vessel (rainwater harvesting, Spec 6)

- Storage and release in a stormwater planter. (Spec 9, Appendix A)

Table 1. Summary of Stormwater Functions Provided by Rooftop Disconnection1

(From Spec. No. 1, Table 1.1, page 6)

FUNCTION PROVIDED BY SIMPLE ROOFTOP DISCONNECTION	HSG SOILS A and B	HSG SOILS C and D
Annual Runoff Volume Reduction (RR)	50%	25%
Total Phosphorus (TP) EMC Reduction by BMP Treatment Process	0	0
Total Phosphorus (TP) Mass Load Removal	50%	25%
Total Nitrogen (TN) EMC Reduction by BMP Treatment Process	0	0
Total Nitrogen (TN) Mass Load Removal	50%	25%
Channel & Flood Protection	**Partial:** Designers can use the VRRM Compliance spreadsheet to adjust curve number for each design storm for the contributing drainage area (CDA), based on annual runoff reduction achieved	

NOTE: Stormwater functions of disconnection can be boosted if an acceptable alternate runoff reduction practice is employed. Acceptable practices and their associated runoff reduction rates are listed below. Designers should consult the applicable specification number for design standards.

Alternate Practice	Specification No.	Runoff Reduction Rate
Soil compost-amended filter path	4	50%[2]
Dry well or french drain #1 (Micro-infiltration #1)	8	50%
Dry well or french drain #2 (Micro-infiltration #2)	8	90%
Rain garden #1, front yard bioretention (Micro-bioretention #1)	9	40%
Rain garden #2, front yard bioretention (Micro-bioretention #2)	9	80%
Rainwater harvesting	6	Defined by user
Stormwater Planter (Urban Bioretention)	9 (Appendix A)	40%

[1] CWP and CSN (2008), CWP (2007)
[2] Compost amendments are not credited with additional volume reduction an HSG A & B soils. Primary use is to improve the volume reduction performance of disconnection in C & D soils.

The following provides the general design criteria for simple disconnection:

- Flow from the downspout should be spread over a minimum 10-foot wide disconnection flow path extending down-gradient from the structure.
- Simple disconnection is generally not advisable for residential lots less than 6,000 square feet in area, although it may be possible to employ one of the alternate disconnection runoff reduction practices on these lots (e.g., cistern, infiltration, etc.).
- A pea-gravel or river stone diaphragm, or other accepted flow spreading device should be installed at the downspout outlet to distribute flows evenly across the flow path.

- Where it is determined that the disconnection can be safely spread across a yard area meeting the minimum dimensions (i.e. the flow will remain sufficiently spread beyond the level spreader and will not create nuisance conditions), a defined flow path cross-section (as shown in **Figure 1.3**) need not be constructed.
- Simple disconnection can be used on any post-construction Hydrologic Soil Group. However, the erodibility of soils must be considered. Also, for Soil Groups C or D, alternate disconnection runoff reduction practices (e.g., compost-amended filter path, rain garden, micro-infiltration, rainwater harvesting, etc.) can be used to boost reduction of runoff volume as well as provide for pollutant EMC reduction.
- Maintenance of a simple disconnection flow path typically involves traditional lawn or landscaping maintenance. In some cases, runoff from a simple disconnection may be directed to a more natural, undisturbed setting (i.e., where lot grading and clearing is "fingerprinted" and the proposed filter path is protected), thereby reducing or even eliminating the need for maintenance.

Table 2: Simple Rooftop Disconnection Design Criteria[1]
(From Spec. No. 1, Table 1.2, page 7)

DESIGN FACTOR	SIMPLE DISCONNECTION
Maximum impervious (Rooftop) Area Treated	1,000 sq. ft. per disconnection
Longest flow path (roof/gutter)	75 feet
Disconnection Length	Equal to longest flow path, but no less than 40 feet [2]
Disconnection slope	< 2%, or < 5% with turf reinforcement [3]
Distance from buildings or foundations	Extend downspouts 5 ft. [4] (15 ft. in karst areas) away from building *if grade is less than 1%*.
Type of Pretreatment	External (leaf screens, etc)

[1] For alternative runoff reduction practices, see the applicable specification for design criteria. See Table 1 in this specification for eligible practices and associated specification numbers.

[2] An alternative runoff reduction practice must be used when the disconnection length is less than 40 feet.

[3] Turf reinforcement may include EC-2, EC-3, or other appropriate reinforcing materials that are confirmed by the designer to be non-erosive for the specific characteristics and flow rates anticipated at each individual application, and acceptable to the plan approving authority.

[4] Note that the downspout extension of 5 feet is intended for simple foundations. The use of a dry well or french drain adjacent to an in-ground basement or finished floor area should be carefully designed and coordinated with the design of the structure's water-proofing system (foundation drains, etc.), or avoided altogether.

Alternate Rooftop Disconnection

Alternate Rooftop Disconnection is applied where there is not adequate room to fit the design specifications for Simple Disconnection.

<u>Alternate Disconnection: Soil Compost-Amended Filter Path</u>

The incorporation of compost amendments should conform to Stormwater Design Specification No. 4 (*Soil Compost Amendments*), and include the following design elements:

- Flow from the downspout should be spread over a 10-foot wide flow path extending down-gradient from the structure.
- The compost-amended filter path should be 10 feet wide and at least 20 feet in length within the longer disconnection flow path.
- A pea-gravel or river stone diaphragm or other accepted flow spreading device should be installed at the downspout outlet to distribute flows evenly across the filter path.
- The compost-amended filter path should have adequate “freeboard” so that flow remains within the amended soil strip and is not diverted away from the strip. In general, this means that the strip should be lower than the surrounding land area in order to keep flow in the filter path. Similarly, the flow area of the filter path as well as the larger disconnection flow path should be level to discourage concentrating the flow.
- Use 2 to 4 inches of compost and till to a depth of 6 to 10 inches within the filter path.

Alternate Disconnection: Dry Wells and French Drains (Micro-Infiltration)

Table 3. Micro-Infiltration Design Criteria
(From Spec. No. 1, Table 1.3, page 8)

DESIGN FACTOR	MICRO-INFILTRATION DESIGN
Roof Area Treated	250 to 2,500 sq. ft.
Typical Practices	Dry Well and French Drain
Recommended Maximum Depth	3 feet
Runoff Reduction Sizing	See Specification No. 8: Infiltration
Minimum Soil Infiltration Rate	0.5 inches/hour
Observation Well	No
Type of Pretreatment	External (leaf screens, grass strip, etc)
UIC Permit Needed	No
Head Required	Nominal, 1 to 3 feet
Required Soil Test	One soil profile and one infiltration test per practice
Building Setbacks	5 ft. down-gradient [1], 25 ft. up-gradient
[1] Note that the building setback of 5 feet is intended for simple foundations. The use of a dry well or french drain adjacent to an in-ground basement or finished floor area should be carefully designed and coordinated with the design of the structure's waterproofing system (foundation drains, etc.), or avoided altogether.	

Alternate Disconnection: Rain Gardens and Front Yard Bioretention (Micro-Bioretention)

Table 4. Micro-Bioretention (Rain Garden) Design Criteria
(From Spec. No. 1, Table 1.4, page 9)

DESIGN FACTOR	MICRO BIORETENTION (I.E., RAIN GARDEN)
Impervious Area Treated[1]	1,000 ft^2
Type of Inflow	Sheetflow or roof leader
Runoff Reduction Sizing[1]	Surface Area= 5% of roof area (Level 1); 6% of roof area (Level 2)
Minimum Soil Infiltration Rate	0.5 inches/hour (or use underdrain)
Observation Well/ Cleanout Pipes	No
Type of Pretreatment	External (leaf screens, etc)
Underdrain and gravel layer	Level 1: Yes; Level 2: Optional per soils[1]
Minimum Filter Media Depth	18 inches (Level 1); 24 inches (Level 2)
Media Source	Mixed on-site
Head Required	Nominal, 1 to 3 feet
Required Soil Borings	One, only when an underdrain is not used
Building Setbacks	5 ft down-gradient, 25 ft up-gradient
[1]Refer to Design Specification No. 9, Table 2, Micro-Bioretention for Level 1 and Level 2 Design Criteria, and sizing criteria for individual and multiple downspout applications.	

Alternate Disconnection: Rain Tanks & Cisterns

This form of disconnection must conform to the design requirements outlined in Stormwater **Design Specification No. 6: Rainwater Harvesting**). The actual runoff reduction rate for a particular design can be determined using the design spreadsheet referenced in **Specification**

No. 6: Rainwater Harvesting. The runoff reduction rates for rain tanks and cisterns depends on their storage capacity and ability to draw down water between storms for reuse as potable water, grey-water or for irrigation. All devices should have a suitable overflow area to route extreme flows into the next treatment practice or the stormwater conveyance system.

Alternate Disconnection: Stormwater Planter (Urban Bioretention)

This form of disconnection must conform to the design requirements for stormwater planters, as outlined in Appendix A (Urban Bioretention) of Stormwater Design Specification No. 9 (Bioretention). The design specifications for Urban Bioretention is comparable to Micro-Bioretention, with the exception of being contained in a box or other form in a highly urban setting. Foundation planters are a useful option to disconnect and treat rooftop runoff, particularly in ultra-urban areas. They consist of confined planters that store and/or infiltrate runoff in a soil bed to reduce runoff volumes and pollutant loads

Notes

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 2

SHEET FLOW TO A VEGETATED FILTER STRIP OR CONSERVED OPEN SPACE

Filter strips are vegetated areas that treat sheet flow delivered from adjacent impervious and managed turf areas by slowing runoff velocities and allowing sediment and attached pollutants to settle and/or be filtered by the vegetation. The two design variants of filter strips are (1) *Conserved Open Space* and (2) designed *Vegetated Filter Strips*. The design, installation, and management of these design variants are quite different, as outlined in this specification.

Table 5: Summary of Stormwater Functions Provided by Filter Strips[1]

(From Spec. No. 2, Table 2.1, page 2)

Stormwater Function	Conservation Area		Vegetated Filter Strip	
	HSG Soils A and B	HSG Soils C and D	HSG Soils A	HSG Soils B [4], C and D
	Assume no CA [2] in Conservation Area		No CA [3]	With CA [2]
Annual Runoff Vol. Reduction (RR)	75%	50%	50%	50%
Total Phosphorus (TP) EMC Reduction[5] by BMP Treatment Process	0		0	
Total Phosphorus (TP) Mass Load Removal	75%	50%	50%	50%
Total Nitrogen (TN) EMC Reduction by BMP Treatment Process	0		0	
Total Nitrogen (TN) Mass Load Removal	75%	50%	50%	50%
Channel Protection and Flood Mitigation	**Partial.** Designers can use the VRRM Compliance spreadsheet to adjust curve number for each design storm for the contributing drainage area; *and* designers can account for a lengthened Time-of-Concentration flow path in computing peak discharge.			

[1] CWP and CSN (2008); CWP (2007)

[2] CA = Compost Amended Soils (see Design Specification No. 4)

[3] Compost amendments are generally not applicable for undisturbed A soils, although it may be advisable to incorporate them on mass-graded A or B soils and/or filter strips on B soils, in order to maintain runoff reduction rates.

[4] The plan approving authority may waive the requirement for compost amended soils for filter strips on B soils under certain conditions (see Section 6.2 below)

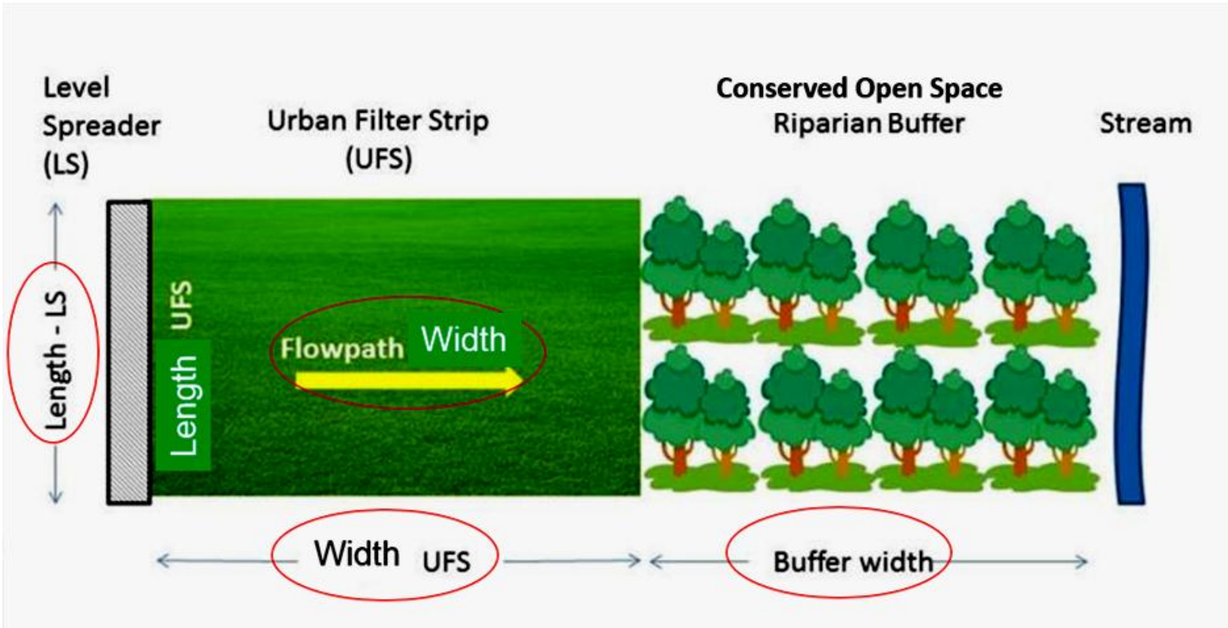
[5] There is insufficient monitoring data to assign a nutrient removal rate for filter strips at this time.

Table 6. Filter Strip Design Criteria

(From Spec. No. 2, Table 2.2, page 3)

Design Issue	Conserved Open Space	Vegetated Filter Strip
Soil and Vegetative Cover (Sections 6.1 and 6.2)	Undisturbed soils and native vegetation	Amended soils and dense turf cover or landscaped with herbaceous cover, shrubs, and trees
Overall Slope and Width (perpendicular to the flow) (Section 5)	0.5% to 3% Slope – Minimum 35 ft width 3% to 6% Slope – Minimum 50 ft width The first 10 ft. of filter must be 2% or less in all cases [2]	1% [1] to 4% Slope – Minimum 35 ft. width 4% to 6% Slope – Minimum 50 ft. width 6% to 8% Slope – Minimum 65 ft. width The first 10 ft. of filter must be 2% or less in all cases
Sheet Flow (Section 5)	Maximum flow length of 150 ft. from adjacent pervious areas; Maximum flow length of 75 ft. from adjacent impervious areas	
Concentrated Flow (Section 6.3)	Length of ELS [6] Lip = 13 lin. ft. per each 1 cfs of inflow if area has 90% Cover [3] Length = 40 lin. ft. per 1 cfs for forested or re-forested Areas [4] (ELS [6] length = 13 lin.ft. min; 130 lin.ft. max.)	Length of ELS [6] Lip = 13 lin.ft. per each 1 cfs of inflow (13 lin.ft. min; 130 lin.ft. max.)
Construction Stage (Section 8)	Located outside the limits of disturbance and protected by ESC controls	Prevent soil compaction by heavy equipment
Typical Applications (Section 5)	Adjacent to stream or wetland buffer or forest conservation area	Treat small areas of IC (e.g., 5,000 sf) and/or turf-intensive land uses (sports fields, golf courses) close to source
Compost Amendments (Section 6.1)	No	Yes (B, C, and D soils) [5]
Boundary Spreader (Section 6.3)	GD [6] at top of filter	GD [6] at top of filter PB [6] at toe of filter

[1] A minimum of 1% is recommended to ensure positive drainage.
[2] For Conservation Areas with a varying slope, a pro-rated length may be computed only if the first 10 ft. is 2% or less.
[3] Vegetative Cover is described in **Section 6.2**.
[4] Where the Conserved Open Space is a mixture of native grasses, herbaceous cover and forest (or re-forested area), the length of the ELS [6] Lip can be established by computing a weighted average of the lengths required for each vegetation type. Refer to **Section 6.3** for design criteria
[5] The plan approving authority may waive the requirement for compost amended soils for filter strips on B soils under certain conditions (see **Section 6.1**).
[6] ELS = Engineered Level Spreader; GD = Gravel Diaphragm; PB = Permeable Berm.


Level
Spreader
(LS)
Urban Filter Strip
(UFS)
Conserved Open Space
Riparian Buffer
Stream
Length - LS
UFS
Length
Flowpath
Width
Width UFS
Buffer width

Notes

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 3

GRASS CHANNELS

Grass channels can provide a modest amount of runoff filtering and volume attenuation within the stormwater conveyance system resulting in the delivery of less runoff and pollutants than a traditional system of curb and gutter, storm drain inlets and pipes. The performance of grass channels will vary depending on the underlying soil permeability (Table 1). Grass channels, however, are not capable of providing the same stormwater functions as dry swales as they lack the storage volume and filtering capabilities associated with the engineered soil media (see Specification No. 10). Their runoff reduction performance can be boosted when compost amendments are added to the bottom of the swale (See Specification No. 4).

Table 7. Summary of Stormwater Functions Provided by Grass Channels[1]

(From Spec. No. 3, Table 3.1, page 2)

Stormwater Function	HSG Soils A and B		HSG Soils C and D	
	No CA [2]	With CA	No CA	With CA
Annual Runoff Volume Reduction (RR)	20%	NA [3]	10%	30%
Total Phosphorus (TP) EMC Reduction[4] by BMP Treatment Process	15%		15%	
Total Phosphorus (TP) Mass Load Removal	32%		24% (no CA) to 41% (with CA)	
Total Nitrogen (TN) EMC Reduction[4] by BMP Treatment Process	20%		20%	
Total Nitrogen (TN) Mass Load Removal	36%		28% (no CA) to 44% (with CA)	
Channel & Flood Protection	**Partial.** Designers can use the RRM spreadsheet to adjust curve number for each design storm for the contributing drainage area, based on annual runoff reduction achieved. Also, the Tc for the grass swale flow path should reflect the slope and appropriate roughness for the intended vegetative cover.			

[1] CWP and CSN (2008) and CWP (2007).
[2] CA= Compost Amended Soils, see Stormwater Design Specification No. 4.
[3] Compost amendments are generally not applicable for A and B soils, although it may be advisable to incorporate them on mass-graded and/or excavated soils to maintain runoff reduction rates. In these cases, the 30% runoff reduction rate may be claimed, regardless of the pre-construction HSG.
[4] Change in event mean concentration (EMC) through the practice. Actual nutrient mass load removed is the product of the pollutant removal rate and the runoff volume reduction rate (see Table 1 in the *Introduction to the New Virginia Stormwater Design Specifications*).

Table 8. Grass Channel Design Guidance

(From Spec. No. 3, Table 3.2, page 2

Design Criteria
The bottom width of the channel should be between 4 to 8 feet wide.
The channel side-slopes should be 3H:1V or flatter.
The maximum total contributing drainage area to any individual grass channel is 5 acres.
The longitudinal slope of the channel should be no greater than 4%. (Check dams may be used to reduce the effective slope in order to meet the limiting velocity requirements.)
The maximum flow velocity of the channel must be less than 1 foot per second during a 1-inch storm event.
The dimensions of the channel should ensure that flow velocity is non-erosive during the 2-year and 10-year design storm events and the 10-year design flow is contained within the channel (minimum of 6 inches of freeboard).

[1] The design of grass channels should consider the entire T_V of the contributing drainage area (rather than the T_VBMP which would reflect a decrease in T_V based on upstream runoff reduction practices) in order to ensure non-erosive conveyance during all design storm conditions.

Sizing of Grass Channels

- The longitudinal slope of the channel should be between 1% and 2. Longitudinal slopes up to 4% are acceptable; however, check dams will likely be required in order to meet the allowable maximum flow velocities.
- Hydraulic capacity should be verified using Manning's Equation or an accepted equivalent method, such as erodibility factors and vegetal retardance (NOVA 2007).
    - The flow depth for the *Tv* peak flow (1-inch rainfall) should be maintained at 3 inches or less.
    - Manning's "n" value for grass channels should be 0.2 for flow depths up to 4 inches, decreasing to 0.03 at a depth of 12 inches (which would apply to the 2-year and 10-year storms if an on-line application – NOVA, 2007; Haan et. al, 1994).
    - Peak Flow Rates for the 2-year and 10-year frequency storms must be non-erosive, in accordance with Design Specification **Table 3.3**, or subject to a site-specific analysis of the channel lining material and vegetation; and the 10-year peak flow rate must be contained within the channel banks (with a minimum of 6 inches of freeboard).
- Calculations for peak flow depth and velocity should reflect any increase in flow along the length of the channel, as appropriate. If a single flow is used, the flow at the outlet should be used.
- The hydraulic residence time (the time for runoff to travel the full length of the channel) should be a minimum of 9 minutes for the *Tv* (1-inch rainfall) design storm (Spyridakis, Mar, and Horner, 1982; Keblin, Walsh, Malina, and Charbeneau, 1998; Washington State Department of Ecology, 2005). If flow enters the swale at several locations, a 9 minute minimum hydraulic residence time should be demonstrated for each entry point, using Equations 3.1 and 3.2 below (Equations 5-1 and 5-2, NOVA 2007).
- The minimum length or residence time may be achieved with multiple swale segments connected by culverts with energy dissipaters.

The bottom width of the grass channel is therefore sized to maintain the appropriate flow geometry as follows:

Manning's Equation
(Spec. No. 3, Equation 3.1, page 11)

$$V = \left[\left(\frac{1.49}{n}\right) D^{2/3} s^{1/2}\right]$$

Where:

V = flow velocity (ft./sec.)

n = roughness coefficient (0.2, or as appropriate)

D = flow depth (ft.) (NOTE: D approximates hydraulic radius for shallow flows)

s = channel slope (ft./ft.)

Continuity Equation
(Spec. No. 3, Equation 3.2, page 12)

$$q_{pTv} = VA = V(W \times D)$$

Where:

q_{pTv} = design *Tv* peak flow rate (cfs) (**Section 11.5.3** of **Chapter 11** of the *Virginia Stormwater Management Handbook* (2nd Edition, 2013)

A = flow cross sectional area (ft^2)

V = design flow velocity (ft./sec.)

W = channel width (ft.)

D = flow depth (ft.)

(NOTE: channel width (W) x depth (D) approximates the cross sectional flow area for shallow flows.)

Combining Equations 3.1 and 3.2, and re-writing them provides a solution for the minimum width:

Minimum Width
(Spec. No. 3, Equation 3.3, page 12)

$$W = (n)(q_{pTv})/(1.49D^{5/3}s^{1/2})$$

Solving Equation 3.2 for the corresponding velocity provides:

Corresponding Velocity
(Spec. No. 3, Equation 3.4, page 12)

$$V = {}^{q_{pTv}}\!/_{(W \times D)}$$

The resulting velocity should be less than 1 ft./sec. The width, slope, or Manning's "*n*" value can be adjusted to provide an appropriate channel design for the site conditions. However, if a higher density of grass is used to increase the Manning's "*n*" value and decrease the resulting channel width, it is important to provide material specifications and construction oversight to ensure that the denser vegetation is actually established. Equation 3.5 can then be used to ensure adequate hydraulic residence time.

Grass Channel Length for Hydraulic Residence Time of 9 minutes (540 seconds)
(Spec. No. 3, Equation 3.5, page 12)

$$L = 540V$$

Where:

L = minimum swale length (ft.)

V = flow velocity (ft./sec.)

Pretreatment

Pretreatment is recommended for grass channels to dissipate energy, trap sediments and slow down the runoff velocity. The selection of a pre-treatment method depends on whether the channel will experience sheet flow or concentrated flow. Options include:

- ***Check dam*** (channel flow): The most common form of pre-treatment is the use of wooden or stone check dams.
- ***Tree Check dams*** (channel flow): These are street tree mounds that are placed within the bottom of grass channels up to an elevation of 9 to 12 inches above the channel invert. One

side has a gravel or river stone bypass to allow runoff to percolate through (Cappiella et al, 2006).

- ***Grass Filter Strip*** (sheet flow): Grass filter strips extend from the edge of the pavement to the bottom of the grass channel at a slope of 5:1 or less. Alternatively, provide a combined 5 feet of grass filter strip at a maximum 5% (20:1) cross slope and 3:1 or flatter side slopes on the grass channel.
- ***Gravel or Stone Diaphragm*** (sheet flow): The gravel diaphragm is located at the edge of the pavement or the edge of the roadway shoulder and extends the length of the channel to pre-treat lateral runoff. This requires a 2 to 4 inch elevation drop from a hard-edged surface into a gravel or stone diaphragm.
- ***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 channel.

Notes

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 4

SOIL COMPOST AMENDMENT

Soil restoration is an Environmental Site Design (ESD) practice applied after construction, to deeply till compacted soils and restore their porosity by amending them with compost. These soil amendments can reduce the generation of runoff from compacted urban lawns and may also be used to enhance the runoff reduction performance of areas that receive runoff, such as downspout disconnections, grass channels, and filter strips.

Table 9: Stormwater Functions of Soil Compost Amendments[1]
(From Spec. No. 4, Table 4.1, page 2)

Stormwater Function	HSG Soils A and B		HSG Soils C and D	
	No CA [2]	With CA	No CA	With CA
Annual Runoff Volume Reduction (RR)				
Simple Rooftop Disconnection	**50%**	**NA [3]**	**25%**	**50%**
Filter Strip	**50%**	**NA [3]**	**NA [4]**	**50%**
Grass Channel	**20%**	**NA [3]**	**10%**	**30%**
Total Phosphorus (TP) EMC Reduction[4] by BMP Treatment Practice	**0**		**0**	
Total Phosphorus (TP) Mass Load Removal	**Same as for RR (above)**		**Same as for RR (above)**	
Total Nitrogen (TN) EMC Reduction by BMP Treatment Practice	**0**		**0**	
Total Nitrogen (TN) Mass Load Removal	**Same as for RR (above)**		**Same as for RR (above)**	
Channel Protection & Flood Mitigation	**Partial.** Designers can use the RRM spreadsheet to adjust the curve number for each design storm for the contributing drainage area, based on annual runoff volume reduction achieved.			

[1] CWP and CSN (2008), CWP (2007)
[2] CA = Compost Amended Soils,
[3] Compost amendments are generally not applicable for A and B soils, although it may be advisable to incorporate them on mass-graded B soils to maintain runoff reduction rates.
[4] Filter strips in HSG C and D should use composted amended soils to enhance runoff reduction capabilities. See Stormwater Design Specification No. 2: Sheetflow to Vegetated Filter Strip or Conserved Open Space.

Compost amended soils are suitable for any pervious area where soils have been or are expected to be compacted by the grading and construction process. They are particularly well suited when existing soils have low infiltration rates (HSG C and D) and when the pervious area will be used to filter runoff (downspout disconnections and grass channels). The area or strip of amended soils should be hydraulically connected to the stormwater conveyance system. Soil restoration is recommended for sites that will experience mass grading: the removal and stockpiling of existing topsoil (the A horizon) and replacing it on top of the newly graded (and compacted) landscape.

Compost amendments are **not** recommended where:

- Existing soils have high infiltration rates (e.g., HSG A and B), although compost amendments may be needed at mass-graded B soils in order to maintain runoff reduction rates.
- The water table or bedrock is located within 1.5 feet of the soil surface.
- Slopes exceed 10%.
- Existing soils are saturated or seasonally wet.

- Application would harm roots of existing trees (keep amendments outside the tree drip line).
- The downhill slope runs toward an existing or proposed building foundation.
- The contributing impervious surface area exceeds the surface area of the amended soils.

Compost amendments can be applied to the entire pervious area of a development or be applied only to select areas of the site to enhance the performance of runoff reduction practices. Some common design applications include:

- Reduce runoff from compacted lawns (while also enhancing the long term viability of the turf).
- Increase runoff reduction for rooftop disconnections directed over otherwise poor soils.
- Increase runoff reduction within a grass channel.
- Increase runoff reduction within a vegetated filter strip.
- Increase the runoff reduction function of a tree cluster or reforested area of the site.

The depth of compost amendment is based on the relationship of the surface area of the soil amendment to the contributing area of impervious cover that it receives. **Table 10** presents some general guidance derived from soil modeling by Holman-Dodds (2004) that evaluates the required depth to which compost must be incorporated. Some adjustments to the recommended incorporation depth were made to reflect alternative recommendations of Roa Espinosa (2006), Balousek (2003), Chollak and Rosenfeld (1998) and others.

Table 10. Short-Cut Method to Determine Compost and Incorporation Depths
(From Spec. No. 4, Table 4.3, page 5)

	Contributing Impervious Cover to Soil Amendment Area Ratio [1]			
	IC/SA = 0 [2]	IC/SA = 0.5	IC/SA = 0.75	IC/SA = 1.0 [3]
Compost (in) [4]	2 to 4 [5]	3 to 6 [5]	4 to 8 [5]	6 to 10 [5]
Incorporation Depth (in)	6 to 10 [5]	8 to 12 [5]	15 to 18 [5]	18 to 24 [5]
Incorporation Method	Rototiller	Tiller	Subsoiler	Subsoiler

Notes:
[1] IC = contrib. impervious cover (sq. ft.) and SA = surface area of compost amendment (sq. ft.)
[2] For amendment of compacted lawns that do not receive off-site runoff
[3] In general, IC/SA ratios greater than 1 should be avoided, unless applied to a simple rooftop disconnection
[4] Average depth of compost added
[5] Lower end for B soils, higher end for C/D soils

Note: Updated compost material specifications are provided in the draft edition of Design Specification No. 4

Notes

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 5

Vegetated Roof

Table 11: Stormwater Functions of Vegetated Roof 1
(From Spec. No. 5, Table 5.1, page 2)

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	45%	60%
Total Phosphorus (TP) EMC Reduction[2] by BMP Treatment Process	0	0
Total Phosphorus (TP) Mass Load Removal	45%	60%
Total Nitrogen (TN) EMC Reduction[2] by BMP Treatment Process	0	0
Total Nitrogen (TN) Mass Load Removal	45%	60%
Channel Protection & Flood Mitigation [3]	Use the following Curve Numbers (CN) for Design Storm events: 1-year storm = 64; 2-year storm = 66; 10-year storm = 72; and the 100 year storm = 75	

[1] Sources: CWP and CSN (2008) and CWP (2007).
[2] Moran et al (2004) and Clark et al (2008) indicate no nutrient reduction or even negative nutrient reduction (due to leaching from the media) in early stages of vegetated roof development.
[3] See Miller (2008), NVRC (2007) and MDE (2008)

Table 12: Vegetated Roof Design Guidance1
(From Spec. No. 5, Table 5.2, page 3)

Level 1 Design (RR:45; TP:0; TN:0)	Level 2 Design (RR: 60; TP:0; TN:0)
Tv = 1.0 (Rv)[1] (A)/12	Tv = 1.1 (Rv) [1] (A)/12
Depth of media up to 4 inches	Media depth 4 to 8 inches
Drainage mats	2-inch stone drainage layer
No more than 20% organic matter in media	No more than 10% organic matter in media
All Designs: Must be in conformance to ASTM (2005) International Green (Vegetated) Roof Stds.	
[1]Rv represents the runoff coefficient for a conventional roof, which will usually be 0.95. The runoff reduction rate applied to the vegetated roof is for "capturing" the Treatment Volume (Tv) compared to what a conventional roof would produce as runoff.	

$$Vegetated\ Roof\ Volume = (RA * D * P)/12$$

Where:

RA Storage Volume = Roof area storage volume provided in the media (cu. ft.)
RA = vegetated roof area (sq. ft.)
D = media depth (in.)
P = media porosity (usually 0.25, but consult manufacturer specifications)

<u>Functional Elements of a Vegetated Roof System</u>

A vegetated roof is composed of up to eight different systems or layers, from bottom to top, that are combined together to protect the roof and maintain a vigorous cover. Designers can employ a wide range of materials for each layer, which can differ in cost, performance, and structural load. The entire system as a whole must be assessed to meet design requirements. Some manufacturers offer proprietary vegetated roofing systems, whereas in other cases, the designer or architect must assemble their own system, in which case they are advised to consult Weiler and Scholz-Barth (2009), Snodgrass and Snodgrass (2006) and Dunnett and Kingsbury (2004).

- Deck Layer
- Waterproofing Layer
- Insulation Layer
- Root Barrier
- Drainage Layer and Drainage System
- Root-Permeable Filter Fabric
- Growing Media
- Plant Cover

Notes

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 6

Rainwater Harvesting

Rainwater harvesting systems intercept, divert, store and release rainfall for future use. Rainwater that falls on a rooftop is collected and conveyed into an above- or below-ground storage tank where it can be used for non-potable water uses and on-site stormwater disposal/infiltration. Non-potable uses may include flushing of toilets and urinals inside buildings, landscape irrigation, exterior washing (e.g. car washes, building facades, sidewalks, street sweepers, fire trucks, etc.), fire suppression (sprinkler) systems, supply for chilled water cooling towers, replenishing and operation of water features and fountains, and laundry, if approved by the local authority. Replenishing of pools may be acceptable if special measures are taken, as approved by the appropriate regulatory authority.

The design and implementation of a rainwater harvesting system must be coordinated with the end user of the building or structure. The designer must quantify the water supply (system contributions or inputs based on the design rainfall capture and roof area) and demand (indoor year-round or seasonal uses, and outdoor uses) for the subject project. Using this design specification and the accompanying **Virginia Cistern Design (VCD) spreadsheet**, the designer should estimate the system size and preferred location, and identify the associated plumbing and pumping system requirements to meet the water demand (e.g., hydraulic lift or pump size, pressure tank, water distribution system, etc.), and ensure that the system meets the intended use and configuration of the proposed development and end user.

This specification provides guidance for the design of a cistern that collects roof runoff. The collection and reuse of surface runoff from parking lots or other surfaces is not addressed in this specification (since a much more robust system to ensure the cleanliness of the runoff would be required so as to not interfere with the mechanical components of the system, as well as to ensure the relative cleanliness of the water for the intended use).

Table 13: Summary of Stormwater Functions Provided by Rainwater Harvesting
(From Spec. No. 6, Table 6.1, page 2)

Stormwater Function	Performance
Annual Runoff Volume Reduction (RR)	Variable up to 90% [2]
Total Phosphorus (TN) EMC Reduction[1] by BMP Treatment Process	0%
Total Phosphorus (TN) Mass Load Removal	Variable up to 90% [2]
Total Nitrogen (TN) EMC Reduction[1] by BMP Treatment Process	0%
Total Nitrogen (TN) Mass Load Removal	Variable up to 90% [2]
Channel Protection	Partial: reduced curve numbers and increased Time of Concentration
Flood Mitigation	Partial: reduced curve numbers and increased Time of Concentration

[1] Nutrient mass load removal is equal to the runoff volume reduction rate. Zero pollutant removal rate is applied to the rainwater harvesting system only. Nutrient removal rates for secondary practices will be in accordance with the design criteria for those practices.
[2] Credit is variable and determined using the Cistern Design Spreadsheet. Credit up to 90% is possible if all water from storms with rainfall of 1 inch or less is used through demand, and the tank is sized such that no overflow from this size event occurs. The total credit may not exceed 90%.

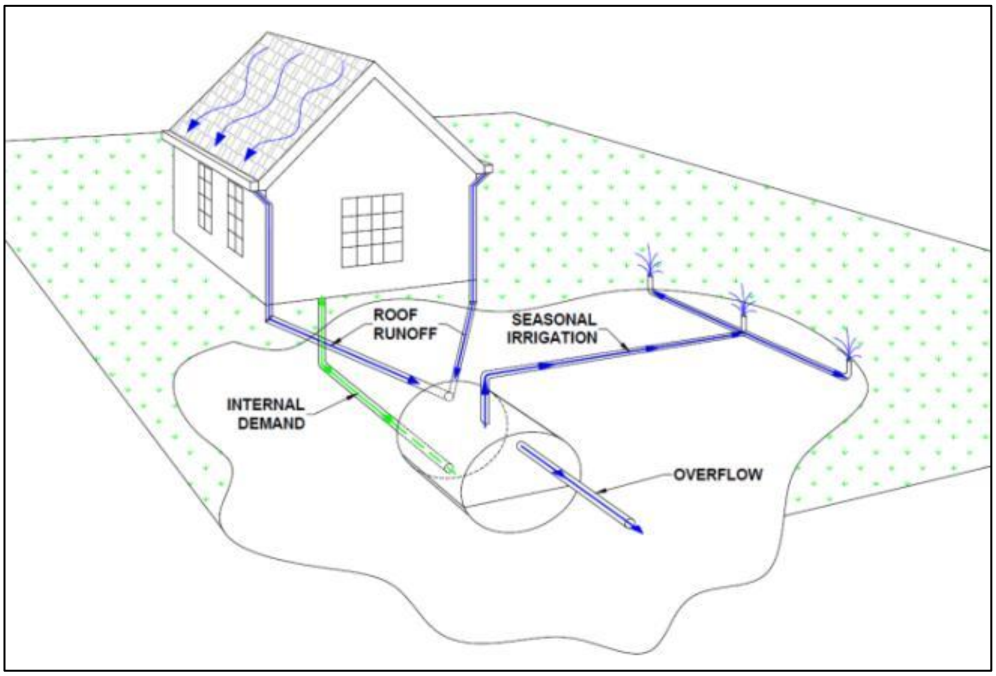
Physical Feasibility and Applications

- Available Space
- Site Topography and Hydraulic Head
- Water Table
- Soils
- Proximity of Underground Utilities
- Contributing Drainage Area
- Rooftop Material
- Water Quality of Rainwater
- Hotspot Land Uses
- Setbacks from Buildings
- Vehicle Loading

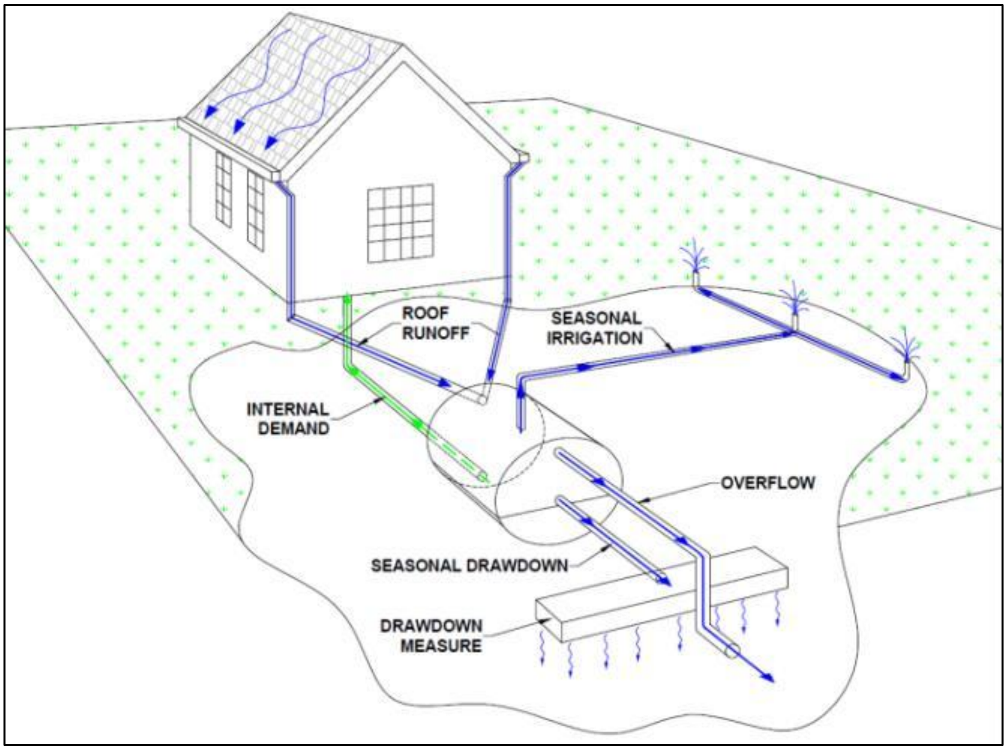
<u>Stormwater Uses</u>

Annual runoff reduction volume credit is only awarded for dedicated year-round drawdown/demand for the water:

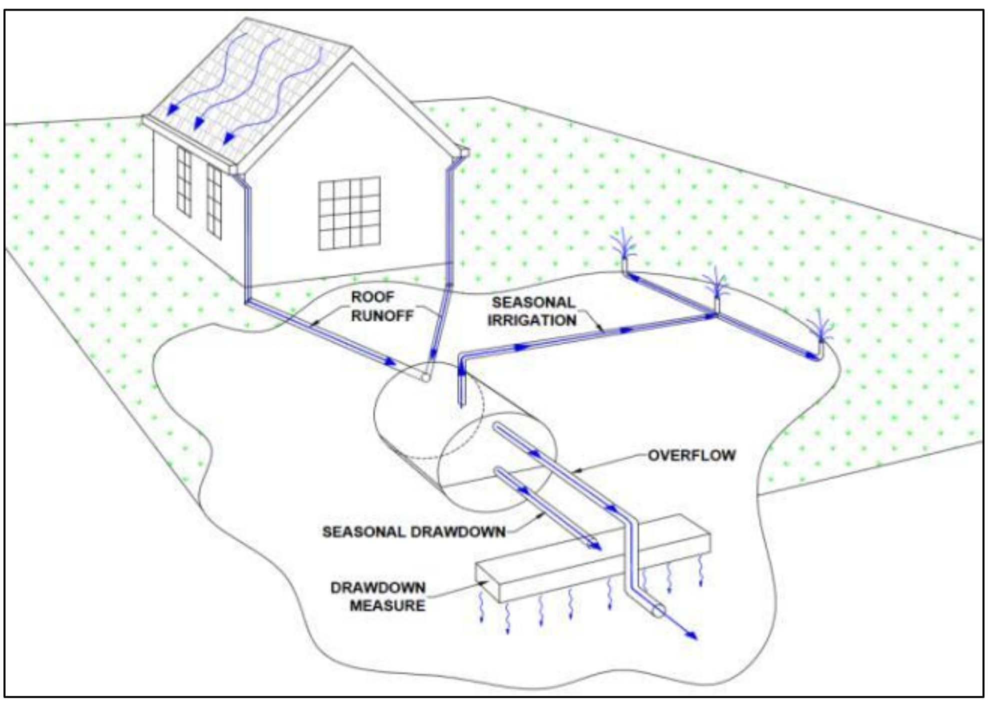
- Year-round indoor use with seasonal indoor and/or outdoor uses;
- Year-round indoor use with seasonal indoor and/or outdoor uses that are supplemented with a secondary runoff reduction drawdown practice; and
- Seasonal indoor and/or outdoor uses that are supplemented with a secondary runoff reduction drawdown practice.



Configuration 1: Year-round indoor use with optional seasonal outdoor use



Configuration 2: Year-round indoor use with seasonal indoor and/or outdoor uses that are supplemented with a secondary runoff reduction drawdown practice



Configuration 3: Seasonal only indoor and/or outdoor uses that are supplemented with a secondary runoff reduction drawdown practice

Notes

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 7

Permeable Pavement

Permeable pavements are alternative paving surfaces that allow stormwater runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. A variety of permeable pavement surfaces are available, including **pervious concrete**, **porous asphalt** and permeable **grid pavers** and **interlocking concrete pavers**. While the specific design may vary, all permeable pavements have a similar structure, consisting of a permeable surface pavement layer, an underlying stone aggregate reservoir layer and a filter layer or fabric installed on the bottom (See **Figure 7.1** below).

The thickness of the reservoir layer is determined by both a structural and hydrologic design analysis. The reservoir layer serves to retain stormwater and also supports the design traffic loads for the pavement. In low-infiltration soils, some or all of the filtered runoff is collected in an underdrain and returned to the storm drain system. If infiltration rates in the native soils permit, permeable pavement can be designed without an underdrain, to enable full infiltration of runoff. A combination of these methods can be used to infiltrate a portion of the filtered runoff.

Table 14: Summary of Stormwater Functions Provided by Permeable Pavement
(From Spec. No. 7, Table 7.1, page 2)

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	45%	75%
Total Phosphorus (TP) EMC Reduction[1] by BMP Treatment Process	25%	25%
Total Phosphorus (TP) Mass Load Removal	59%	81%
Total Nitrogen (TN) EMC Reduction[1]	25%	25%
Total Nitrogen (TN) Mass Load Removal	59%	81%
Channel Protection	● Use VRRM Compliance spreadsheet to calculate a Curve Number (CN) adjustment[2]; ***OR*** ● Design extra storage in the stone underdrain layer and peak rate control structure (optional, as needed) to accommodate detention of larger storm volumes.	
Flood Mitigation	Partial. May be able to design additional storage into the reservoir layer by adding perforated storage pipe or chambers.	

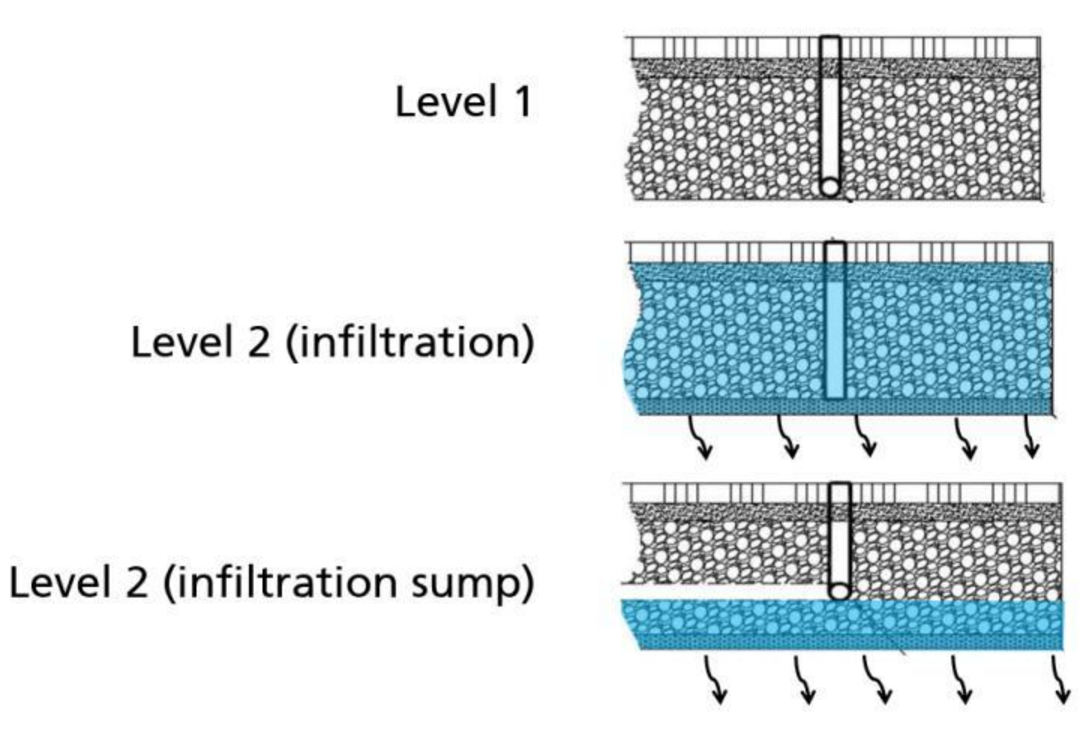
[1] Change in event mean concentration (EMC) through the practice. Actual nutrient mass load removed is the product of the removal rate and the runoff reduction rate (see Table 1 in the *Introduction to the New Virginia Stormwater Design Specifications*).
[2] NRCS TR-55 Runoff Equations 2-1 thru 2-5 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).

Table 15. Permeable Pavement Design Criteria
(From Spec. No. 7, Table 7.3, page 4)

Level 1 Design	Level 2 Design
Tv_{BMP} = (1)(Rv)(A) / 12 + any remaining volume from an upstream BMP(s) [1]	Tv_{BMP} = (1.1)(Rv)(A) / 12
Soil infiltration is less than 0.5 in./hr.	Soil infiltration rate exceeds 0.5 in./hr to remove underdrain requirement, or a drawdown design in accordance with **Section 6**.
Underdrain required	1. No underdrain; ***OR*** 2. If an underdrain is used, a 12-inch (minimum) stone reservoir infiltration sump below the underdrain invert that meets the drawdown requirements of Section 6 must be provided; ***OR*** 3. The Tv stone reservoir volume has at least a 48-hour drain time, as regulated by a control structure.
CDA[1] = The permeable pavement area plus upgradient parking, as long as the ratio of external contributing area to permeable pavement does not exceed 2:1.	CDA = The permeable pavement area;

[1] The contributing drainage area to the permeable pavements should be limited to paved surfaces in order to avoid sediment wash-on, and. When pervious areas are conveyed to permeable pavement, sediment source controls and/or pre-treatment must be provided. The pre-treatment may qualify for a runoff reduction credit if designed accordingly.

Permeable Pavement Design Levels



Minimum Depth of Stone Reservoir Layer

(Spec. No. 7, Equation 7.1, page 9)

$$d_p = \frac{\{(d_c \times R) + P - (i/2 \times t_f)\}}{V_r}$$

Where:

d_p = The depth of the reservoir layer (ft.)

d_c = The depth of runoff from the contributing drainage area (not including the permeable paving surface) for the Treatment Volume (Tv/A_c), or other design storm (ft.)

R = A_c/A_p = The ratio of the contributing drainage area (A_c, not including the permeable paving surface) to the permeable pavement surface area (A_p) [NOTE: The maximum value for the Level 1 design is R = 2, (the external drainage area A_c is twice that of the permeable pavement area A_p; and for Level 2 design R = 0 (the drainage area is made up solely of permeable pavement A_p]**.**

P = The rainfall depth for the Treatment Volume (Level 1 = 1 inch; Level 2 = 1.1 inch), or other design storm (ft.)

i = The field-verified infiltration rate for native soils (ft./day)

t_f = The time to fill the reservoir layer (day) – typically 2 hours or 0.083 day

V_r or η_r = The porosity (or void ratio) for the reservoir layer (0.4)

NOTES for Depth of Stone Reservoir Layer Equation or d_{stone} Equation (Equation 7.1, Section 6.1, Design specification No. 7):

- When contributing drainage area consists of pervious or combined pervious and impervious, the term d_c must be adjusted to reflect the weighted runoff depth using the corresponding weighted volumetric runoff coefficient as calculated using the VRRM Compliance Spreadsheet (or refer to **SWM Handbook** for the weighted Rv computation formula).
- The area of contributing drainage is limited to a ratio of **2:1** (external drainage area to the area of permeable pavement), and is allowed only on Level 1 installations.
- In cases of highly permeable soils, designers may modify d_{stone} equation (to account for the outflow of the exfiltration into the subsoils.

Maximum Depth of Stone Reservoir Layer
(Spec. No. 7, Equation 7.2, page 9)

$$d_{p-max} = \frac{{}^{1}\!/_{2}\, i \times t_d}{\eta_r}$$

Where:

$d_{p\text{-}max}$ = The maximum depth of the infiltration reservoir or the infiltration sump (ft.)

i = The field-verified infiltration rate for the native soils (ft/day)

t_d = The maximum allowable time to drain the reservoir layer or sump, 48 hours

η_r or V_r = porosity (or void ratio) of reservoir layer

Maintenance Agreements

- All permeable pavement installations (like all BMPs) must be covered by a long term maintenance agreement and drainage easement consistent with the provisions of the VSMP regulations to allow inspection and maintenance.
- The maintenance agreements should include provisions to make the owner aware of the special routine operational requirements to ensure long term performance:
  - Identify the conventional parking lot maintenance tasks **that must be avoided** (e.g., sanding, re-sealing, re-surfacing, power-washing).
  - Post signs to indicate the stormwater function and special maintenance requirements.

- On micro-scale or small-scale permeable pavement (on residential lots), owners should be provided a simple document that explains the purpose of the permeable pavement and outlines the routine maintenance needs.
- The long-term maintenance plan.
- The basic parameters of the deed restriction, drainage easement or other mechanism enforceable by the VSMP Authority to help ensure that the permeable pavement system is maintained and functioning.

Notes

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 8

Infiltration Practices

Infiltration practices use temporary surface or underground storage to allow incoming stormwater runoff to exfiltrate into underlying soils. Runoff first passes through multiple pre-treatment mechanisms to trap sediment and organic matter before it reaches the practice. As the stormwater penetrates the underlying soil, chemical and physical adsorption processes remove pollutants. Infiltration practices have the greatest runoff reduction capability of any stormwater practice and are suitable for use in residential and other urban areas where *measured* soil permeability rates exceed 1/2 inch per hour. To prevent possible groundwater contamination, infiltration should not be used at sites designated as stormwater hotspots.

Table 16: Summary of Stormwater Functions Provided by Infiltration Practices
(From Spec. No. 8, Table 8.1, page 2

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	50%	90%
Total Phosphorus (TP) EMC Reduction[1] by BMP Treatment Process	25%	25%
Total Phosphorus (TP) Mass Load Removal	63%	93%
Total Nitrogen (TN) EMC Reduction[1] by BMP Treatment Process	15%	15%
Total Nitrogen (TN) Mass Load Removal	57%	92%
Channel and Flood Protection	• Use the Virginia Runoff Reduction Method (VRRM) Compliance Spreadsheet to calculate the Curve Number (CN) Adjustment ***OR*** • Design for extra storage (optional; as needed) on the surface or in the subsurface storage volume to accommodate larger storm volumes, and use NRCS TR-55 Runoff Equations [2] to compute the CN Adjustment.	
[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 (RR) 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).		

Table 17. Infiltration Design Guidelines
(From Spec. No. 8, Table 8.2, page 2)

Level 1 Design (RR:50; TP:25; TN:15)	Level 2 Design (RR:90; TP:25; TN:15)
Sizing: T_V = [(Rv)(A)/12] + any remaining volume from upstream BMP(s)	Sizing: T_V = [1.1(Rv)(A)/12] + any remaining volume from upstream BMP(s)
At least two forms of pre-treatment (see **Table 8.6**)	At least three forms of pre-treatment (see **Table 8.6**)
Soil infiltration rate 1/2 to 1 in./hr. (see **Section 6.1** & **Appendix 8-A**); number of tests depends on the scale (**Table 8.4**)	Soil infiltration rates of 1.0 to 4.0 in/hr (see **Section 6.1** & **Appendix 8-A**); number of tests depends on the scale (**Table 8.4**)
Minimum of 2 feet between the bottom of the infiltration practice and the seasonal high water table or bedrock (**Section 5**)	
T_V infiltrates within 36 to 48 hours (**Section 6.6**)	
Building Setbacks – see **Table 8.4**	
All Designs are subject to hotspot runoff restrictions/prohibitions	

Applicability

- **Minimum Depth to Water Table or Bedrock.** A minimum vertical distance of 2 feet must be provided between the bottom of the infiltration practice and the seasonal high water table or bedrock layer.

- ***Soils.*** Native soils in proposed infiltration areas must have a minimum infiltration rate (permeability or hydraulic conductivity per **BMP Design Specification Appendix 8-A**) of 1/2 inch per hour (typically Hydrologic Soil Group A and B soils meet this criterion). Initially, soil infiltration rates can be estimated from NRCS soil data, but they must be confirmed by an on-site infiltration evaluation.
- **Use on Urban Soils/Redevelopment Sites.** Sites that have been previously graded or disturbed do not retain their original soil permeability due to compaction. Therefore, such sites are not good candidates for infiltration practices. In addition*, i*nfiltration practices should never be situated above fill soils.
- **High Loading Situations.** Infiltration practices are *not* intended to treat sites with high sediment or trash/debris loads, because such loads will cause the practice to clog and fail.
- **Groundwater Protection.** The BMP Specification provides a list of potential stormwater hotspots that pose a risk of groundwater contamination. Infiltration of runoff from designated hotspots is highly restricted or prohibited.

Sizing of Infiltration Facilities

Different equations apply to Surface Infiltration Basins and Underground Infiltration Trenches:

Maximum Depth of Infiltration Practices

(Spec. No. 8, Equations 8.1 and 8.2, page 10)

Maximum Surface Basin Depth

$$d_{max} = \left(\tfrac{1}{2} f \times t_d\right) \Big/ 12$$

Maximum Underground Reservoir Depth

$$d_{max} = (1/2\, f \times t_d) \Big/ (\eta \times 12)$$

Where:

d_{max}	=	maximum depth of the infiltration practice (feet)
f	=	measured infiltration rate (in./hr)
t_d	=	maximum drawn down time (normally 48 hours)
η	=	porosity of the stone reservoir (assume 0.4)

Maximum depths are prescribed in the Design Specification for each scale of Infiltration. Designers should use **whichever value is *less*** for subsequent design:

Table 18. Maximum Depth (in feet) for Infiltration Practices
(From Spec. No. 8, Table 8.5, page 11)

Mode of Entry	Scale of Infiltration		
	Micro Infiltration	Small Scale Infiltration	Conventional Infiltration
Surface Basin	1.0	1.5	2.0
Underground Reservoir	3.0	5.0	varies

Once the maximum depth is known, the surface area needed for an infiltration practice is calculated (Spec. No. 8, Equations 8.3 and 8.4, page 11):

Surface Basin Surface Area

$$SA = Tv_{BMP} / \left[d + \left((1/2) f \times t_f \right) / 12 \right]$$

Underground Reservoir Surface Area

$$SA = Tv_{BMP} / \left[(\eta \times d) + \left((1/2) f \times t_f / 12 \right) \right]$$

Where:

SA = Surface area (ft^2)

Tv_{BMP} = Design volume for the BMP, e.g., treatment volume from the contributing drainage area plus any remaining volume from upstream runoff reduction practices (ft^3)

η = Porosity of stone reservoir (assume 0.4)

d = Infiltration depth (maximum depends on the scale of infiltration and the results of equation for d_{max} above (ft.)

f = Measured infiltration rate (in./hr)

t_f = Time to fill the infiltration facility (typically 2 hours)

Pre-Treatment

Every infiltration practice must include multiple pre-treatment techniques to ensure long term function and performance. The nature of pre-treatment practices depends on the scale at which infiltration is applied.

Table 19. Required Pre-treatment Elements for Infiltration Practices
(From Spec. No. 8, Table 8.6, page 12)

Pre-treatment [1]	Scale of Infiltration		
	Micro Infiltration	**Small-Scale Infiltration**	**Conventional Infiltration**
Number and Volume of Pre-treatment Techniques Employed	**2** external techniques; no minimum pre-treatment volume required.	**3** techniques; **15%** minimum pre-treatment volume required (inclusive).	**3** techniques; **25%** minimum pre-treatment volume required (inclusive); at least **one** separate pre-treatment cell.
Acceptable Pre-treatment Techniques[1]	Leaf gutter screens Grass filter strip Upper sand layer Washed bank run gravel	Grass filter strip Grass channel Plunge pool Gravel diaphragm	Sediment trap cell Sand filter cell Sump pit Grass filter strip Gravel diaphragm

[1] A minimum of 50% of the runoff reduction volume must be pre-treated by a filtering or bioretention practice *prior* to infiltration *if* the site is a restricted stormwater hotspot

Notes

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 9

Bioretention

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*.

Table 20: Summary of Stormwater Functions Provided by Bioretention Basins
(From Spec. No. 9, Table 9.1, page 2)

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).

There are three basic scales of Bioretention:

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.

Note: The sizing for all three scales is different in the 2011 Design Specifications.

Micro-Bioretention is based on a simple percentage of the contributing drainage area (3% Level 1, and 4% Level 2).

Regular Bioretention is sized according to providing adequate volume in the surface ponding, soil media, and stone reservoir to store the Tv_{BMP}.

Urban Bioretention is sized based on surface area (SA), in square feet, equal to the Tv_{BMP} (cubic feet) divided by two. The draft version of the specifications attempted to rectify this discrepancy by standardizing the sizing as a function of storage volume equivalent to the Tv_{BMP} (Regular Bioretention).

Table 21. Micro-Bioretention Design Criteria[1]
(From Spec. No. 9, Table 9.2, page 4)

Level 1 Design (RR 40 TP: 25)	Level 2 Design (RR: 80 TP: 50)
Sizing: Filter surface area (sq. ft.) = 3% [2] of the contributing drainage area (CDA).	Sizing: 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 phosphorus index (P-Index) of between 10 and 30, ***OR*** Between 7 and 23 mg/kg of P in the soil media	
Sub-soil testing: not needed if an underdrain is used; Min infiltration rate > 1 inch/hour in order to remove the underdrain requirement.	Sub-soil testing: one per practice; Min infiltration rate > 1/2 inch/hour; Min infiltration rate > 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: 10 feet down-gradient; 25 feet up-gradient	
[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 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.	

Table 22. Bioretention Filter and Basin Design Criteria

(From Spec. No. 9, Table 9.1, page 5)

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} / Storage Depth [1]	Sizing (**Section 6.1**): Tv_{BMP} = [(1.25)(Rv)(A) / 12] + any remaining volume from upstream BMP Surface Area (sq. ft.) = Tv_{BMP} /Storage Depth [1]
Recommended maximum contributing drainage area = 2.5 acres	
Maximum Ponding Depth = 6 to 12 inches [2]	Maximum Ponding Depth = 6 to 12 inches [2]
Filter Media Depth minimum = 24 inches; recommended maximum = 6 feet	Filter Media Depth minimum = 36 inches; recommended maximum = 6 feet
Media & Surface Cover (**Section 6.6**) = supplied by vendor; tested for acceptable phosphorus index (P-Index) of between 10 and 30, ***OR*** Between 7 and 23 mg/kg of P in the soil media	
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 per 1,000 sq. ft. 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**): 0 to 0.5 acre CDA = 10 feet if down-gradient from building or level (coastal plain); 50 feet if up-gradient. 0.5 to 2.5 acre CDA = 25 feet if down-gradient from building or level (coastal plain); 100 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 (V_r) of the soil media and gravel layers multiplied by their respective depths, plus the surface ponding depth. Refer to **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.	

Sizing

- Sizing of the surface area (SA) for bioretention practices is based on the computed BMP design Treatment Volume, Tv_{BMP}.
- 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.

The accepted porosity (η) for each of the materials is:

Bioretention Soil Media η = 0.25
Gravel η = 0.40
Surface Storage = 1.0

Level 1: 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 computed as:

$$(2\text{ ft.} \times 0.25) + (1\text{ ft.} \times 0.40) + (0.5 \times 1.0) = 1.40\text{ ft.}$$

And the corresponding surface area (SA) is computed as:

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

Where:

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

Level 2: The equivalent storage depth for Level 2 with a 6-inch surface ponding depth, a 36-inch soil media depth, and a 12-inch gravel layer is computed as:

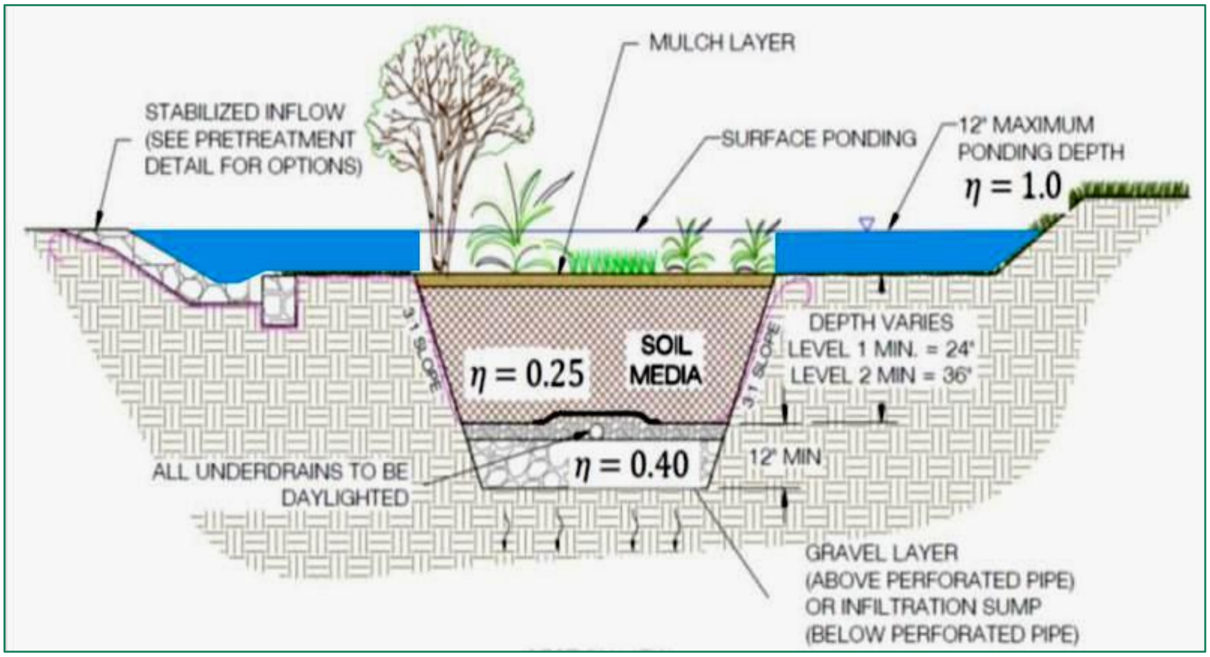
$$(3\text{ ft.} \times 0.25) + (1\text{ ft.} \times 0.40) + (0.5 \times 1.0) = 1.65\text{ ft}$$

And the corresponding surface area (SA) is computed as:

$$SA\ (\text{sq. ft.}) = (Tv_{BMP}) / 1.65\text{ ft.}$$

Where:

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



The oversizing of the surface ponding is limited in terms of a maximum depth of 6 to 12 inches. The area of surface ponding in excess of the soil media is also limited (as a function of the soil media surface area) to avoid excessive loading of the soil media as follows:

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

Bioretention Geometry

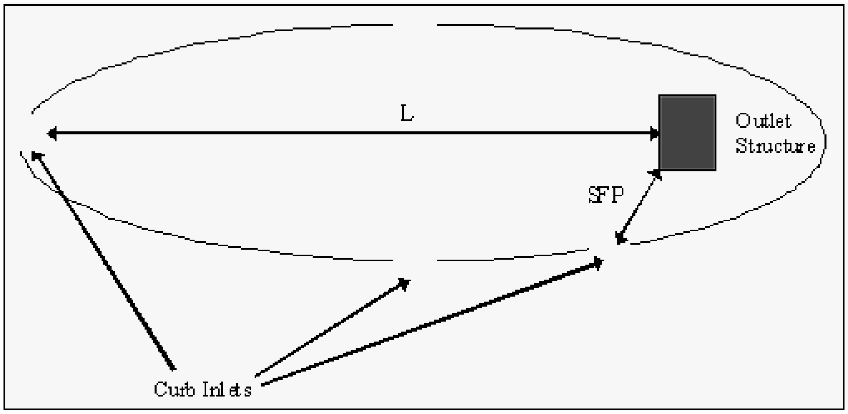
The ratio of Shortest Flow Path to Overall Length is defined as:

$$SFP / L$$

Where:

SFP = length of the shortest flow path

L = length from the most distant inlet to the outlet



Level 1 designs: the SFP/L ratio ≥ 0.3

Level 2 designs: the SFP/L ratio ≥ 0.8

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.

The shortest flow path ratio may be waived 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.

In these instances the hydraulic geometry is not important.

Pre-Treatment

Pre-treatment requirements are identified in Section 6.4 of Spec. No. 9 for both Level 1 and Level 2. Level 2 requires two methods of pre-treatment.

Urban Bioretention

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.

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 for 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.

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**).

Table 23: Summary of Stormwater Functions Provided by Urban Bioretention Areas
(From Spec. No. 9-A, Table 9-A.1, page 42)

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	40% (for Water Quality credit in the VRRM 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 Protection	None; 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*).		

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

Table 24. Urban-Bioretention Design Criteria
(From Spec. No. 9-A, Table 9-A.2, page 43)

Level 1 Design Only (RR: 40; TP: 25)
Sizing (Refer to **Section 9-A-6.1**): Surface Area (sq. ft.) = $T_v/2$ = {[(1.0 inch)(R_v)(A)/12)] + any remaining volume from upstream BMP }/2
Underdrain = Schedule 40 PVC with clean-outs (Refer to the Main Bioretention Design Specification, **Section 6.7**)
Maximum Drainage Area = 2,500 sq. ft.
Maximum Ponding Depth = 6 to 12 inches [1]
Filter media depth minimum = 30 inches; recommended maximum = 48 inches
Media and Surface Cover (Refer to the Main Bioretention Design Specification, **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] 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**).

Contributing Drainage Area

Urban bioretention is sized similar to bioretention and micro-bioretention practices and has only one design level:

- Drainage area limited to 2,500 sq. ft. (100% impervious); to each unit when using the minimum soil depth of 18 inches.
- 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.
- 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).

Notes

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 10

Dry Swales

Dry swales are essentially bioretention cells that are shallower, configured as linear channels, and covered with turf or other surface material (other than mulch and ornamental plants).

The dry swale is a soil filter system that temporarily stores and then filters the desired Treatment Volume (Tv). Dry swales rely on a pre-mixed soil media filter below the channel that is the same as that used for bioretention. If soils are extremely permeable, runoff infiltrates into underlying soils. In most cases, however, the runoff treated by the soil media flows into an underdrain, which conveys treated runoff back to the conveyance system further downstream. The underdrain system consists of a perforated pipe within a gravel layer on the bottom of the swale, beneath the filter media. Dry swales may appear as simple grass channels with the same shape and turf cover, while others may have more elaborate landscaping. Swales can be planted with turf grass, tall meadow grasses, decorative herbaceous cover, or trees.

Table 25: Summary of Stormwater Functions Provided by Dry Swale
(From Spec. No. 10, Table 10.1, page 2)

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	40%	60%
Total Phosphorus (TP) EMC Reduction[1] by BMP Treatment Process	20%	40%
Total Phosphorus (TP) Mass Load Removal	52%	76%
Total Nitrogen (TN) EMC Reduction[1] by BMP Treatment Process	25%	35%
Total Nitrogen (TN) Mass Load Removal	55%	74%
Channel Protection	Use the Virginia Runoff reduction Method (VRRM) Compliance Spreadsheet to calculate the Curve Number (CN) Adjustment ***OR*** Design for 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.	
Flood Mitigation	Partial. Reduced Curve Numbers and Time of Concentration	

[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).

Table 26. Dry Swale Design Criteria
(From Spec. No. 10, Table 10.2, page 3)

<table>
<tr><th>Level 1 Design (RR:40; TP:20; TN:25)</th><th>Level 2 Design (RR:60; TP:40; TN: 35)</th></tr>
<tr><td>Sizing (Sec. 6.1):
Tv_{BMP} = [(1)(Rv)(A) / 12] + any remaining volume from upstream BMP
Surface Area (sq. ft.) = Tv_{BMP} / Storage depth [1]</td><td>Sizing (Sec. 6.1):
Tv_{BMP} = [(1.1)(Rv)(A) / 12] + any remaining volume from upstream BMP
Surface Area sq. ft.) = Tv_{BMP} / Storage Depth [1]</td></tr>
<tr><td>Effective swale slope ≤ 2%[2]</td><td>Effective swale slope ≤ 1%[2]</td></tr>
<tr><td>Media Depth: minimum = 18 inches;
Recommended maximum = 36 inches</td><td>Media Depth minimum = 24 inches
Recommended maximum = 36 inches</td></tr>
<tr><td>Sub-soil testing (Section 6.2): not needed if an underdrain is used; min. infiltration rate must be > 1/2 inch/hour to remove the underdrain requirement;</td><td>Sub-soil testing (Section 6.2): one per 200 linear feet of filter surface; min. infiltration rate must be > 1/2 inch/hour to remove the underdrain requirement</td></tr>
<tr><td>Underdrain (Section 6.7): Schedule 40 PVC with clean-outs</td><td>Underdrain and 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 the soil infiltration requirements are met (see Section 6.2)</td></tr>
<tr><td colspan="2">Media (Section 6.6): supplied by the vendor; tested for an acceptable hydraulic conductivity (or permeability) and phosphorus content [3]</td></tr>
<tr><td colspan="2">Inflow: sheet or concentrated flow with appropriate pre-treatment</td></tr>
<tr><td colspan="2">Pre-Treatment (Section 6.4): a pretreatment cell, grass filter strip, gravel diaphragm, gravel flow spreader, or another approved (manufactured) pre-treatment structure.</td></tr>
<tr><td>On-line design</td><td>Off-line design or multiple treatment cells</td></tr>
<tr><td>Turf cover</td><td>Turf cover, with trees and shrubs</td></tr>
<tr><td colspan="2">Building Setbacks [4] (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)</td></tr>
<tr><td colspan="2">[1] The storage depth is the sum of the porosity (η) of the soil media and gravel layers multiplied by their respective depths, plus the surface ponding depth (Refer to Section 6.1)
[2] The effective swale slope can be achieved through the use of check dams – 12-inch height maximum
[3] Refer to Stormwater Design Specification No. 9: Bioretention for soil specifications
[4] 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.</td></tr>
</table>

Notes

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 11

Wet Swales

Wet swales can provide runoff filtering and treatment within a conveyance system and are a cross between a wetland and a swale. Linear on-line or off-line wetland cells are formed within the channel to intercept shallow groundwater or retain runoff to create saturated soil or shallow standing water conditions (typically less than 6 inches deep) in order to maintain a wetland plant community. The saturated soil and wetland vegetation provide an ideal environment for gravitational settling, biological uptake, and microbial activity.

Designers should note that a wet swale does not provide a runoff volume reduction credit and is therefore typically the final element in the roof-to-stream pollutant removal sequence, and **should therefore be considered only if there is remaining pollutant removal required after all other upland runoff reduction options have been considered and properly credited.**

Table 27: Summary of Stormwater Functions Provided by Wet Swale Practices
(From Spec. No. 11, Table 11.1, page 2)

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	0%	0%
Total Phosphorus (TP) EMC Reduction[1] by BMP Treatment Process	20%	40%
Total Phosphorus (TP) Mass Load Removal	20%	40%
Total Nitrogen (TN) EMC Reduction[1] by BMP Treatment Process	25%	35%
Total Nitrogen (TN) Mass Load Removal	25%	35%
Channel Protection	Limited – reduced Time of Concentration; and partial detention volume can be provided above the Treatment Volume (*Tv*), within the allowable maximum ponding depth.	
Flood Mitigation	Limited	
[1] Change in event mean concentration (EMC) through the practice.		

Table 28. Wet Swale Design Criteria
(From Spec. No. 11, Table 11.2, page 2)

Level 1 Design (RR:0; TP:20; TN:25)	Level 2 Design (RR:0; TP:40; TN:35)
Tv_{BMP} = [(1.0)(R_v)(A)] / 12 + any remaining volume from upstream BMP(s)	Tv_{BMP} = [(1.25)(R_v)(A)] / 12 + any remaining volume from an upstream BMP(s)
Swale slopes less than 2% [1]	Swale slopes less than 1% [1]
On-line design	Off-line swale cells
Minimal planting; volunteer vegetation	Wetland planting within swale cells
Turf cover in buffer	Trees, shrubs, and/or ground cover within swale cells and buffer
[1] Wet Swales are generally recommended only for flat coastal plain conditions with a high water table. A linear wetland is always preferred to a wet swale. However, check dams or other design features that lower the effective longitudinal grade of the swale can be applied on steeper sites, to comply with these criteria.	

Notes

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 12

Filtering Practices

Stormwater filters are a useful practice to treat stormwater runoff from small, highly impervious sites. Stormwater filters capture, temporarily store, and treat stormwater runoff by passing it through an engineered filter media, collecting the filtered water in an underdrain, and then returning it back to the storm drainage system. The filter consists of two chambers: the first is devoted to settling, and the second serves as a filter bed consisting of a sand or other filter media.

Stormwater filters are a versatile option because they consume very little surface land and have few site restrictions.

Table 29: Summary of Stormwater Functions Provided by Filtering Practices
(From Spec. No. 12, Table 12.1, page 2)

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	0%	0%
Total Phosphorus (TP) EMC Reduction[1] by BMP Treatment Process	60%	65%
Total Phosphorus (TP) Mass Load Removal	60%	65%
Total Nitrogen (TN) EMC Reduction[1] by BMP Treatment Process	30%	45%
Total Nitrogen (TN) Mass Load Removal	30%	45%
Channel Protection	Limited – Runoff diverted off-line into a storage facility for treatment can be supplemented with an outlet control to provide peak rate control.	
Flood Mitigation	None. Most filtering practices are off-line and do not materially change peak discharges.	
[1] Change in the event mean concentration (EMC) through the practice..		

Table 30. Filtering Practice Design Criteria
(From Spec. No. 12, Table 12.2, page 2)

Level 1 Design (RR:0; TP:60; TN:30)	Level 2 Design (RR:0 [1]; TP:65; TN:45)
Tv = [(1.0)(Rv)(A)] / 12 + any remaining volume from upstream BMP(s)	Tv = [(1.25)(Rv)(A)] / 12 + any remaining volume from upstream BMP(s)
One cell design[2]	Two cell design[2]
Sand media	Sand media with an organic layer
Contributing Drainage Area (CDA) contains pervious area	CDA is nearly 100% impervious
[1] May be increased if the 2nd cell is utilized for infiltration in accordance with Stormwater Design Specification No. 8 (Infiltration) or Stormwater Design Specification No. 9 (Bioretention). The Runoff Reduction (RR) credit should be proportional to the fraction of the Tv designed to be infiltrated. [2] A pretreatment sedimentation chamber or forebay is not considered a separate cell	

Notes

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 13

Constructed Wetlands

Constructed wetlands, sometimes called stormwater wetlands, are shallow basins that receive stormwater inputs for water quality treatment. The constructed wetland permanent pool is typically six inches to 18 inches deep (although it may have greater depths in the forebay and micropool) and possesses variable microtopography to promote dense and diverse wetland cover. Runoff from each new storm displaces runoff from previous storms, and the long residence time allows multiple pollutant removal processes to operate. The wetland environment provides an ideal environment for gravitational settling, biological uptake, and microbial activity.

Constructed wetlands can also help to meet channel protection requirements by utilizing detention storage above the permanent pool to reduce peak flows from the 1-year design storm using the energy balance method described in the Virginia Stormwater Management Program (VSMP) regulations.

Designers should note that a constructed wetland is typically the final element in the roof-to-stream pollutant removal sequence and provides no volume reduction credit, and **should therefore be considered only if there is remaining pollutant removal or Channel Protection Volume to manage after all other upland runoff reduction options have been considered and properly credited.**

Table 31: Summary of Stormwater Functions Provided by Constructed Wetlands
(From Spec. No. 13, Table 13.1, page 2)

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	0%	0%
Total Phosphorus (TP) EMC Reduction[1] by BMP Treatment Process	50%	75%
Total Phosphorus (TP) Mass Load Removal	50%	75%
Total Nitrogen (TN) EMC Reduction[1] by BMP Treatment Process	25%	55%
Total Nitrogen (TN) Mass Load Removal	25%	55%
Channel Protection	Yes. Up to 1 foot of detention storage volume can be provided above the normal pool.	
Flood Mitigation	Yes. Flood control storage can be provided above the normal pool.	
[1] Change in event mean concentration (EMC) through the practice.		

Table 32. Constructed Wetlands Design Criteria
(From Spec. No. 13, Table 13.2, page 3)

Level 1 Design (RR:0; TP:50; TN:25)	Level 2 Design (RR:0; TP:75; TN:55)
Tv_{BMP} = [(1.0)(R_V)(A)] / 12 + any remaining volume from upstream BMP(s)	Tv_{BMP} = [(1.5)(R_V)(A)] / 12 + any remaining volume from upstream BMP(s)
Single cell (with a forebay and micropool outlet)[1,2] **Section 6.5**	Multiple cells or a multi-cell pond/wetland combination[1,2] **Sections 6.2 and 6.5**
Extended Detention (ED) for 50% of Tv (24 hr)[3] or Detention storage (up to 12 inches) above the wetland pool for channel protection (1-year storm event); **Section 6.2**	No ED or detention storage. (limited water surface fluctuations allowed during the 1-inch and 1-year storm events; **Section 6.2)**
Uniform wetland depth [2] Allowable mean wetland depth is > than 1 foot; **Section 6.2**	Diverse microtopography with varying depths [2]**;** Allowable mean wetland depth ≤1 foot; **Section 6.2**
The surface area of the wetland is *less* than 3% of the contributing drainage area (CDA); **Section 6.2**.	The surface area of the wetland is *more* than 3% of the CDA; **Section 6.2**
Length/Width ratio *OR* Flow path = 2:1 or more Length of shortest flow path/overall length = 0.5 or more [3] **Section 6.3**	Length/Width ratio *OR* Flow path = 3:1 or more Length of shortest flow path/overall length = 0.8 or more [4] **Section 6.3**
Emergent wetland design, **Section 6.7**	Emergent and Upland wetland design, **Section 6.7**

[1] Pre-treatment Forebay required – refer to **Section 6.5**
[2] Internal Tv storage volume geometry – refer to **Section 6.6**
[3] Extended Detention may be provided to meet a maximum of 50% of the Treatment Volume; Refer to Design Specification 15 for ED design – refer to **Section 6.2**
[4] In the case of multiple inlets, the flow path is measured from the dominant inlets (that comprise 80% or more of the total pond inflow), **Section 6.3**

Notes

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 14

Wet Ponds

Wet ponds consist of a permanent pool of water that promotes a better environment for gravitational settling, biological uptake and microbial activity. Runoff from each new storm enters the pond and partially displaces pool water from previous storms. The pool also acts as a barrier to re-suspension of sediments and other pollutants deposited during prior storms. When sized properly, wet ponds have a residence time that ranges from many days to several weeks depending on the volume of the permanent pool, which allows numerous pollutant removal mechanisms to operate. Wet ponds can also include extended detention of a portion of the Treatment Volume (Tv) above the permanent pool or a multiple cell design in order to improve performance and meet the Level 2 performance goal.

Wet ponds can also help to meet channel protection requirements by utilizing detention storage above the permanent pool and extended detention storage volumes to reduce peak flows from the 1-year design storm using the energy balance method described in the Virginia Stormwater Management Program (VSMP) regulations.

Designers should note that a wet pond is typically the final element in the roof-to-stream pollutant removal sequence and provides no volume reduction credit, and **should therefore be considered**

only if there is remaining pollutant removal or Channel Protection Volume to manage after all other upland runoff reduction options have been considered and properly credited.

In instances where a wet pond is proposed as an aesthetic amenity, the design parameters contained here represent good engineering design to maintain a healthy pond. The treatment volume requirements for water quality and detention requirements for channel protection may be more economically met through the upstream runoff reduction practices; however, the basic wet pond features related to aesthetics (pool volume and geometry) and safety (aquatic and safety benches, side slopes, maintenance, etc.) remain as important neighborhood or site design features.

Table 33: Summary of Stormwater Functions Provided by Wet Ponds
(From Spec. No. 14 Table 14.1, page 2)

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR) [1]	0%	0%
Total Phosphorus (TP) EMC Reduction[2] **by BMP Treatment Process**	50% (45%) [3]	75% (65%) [3]
Total Phosphorus (TP) Mass Load Removal	50% (45%) [3]	75% (65%) [3]
Total Nitrogen (TN) EMC Reduction[2] **by BMP Treatment Process**	30% (20%) [3]	40% (30%) [3]
Total Nitrogen (TN) Mass Load Removal	30% (20%) [3]	40% (30%) [3]
Channel Protection	Yes; detention storage can be provided above the permanent pool.	
Flood Mitigation	Yes; flood control storage can be provided above the permanent pool.	
[1] Runoff Reduction rates for ponds used for year round irrigation can be determined through a water budget computation. [2] Change in event mean concentration (EMC) through the practice. [3] Number in parentheses is slightly lower EMC removal rate in the coastal plain (or any location) if the wet pond is influenced by groundwater. See **Section 6.2** of this design specification and CSN Technical Bulletin No. 2. (2009).		

Table 34. Wet Pond Design Guidance
(From Spec. No. 14, Table 14.2, page 3)

Level 1 Design (RR:0 [1]; TP: 50 [5]; TN:30 [5])	Level 2 Design (RR:0 [1]; TP: 75 [5]; TN:40 [5])
Tv_{BMP} = [(1.0)(Rv)(A)/12] + any remaining volume from upstream BMP(s)	Tv_{BMP} = [(1.5) (Rv) (A) /12] + any remaining volume from upstream BMP(s)
Single Pond Cell (with forebay) **Section 6.5**	Wet ED [2] (24 hr) and/or a Multiple Cell Design [3] **Sections 6.2 and 6.5**
Length/Width ratio OR Flow path = 2:1 or more; Length of shortest flow path / overall length [4] = 0.5 or more **Section 6.3**	Length/Width ratio OR Flow path = 3:1 or more; Length of shortest flow path/overall length[4] = 0.8 or more **Section 6.3**
Standard aquatic benches **Section 6.3**	Wetlands more than 10% of pond area **Section 6.3**
Turf in pond buffers **Section 6.7**	Trees, shrubs, and herbaceous plants in pond buffers; Shoreline landscaping to discourage geese **Section 6.7**
No Internal Pond Mechanisms	Aeration (preferably bubblers that extend to or near the bottom or floating islands **Section 6.8**

[1] Runoff volume reduction can be computed for wet ponds designed for water reuse and upland irrigation.
[2] Extended Detention may be provided to meet a maximum of 50% of the Level 2 Treatment Volume; Refer to Design Specification 15 for ED design; **Section 6.2**
[3] At least three internal cells must be included, including the forebay
[4] In the case of multiple inflows, the flow path is measured from the dominant inflows (that comprise 80% or more of the total pond inflow) **Section 6.3**
[5] Due to groundwater influence, slightly lower TP and TN removal rates in coastal plain (**Section 7.2**) and CSN Technical Bulletin No. 2. (2009)

Notes

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 15

Extended Detention (ED) Pond

An Extended Detention (ED) Pond relies on 24 to 36 hour detention of stormwater runoff after each rain event. An under-sized outlet structure restricts stormwater discharge so it backs up and is stored within the basin. The temporary ponding enables particulate pollutants to settle out and reduces the maximum peak discharge to the downstream channel, thereby reducing the effective shear stress on banks of the receiving stream. ED differs from stormwater detention as ED is designed to achieve a minimum drawdown time, rather than a maximum peak rate of flow. A design maximum peak rate of flow, or peak discharge, is commonly used to meet channel protection or flood control requirements and often only detains flows for a few minutes or hours. However, in some cases, detention designed for channel protection using the “energy balance” method described in the Virginia Stormwater Management Program (VSMP) regulations (9VAC25-870-66) may result in extended drawdown times. Therefore, designers are encouraged to evaluate the channel protection detention drawdown as compared to the ED requirements in order to optimize the design to meet both criteria.

ED ponds rely on gravitational settling as their primary pollutant removal mechanism. Consequently, they generally provide fair-to-good removal for particulate pollutants, but low or negligible removal for soluble pollutants, such as nitrate and soluble phosphorus. The use of ED alone generally results in the lowest overall pollutant removal rate of any single stormwater treatment option. Alternatively, an ED component is combined with wet ponds (Design Specification

No. 14) and constructed wetlands (Design Specification No. 15) to help maximize pollutant removal rates of those practices.

Designers should note that an ED pond is typically the final element in the roof to stream pollutant removal sequence and provides limited volume reduction credit (Level 2 only), and **should therefore be considered only if there is remaining Treatment Volume or Channel Protection Volume to manage after all other upland runoff reduction practices have been considered and properly credited.**

Table 35: Summary of Stormwater Functions Provided by ED Ponds
(From Spec. No. 15, Table 15.1, page 2)

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	0%	15%
Total Phosphorus (TP) EMC Reduction[1] by BMP Treatment Process	15%	15%
Total Phosphorus (TP) Mass Load Removal	15%	31%
Total Nitrogen (TN) EMC Reduction[1] by BMP Treatment Process	10%	10%
Total Nitrogen (TN) Mass Load Removal	10%	24%
Channel Protection	Yes; storage volume can be provided to accommodate the full Channel Protection Volume (CP_V)	
Flood Mitigation	Yes; flood control storage can be provided above the maximum extended detention volume	
[1] Change in 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*).		

Table 36. ED Pond Design Criteria
(From Spec. No. 15, Table 15.2, page 2)

Level 1 Design (RR:0; TP:15; TN:10)	Level 2 Design (RR:15; TP:15; TN:10)
Tv_{BMP} = [(1.0) (Rv) (A)] / 12 + any remaining volume from upstream BMP(s)	Tv_{BMP} = [(1.25) (R_V) (A)] / 12 + any remaining volume from upstream BMP(s)
A minimum of 15% of the Tv in the permanent pool (forebay, micropool) **Section 6.5**	A minimum of 40% of Tv in the permanent pool (15% in forebays and micropool, and 25% in constructed wetlands) **Sections 6.2 and 6.5**
Length/Width ratio *OR* flow path = 2:1 or more; Length of the shortest flow path / overall length = 0.4 or more. **Section 6.3**	Length/Width ratio *OR* flow path = 3:1 or more; Length of the shortest flow path / overall length = 0.7 or more. **Section 6.3**
Average Tv ED time = 24 hours or less. **Section 6.2**	Average Tv ED time = 36 hours. **Section 6.2**
Vertical Tv ED fluctuation may exceed 4 feet. **Section 6.3**	Maximum vertical Tv ED limit of 4 feet. **Section 6.3**
Turf cover on floor **Section 6.7**	Trees, shrubs, and herbaceous plants in upper elevations, and emergent plants in wet features **Section 6.7**
Forebay and micropool **Section 6.5**	Incudes additional cells or features (deep pools, wetlands, etc.) **Sections 6.2 and 6.5**

Notes