Module 6: Environmental site design and BMPs

Module 6 Objectives

After completing this module, you will be able to:

- Discuss the benefits of using Environmental Site Design
- Realize how the Runoff Reduction Method can be used to demonstrate the reduction of post-development runoff and pollutant removal
- Use the BMP Clearinghouse to find the design standards and specifications of all stormwater best management practices (BMPs) approved for use in Virginia to control the quality and/or quantity of stormwater runoff

Module 6 Content

6a. Environmental Site Design (ESD)

6b. Virginia Runoff Reduction Method

6c. BMP Clearinghouse

6a. Environmental Site Design (ESD)

Environmental Site Design (ESD) is grounded in the belief that environmental balance can be maintained as new communities are developed throughout our watersheds if basic principles are obeyed. ESD requires an understanding of our natural systems and making the commitment to work within the limits of these systems whenever and wherever possible.

Stormwater management through ESD

ESD views stormwater as a precious resource that must be used carefully, rather than a waste product in need of disposal. In the context of stormwater management, the goal of ESD should be to promote runoff control through the use of the natural drainage systems and to reduce the environmental impact of commonly used land development and drainage methods.

In addition to maintaining natural drainage, ESD should:

- Provide a natural open-space based drainage system using undeveloped flood plains and drainage swales
- Avoid channelization within the natural drainage system
- Maintain forest cover and other natural vegetation to the extent feasible

These practices will result in maintenance or enhancement of the normal water table level.

ESD employs small-scale stormwater management practices, non-structural techniques, and better site planning to mimic natural hydrologic runoff characteristics and minimize the impact of land development on water resources. This includes:

- Optimizing conservation of natural features (e.g., drainage patterns, soil, vegetation)
- Minimizing impervious surfaces (e.g., pavement, concrete channels, rooftops)
- Slowing down runoff to maintain discharge timing and to increase infiltration and evapotranspiration on the development site

- Using other non-structural practices or innovative technologies approved by DEQ

Benefits of ESD

The application of ESD principles can help developers and local governments recognize increased economic and environmental benefits through reduced infrastructure requirements, decreased need for clearing and grading of sites, and less expenditure to meet stormwater management requirements due to reduced runoff volumes and pollutant export from sites.

It is important to recognize that ESD practices are more appropriately applied to greenfield development, where there is ample space and soil conditions to apply the principles and practices. ESD principles may be difficult to apply at typical redevelopment sites, where space is limited and costly and "urban" (mixed, dense) soils exist.

8 principles of ESD

1. Achieve multiple objectives
2. Integrate stormwater management and design *early* in the site planning and design process
3. Prevent problems to avoid having to mitigate them
4. Conserve resources and minimize land cover changes
5. Design the development to fit the terrain
6. Apply decisions that have the effect of maintaining the natural site hydrology
7. Manage stormwater as close to the point of origin (generation) as possible to minimize collection and conveyance
8. Rely to the maximum on natural processes that occur within the soil and the plant community

Environmental Site Design Techniques and Practices

Table 6-1

Conserving natural features and resources	
Preserve undisturbed natural areas	Preserve or plant native trees
Preserve riparian buffers	Avoid floodplains
Avoid steep slopes	
Using low impact site design techniques	
Fit the design to the terrain	Locate development in less sensitive areas
Reduce the limits of clearing and grading	Use open space development
Consider creative development design	Reduce roadway lengths and widths
Reduce impervious footprints	Reduce the parking footprints
Reduce setbacks and frontages	Use fewer or alternative cul-de-sacs
Create parking lot stormwater "islands"	
Using natural features and runoff reduction to manage stormwater	
Use buffers and undisturbed filter areas	Use creative site grading, berming and terracing (terraforming)
Use natural drainageways and vegetated swales instead of storm sewers and curb and gutter	Drain runoff to pervious areas
Infiltrate site runoff or capture it for reuse	Restore or daylight streams at redevelopment projects

6b. Runoff Volume Reduction and the Virginia Runoff Reduction Method

The Regulations have brought about a shift to the runoff reduction paradigm by establishing post-development **treatment volume (Tv)** criteria, which represents the volume of runoff that must be reduced and/or treated and post-development on-site **runoff volume reduction** standards.

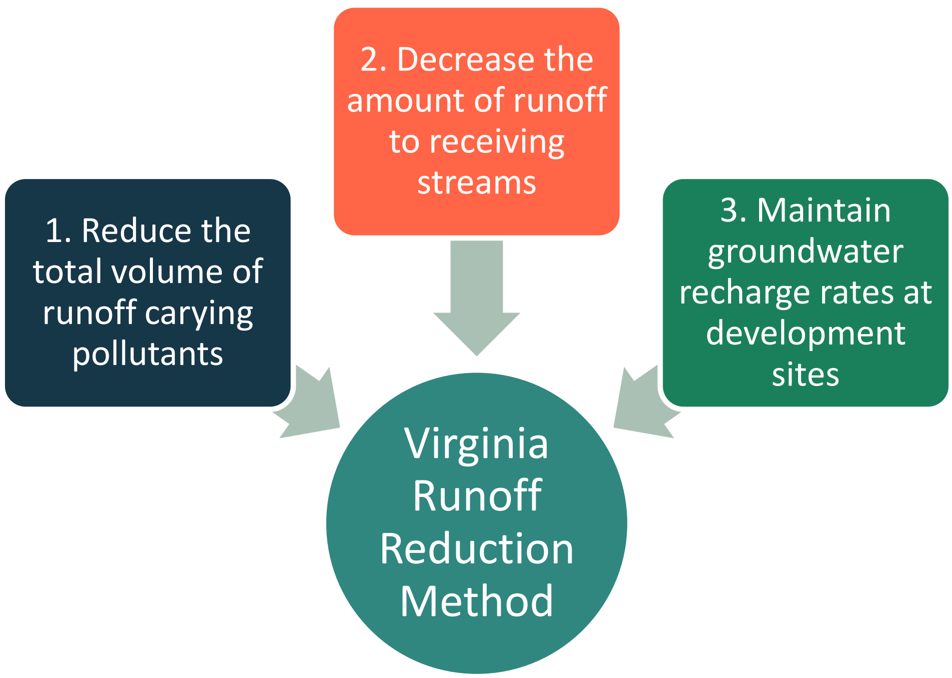
BMP Structures Designed to Achieve Part II C Technical Criteria (Old way)	vs	BMP Structures Designed to Achieve Part II B Technical Criteria (New way)
BMP designed to "treat" the first flush (1/2 inch) of runoff from impervious surface to remove pollutants (Doesn't take into account the intensity of rain)	**Event**	Treatment volume (Tv) 1-inch rainfall event statewide standard
Impervious surface	**Land Use(s)**	Forest/open space, turf, impervious
Average land cover condition	**New Design Criteria**	0.41 lbs./acre/yr of P
10% reduction of phosphorus	**Redevelopment Criteria**	< 1 acre = 10% P reduction > 1 acre = 20% P reduction
Simple Method, Blue Book, BMPs	**Compliance Methodology**	Runoff Reduction, BMP Clearinghouse
P = Phosphorus		

Benefits of treatment volume (Tv) for evaluating runoff reduction practices and sizing BMPs:

- Provides effective stormwater treatment for approximately 90% of the annual runoff volume from the site, and larger storms will be partially treated
- Storage is a direct function of impervious cover and disturbed soils, which provides designers incentives to minimize the area of both at a site
- Provides adequate storage to treat pollutants for a range of storm events
- Provides an objective measure to gauge the aggregate performance of environmental site design, runoff reduction and other innovative practices, and conventional BMPs together using a common currency (runoff volume)

- Calculating the TV explicitly acknowledges the difference between forest and turf cover and disturbed and undisturbed soils, creating incentives to conserve forests and reduce mass grading and provide a defensible basis for computing runoff reduction volumes for these actions

The water quality and quantity objectives of Part II B are integrated into the Virginia Runoff Reduction Method (RRM) compliance calculation spreadsheet. By meeting the requirements of the RRM, a BMP's treatment for water quality is improved and runoff volume is reduced.



The VRRM is accompanied by two compliance spreadsheets. The first is applicable to new development and is referred to as the **VRRM Compliance Spreadsheet.** The second is applicable to development on prior developed lands and is referred to simply as the **VRRM Redevelopment Compliance Spreadsheet**. The spreadsheets are designed to help designers and plan reviewers quickly evaluate the implementation of BMPs on a given site and verify compliance with the local and/or state stormwater requirements.

The spreadsheets do the following:

- Provide a summary of land cover for the entire site in its developed condition, the pollutant load (Total Phosphorus and Total Nitrogen), and the corresponding design Treatment Volume
- The Redevelopment spreadsheet provides a summary of the pre and post development (or pre and post redevelopment) land cover, pollutant load, and corresponding design Treatment Volume
- Allow the designer to quickly evaluate the effectiveness of different BMPs and BMP combinations in up to five different drainage areas.
- Provide a summary for each drainage area that includes the land cover, runoff volume and pollutant load generated in the drainage area, the BMPs selected, and the runoff volume and pollutant load reduced by the selected BMPs.
- Calculate the volume reduction credited towards compliance with quantity control requirements in each drainage area (i.e., channel and flood protection requirements).
- Provide an overall compliance summary report that itemizes BMP implementation in each drainage area as well as overall site compliance.

NOTE: The RRM compliance spreadsheets are not BMP design tools. When a BMP is selected in a spreadsheet, it is assumed that the designer will locate and design the BMP according to the design criteria provided in the Virginia BMP Design Specifications. Please refer to the Virginia BMP Clearinghouse website, found online at vwrrc.vt.edu/swc/PostConstructionBMPs.html, for the latest BMP design criteria.

In most cases, designers will need to analyze a lot of design options with the spreadsheet, and will end up with a system or sequence of multiple practices across the site. While the compliance spreadsheet helps determine whether a site is in compliance, designers must still meet design criteria for individual practices at the site.

6c. BMP Clearinghouse http://vwrrc.vt.edu/swc/

The Virginia Stormwater Management BMP Clearinghouse is a website that serves several key purposes:

- Disseminate the design standards and specifications of all stormwater best management practices (BMPs) approved for use in Virginia to control the quality and/or quantity of stormwater runoff. This information covers the following categories of stormwater BMPs:
  - Traditional practices (ex. detention or wet ponds)
  - Low impact development (LID) practices (ex. roof drain disconnection)
  - Environmental site design (ESD) practices (ex. cluster development)
  - Manufactured treatment devices (MTDs) (ex. hydrodynamic separators)
- Disseminate the results of Virginia's process to evaluate and certify the performance claims of manufactured/proprietary BMPs approved for use in Virginia
- Provide information and links to related websites for those who must comply with the Virginia Stormwater Management Law and Regulations

VSMP and BMPs

The new Regulations have brought a shift to the runoff reduction paradigm, where designers focus on reducing the post-development stormwater runoff volume from a site, as well as meeting more stringent nutrient load reduction requirements.

The BMP Clearinghouse is jointly administered by the Virginia Department of Environmental Quality (DEQ), and the Virginia Water Resources Research Center (VWRRC). DEQ and VWRRC have jointly established an oversight committee, called the Virginia Stormwater BMP Clearinghouse Committee. Committee members represent various stakeholder groups involved with stormwater management. The Committee provides advice and direction for the Clearinghouse project and is governed by a charter.

Post construction BMPs

Since the early 1980's, land developers, particularly in fast-growing regions of the United States, have been required by states and municipalities to manage the stormwater runoff from their development sites.

In the last decade, a new type of BMP has evolved that is aimed at reducing the volume of stormwater runoff leaving the development site and, therefore, mimicking the hydrologic patterns that existed at a site before it was developed. This is a way to minimize our "human footprint" or our interference with natural processes. These new kinds of practices have been labeled Low Impact Development (LID) BMPs and include green roofs, bioretention, rain gardens, rooftop disconnection, dry swales, and wet swales.

ESD and **LID** –BMPs that keeps the volume of stormwater runoff leaving a developed site the same as or better than the pre-development conditions.

LID practices can be linked with Environmental Site Design (ESD) techniques, which include conserving open space and natural areas, and reducing the amount of imperviousness and infrastructure on lots, residential streets, and parking areas. LID and ESD techniques can significantly reduce the amount of impervious cover and the overall development costs while providing greater protection of natural systems and processes.

Virginia stormwater design specifications for 15 non-proprietary BMPs

DEQ has developed an updated set of 15 non-proprietary BMP standards and specifications for use in complying with the Virginia Stormwater Management Act and Regulations, which put a premium on maximizing the degree of runoff volume reduction and nutrient removal achieved at a developed site. Each BMP has a different capability to reduce annual runoff volumes, as well as a different treatment efficiency to reduce the event mean concentration (EMC) of nutrients as they pass through the BMP.

Table 6-1 on the next page lists each BMP's runoff volume reduction rates (RR) and pollutant removal rates for total phosphorus (TP). The legend below accompanies the table.

Table 6-1 Legend

[1] Lower rate is for hydrologic soil groups (HSG) C and D, higher rate is for HSG soils A and B
[2] The removal can be increased to 50% for C and D soils by adding soil compost amendments, and may be higher yet if combined with secondary runoff reduction practices
[3] Credit up to 90% is possible if all water from storms of 1-inch or less is used through demand, and tank is sized such that no overflow occurs. Total credit not to exceed 90%
[4] Lower nutrient removal in parentheses applies to wet ponds in coastal plain terrain
[5] See BMP design specification for an explanation of how additional pollutant removal can be achieved.

EMC = Event mean concentration

BMP Pollutant Removal Efficiencies (March 1, 2011)
vwrrc.vt.edu/swc
Table 6-1

Practice Number	Practice	**Removal of TP by runoff reduction** (RR as %) (Based upon 1 inch of rainfall)	**Removal of TP by treatment – pollutant (EMC) reduction** (PR as %)	**Total mass load removal of TP** (TR as %)
1	Rooftop disconnection	25 or 50 [1]	0	25 or 50 [1]
2	Sheet flow to vegetated filter or conserved open space 1	25 or 50 [1]	0	25 or 50 [1]
	Sheet flow to vegetated filter or conserved open space 2 [5]	50 to 75 [1]	0	50 to 75 [1]
3	Grass channel	10 to 20 [1]	15	23
4	Soil amendments	Used to decrease runoff coefficient for turf cover at the site. See the design specs for roof disconnection, sheet flow to vegetated filter or conserved open space, and grass channels		
5	Vegetated roof 1	45	0	45
	Vegetated roof 2	60	0	60
6	Rainwater harvesting	Up to 90 [3,5]	0	Up to 90 [3,5]
7	Permeable pavement 1	45	25	59
	Permeable pavement 2	75	25	81
8	Infiltration 1	50	25	63
	Infiltration 2	90	25	93
9	Bioretention 1	40	25	55
	Bioretention 2	80	50	90
	Urban Bioretention	40	25	55
10	Dry swale 1	40	20	52
	Dry swale 2	60	40	76
11	Wet swale 1	0	20	20
	Wet swale 2	0	40	40
12	Filtering practice 1	0	60	60
	Filtering practice 2	0	65	65
13	Constructed wetland 1	0	50	50
	Constructed wetland 2	0	75	75
14	Wet pond 1	0	50 (45) [4]	50 (45) [4]
	Wet pond 2	0	75 (65) [4]	75 (65) [4]
15	Extended detention pond 1	0	15	15
	Extended detention pond 2	15	15	31

Design Specification No. 1: Rooftop (and impervious area) 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 rooftops and/or on-lot residential impervious surfaces are directed to pervious areas
2. Disconnection leading to an alternative runoff reduction practice(s) adjacent to the roof

Summary of Stormwater Functions Provided by Rooftop Disconnection
vwrrc.vt.edu/swc
Table 6-2

	HSG A and B	HSG C and D
Annual runoff volume reduction	50%	25%
Total phosphorus EMC reduction by BMP treatment process	0	0
Total phosphorus mass load removal	50%	25%
Total nitrogen EMC reduction by BMP treatment process	0	0
Total nitrogen mass load removal	50%	25%
Channel & flood protection	**Partial:** Designers can use the RRM spreadsheet to adjust curve number for each design storm for the contributing drainage area (CDA), based on annual runoff reduction achieved	

EMC = Event mean concentration
HSG = Hydrologic soils group
Note: Stormwater functions of disconnection can be boosted if an acceptable alternative 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.

Alternative practice	Specification number	Runoff reduction rate
Soil compost-amended filter path	4	50%
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	40%

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 are conserved open space and vegetated filter strips.

In both instances, stormwater must enter the filter strip or conserved open space as sheet flow. If the inflow is from a pipe or channel, an engineered level spreader must be designed in accordance with the DEQ criteria to convert the concentrated flow to sheet flow.

Summary of Stormwater Functions Provided by Conservation Areas and Filter Strips
vwrrc.vt.edu/swc
Table 6-3

	Conservation area		Vegetated filter strip	
	HSG A&B	HSG C&D	HSG A&B	HSG C&D
	Assume no CA[2] in conservation area		No CA [3]	With CA[2]
Annual runoff volume reduction	75%	50%	50%	50%
Total phosphorus EMC reduction[5] by BMP treatment process	0		0	
Total phosphorus mass load removal	75%	50%	50%	50%
Total nitrogen EMC reduction by BMP treatment process	0		0	
Total nitrogen mass load removal	75%	50%	50%	50%
Channel & flood protection	**Partial:** Designers can use the RRM spreadsheet to adjust curve number for each design storm for the contributing drainage area (CDA); 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 number 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 requirements for compost amended soils for filter strips on B soils under certain conditions
[5]There is insufficient monitoring data to assign a nutrient removal rate for filter strips at this time

Design Specification No.3: Grass channels

Grass channels can provide a modest amount of runoff filtering and volume reduction 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 6-4).

Grass channels can also be used to treat runoff from the managed turf areas of turf-intensive land uses, such as sports fields and golf courses, and drainage areas with combined impervious and turf cover (e.g., roads and yards).

Summary of Stormwater Functions Provided by Grass Channels
vwrrc.vt.edu/swc
Table 6-4

	HSG Soils A and B		HSG Soils C and D	
	No CA[2]	**With CA**	**No CA**	**With CA**
Annual runoff volume reduction	20%	NA[3]	10%	30%
Total phosphorus EMC reduction[4] by BMP treatment process	15%		15%	
Total phosphorus mass load removal	32%		24% (no CA) to 41% (with CA)	
Total nitrogen EMC reduction[4] by BMP treatment process	20%		20%	
Total nitrogen 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 (CDA), 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); CWP (2007)
[2]CA = Compost amended soils (see design specification number 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*).

Design Specification No. 4: Soil compost amendments

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 downspout disconnections, grass channels, and filter strips (Table 6-5).

Summary of Stormwater Functions Provided by Soil Compost Amendments
vwrrc.vt.edu/swc
Table 6-5

Annual runoff volume reduction (RR)	**HSG Soils A and B**		**HSG Soils C and D**	
	No CA[2]	**With CA**	**No CA**	**With CA**
Simple rooftop disconnection	50%	NA[3]	25%	50%
Filter strips	50%	NA[3]	NA[4]	50%
Grass channel	20%	NA[3]	10%	30%
Total phosphorus EMC reduction[4] by BMP treatment process	0		0	
Total phosphorus mass load removal	Same as for RR above		Same as for RR above	
Total nitrogen EMC reduction[4] by BMP treatment process	0		0	
Total nitrogen mass load removal	Same as for RR above		Same as for RR above	
Channel & flood protection	**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 (see design specification number 4)
[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 strops 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.

Design Specification No. 5: Vegetated roofs

Vegetated roofs are alternative roof surfaces that typically consist of waterproofing and drainage materials and an engineered growing media that is designed to support plant growth. Vegetated roofs capture and temporarily store stormwater runoff in the growing media before it is conveyed into the storm drain system. A portion of the captured stormwater evaporates or is taken up by plants, which helps reduce runoff volumes, peak runoff rates, and pollutant loads on development sites.

There are two different types of vegetated roof systems. The first, *intensive* vegetated roofs have a deeper growing media layer that ranges from 6 inches to 4 feet thick, which is planted with a wider variety of plants, including trees. The second, *extensive* systems typically have much shallower growing media (2 to 6 inches), which is planted with carefully selected drought tolerant vegetation. Extensive vegetated roofs are much lighter and less expensive than intensive vegetated roofs and are recommended for use on most development and redevelopment sites.

Summary of Stormwater Functions Provided by Vegetated Roofs
vwrrc.vt.edu/swc
Table 6-6

	Level 1 Design	Level 2 Design
Annual runoff volume reduction (RR)	45%	60%
Total phosphorus EMC reduction[2] by BMP treatment process	0	0
Total phosphorus mass load removal	45%	60%
Total nitrogen EMC reduction[2] by BMP treatment process	0	0
Total nitrogen mass load removal	45%	60%
Channel & flood protection	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]CWP and CSN (2008); 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)

Design Specification No. 6: Rainwater harvesting

Rainwater harvesting systems intercept, divert, store, and release rainfall for future use. The term rainwater harvesting is used in this specification, but it is also known as a cistern or rainwater harvesting system. 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.), and fire suppression (sprinkler) systems.

In many instances, rainwater harvesting can be combined with a secondary (down-gradient) runoff reduction practice to enhance runoff volume reduction rates and/or provide treatment of overflow from the rainwater harvesting system.

Summary of Stormwater Functions Provided by Rainwater Harvesting
vwrrc.vt.edu/swc
Table 6-7

	Performance
Annual runoff volume reduction (RR)	Variable up to 90%[2]
Total phosphorus EMC reduction[1] by BMP treatment process	0%
Total phosphorus mass load removal	Variable up to 90%[2]
Total nitrogen EMC reduction[1] by BMP treatment process	0%
Total nitrogen 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 removal is equal to the runoff reduction rate. Zero additional 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 sized such that no overflow from this size event occurs. The total credit may not exceed 90%.

Design Specification No. 7: Permeable pavement

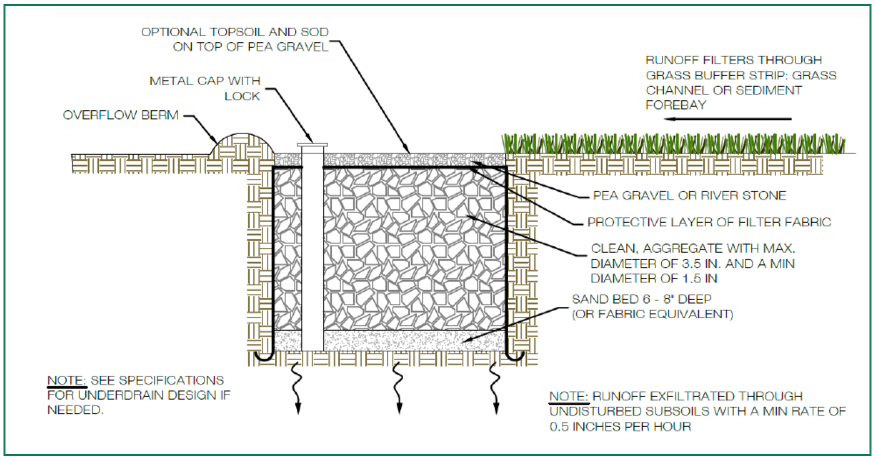
Permeable pavements are alternative paving surfaces that allow stormwater runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. A variety of permeable pavement surfaces are available, including **pervious concrete**,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

Summary of Stormwater Functions Provided by Permeable Pavement
vwrrc.vt.edu/swc
Table 6-8

	Level 1 Design	Level 2 Design
Annual runoff volume reduction (RR)	45%	75%
Total phosphorus EMC reduction[1] by BMP treatment process	25%	25%
Total phosphorus mass load removal	59%	81%
Total nitrogen EMC reduction[1]	25%	25%
Total nitrogen mass load removal	59%	81%
Channel protection	• Use the spreadsheet to calculate a curve number (CN) adjustment; or • Design extra storage (optional, as needed) in the stone underdrain layer to accommodate larger storm volumes, and use NRCS TR-55 Runoff Equations[2] to compute a CN adjustment	
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 removal is the product of the removal rate and the runoff reduction rate (see Table 1 in the *Introduction to the New Virginia Stormwater Design Specifications)*.
[2]NRCS TR-55 Runoff Equations 2-1 thru 2-5 and Figure 2-1 can be used to compute a curve number adjustment for larger storm events based on the retention storage provided by the practice(s).
Sources: CWP and CSN (2008) and CWP (2007)

Design Specification No. 8: Infiltration



Infiltration practices use temporary surface or underground storage to allow incoming stormwater runoff to go into underlying soils. Runoff first passes through multiple pretreatment 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 utilized at sites designated as stormwater hotspots.

Summary of Stormwater Functions Provided by Infiltration
vwrrc.vt.edu/swc
Table 6-9

	Level 1 Design	Level 2 Design
Annual runoff volume reduction (RR)	50%	90%
Total phosphorus EMC reduction[1] by BMP treatment process	25%	25%
Total phosphorus mass load removal	63%	93%
Total nitrogen EMC reduction[1] by BMP treatment process	15%	15%
Total nitrogen mass load removal	57%	92%
Channel and flood protection	• Use the RRM spreadsheet to calculate a curve number (CN) adjustment; or • Design 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 event mean concentration (EMC) through the practice. Actual nutrient mass load removal is the product of the removal rate and the runoff reduction rate (see Table 1 in the *Introduction to the New Virginia Stormwater Design Specifications)*.
[2]NRCS TR-55 Runoff Equations 2-1 thru 2-5 and Figure 2-1 can be used to compute a curve number adjustment for larger storm events based on the retention storage provided by the practice(s).
Sources: CWP and CSN (2008) and CWP (2007)

Design Specification No. 9: Bioretention Basins

Individual bioretention areas can serve highly impervious drainage areas less than two 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*. A bioretention facility without an underdrain system or with a storage sump in the bottom is commonly referred to as a b*ioretention basin*. Small-scale or micro-bioretention used on an individual residential lot is commonly referred to as a r*ain garden*.

Summary of Stormwater Functions Provided by Bioretention Basins
vwrrc.vt.edu/swc
Table 6-10

	Level 1 Design	Level 2 Design
Annual runoff volume reduction (RR)	40%	80%
Total phosphorus EMC reduction[1] by BMP treatment process	25%	50%
Total phosphorus mass load removal	55%	90%
Total nitrogen EMC reduction[1] by BMP treatment process	40%	60%
Total nitrogen mass load removal	64%	90%
Channel and flood protection	• Use the RRM spreadsheet to calculate the cover number (CN); or • Design extra storage (optional, as needed) on the surface, in the engineer 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 removal is the product of the removal rate and the runoff reduction rate (see Table 1 in the *Introduction to the New Virginia Stormwater Design Specifications)*.
[2]NRCS TR-55 Runoff Equations 2-1 thru 2-5 and Figure 2-1 can be used to compute a curve number adjustment for larger storm events based on the retention storage provided by the practice(s).
Sources: CWP and CSN (2008) and CWP (2007)

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). They are 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 similar to 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.

Summary of Stormwater Functions Provided by Dry Swales
vwrrc.vt.edu/swc
Table 6-11

	Level 1 Design	Level 2 Design
Annual runoff volume reduction (RR)	40%	60%
Total phosphorus EMC reduction[1] by BMP treatment process	20%	40%
Total phosphorus mass load removal	52%	76%
Total nitrogen EMC reduction[1] by BMP treatment process	25%	35%
Total nitrogen mass load removal	55%	74%
Channel protection	• Use the RRM spreadsheet to calculate the cover number (CN); or • Design extra storage (optional, as needed) on the surface, 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 conentration	

[1]Change in event mean concentration (EMC) through the practice. Actual nutrient mass load removal is the product of the removal rate and the runoff reduction rate (see Table 1 in the *Introduction to the New Virginia Stormwater Design Specifications)*.
[2]NRCS TR-55 Runoff Equations 2-1 thru 2-5 and Figure 2-1 can be used to compute a curve number adjustment for larger storm events based on the retention storage provided by the practice(s).
Sources: CWP and CSN (2008) and CWP (2007)

Design Specification No. 11: Wet swales

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

Summary of Stormwater Functions Provided by Wet Swales
vwrrc.vt.edu/swc
Table 6-11

	Level 1 Design	Level 2 Design
Annual runoff volume reduction (RR)	0%	0%
Total phosphorus EMC reduction[1] by BMP treatment process	20%	40%
Total phosphorus mass load removal	20%	40%
Total nitrogen EMC reduction[1] by BMP treatment process	25%	35%
Total nitrogen mass load removal	25%	35%
Channel protection	Limited – Reduced time of concentration (TOC); and partial channel protection volume (CPv) can be provided above the treatment volume (Tv), within the allowable maximum ponding depth	
Flood mitigation	Limited – reduced TOC	

[1]Change in event mean concentration (EMC) through the practice.
Sources: CWP and CSN (2008) and CWP (2007)

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 sand or organic filter media.

Summary of Stormwater Functions Provided by Filtering Practices
vwrrc.vt.edu/swc
Table 6-13

	Level 1 Design	Level 2 Design
Annual runoff volume reduction (RR)	0%	0%
Total phosphorus EMC reduction[1] by BMP treatment process	60%	65%
Total phosphorus mass load removal	60%	65%
Total nitrogen EMC reduction[1] by BMP treatment process	30%	45%
Total nitrogen mass load removal	30%	45%
Channel protection	Limited – The treatment volume diverted off-line into a storage facility for treatment can be used to calculate a curve number (CN) adjustment	
Flood mitigation	None – Most filtering practices are off-line and do not materially change peak discharges	

[1]Change in event mean concentration (EMC) through the practice.
Sources: CWP and CSN (2008) and CWP (2007)

Design Specification No. 13: Constructed wetlands

Constructed wetlands, sometimes called stormwater wetlands, are shallow depressions that receive stormwater inputs for water quality treatment. Wetlands are typically less than one-foot deep (although they have greater depths at the forebay and in micropools) and possess 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 are the final element in the roof-to-stream runoff reduction sequence. They should only be considered for use after all other upland runoff reduction opportunities have been exhausted and there is still a remaining water quality or channel protection volume to manage.

Summary of Stormwater Functions Provided by Constructed Wetlands
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Table 6-14

	Level 1 Design	Level 2 Design
Annual runoff volume reduction (RR)	0%	0%
Total phosphorus EMC reduction[1] by BMP treatment process	50%	75%
Total phosphorus mass load removal	50%	75%
Total nitrogen EMC reduction[1] by BMP treatment process	25%	55%
Total nitrogen mass load removal	25%	55%
Channel protection	Yes – Up to one 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.
Sources: CWP and CSN (2008) and CWP (2007)

Design Specification No. 14: Wet pond

Wet ponds consist of a permanent pool of standing 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, which allows numerous pollutant removal mechanisms to operate. Wet ponds can also provide extended detention above the permanent pool to help meet channel protection requirements.

Summary of Stormwater Functions Provided by Wet Ponds
vwrrc.vt.edu/swc
Table 6-15

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 = [(1.0)(Rv)(A)/12]-volume reduced by upstream BMP	Tv = [1.5 (Rv)(A)/12]-volume reduced by upstream BMP
Single pond cell (with forebay)	Wet ED[2] (24 hr) and/or a multiple cell design[3]
Length/width ration or flow path = 2:1 or more	Length of shortest flow path/overall length[4] = 0.8 or more
Standard aquatic benches	Wetlands more than 10% of pond area
Turf in pond buffers	Pond landscaping to discourage geese
No internal pond mechanisms	Aeration (preferably bubblers that extend to or near the bottom of floating islands)
Flood mitigation	Yes – Flood control storage can be provided above the permanent pool

[1]Runoff reduction rates 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 treatment volume; refer to design specification 15 for extended detention design.
[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).
[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)
Sources: CSN (2009), CWP and CSN (2008), and CWP (2007)

Design Specification No. 15: Extended detention (ED) pond

An Extended Detention (ED) Pond relies on 12 to 24 hour detention of stormwater runoff after each rain event. An under-sized outlet structure restricts stormwater flow 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 is normally combined with wet ponds (Design Specification No 14) or constructed wetlands (Design Specification No 15) to maximize pollutant removal rates. Designers should note that an ED pond is the final element in the roof to stream runoff reduction sequence, so one should 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. Designers may need to submit documentation to the local plan review authority showing that all other runoff reduction opportunities have been exhausted and were found to be insufficient, leaving additional water quality or channel protection volume to manage.

Summary of Stormwater Functions Provided by Extended Detention Ponds
vwrrc.vt.edu/swc
Table 6-16

	Level 1 Design	Level 2 Design
Annual runoff volume reduction (RR)	0%	15%
Total phosphorus EMC reduction[1] by BMP treatment process	15%	15%
Total phosphorus mass load removal	15%	31%
Total nitrogen EMC reduction[1] by BMP treatment process	10%	10%
Total nitrogen mass load removal	10%	24%
Channel protection	Yes – Storage volume can be provided to accommodate the full channel protection volume (CPv)	
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)*.
Sources: CWP and CSN (2008) and CWP (2007)

Resources

Draft Virginia Stormwater Management Handbook

DEQ Training FAQs -

http://www.deq.virginia.gov/ConnectWithDEQ/TrainingCertification.aspx

US EPA (General stormwater information):

http://water.epa.gov/action/weatherchannel/stormwater.cfm

USGS Water Cycle and Stream Flow:

http://ga.water.usgs.gov/edu/watercyclestreamflow.html

USGS National Water-Quality Assessment Program: http://water.usgs.gov/nawqa/

USGS NAWQAP - Ecological Health in the Nation's Streams:

http://water.usgs.gov/nawqa/ecology/pubs/cir-1391/index.html

US EPA SWPPP Guidance and Resources:

http://cfpub.epa.gov/npdes/stormwater/swppp.cfm

Regional Staff Assigned to Local VSMP Program Review & Development			
Stormwater Compliance & Planning Staff	**Supervisor**	**Program Manager**	**Regional Office**
Elizabeth Abe Ian Edwards Tim Ott Don Packard	Cody Boggs	Robert Weld	Blue Ridge Regional Office
Marian Carroll Mike Lee Troy Smith Debbie Switzer	Kelly Vanover	Trisha Beasley	Northern Regional Office
David Aho Matt Grant Kevin Landry Xing Lin Matt Stafford Mike Vanlandingham Pantea Westermann	John McCutcheon	Allison Dunaway	Piedmont Regional Office
Erin Belt Shawn Fluharty Ved Malhotra	Noah Hill	Bert Parolari	Tidewater Regional Office
Jonathan Chapman Martha Chapman Phyllis Hinch	Kelly Miller	Mark Trent	Southwest Regional Office
Paul DeMarsh John Mlinarcik Derek Tribble	Gary Flory	Keith Fowler	Valley Regional Office
Jay Carter Nathan Hughes V'lent Lassiter	Joan Salvati	Fred Cunningham	Central Office

Nancy Miller			
Daniel Moore			
Shawn Smith			

References

This participant guide provides an overview of the information and concepts in the Draft Virginia Stormwater Handbook and the Virginia Stormwater Management Program (including overviews of federal and Virginia stormwater legislations and BMP Clearinghouse information). Fully cited information and references can be found in these sources. Sources for non-original figures in Module 2 (Why Stormwater Management Matters) that do not appear in the Handbook are listed within figure captions.

Notes

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