Moving Forward:
The Virginia Stormwater Management Regulations, TMDLs, Impaired Waters, and SWPPPs

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VA Stormwater Management Regulation

Timeline

2010

- **Spring**: HB 1220 and SB 395 delay regulations until 280 days after approval of the TMDL but no later than December 1, 2011.

2011

- **May 24:** Board adopted final regulations
- **September 13:** Statutory effective date of VA SWM Regulations; local program development begins (regulations implemented at local level)

2012

- Construction General Permit Regulatory Advisory Panel (RAP) reviewed General Permit

2013

- **February 26, 2013:** Construction General Permit reviewed by Soil and Water Conservation Board.

2014

- **June:** Completion of local program development (deadline extended from June 2013)
- **July 1:** Implementation date for SW regulations and new general permit

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VA Stormwater Management Regulation

Major Elements to be Discussed Today

- **Grandfathering** (*4VAC50-60-48*)
- **Stormwater Pollution Prevention Plan Requirements** (Effluent Limit Guidelines; *4VAC50-60-54.F*)
- **Water Quality** (*4VAC50-60-63*)
- **Water Quantity** (*4VAC50-60-66*)
- **Offsite Compliance Options** (*4VAC50-60-69*)

Note: Information contained in this presentation represents the version of the Stormwater Regulations that became effective on September 13, 2011 (available at http://www.dcr.virginia.gov/documents/swmfinregspublishedvareg.pdf).

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Grandfathering

Development site in Gainesville, Virginia in April, 2011

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Time Limits and Grandfathering

4VAC50-60-47.1 and 4VAC50-60-48

Time Limits on Applicability of Approved Design Criteria

- After July 1, 2009, sites with VSMP permit shall be covered under existing permit criteria for additional 2 permits (after June 30, 2014 expiration; *4VAC50-60-47.1*)

Grandfathering

- Until June 30, 2019, land disturbing activity (with conditions below) approved by locality by July 1, 2012 and no VSMP permit by July 1, 2014 (*4VAC50-60-48.A*)
  - Conditions: Proffered or conditional zoning plan, preliminary or final subdivision plat, preliminary or final site plan, or zoning with a plan of development
  - Grandfathered until June 30, 2019 (*4VAC50-60-48.C*)

- Project with issued governmental bonding or public debt financing by July 1, 2012 (*4VAC50-60-48.B*)
  - Grandfathered until June 30, 2019 (*4VAC50-60-48.C*)

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SW Pollution Prevention Plan Reqs.

Stream in Arlington, Virginia, on 6/27/10 (Source: Aileen Winquist – Arlington County)

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SW Pollution Prevention Plan Reqs.

Verbatim from the Regulations

NTU requirements (were 280 NTUs) removed due to lawsuit, but EPA still required DCR to add the following (verbatim):

***4VAC50-60-54*. Stormwater pollution prevention plan requirements.**

F. The stormwater pollution prevention plan must address the following requirements, to the extent otherwise required by state law or regulations and any applicable requirements of a VSMP permit:

1. ***Control stormwater volume and velocity** within the site to minimize soil erosion;*

2. ***Control stormwater discharges**, including both peak flow rates and total stormwater volume, to minimize erosion at outlets and to minimize downstream channel and stream bank erosion;*

100 NTUs

1000 NTUs

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SW Pollution Prevention Plan Reqs.– cont.

Verbatim from the Regulations

4VAC50-60-54. Stormwater pollution prevention plan requirements.

3. ***Minimize the amount of soil exposed*** *during construction activity;*

4. ***Minimize the disturbance of steep slopes;***

5. ***Minimize sediment discharges from the site.*** *design, installation and maintenance of erosion and sediment controls must address factors such as the amount, frequency, intensity and duration of precipitation, the nature of resulting stormwater runoff, and soil characteristics, including the range of soil particle sizes expected to be present on the site;*

E&S Inspection

6. ***Provide and maintain natural buffers around surface waters****, direct stormwater to vegetated areas to increase sediment removal and maximize stormwater infiltration, unless infeasible;*

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SW Pollution Prevention Plan Reqs.– cont.

Verbatim from the Regulations

***4VAC50-60-54*. Stormwater pollution prevention plan requirements.**

7. ***Minimize soil compaction and, unless infeasible, preserve topsoil****; and*

8. ***Stabilization of disturbed areas*** *must, at a minimum, be initiated immediately whenever any clearing, grading, excavating, or other earth disturbing activities have permanently ceased on any portion of the site, or temporarily ceased on any portion of the site and will not resume for a period exceeding 14 calendar days.*

E&S Inspection

This may be a problem because E & S plans and regulations don't appear to meet all of the requirements (although this is debatable).

→ VSMP permit is going to the Soil and Water Conservation Board on Feb. 26, 2013 and provides implementation direction

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Water Quality

Algae blooms near Norfolk Yacht Club on 8/8/09 (Source: Ryan C. Henriksen – The Virginian Pilot)

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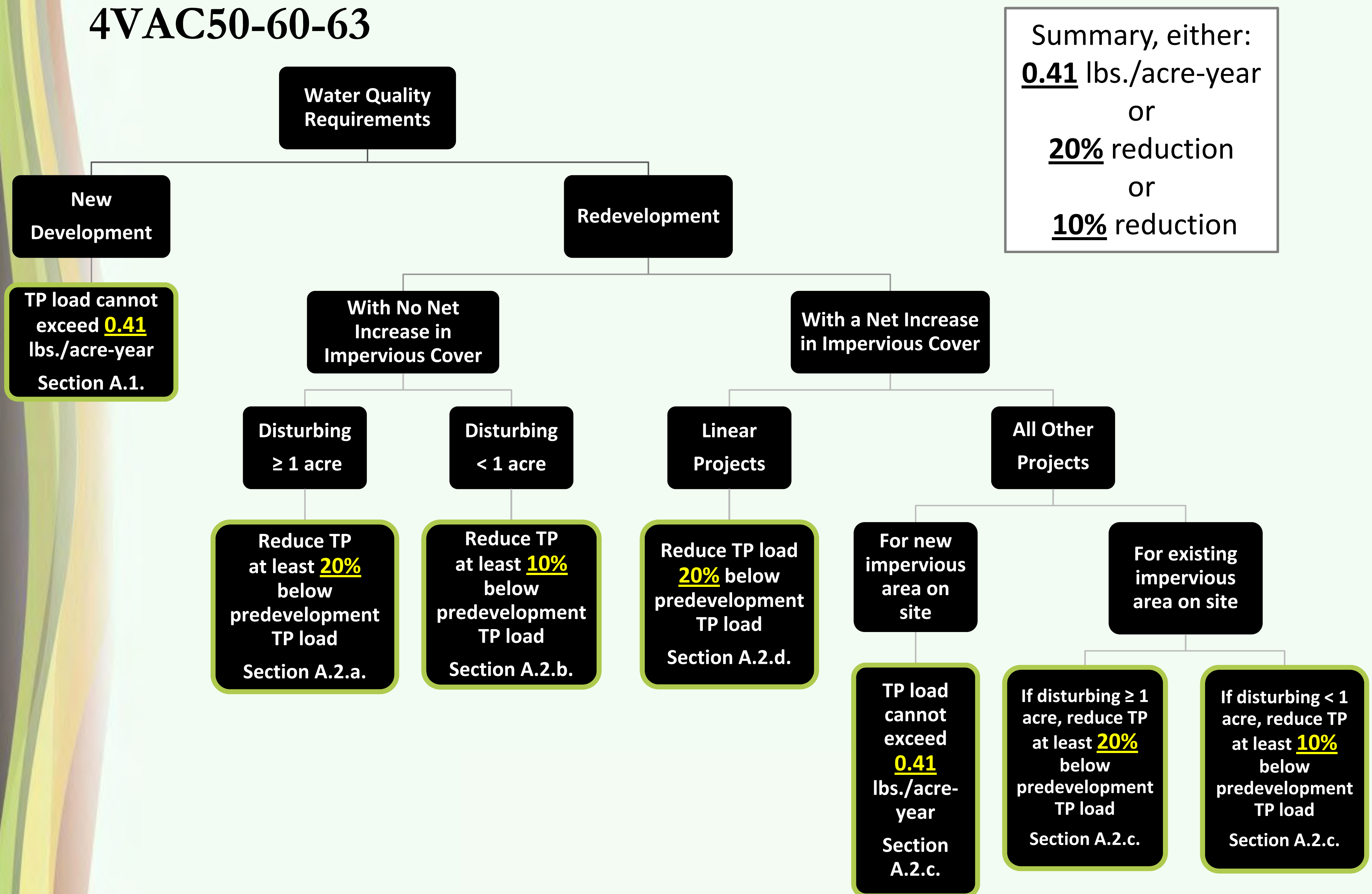
Water Quality

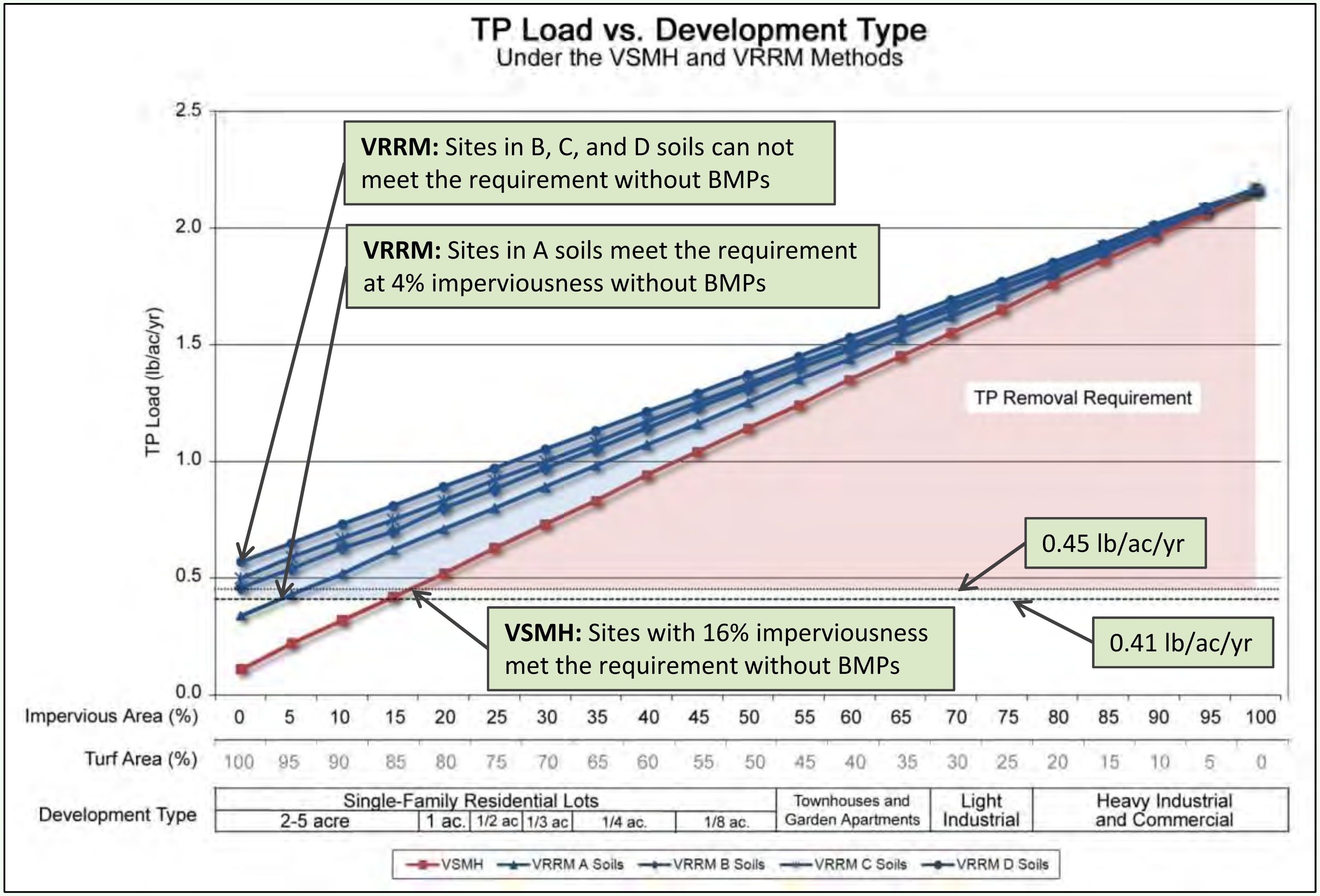
4VAC50-60-63



4VAC50-60-63.A.1

Comparing the new 0.41 lb/ac/yr to the old 0.45 lb/ac/yr

- Each uses different calculation methods
- The loading rates are not comparable; therefore, the requirements are not comparable either!



4VAC50-60-63.A.1

Comparing the new 0.41 lb/ac/yr to the old 0.45 lb/ac/yr

Why the difference in loading-rate calculations?

VSMH: Under the VSMH, TP loads were calculated using the Simple Method.

The old regulations required a loading rate of 0.45 lb/ac/yr based on a calculation of average land cover (excluding urban) and loading rates, as follows:

F_{va} = relative total phosphorus load for Virginia's Chesapeake Bay Watershed

= (%forest x F_{forest}) + (%pasture x $F_{pasture}$) + (%conservation till x $F_{cons.\ till}$) + (%conventional till x $F_{conv.\ till}$)

= (0.66 x 0.12) + (0.21 x 0.59) + (0.07 x 1.52) + (0.06 x 2.42)

= 0.45 lb/ac/yr

(See the Chesapeake Bay Local Assistance Department's Local Assistance Manual, November 1989.)

VRRM: The VRRM calculates loading rates based on a modified Simple Method which accounts for soil types as well as for TP loads from forested land and turf.

The new regulations require a loading rate of 0.41 lb/ac/yr based on the discussion on the following slides. (See slides 14-17.)

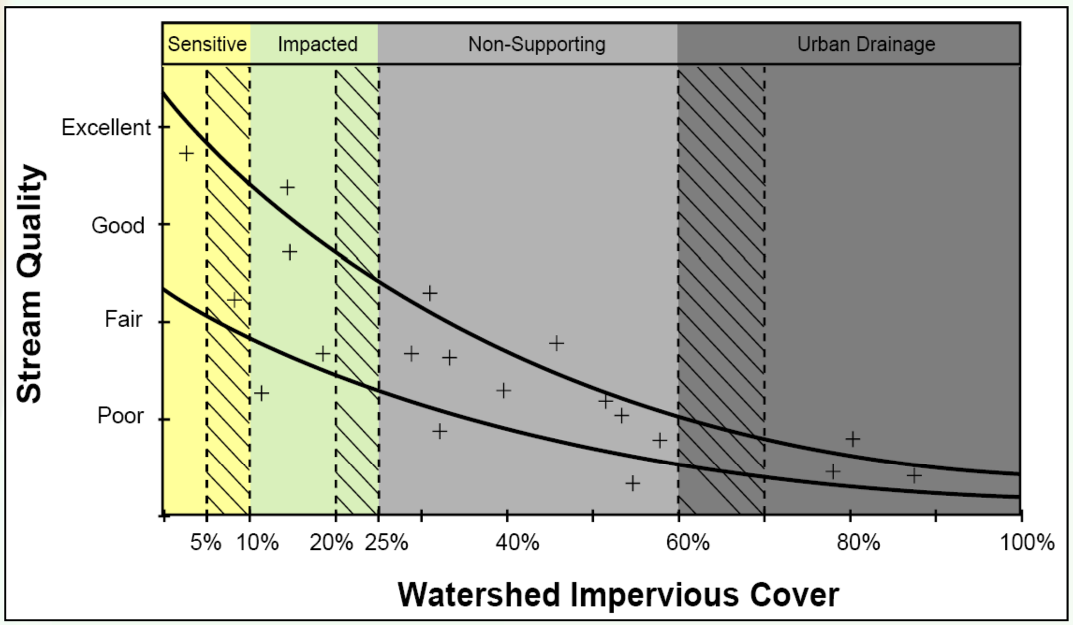
4VAC50-60-63.A.1

Why 0.41 lb/ac/yr?

How should the allowable loading rate be calculated state-wide?

- The subcommittee recommended ***0.36 lb/ac/yr*** TP based on a Modified VRRM calculation (to account for forest):
  - Assumes 7.5% impervious cover[1], 30% turf, and 62.5% VA-average forest cover
  - Assumes 1.15% HSG A, 61.28% HSG B, 28.60% HSG C, and 8.97% HSG D[2]

- Other Options:
  - 10% impervious cover, 30% turf, 60% forest = **0.41 lb/ac/yr**
  - 5% impervious cover, 30% turf, 65% forest = **0.30 lb/ac/yr**



[1] Schueler, T., Fraley-McNeal, L., and Cappiella, K. "Is Impervious Cover Still Important? Review of Recent Research." Journal of Hydrologic Engineering, April, 2009.

[2] Weighted average soil cover was derived from STATSGO state-wide soils database soils breakdown for Virginia outside of the Chesapeake Bay Watershed. STATSGO breakdown: 210 mi^2 HSG A; 0 mi^2 HSG A/D; 11,207 mi^2 HSG B; 0 mi^2 HSG B/D; 5,231 mi^2 HSG C; 373 mi^2 HSG C/D; 1,153 mi^2 HSG D; 115 mi^2 Unrated. C/D and unrated soils were assigned to HSG D.

4VAC50-60-63.A.1

Why 0.41 lb/ac/yr? (cont.)

Jantz, P., Goetz, S., and Jantz, C. 2005. *Urbanization and the Loss of Resource Lands in the Chesapeake Bay Watershed*. Journal of Environmental Management. 36 (6): 808-825.

Page 823 –

In our most conservative estimate, we calculate that at least 388 km^2 of forest lands, 1,016 km^2 of agricultural lands, and 2 km^2 of wetlands, have been lost to commercial and residential development within the CBW since 1990. As much as 826 km^2 of forests, 1,543 km^2 of agricultural lands, and 60 km^2 of wetlands have been converted, although we emphasize the more moderate results derived from the land cover agreement map indicating losses of 504 km^2 for forests, 1,266 km^2 for agricultural lands, and 2 km^2 for wetlands. However, we would expect functional losses,

Chesapeake Bay Watershed:

Conservative Estimate
388 + 1,016 + 2 = 1,406 km^2 converted
390 / 1,406 = **28%** converted from forest (with wetlands)
1,106 / 1,406 = **72%** converted from agriculture

Unconservative Estimate
826 + 60 + 1,543 = 2,429 km^2 converted
886 / 2,429 = **36%** converted from forest (with wetlands)
1,543 / 2,429 = **64%** converted from agriculture

Moderate Estimate
504 + 1,266 + 2 = 1,772 km^2 converted
506 / 1,722 = **29%** converted from forest (with wetlands)
1,266 / 1,722 = **71%** converted from agriculture

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4VAC50-60-63.A.1

Why 0.41 lb/ac/yr? (cont.)

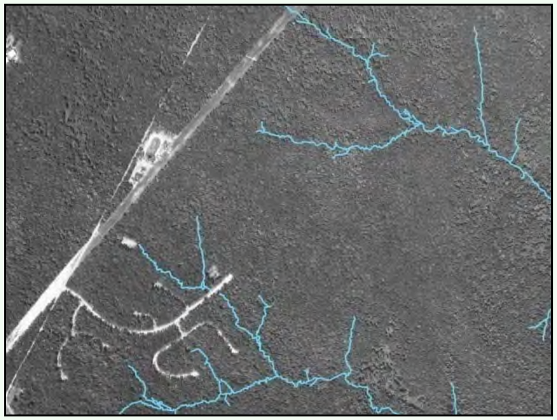
Based on historic development trends per Jantz et. al, **TP = 0.51 to 0.56 lb/ac/yr** to achieve no-net-increase above the allowable average 2025 nutrient loads from previous land uses per the November 2010 WIP.

TP Load Based on Varying Percentages of Previous Land Uses Converted to Development					
Source[1]	% Forest	Forest TP Load (lb/ac/yr)[2]	% Agriculture	Agriculture TP Load (lb/ac/yr)[2]	**Total TP Load (lb/ac/yr)[3]**
Conservative Estimate	28%	0.11	72%	0.74	**0.56**
Unconservative Estimate	36%		64%		**0.51**
Moderate Estimate	29%		71%		**0.56**

1. Historic development trends were derived from: Jantz, P., Goetz, S., and Jantz, C. 2005. *Urbanization and the Loss of Resource Lands in the Chesapeake Bay Watershed*. Journal of Environmental Management. 36 (6): 823.

2. Calculated as the draft WIP 2025 forest and agricultural allocations divided by 2010 sector acreages (which were transmitted to WSSI via e-mail from Russ Perkinson on 8/12/2010).
(For forest: 1,072,000 lb/yr / 9,776,274 ac = 0.11 lb/ac/yr. For agriculture: 2,097,000 lb/yr / 2,836,970 ac = 0.74 lb/ac/yr)

3. Total TP Load is calculated as the sum of (% Forest x Forested TP Load + % Agriculture x Agriculture TP Load)



4VAC50-60-63.A.1

Why 0.41 lb/ac/yr? (cont.)

November 2010 Final Phase I Virginia WIP:

> *"The Tier 1 load-balancing approach uses the allocation loads for forest, cropland, pasture, and hay land uses in the Chesapeake Bay Program's Phase 5.3 Watershed Model to calculate the average pollutant loads from a generic pre-development acre based on the mix of projected land to be developed for Virginia's Chesapeake Bay watershed."*
> (Final WIP, pg. 86)

State-wide Requirement Based on Percentage of Impervious Cover and STATSGO average soil cover		Current Compromise	Chesapeake Bay Requirement Based on "No Increase" from previous land uses	
5% impervious, 65% forest, 30% turf	**0.30**		**0.51**	36% forest, 64% agriculture
7.5% impervious, 62.5% forest, 30% turf	**0.36**	**0.41**	**0.56**	28% forest, 72% agriculture
10% impervious, 60% forest, 30% turf	**0.41**		**0.56**	29% forest, 71% agriculture

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4VAC50-60-63.A.2

Why 10% and 20% Reductions for Redevelopment?

The Chesapeake Bay Preservation Act previously required a TP load reduction of 10% for redeveloped sites.

The new regulations sought to improve over current conditions without discouraging redevelopment; therefore, the SAG agreed on a 20% TP load reduction requirement for redeveloped sites.

However, a 20% TP load reduction is difficult for small sites, so the previous 10% TP load reduction requirement was maintained for sites <1 ac.

Water Quality - cont.

What does this mean for new development?

This means **more BMPs** and **more infiltration** (where possible).

For example in Fairfax County, consider:
A downtown commercial site on C soils (80% impervious and 20% turf)

Under the old regulations, the site produces: **1.76 lb/ac/yr TP**
Under the old regulations, the load must be reduced by 40% to: **1.06 lb/ac/yr TP**

This currently can be done with extended detention ponds.

Extended detention pond

Extended detention pond

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Water Quality - cont.

What does this mean for new development?

Same site:

A downtown commercial site on C soils (80% impervious and 20% turf)

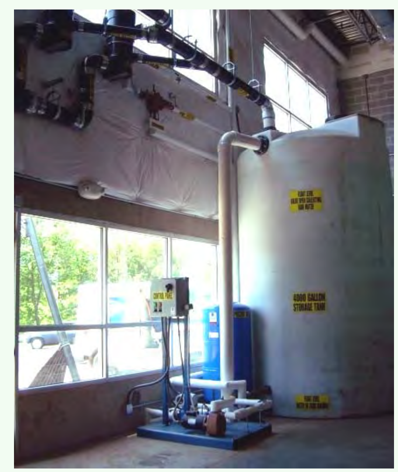
Under the new regulations, the site produces: **1.83 lb/ac/yr TP**
Under the new regulations, the load must be reduced by 78% to: **0.41 lb/ac/yr TP**

- This cannot be accomplished with extended detention alone; requires additional BMPs (rain gardens, cisterns, permeable pavements, infiltration, wetlands, etc.) or trading.

The debate on trading is ongoing:

- Who sets the price of credits- the market or the government?
- How much can be traded? What percentage must be achieved on-site?
- How will acceptable service areas be determined?

Pervious pavers



Cistern

Quantity Control

Snakeden Branch in Reston, Virginia, prior to restoration

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Quantity Control

4VAC50-60-66 Overview

4VAC50-60-66 requires the energy balance method on the 1-year storm event.

- Executive Order 13508 requires developers to match pre-development hydrology. The energy balance method provides a practical solution for sites that can not meet pre-development hydrology.

4VAC50-60-66 defines requirements for three outfall conditions:

- Man-made conveyance systems;
- Restored conveyance systems; and
- Natural conveyance systems.

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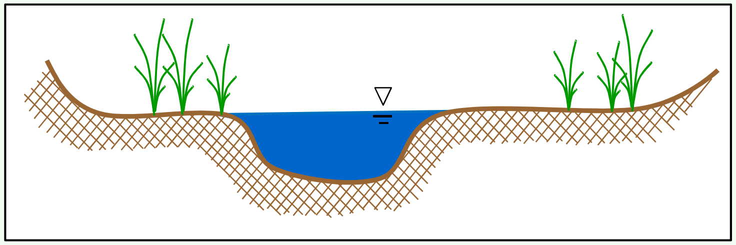
Energy Balance

The theory behind 4VAC50-60-66.B

- Stable streams in this region and climatic epoch formed in forested watersheds and achieve stability by overbank flooding in the 1-1.5 year event.

- To prevent degradation, need to match peak flow, volume, and timing of such conditions.



Stream cross section at bankfull stage

- Traditional SW management controls peak flow, but increases volume, which increases stream power (and power degrades streams).

- Goal of the energy balance method:
  - Keeps pre-development power same by reducing peak flow rate if volume increases;
  - Provides a quantifiable incentive to match pre-development volume to the MEP; and
  - Mass Balance Equation: $Q*Rv_{post} = Q*RV_{forest}$

- Economic considerations of proposed version use pre-development conditions instead of forest (unlike state law and Fairfax County PFM), coupled with improvement factor, I.F. (The I.F. is required because state law requires an improvement on existing conditions.)

  - I.F. of 0.8 yields same ballpark SW sizing as forest conditions

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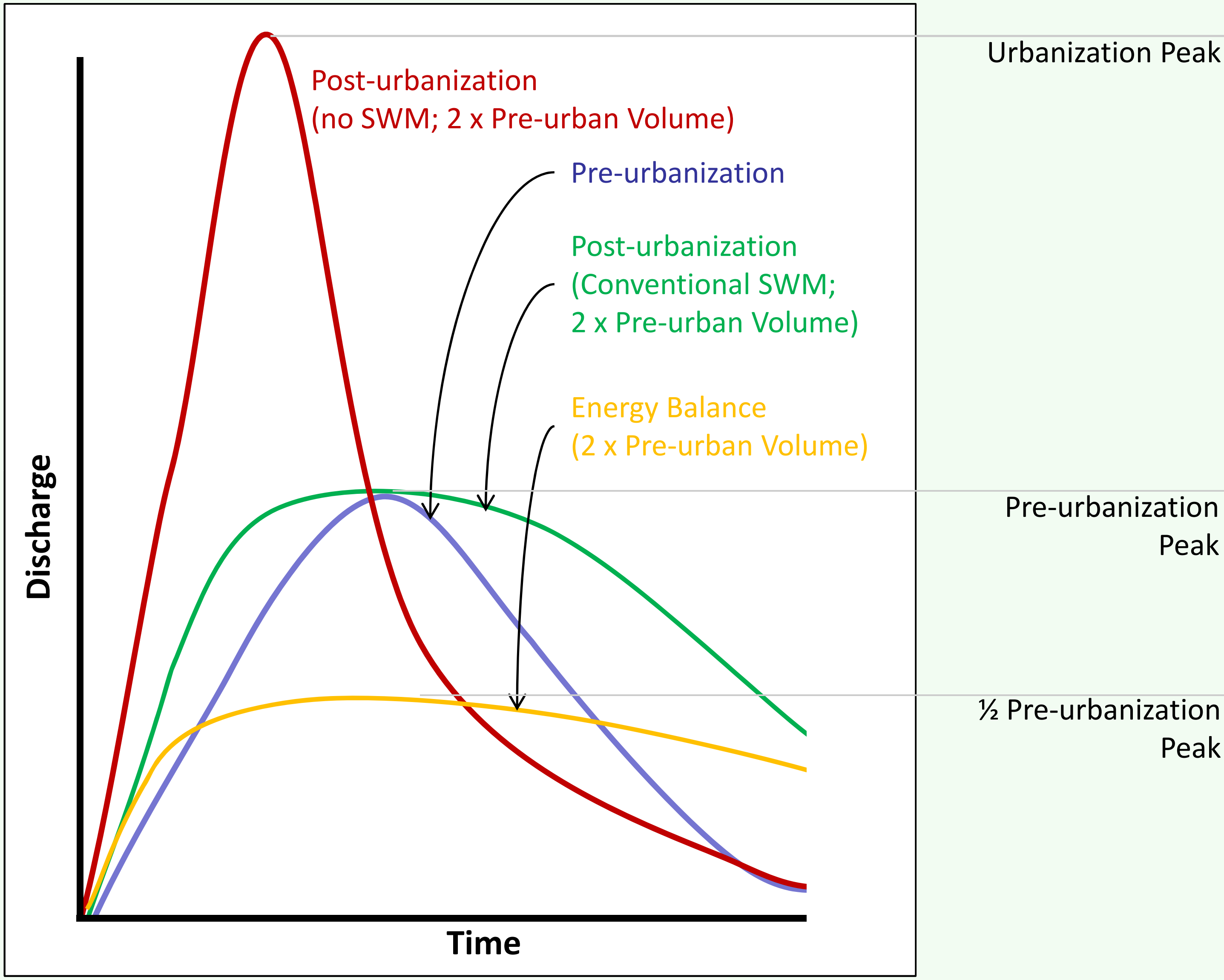
Energy Balance

The theory behind 4VAC50-60-66.B

Assume: $RV_{post} = 2*RV_{pre}$



Energy Balance

The theory behind 4VAC50-60-66.B

Restored conveyance system

Energy Balance Method:

Allowable 1-yr, 24-hr peak flow rate:

$Q_{developed} \leq I.F. \times Q_{pre\text{-}developed} \times RV_{pre\text{-}developed} / RV_{developed}$

$Q_{developed}$ shall not be required to be less than $[Q_{forested} \times RV_{forested}] / Rv_{developed}$

$Q_{developed}$ must be $\leq Q_{pre\text{-}developed}$

Where:

- Q = Peak flow rate of runoff
- RV = Volume of runoff
- Improvement Factor (I.F.) = 0.8 for sites > 1 ac
0.9 for sites ≤ 1 ac
- Pre-developed = conditions prior to development, not pre-colonial conditions

Natural conveyance system

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Quantity Control

4VAC50-60-66

4VAC50-60-66 defines requirements for three outfall conditions:

1. **Manmade conveyance systems**
   1. Convey the 2-year, 24-hour storm (after SWM) without erosion, OR
   2. Allowable 1-yr, 24-hr peak flow rate for all conditions (see below)

2. **Restored conveyance systems**
   1. Discharge was considered in the design of the restored system, OR
   2. Allowable 1-yr, 24-hr peak flow rate for all conditions (see below)

3. **Natural conveyance systems**
   1. Allowable 1-yr, 24-hr peak flow rate for all conditions (see below)

- $Q_{developed} \leq IF \times Q_{pre\text{-}developed} \times RV_{pre\text{-}developed} / RV_{developed}$
- $Q_{developed}$ shall not be required to be less than $[Q_{forested} \times RV_{forested}] / Rv_{developed}$
- $Q_{developed}$ must be $\leq Q_{pre\text{-}developed}$

Where:

- Q = Peak flow rate of runoff
- RV = Volume of runoff
- Improvement Factor (IF) = 0.8 for sites > 1 ac; 0.9 for sites $\leq$ 1 ac
- Pre-developed = conditions prior to development, not pre-colonial conditions

Quantity Control - cont.

Limits of Analysis (4VAC50-60-66.B.4)

Stormwater conveyance systems shall be analyzed for channel protection to a point where either one of the following is satisfied:

1. Based on area
   Prior to any land disturbance, the site's contributing drainage area to site discharge point is ≤ 1.0% of total watershed area draining to that point of discharge, or

2. Based on peak flow rate
   Based on peak flow rate, the site's peak flow rate from the one-year 24-hour storm is less than or equal to 1.0% of the existing peak flow rate from the one-year 24-hour storm prior to the implementation of any stormwater quantity control measures.

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Quantity Control

Flood Protection (4VAC50-60-66.C)

1. For stormwater conveyance systems that currently **do not experience localized flooding** during the 10-year, 24-hour storm event:

   a) Confine the post-development peak flow rate from the 10-year, 24-hour storm event within the stormwater conveyance system.

1. For stormwater conveyance systems that currently **do experience localized flooding** during the 10-year, 24-hour storm event:

   a) Confine the post-development peak flow rate from the 10-year, 24-hour storm event within the stormwater conveyance system; or

   b) Release a post-development peak flow rate for the 10-year, 24-hour storm event that is less than the pre-development peak flow rate from the 10-year, 24-hour storm event.

Note:

- **1a and 2a are the same**
- **Likely localities will be stricter, as many are already**

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Flood Protection Definitions

4VAC50-60-66.C

* 4VAC50-60-10. Definitions:

"Stormwater conveyance system“ means a combination of drainage components that are used to convey stormwater discharge, either within or downstream of the land-disturbing activity. This includes:
1. "**Manmade stormwater conveyance system**" means a pipe, ditch, vegetated swale, or other stormwater conveyance system constructed by man except for restored stormwater conveyance systems;
2. "**Natural stormwater conveyance system**" means the main channel of a natural stream and the flood-prone area adjacent to the main channel; or
3. "**Restored stormwater conveyance system**" means a stormwater conveyance system that has been designed and constructed using natural channel design concepts. Restored stormwater conveyance systems include the main channel and the flood-prone area adjacent to the main channel.

"Flood-prone area" means the component of a natural or restored stormwater conveyance system that is outside the main channel. Flood-prone areas may include, but are not limited to, the floodplain, the floodway, the flood fringe, wetlands, riparian buffers or other areas adjacent to the main channel.

"Floodplain" means the area adjacent to a channel, river, stream, or other water body that is susceptible to being inundated by water associated with the 100-year flood or storm event. This includes, but is not limited to, the floodplain designated by the Federal Emergency Management Agency.

"Floodway" means the channel of a river or other watercourse and the adjacent land areas, usually associated with flowing water, that must be reserved in order to discharge the 100-year flood or storm event without cumulatively increasing the water surface elevation more than one foot. This includes, but is not limited to, the floodway designated by the Federal Emergency Management Agency.

"Flood fringe" means the portion of the floodplain outside the floodway that is usually covered with water from the 100-year flood or storm event. This includes, but is not limited to, the flood or floodway fringe designated by the Federal Emergency Management Agency.

Quantity Control

Summary- What does this mean for the private sector?

- Requires the Energy Balance of the 1-year, 24-hour storm with an improvement factor and no increase in 10-year peak flows, rather than conventional 2- and 10-year peak flow analysis;
- **No longer requires Adequate Outfall (MS-19) – Unless locality says otherwise**
  4VAC50-60-66.A: *“Compliance with the minimum standards set out in this section shall be deemed to satisfy the requirements of 4VAC50-30-40.19”*
- Pond footprints will typically be similar (±15%) because the 10-year Flood Protection governs the overall size (which matches most current requirements);
- The size of the 2-year orifice will be reduced to meet 1-year Energy Balance requirement; and
- The 1-year detention volume will usually be greater than the current 2-year volume requirement.

The regulations will result in the more effective use of SWM facilities to protect streams and reduce erosion/sediment at minimal cost.

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Offsite Compliance Options (Nutrient Trading)

(Source: Nutrient Credit Trading for the Chesapeake Bay, An Economic Study)

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Offsite Compliance

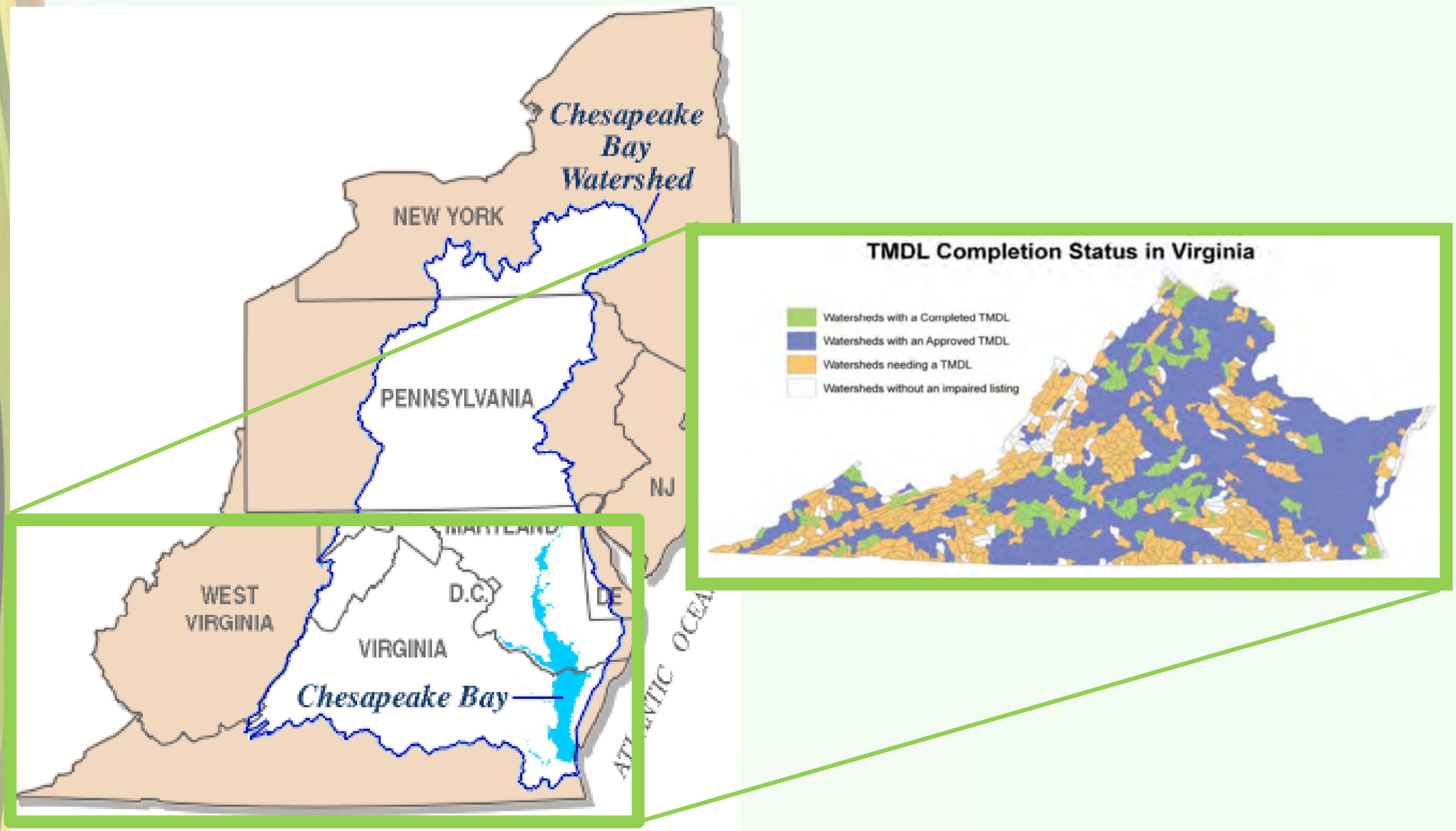
4VAC50-60-69

- Off-site compliance options include:
  - Adopted comprehensive SW management plan in local watershed of project
  - Locality pollutant loading pro rata share program
  - Nonpoint nutrient offset program established by VA Code
  - Other options approved by applicable state agency or board
  - Other properties within same or upstream HUC can be used to meet project TP reductions

- Offsite compliance options must meet only one of the following:
  - At least 75% of required phosphorus nutrient reductions are achieved on-site;
  - < 5 acres of land will be disturbed; or
  - Post construction phosphorus control requirement is < 10 pounds per year.

Localities may desire restrictions to prevent local water quality degradation

SWM Regulations, Impaired Waters, and TMDLs



Chesapeake Bay Watershed

VA Stormwater Management Regulation

What is connection to TMDL/impaired waters list?

- Stormwater Pollution Prevention Plan (SWPPP) must comply with TMDLs/impaired waters
  - **4VAC50-60-54.A**: "A stormwater pollution prevention plan shall include…a description of any additional control measures necessary to address a TMDL…"
  - **4VAC50-60-54.E**: "…if a specific WLA for a pollutant has been established in a TMDL and is assigned to stormwater discharges from a construction activity, additional control measures must be identified and implemented by the operator so that discharges are consistent with the assumptions and requirements of the WLA in a State Water Control Board approved TMDL."
  - **4VAC50-60-1170.1.B.5**: "Impaired waters limitation. Discharges to waters that have been identified as impaired…are not eligible for coverage under this permit unless the operator implements strategies and control measures consistent with…"

Note: *New permit language is changing these references*

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VA Stormwater Management Regulation

What is connection to TMDL/impaired waters list?

- Water quality requirements **comply with Bay TMDL**
  - Virginia Phase I WIP: "Allocations for newly developed land will be set at a level that results in **no increase above 2025 average nutrient loads per acre from previous uses**; unless offsets are obtained in the event on-site controls will not fully achieve allowable loads."
  - By satisfying VA SWM regulations, it is assumed (Yikes!) that you comply with Bay TMDL requirements.
- Bay WIP is "silent" on sediment for stormwater
  - VSMP in RAP is expected to provide conditions that meet Bay TMDL for TP, TN and TSS.

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VA Stormwater Management Regulation

SWPPP compliance with all other TMDLs/impaired waters

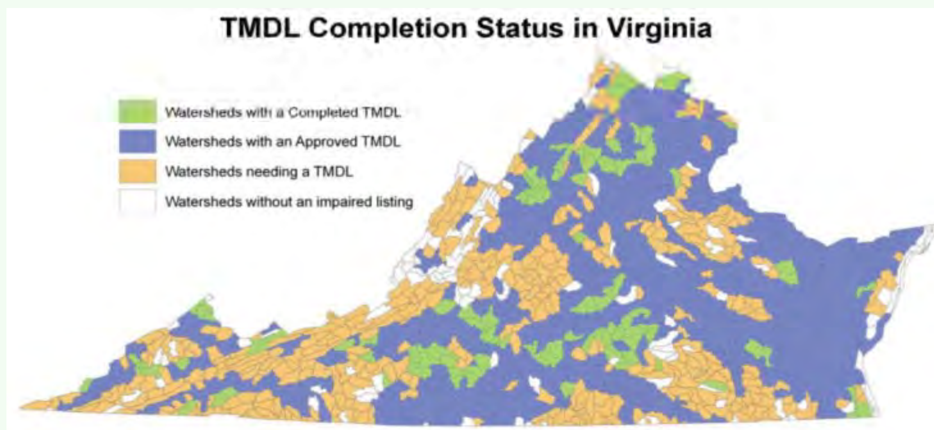
- Current problem: No easy way to determine if site is covered by TMDL/impaired water nor what is expected
  - DEQ and DCR – draft maps available online
  - Draft Construction General Permit regulations use enhanced inspection program to meet TMDL/impaired water requirements

- Interactive GIS maps, shapefiles, and reports will be available for all Virginia TMDLs
  - VEGIS (Virginia Environmental Geographic Information Systems): http://www.deq.virginia.gov/ConnectWithDEQ/VEGIS.aspx
  - http://www.deq.virginia.gov/programs/water/waterqualityinformationtmdls/waterqualityassessments/2012305b303dintegratedreport.aspx

- TMDLs "overlap" with Bay TMDL and may be more stringent (especially TSS)

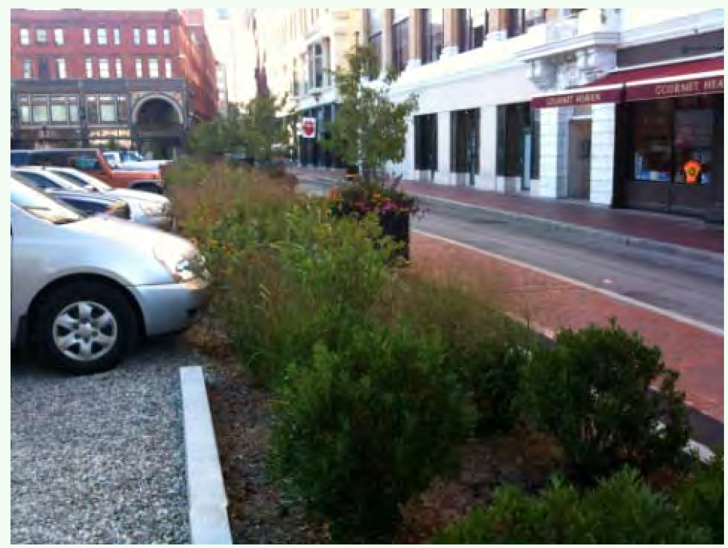
- Currently no enforcement of these TMDLs but there will be after 7/1/2014

This issue is being solved in the GP going to the SWCB on 2/26/13



Virginia TMDL status in December 2011
Source: Draft 2012 305(b)/303(d) Water Quality Assessment Integrated Report

Local Implementation



VA Stormwater Management Regulation

Status of County Implementation

- Implementation of Virginia Stormwater Management Regulations will be at local level
- Counties must take over reviews and inspections for Virginia Stormwater Management Program (VSMP) general permits
- Online from DCR with local approval
- Local county implementation status:

Fairfax County

- **Status**

Currently preparing a draft Ordinance (will be available at: *http://www.fairfaxcounty.gov/dpwes/stormwaterordinance.htm*)

- **Timeline:**
  - **Fall 2012**: Stakeholder meetings and small group work sessions to guide ordinance development
  - **Early 2013**: Large Stakeholder Meetings
  - **February 2013**: Preliminary submission package to DCR
  - **July 2013**: Planning Commission Hearing
  - **December 2013**: Board Hearing and Adoption

Loudoun County

- **Status**

County staff team organized and working towards progress submittal to DCR

- **Timeline:**
  - **April 1, 2013**: Progress submittal to DCR with: ID of authority to accept registration statements; draft of ordinance; and draft staffing and funding plan
  - FSM to follow

Prince William County

- **Status**

County will have one ordinance (including Bay, SW, and E&S); based off of Model Ordinance

- **Timeline:**
  - **January 2013**: Board of Supervisors approved County staff recommendation to proceed
  - **2013**: Stakeholder meeting(s) to guide DCSM

VA Stormwater Management Regulation

County Implementation Concerns, Regs allow for more stringent local standards

- **Adequate outfall requirements** (*4VAC50-60-66.A*)
    - Is a defined channel required?
        - Fairfax County wants defined channel
        - EPA NPDES General Permit says opposite
            - "…if necessary to prevent erosion caused by stormwater flows within the buffer, you must use velocity dissipation devices…construction operators typically will use devices that physically **dissipate stormwater flows so that the discharge is spread out and slowed down.**" (Appendix G, pg. G-7)

- **Flood protection** (*4VAC50-60-66.C* ; slide 15)
    - Only on 10 year vs. 100 year
    - No requirement to improve problems

- **LID practices on private property**
    - Inspection and maintenance
        - Who inspects and maintains?
        - What if LID is removed in the future? or fails?

      OR

    - Overdesign and assume that some will fail/be removed?

Downspout disconnection and Infiltration trench
Source: DCR Stormwater Design Spec No. 8

- **Nutrient trading**
    - Localities may desire restrictions to prevent local water quality degradation

HB 2190 Stringency of SWM Ordinances

- Requires localities to gain appeal of the Department of Conservation and Recreation when a more stringent stormwater management ordinance or stormwater requirements are developed by the localities.

- Localities are prohibited from limiting the use of best management practices approved by the Director of the Department of Conservation and Recreation or the Virginia Soil and Water Conservation Board, except under limited conditions:
  - Site specific limitations are allowed
  - Jurisdiction wide or geographic area restrictions only allowed if the Department or Board deems them to the reasonable.

STATUS – as of 2/16/13:

- Passed the House 77-26
- Passed Senate Committee (Agriculture, Conservation and Natural Resources) 12-3 with substitute
- Goes to Senate Floor
- Substitute Bill being negotiated
- If passed, goes back to House for Reconciliation

Wetland Studies and Solutions, Inc.®

Questions?

Hurricane Sandy damage in Belmar, NJ (Source: Tim Larson – New Jersey governor's office)

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The Virginia Stormwater BMP Clearinghouse

Virginia Stormwater BMP Clearinghouse

4VAC50-60-65.B

Administered by DCR and the Virginia Water Resources Research Center at Virginia Tech, and overseen by a stakeholders' committee

Purpose:

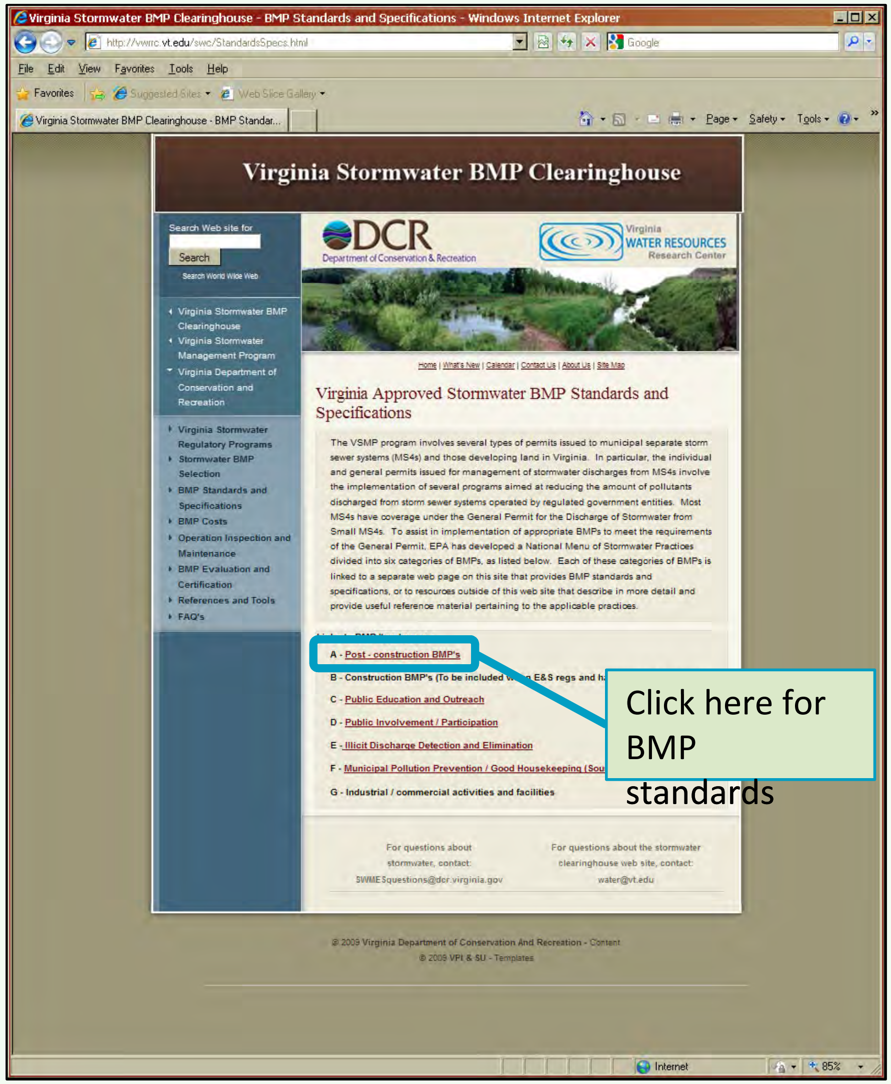
- To disseminate design standards and specifications for all stormwater BMPs approved for use in Virginia;
- To disseminate the evaluation and performance certification of proprietary BMPs approved for use in Virginia; and
- To provide information and links to related websites.

4VAC50-60-65.B: "The BMPs listed in this subsection are approved for use as necessary to effectively reduce the phosphorus load and runoff volume in accordance with the Virginia Runoff Reduction Method. Other approved BMPs found on the Virginia Stormwater BMP Clearinghouse Website at http://www.vwrrc.vt.edu/swc may also be utilized. Design specifications and the pollutant removal efficiencies for all approved BMPs are found on the Virginia Stormwater BMP Clearinghouse Website at http://www.vwrrc.vt.edu/swc."

Virginia Stormwater BMP Clearinghouse

http://vwrrc.vt.edu/swc/StandardsSpecs.html

Website Screenshot



Click here for BMP standards

Virginia Stormwater BMP Clearinghouse

Runoff Reduction and Nutrient Removal Comparison

Two design levels:

Level 1

- Typically less strict design requirements;
- Typically lower runoff reduction; and
- Typically lower EMC removal.

Level 2

- Typically stricter design requirements;
- Typically higher runoff reduction; and
- Typically higher EMC removal.

Table 1. Comparative Runoff Reduction and Nutrient Removal for Practices

Practice	Design Level	Runoff Reduction	TN EMC Removal[3]	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal[6]
Rooftop Disconnect	1 [2]	25 to 50 [1]	0	25 to 50 [1]	0	25 to 50 [1]
		No Level 2 Design				
Sheet Flow to Veg. Filter or Conserv. Open Space	1	50	0	50	0	50
	2 [5]	50 to 75 [1]	0	50 to 75 [1]	0	50 to 75 [1]
Grass Channels	1	10 to 20 [1]	20	28 to 44 [1]	15	24 to 41 [1]
		No Level 2 Design				
Soil Compost Amendment	Can be used to Decrease Runoff Coefficient for Turf Cover at Site. See the design specs for Rooftop Disconnection, Sheet Flow to Vegetated Filter or Conserved Open Space, and Grass Channel					
Vegetated Roof	1	45	0	45	0	45
	2	60	0	60	0	60
Rainwater Harvesting	1	Up to 90 [3, 5]	0	Up to 90 [3, 5]	0	Up to 90 [3, 5]
		No Level 2 Design				
Permeable Pavement	1	45	25	59	25	59
	2	75	25	81	25	81
Infiltration Practices	1	50	15	57	25	63
	2	90	15	92	25	93
Bioretention Practices	1	40	40	64	25	55
	2	80	60	90	50	90
Urban Bioretention	1	40	40	64	25	55
		No Level 2 Design				
Dry Swales	1	40	25	55	20	52
	2	60	35	74	40	76
Wet Swales	1	0	25	25	20	20
	2	0	35	35	40	40
Filtering Practices	1	0	30	30	60	60
	2	0	45	45	65	65
Constructed Wetlands	1	0	25	25	50	50
	2	0	55	55	75	75
Wet Ponds	1	0	30 (20) [4]	30 (20) [4]	50 (45) [4]	50 (45) [4]
	2	0	40 (30) [4]	40 (30) [4]	75 (65) [4]	75 (65) [4]
Ext. Det. Ponds	1	0	10	10	15	15
	2	15	10	24	15	31

Virginia Stormwater BMP Clearinghouse

Specification No. 1: Impervious Surface Disconnection

What is it?

Eliminating direct connections between impervious surfaces and the storm sewer. May be a simple disconnection or a disconnection to an alternative practice.

Simple disconnection directs runoff to pervious areas, providing volume reduction but no additional nutrient removal.

Disconnection to alternative BMP may enhance removal rates. Alternative BMPs include:

- Compost-amended soil;
- Dry well or French drain;
- Rain garden;
- Cistern; or
- Stormwater planters

Impervious surface disconnection
Source: DCR Stormwater Design Spec No. 1

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Impervious Surface Disconnection	1	25 to 50	0	25 to 50	0	25 to 50
	No Level 2 Design					

Virginia Stormwater BMP Clearinghouse

Specification No. 1: Impervious Surface Disconnection (cont.)

Stormwater Functions Summary

Table 1.1. Summary of Stormwater Functions Provided by Rooftop Disconnection[1]

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 RRM 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 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 No.	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 (Appendix A)	40%

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

Design Criteria

Table 1.2: Simple Rooftop Disconnection Design Criteria[1]

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.

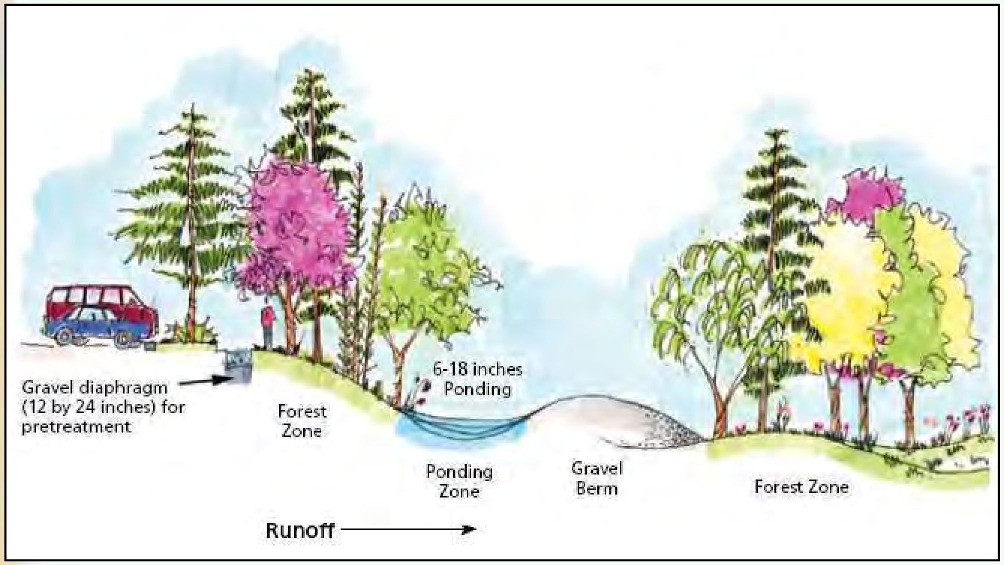
[4] Note that the downspout extension of 5 feet is intended for simple foundations. The use of a dry well or french drain adjacent to an in-ground basement or finished floor area should be carefully designed and coordinated with the design of the structure's water-proofing system (foundation drains,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

Virginia Stormwater BMP Clearinghouse

Specification No. 2: Sheet Flow

What is it?

Direct sheet flow to conserved open space (to protect vegetated areas adjacent to streams) or to vegetated filter strips (to treat small impervious areas or as pretreatment for another practice).



Typical sheet flow to open space DCR Stormwater Design Spec No. 2

Sheet flow to open space
Source: DCR Stormwater Design Spec No. 2

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Sheet Flow to Vegetated Filter or Conserved Open Space	1	50	0	50	0	50
	2	50 to 75	0	50 to 75	0	50 to 75

Virginia Stormwater BMP Clearinghouse

Specification No. 2: Sheet Flow (cont.)

Stormwater Functions Summary

Table 2.1: Summary of Stormwater Functions Provided by Filter Strips [1]

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 RRM 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.

Design Criteria

Table 2.2. Filter Strip Design Criteria

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 lni.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.

Virginia Stormwater BMP Clearinghouse

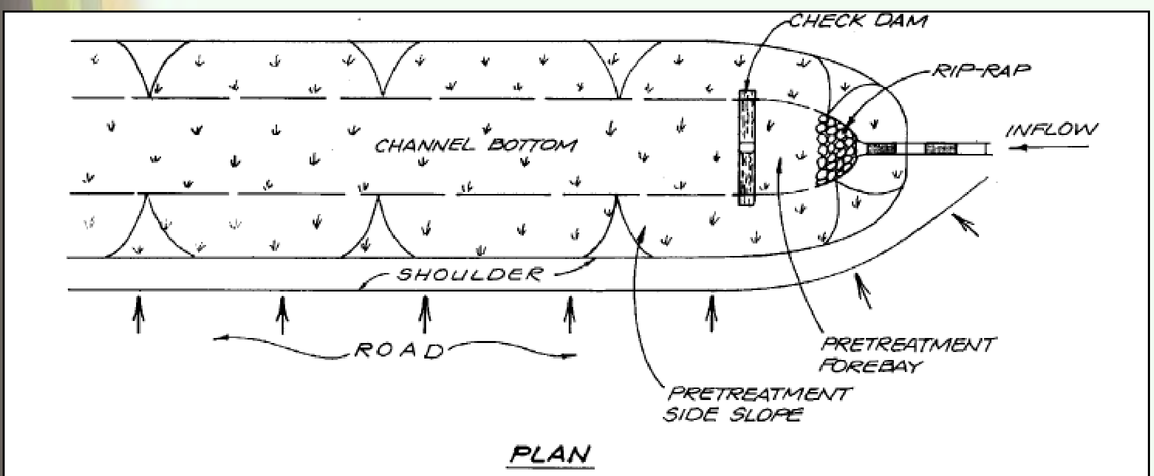
Specification No. 3: Grass Channels

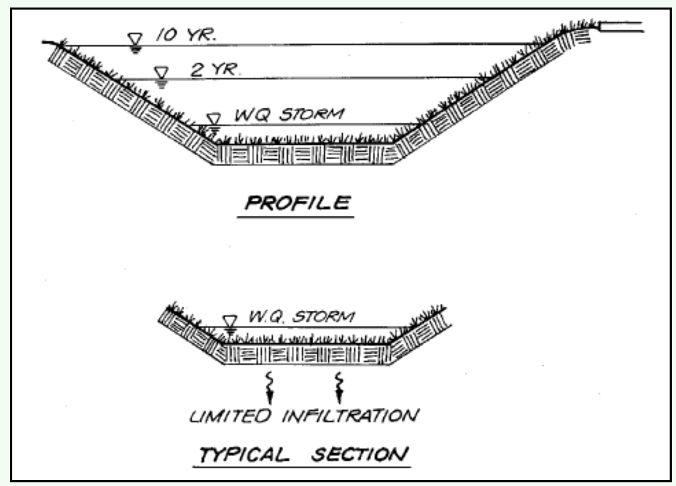
What is it?

Grass-lined conveyance channels to treat runoff from:

- Highways;
- Low- to medium-density residential yards;
- Driveways;
- Ball fields; and
- Small commercial parking areas.

Grass Channel
Source: DCR Stormwater Design Spec No. 3





Grass channel, typical plan and section views
DCR Stormwater Design Spec No. 3

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Grass Channels	1	10 to 20	20	50 to 75	15	24 to 41
	No Level 2 Design					

Virginia Stormwater BMP Clearinghouse

Specification No. 3: Grass Channels (cont.)

Stormwater Functions Summary

Table 3.1. Summary of Stormwater Functions Provided by Grass Channels [1]

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*).

Design Criteria

Table 3.2. Grass Channel Design Guidance

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).

Virginia Stormwater BMP Clearinghouse

Specification No. 4: Soil Compost Amendment

What is it?

Soil may be amended with compost to:

- Reduce runoff from compacted lawns;
- Enhance rooftop disconnections;
- Enhance grass channels;
- Enhance vegetated filter strips; and
- Enhance reforestation areas.

Amendment is not recommended when:

- Existing soils have high infiltration rates;
- The water table or bedrock is within 1.5’ of the soil surface;
- Existing soils are saturated or seasonally wet;
- Amendments would harm the roots of existing trees;
- The downhill slope runs toward a foundation; or
- The contributing impervious surface is larger than the surface area of the amended soils.

Soil compost amendment
Source: DCR Stormwater Design Spec No. 4

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Soil Compost Amendment	Can be used to decrease the runoff coefficient for turf cover at the site. See the design specs for Rooftop Disconnection, Sheet Flow to Vegetated Filter or Conserved Open Space, and Grass Channel.					

Virginia Stormwater BMP Clearinghouse

Specification No. 4: Soil Compost Amendment (cont.)

Stormwater Functions Summary

Table 4.1: Stormwater Functions of Soil Compost Amendments [1]

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, 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 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.

Runoff Coefficients

Table 4.2. Runoff Coefficients for Use for Different Pervious Areas

Hydrologic Soil Group	Undisturbed Soils [1]	Disturbed Soils [2]	Restored and Reforested [3]
A	0.02	0.15	0.02
B	0.03	0.20	0.03
C	0.04	0.22	0.04
D	0.05	0.25	0.05

Notes:
[1] Portions of a new development site, outside the limits of disturbance, which are not graded and do not receive construction traffic.
[2] Previously developed sites, and any site area inside the limits of disturbance as shown on the E&S Control plan.
[3] Areas with restored soils that are also reforested to achieve a minimum 75% forest canopy

Compost Depths

Table 4.3. Short-Cut Method to Determine Compost and Incorporation Depths

	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
[4] Average depth of compost added
[5] Lower end for B soils, higher end for C/D soils

Virginia Stormwater BMP Clearinghouse

Specification No. 5: Vegetated Roof

What is it?

A rooftop covered with soil media and plants. May be:

- *Extensive* with shallow soil and a limited plant palette; or
- *Intensive* with deep soil and a wide plant palette.

Vegetated roofs are recommended for non-residential, multi-family, and mixed-use buildings.

Green roof at WSSI
Source: Wetland Studies and Solutions, Inc.

Green roof at Fairfax County Government Center parking structure
Source: http://www.fairfaxcounty.gov/news/images/roof_garden_.jpg

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Vegetated Roof	1	45	0	45	0	45
	2	60	0	60	0	60

Virginia Stormwater BMP Clearinghouse

Specification No. 5: Vegetated Roof (cont.)

Stormwater Functions Summary

Table 5.1: Summary of Stormwater Functions Provided by Vegetated Roofs [1]

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)

Green roof at Sidwell Friends School
Source: http://www.sidwell.edu/about_sfs/environmental-stewardship/green-buildings/ms-green-building/index.aspx

Design Criteria

Table 5.2. Green Roof Design Guidance

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.	

Material Specifications

Table 5.4. Extensive Vegetated Roof Material Specifications

Material	Specification
Roof	Structural Capacity should conform to ASTM E-2397-05, *Practice for Determination of Live Loads and Dead Loads Associated with Green (Vegetated) Roof Systems*. In addition, use standard test methods ASTM E2398-05 for *Water Capture and Media Retention of Geocomposite Drain Layers for Green (Vegetated) Roof Systems*, and ASTME 2399-05 for *Maximum Media Density for Dead Load Analysis*.
Waterproof Membrane	See Chapter 6 of Weiler and Scholz-Barth (2009) for waterproofing options that are designed to convey water horizontally across the roof surface to drains or gutter. This layer may sometimes act as a root barrier.
Root Barrier	Impermeable liner that impedes root penetration of the membrane.
Drainage Layer	1 to 2 inch layer of clean, washed granular material, such as ASTM D 448 size No. 8 stone. Roof drains and emergency overflow should be designed in accordance with VUSBC.
Filter Fabric	Needled, non-woven, polypropylene geotextile. Density (ASTM D3776) > 16 oz./sq. yd., or approved equivalent. Puncture resistance (ASTM D4833) > 220 lbs., or approved equivalent.
Growth Media	80% lightweight inorganic materials and 20% organic matter (e.g. well-aged compost). Media should have a maximum water retention capacity of around 30%. Media should provide sufficient nutrients and water holding capacity to support the proposed plant materials. Determine acceptable saturated water permeability using ASTM E2396-05.
Plant Materials	Sedum, herbaceous plants, and perennial grasses that are shallow-rooted, self-sustaining, and tolerant of direct sunlight, drought, wind, and frost. See ASTM E2400-06, *Guide for Selection, Installation and Maintenance of Plants for Green (Vegetated) Roof Systems*.

Virginia Stormwater BMP Clearinghouse

Specification No. 6: Rainwater Harvesting

What is it?

Capturing roof runoff for non-potable interior and exterior uses. Note that:

- Credit is only given for dedicated year-round drawdown for the water.
- Irrigation will not receive credit without a secondary practice to treat water during the winter.
- A Virginia-specific amendment to the 2009 Uniform Statewide Building Code limits harvested water storage to 24 hours for irrigation and 72 hours for flushing water closets and urinals.

Underground rainwater harvesting cistern
Source: DCR Stormwater Design Spec No. 6

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Rainwater Harvesting	1	Up to 90	0	Up to 90	0	Up to 90
	No Level 2 Design					

Above-ground rainwater harvesting cistern at WSSI
Source: Wetland Studies and Solutions, Inc.

Virginia Stormwater BMP Clearinghouse

Specification No. 6: Rainwater Harvesting (cont.)

Stormwater Functions Summary

Table 6.1: Summary of Stormwater Functions Provided by Rainwater Harvesting

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 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 practice.

[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%.

Material Considerations

Table 6.2. Advantages and Disadvantages of Various Cistern Materials

Tank Material	Advantages	Disadvantages
Fiberglass	Commercially available, alterable and moveable; durable with little maintenance; light weight; integral fittings (no leaks); broad application	Must be installed on smooth, solid, level footing; pressure proof for below-ground installation; expensive in smaller sizes
Polyethylene	Commercially available, alterable, moveable, affordable; available in wide range of sizes; can install above or below ground; little maintenance; broad application	Can be UV-degradable; must be painted or tinted for above-ground installations; pressure-proof for below-ground installation
Modular Storage	Can modify to topography; can alter footprint and create various shapes to fit site; relatively inexpensive	Longevity may be less than other materials; higher risk of puncturing of water tight membrane during construction
Plastic Barrels	Commercially available; inexpensive	Low storage capacity (20 to 50 gallons); limited application
Galvanized Steel	Commercially available, alterable and moveable; available in a range of sizes; film develops inside to prevent corrosion	Possible external corrosion and rust; must be lined for potable use; can only install above ground; soil pH may limit underground applications
Steel Drums	Commercially available, alterable and moveable	Small storage capacity; prone to corrosion, and rust can lead to leaching of metals; verify prior to reuse for toxics; water pH and soil pH may also limit applications
FerroConcrete	Durable and immoveable; suitable for above or below ground installations; neutralizes acid rain	Potential to crack and leak; expensive
Cast in Place Concrete	Durable, immoveable, versatile; suitable for above or below ground installations; neutralizes acid rain	Potential to crack and leak; permanent; will need to provide adequate platform and design for placement in clay soils
Stone or concrete Block	Durable and immoveable; keeps water cool in summer months	Difficult to maintain; expensive to build

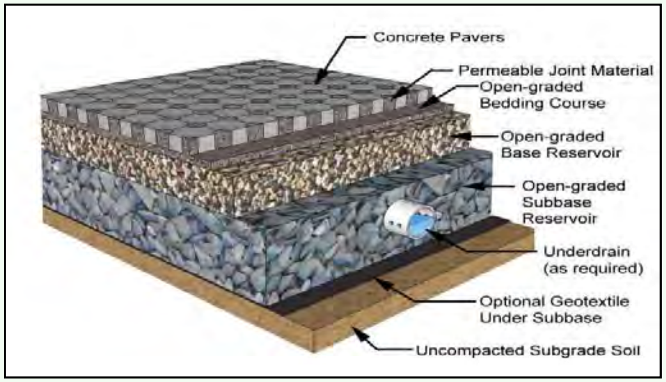
Source: Cabell Brand, 2007, 2009

Virginia Stormwater BMP Clearinghouse

Specification No. 7: Permeable Pavement

What is it?

Alternative paving surface that allows water to filter through a permeable top layer into a gravel reservoir for temporary storage and/or infiltration. May replace impervious surfaces on commercial, institutional, and residential sites.



Typical permeable paver section
DCR Stormwater Design Spec No. 7

Permeable pavers (brick) at the Virginia Capitol Building
Source: Wetland Studies and Solutions, Inc.

Permeable pavers (concrete) at WSSI
Source: Wetland Studies and Solutions, Inc.

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Permeable Pavement	1	45	25	59	25	59
	2	75	25	81	25	81

Virginia Stormwater BMP Clearinghouse

Specification No. 7: Permeable Pavement (cont.)

Stormwater Functions Summary

Table 7.1. Summary of Stormwater Functions Provided by Permeable Pavement

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

Design Criteria

Table 7.3. Permeable Pavement Design Criteria

Level 1 Design	Level 2 Design
Tv = (1)(Rv)(A) / 12 – the volume reduced by an upstream BMP [1]	Tv = (1.1)(Rv)(A) / 12
Soil infiltration is less than 0.5 in./hr.	Soil infiltration rate exceeds 0.5 in./hr.
Underdrain required	Underdrain not required; ***OR*** If an underdrain is used, a 12-inch stone sump must be provided below the underdrain invert; ***OR*** The Tv has at least a 48-hour drain time, as regulated by a control structure.
CDA = 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, to avoid sediment wash-on, and sediment source controls and/or a pre-treatment strip or sump should be used. When pervious areas are conveyed to permeable pavement, pre-treatment must be provided, and the pre-treatment may qualify for a runoff reduction credit.

Material Specifications

Table 7.2. Comparative Properties of the Three Major Permeable Pavement Types

Design Factor	Porous Concrete (PC)	Porous Asphalt (PA)	Interlocking Pavers (IP)
Scale of Application	Small and large scale paving applications	Small and large scale paving applications	Micro, small and large scale paving applications
Pavement Thickness [1]	5 to 8 inches	3 to 4 inches	3 inches [1, 8]
Bedding Layer [1, 8]	None	2 inches No. 57 stone	2 inches of No. 8 stone
Reservoir Layer [2, 8]	No. 57 stone	No. 2 stone	No. 2 stone 3-4 inches of No.57 stone
Construction Properties [3]	Cast in place, seven day cure, must be covered	Cast in place, 24 hour cure	No cure period; manual or mechanical installation of pre-manufactured units, over 5000 sf/day per machine
Design Permeability [4]	10 feet/day	6 feet/day	2 feet/day
Construction Cost [5]	$ 2.00 to $6.50/sq. ft.	$ 0.50 to $1.00/ sq. ft.	$ 5.00 to $ 10.00/ sq. ft.
Min. Batch Size	500 sq. ft.		NA
Longevity [6]	20 to 30 years	15 to 20 years	20 to 30 years
Overflow	Drop inlet or overflow edge	Drop inlet or overflow edge	Surface, drop inlet or overflow edge
Temperature Reduction	Cooling in the reservoir layer	Cooling in the reservoir layer	Cooling at the pavement surface & reservoir layer
Colors/Texture	Limited range of colors and textures	Black or dark grey color	Wide range of colors, textures, and patterns
Traffic Bearing Capacity [7]	Can handle all traffic loads, with appropriate bedding layer design.		
Surface Clogging	Replace paved areas or install drop inlet	Replace paved areas or install drop inlet	Replace permeable stone jointing materials
Other Issues		Avoid seal coating	Snowplow damage
Design Reference	American Concrete Institute # 522.1.08	Jackson (2007) NAPA	Smith (2006) ICPI

[1] Individual designs may depart from these typical cross-sections, due to site, traffic and design conditions.
[2] Reservoir storage may be augmented by corrugated metal pipes, plastic arch pipe, or plastic lattice blocks.
[3] ICPI (2008)
[4] NVRA (2008)
[5] WERF 2005 as updated by NVRA (2008)
[6] Based on pavement being maintained properly, Resurfacing or rehabilitation may be needed after the indicated period.
[7] Depends primarily on on-site geotechnical considerations and structural design computations.
[8] Stone sizes correspond to ASTM D 448: *Standard Classification for Sizes of Aggregate for Road and Bridge Construction.*

Virginia Stormwater BMP Clearinghouse

Specification No. 7: Permeable Pavement (cont.)

Pervious Concrete at WSSI

Porous Asphalt at WSSI

Virginia Stormwater BMP Clearinghouse

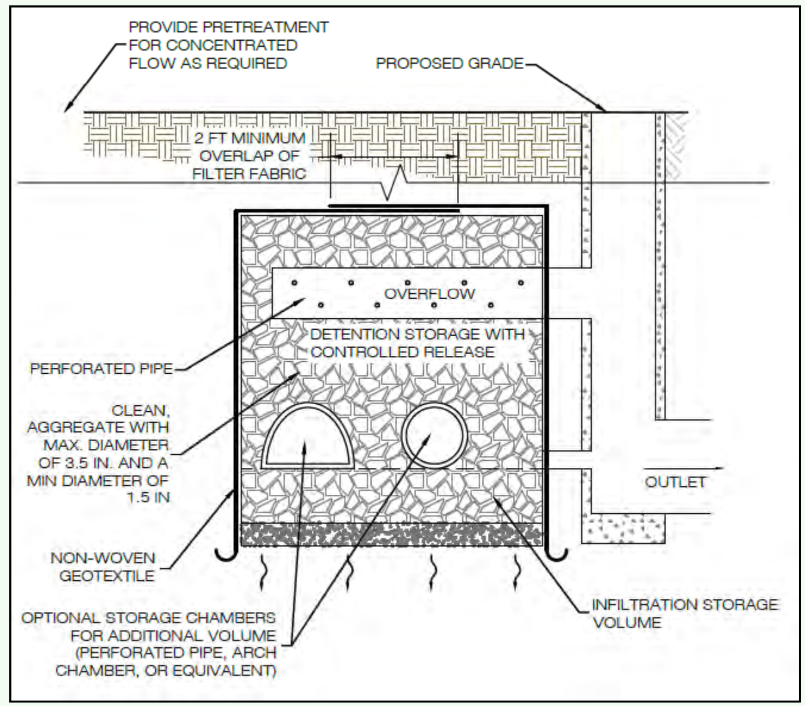
Specification No. 8: Infiltration Practices

What is it?

Temporary surface or below-grade storage to detain and infiltrate runoff into the in-situ soil.

Has the greatest runoff reduction potential of all BMPs, but measured infiltration rates must be greater than 0.5 inches per hour.

Infiltration trench
Source: DCR Stormwater Design Spec No. 8

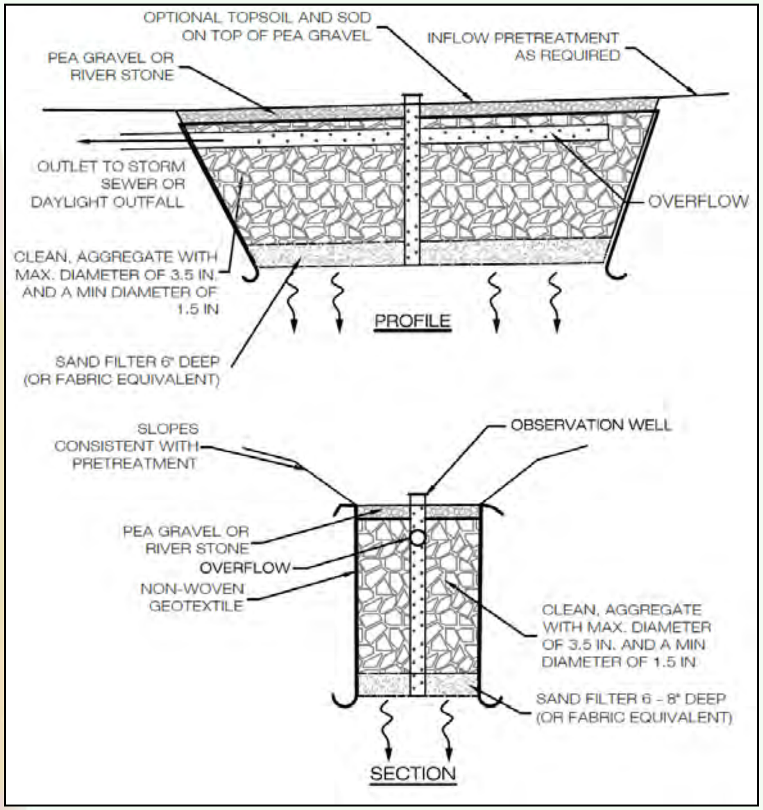


Infiltration with storage chambers, typical section view
DCR Stormwater Design Spec No. 8

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Infiltration Practices	1	50	15	57	25	63
	2	90	15	92	25	93

Virginia Stormwater BMP Clearinghouse

Specification No. 8: Infiltration Practices (cont.)



Infiltration trench typical profile and section views
DCR Stormwater Design Spec No. 8

*Note that this design specification does not define a maximum allowable infiltration rate, but the VSMH requires an infiltration rate between 0.52 and 8.27 in/hr. (See VSMH Standard 3.10.)

Stormwater Functions Summary

Table 8.1. Summary of Stormwater Functions Provided by Infiltration

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 RRM 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).
Sources: CWP and CSN (2008), and CWP (2007)

Design Criteria

Table 8.2. Level 1 and Level 2 Infiltration Design Guidelines

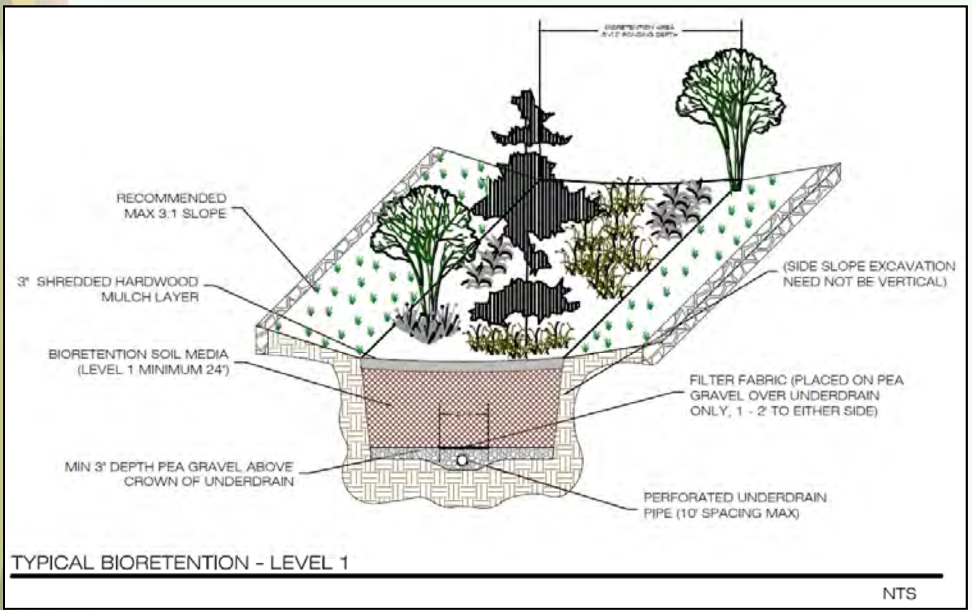
Level 1 Design (RR:50; TP:25; TN:15)	Level 2 Design (RR:90; TP:25; TN:15)
<u>Sizing:</u> $T_v = [(Rv)(A)/12]$ – the volume reduced by an upstream BMP	<u>Sizing:</u> $T_v = [1.1(Rv)(A)/12]$ – the volume reduced by an upstream BMP
At least two forms of pre-treatment (see **Table 8.6**)	At least three forms 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 3)	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 8.3**)
Minimum of 2 feet between the bottom of the infiltration practice and the seasonal high water table or bedrock (**Section 4 5**)	
T_v infiltrates within 36 to 48 hours (**Section 6.6**)	
Building Setbacks – see **Table 8.3**	
All Designs are subject to hotspot runoff restrictions/prohibitions	

Virginia Stormwater BMP Clearinghouse

Specification No. 9: Bioretention Practices

What is it?

Shallow, depressed landscape feature that collects runoff and filters it through a sandy, engineered soil media. Bioretention provides evapotranspiration, infiltration, and storage.



Bioretention typical section view

DCR Stormwater Design Spec No. 9

Bioretention at WSSI
Source: Wetland Studies and Solutions, Inc.

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Bioretention Practices	1	40	40	64	25	55
	2	80	60	90	50	90

Virginia Stormwater BMP Clearinghouse

Specification No. 9: Bioretention Practices (cont.)

Stormwater Functions Summary

Table 9.1. Summary of Stormwater Functions Provided by Bioretention Basins

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

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

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

Material Considerations

Table 9.6. Bioretention Material Specifications

Material	Specification	Notes
Filter Media Composition	Filter Media to contain: • 85%-88% sand • 8%-12% soil fines • 3%-5% organic matter in the form of leaf compost	The volume of filter media based on 110% of the plan volume, to account for settling or compaction.
Filter Media Testing	P-Index range = 10-30, ***OR*** Between 7 and 21 mg/kg of P in the soil media. CECs greater than 10	The media must be procured from approved filter media vendors.
Mulch Layer	Use aged, shredded hardwood bark mulch	Lay a 2 to 3 inch layer on the surface of the filter bed.
Alternative Surface Cover	Use river stone or pea gravel, coir and jute matting, or turf cover.	Lay a 2 to 3 inch layer of to suppress weed growth.
Top Soil For Turf Cover	Loamy sand or sandy loam texture, with less than 5% clay content, pH corrected to between 6 and 7, and an organic matter content of at least 2%.	3 inch surface depth.
Geotextile/Liner	Use a non-woven geotextile fabric with a flow rate of > 110 gal./min./sq. ft. (e.g., Geotex 351 or equivalent)	Apply only to the sides and above the underdrain. For hotspots and certain karst sites only, use an appropriate liner on bottom.
Choking Layer	Lay a 2 to 4 inch layer of sand over a 2 inch layer of choker stone (typically #8 or #89 washed gravel), which is laid over the underdrain stone.	
Stone Jacket for Underdrain and/or Storage Layer	1 inch stone should be double-washed and clean and free of all fines (e.g., VDOT #57 stone).	12 inches for the underdrain; 12 to 18 inches for the stone storage layer, if needed
Underdrains, Cleanouts, and Observation Wells	Use 6 inch rigid schedule 40 PVC pipe (or equivalent corrugated HDPE for micro-bioretention), with 3/8-inch perforations at 6 inches on center; position each underdrain on a 1% or 2% slope located nor more than 20 feet from the next pipe.	Lay the perforated pipe under the length of the bioretention cell, and install non-perforated pipe as needed to connect with the storm drain system. Install T's and Y's as needed, depending on the underdrain configuration. Extend cleanout pipes to the surface with vented caps at the Ts and Ys.
Plant Materials	Plant one tree per 250 square feet (15 feet on-center, minimum 1 inch caliper). Shrubs a minimum of 30 inches high planted a minimum of 10 feet on-center. Plant ground cover plugs at 12 to 18 inches on-center; Plant container-grown plants at 18 to 24 inches on-center, depending on the initial plant size and how large it will grow.	Establish plant materials as specified in the landscaping plan and the recommended plant list. In general, plant spacing must be sufficient to ensure the plant material achieves 80% cover in the proposed planting areas within a 3-year period. If seed mixes are used, they should be from a qualified supplier, should be appropriate for stormwater basin applications, and should consist of native species (unless the seeding is to establish maintained turf).

Virginia Stormwater BMP Clearinghouse

Specification No. 9: Bioretention Practices (cont.)

DCR Specification No. 9 Design Criteria

Table 9.2. Micro-Bioretention (Rain Garden) Design Criteria[1]

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 21 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.

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Bioretention Practices	1	40	40	64	25	55
	2	80	60	90	50	90

Table 9.3. Bioretention Filter and Basin Design Criteria

Level 1 Design (RR 40 TP: 25)	Level 2 Design (RR: 80 TP: 50)
Sizing (**Section 6.1**): Surface Area (sq. ft.) = (T_v – the volume reduced by an upstream BMP) / Storage Depth [1]	Sizing (**Section 6.1**): Surface Area (sq. ft.) = [(1.25)(T_v) – the volume reduced by an upstream 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 21 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.

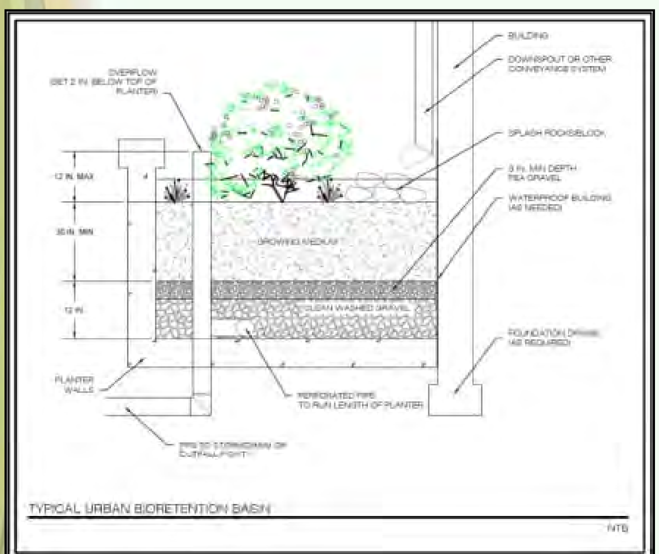
Virginia Stormwater BMP Clearinghouse

Specification No. 9A: Urban Bioretention

What is it?

Bioretention adapted to the ultra-urban climate, including:

- Stormwater planters;
- Extended tree pits; and
- Stormwater curb extensions



Stormwater planter typical section view
DCR Stormwater Design Spec No. 9A

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Urban Bioretention	1	40	40	64	25	55
	No Level 2 Design					

DCR Specification No. 10 Design Criteria

Table 9-A.2. Urban Bioretention Design Criteria

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)] – the volume reduced by an upstream BMP}/2
Underdrain = Schedule 40 PVC with clean-outs (Refer to the Main Bioretention Design Specification, **Section 9.8**)
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 9.8**)
Sub-soil testing (Refer to the Main Bioretention Design Specification, **Section 9.8**)
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 6.8**).

Stormwater planter
Source: DCR Stormwater Design Spec No. 9A

Stormwater curb extension
Source: DCR Stormwater Design Spec No. 9A

Virginia Stormwater BMP Clearinghouse

Specification No. 9A: Urban Bioretention (cont.)

Stormwater Functions Summary

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

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	40% (for Water Quality credit in the RRM 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*).

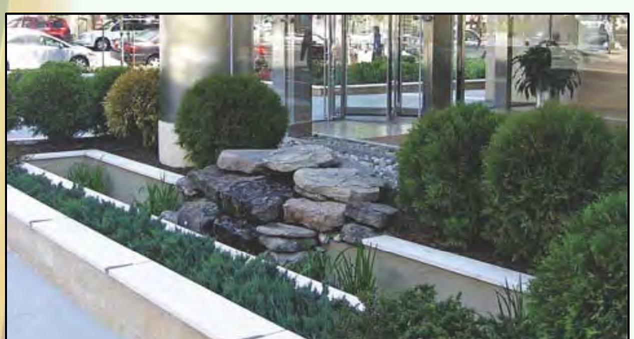
Sources: CWP and CSN (2008) and CWP (2007)

Urban bioretention in Richmond, VA
Source: Wetland Studies and Solutions, Inc.

Design Criteria

Table 9-A.2. Urban Bioretention Design Criteria

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)] – the volume reduced by an upstream BMP}/2
Underdrain = Schedule 40 PVC with clean-outs (Refer to the Main Bioretention Design Specification, **Section 9.8**)
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 9.8**)
Sub-soil testing (Refer to the Main Bioretention Design Specification, **Section 9.8**)
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 6.8**).



Urban bioretention in Washington, D.C.
Source: http://www.cenews.com/magazine-article-cenews.com-9-2009-civil_engineering_design__for_green_building-7592.html

Virginia Stormwater BMP Clearinghouse

Specification No. 10: Dry Swales

What is it?

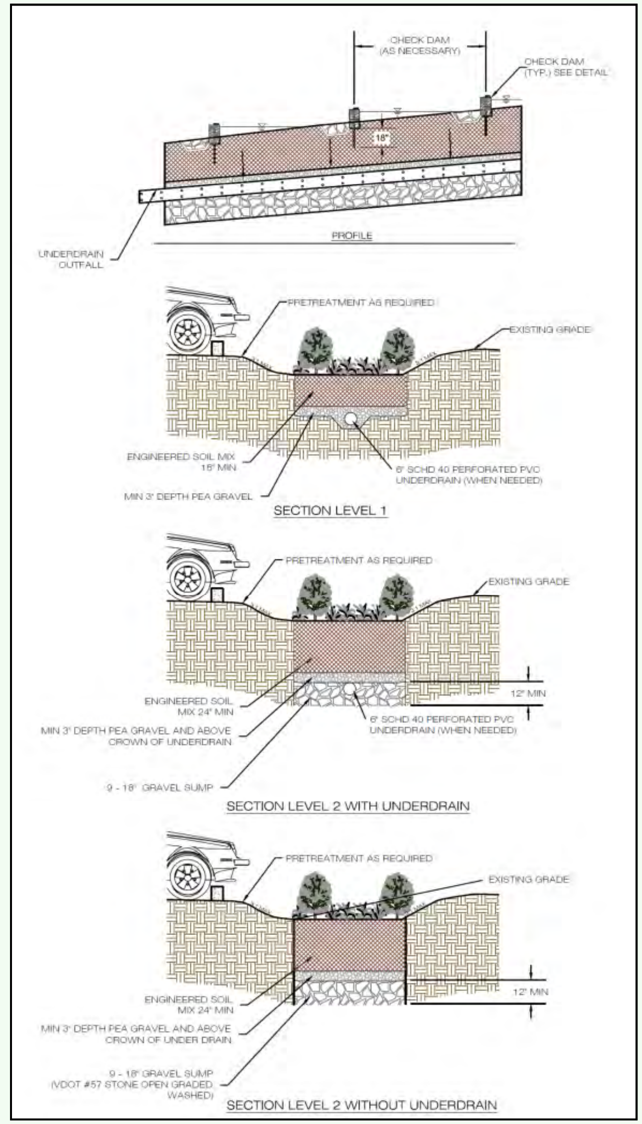
Shallow, linear, sloped bioretention that may be designed as:

- Conveyance swales to accept and convey sheet flow from linear watersheds such as roadways; or
- Treatment swales to accept and convey concentrated runoff from non-linear watersheds.

Dry swales differ from grass channels because they incorporate bioretention soil media.

Dry swale
Source: DCR Stormwater Design Spec No. 10

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Dry Swales	1	40	25	55	20	52
	2	60	35	74	40	76



Dry swale typical section views
DCR Stormwater Design Spec No. 10

Virginia Stormwater BMP Clearinghouse

Specification No. 10: Dry Swales (cont.)

Stormwater Functions Summary

Table 10.1. Summary of Stormwater Functions Provided by Dry Swales

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 RRM Design Spreadsheet to calculate the Cover 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).

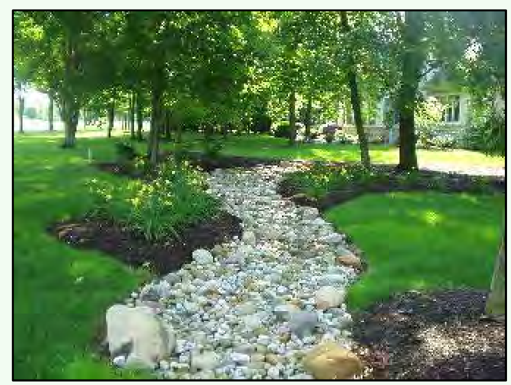
Sources: CWP and CSN (2008), CWP, 2007

Design Criteria

Table 10.2. Dry Swale Design Criteria

Level 1 Design (RR:40; TP:20; TN:25)	Level 2 Design (RR:60; TP:40; TN: 35)
Sizing (Sec. 5.1): Surface Area (sq. ft.) = (T_V – the volume reduced by an upstream BMP) / Storage depth [1]	Sizing (Sec. 5.1): Surface Area sq. ft.) = {(1.1)(T_V) – the volume reduced by an upstream BMP } / Storage Depth [1]
Effective swale slope ≤ 2%	Effective swale slope ≤ 1%
Media Depth: minimum = 18 inches; Recommended maximum = 36 inches	Media Depth minimum = 24 inches Recommended maximum = 36 inches
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;	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
Underdrain (**Section 6.7**): Schedule 40 PVC with clean-outs	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**)
Media (**Section 6.6**): supplied by the vendor; tested for an acceptable phosphorus index: P-Index between 10 and 30; ***OR*** Between 7 and 23 mg/kg of P in the soil media [2]	
Inflow: sheet or concentrated flow with appropriate pre-treatment	
Pre-Treatment (**Section 6.4**): a pretreatment cell, grass filter strip, gravel diaphragm, gravel flow spreader, or another approved (manufactured) pre-treatment structure.	
On-line design	Off-line design or multiple treatment cells
Turf cover	Turf cover, with trees and shrubs
All Designs: acceptable media mix tested for phosphorus index (see **Section 6.6**)	

Dry swale
Source: DCR Stormwater Design Spec No. 10



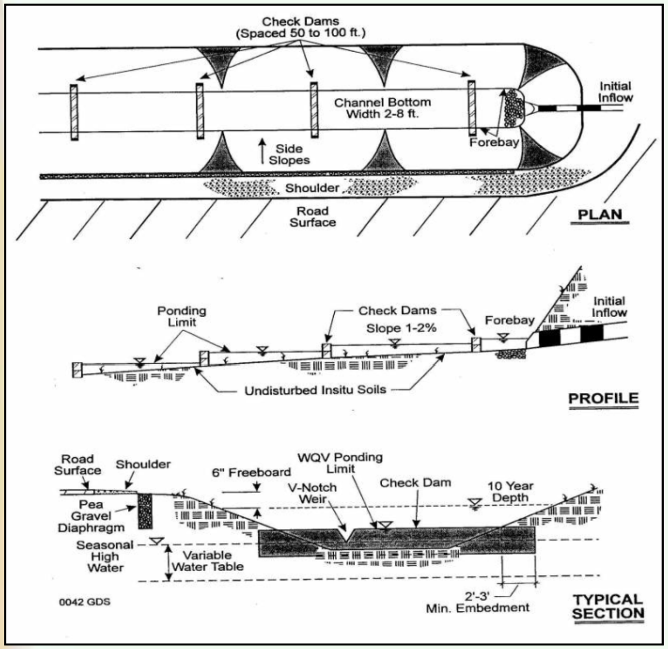
Dry swale
Source: http://www.publicbroadcasting.net/kunc/news.newsmain?action=article&ARTICLE_ID=1661510

Virginia Stormwater BMP Clearinghouse

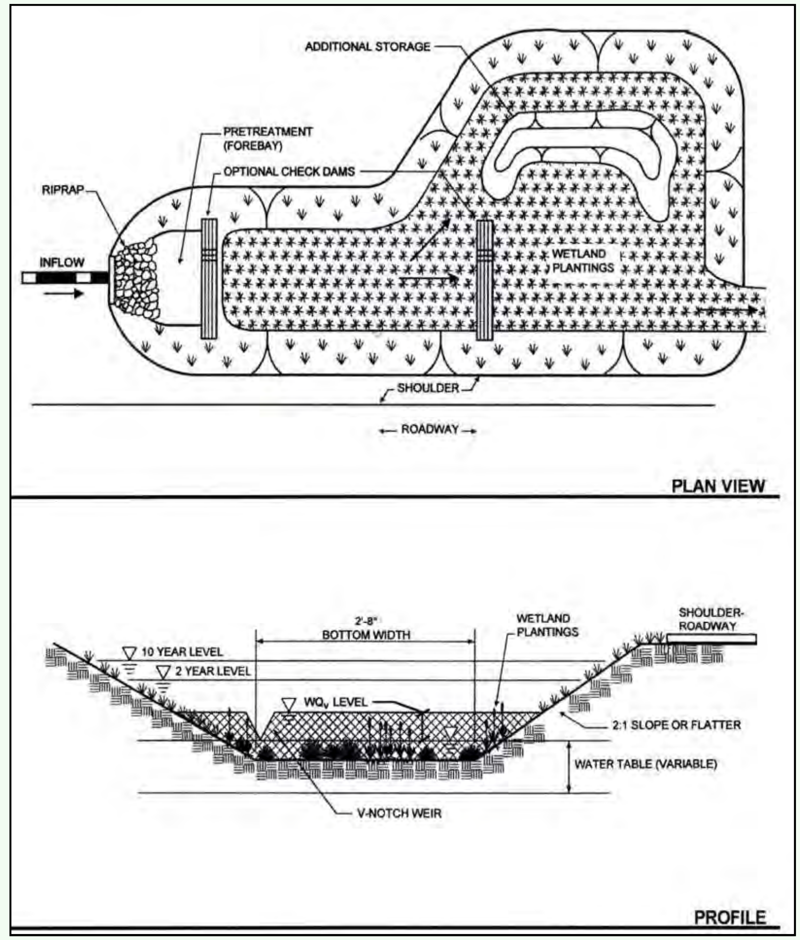
Specification No. 11: Wet Swales

What is it?

A hybrid between a swale and a wetland that is typically only recommended for flat coastal plain locations with high water tables.



Wet swale typical section view
DCR Stormwater Design Spec No. 11



Wet swale with offline wetland, typical section view
DCR Stormwater Design Spec No. 11

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Wet Swales	1	0	25	25	20	20
	2	0	35	35	40	40

Virginia Stormwater BMP Clearinghouse

Specification No. 11: Wet Swales (cont.)

Design Criteria

Table 11.2. Wet Swale Design Criteria

Level 1 Design (RR:0; TP:20; TN:25)	Level 2 Design (RR:0; TP:40; TN:35)
T_V = [(1 inch)(R_V)(A)] / 12 – the volume reduced by an upstream RR BMP	T_V = [(1.25 inch)(R_V)(A)] / 12 – the volume reduced by an upstream RR BMP
Swale slopes less than 2% [1]	Swale slopes less than 1% [1]
On-line design	Off-line swale cells
No planting	Wetland planting within swale cells
Turf cover in buffer	Trees within swale cells

[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 by applied on steeper sites, to comply with these criteria.

Wet swale
Source: http://www.semcog.org/data/lid.report.cfm?lid=174

Wet swale
Source: http://www.mortonroberts.com/suds.html

Stormwater Functions Summary

Table 11.1. Summary of Stormwater Functions Provided by Wet Swales

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 (TOC); and partial Channel Protection Volume (CPv) can be provided above the Treatment Volume (T_V), 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), CWP, 2007

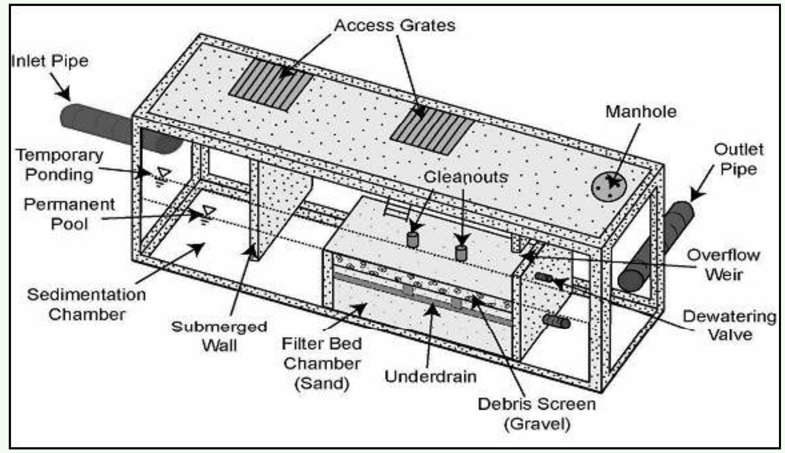
Virginia Stormwater BMP Clearinghouse

Specification No. 12: Filtering Practices

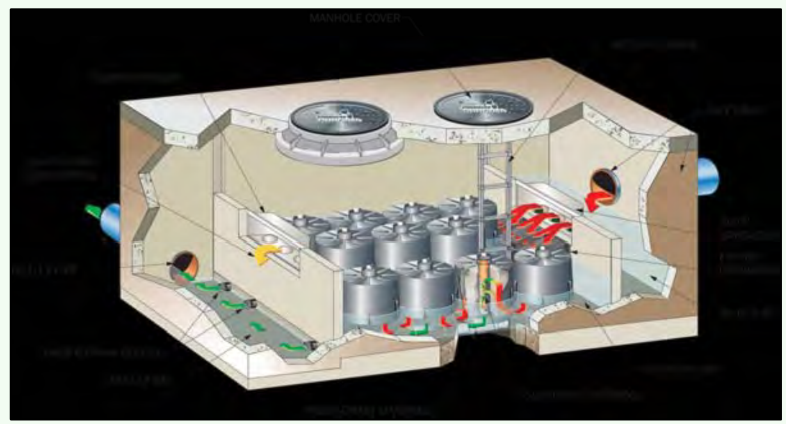
What is it?

Practices that capture and treat runoff through an engineered storage media. May include:

- Non-structural sand filters;
- Surface sand filters;
- Organic media filters;
- Underground sand filters;
- Perimeter sand filters; and
- Proprietary media filters.



Surface sand filter
Source: http://www.cityofsandy.com/index.asp



Proprietary media filters
Source (top): DCR Stormwater Design Spec No. 11
Source (bottom): http://www.hiwtc.com/photo/products/11/00/69/6943.jpg

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Filtering Practices	1	0	30	30	60	60
	2	0	45	45	65	65

Virginia Stormwater BMP Clearinghouse

Specification No. 12: Filtering Practices (cont.)

Stormwater Functions Summary

Table 12.1. Summary of Stormwater Functions Provided by Filtering Practices

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 – 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 the event mean concentration (EMC) through the practice..

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

Design Criteria

Table 12.2. Filtering Practice Design Guidance

Level 1 Design (RR:0; TP:60; TN:30)	Level 2 Design (RR:0 [1]; TP:65; TN:45)
T_v = [(1.0)(Rv)(A)] / 12 – the volume reduced by an upstream BMP	T_v = [(1.25)(Rv)(A)] / 12 – the volume reduced by an upstream BMP
One cell design	Two cell design
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 T_v designed to be infiltrated.

Sand filter below turf
Source:
http://www.kiama.nsw.gov.au/environmental-services/water.html

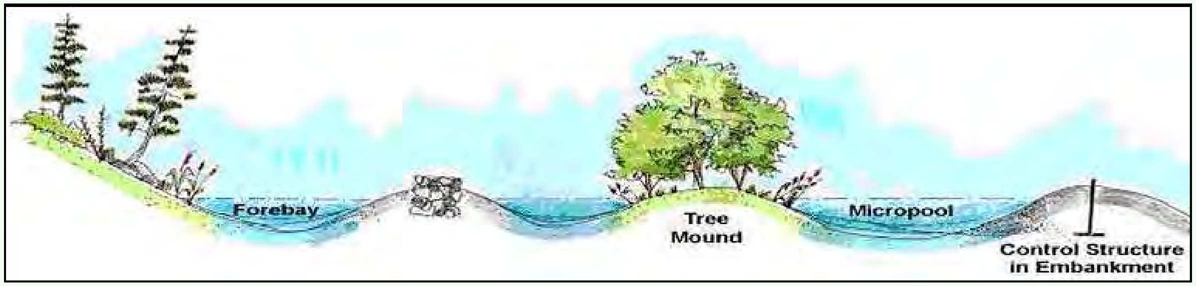
Virginia Stormwater BMP Clearinghouse

Specification No. 13: Constructed Wetlands

What is it?

Shallow depressions that promote evapotranspiration and microbial activity. May be:

- Constructed wetland basin;
- Multi-cell wetland; and
- Pond/wetland combinations.
- (Extended detention wetlands and pocket wetlands are no longer allowed.)



Constructed wetland typical section and plan views
DCR Stormwater Design Spec No. 13

Constructed wetland in Loudoun County
Source: Wetland Studies and Solutions, Inc.

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Constructed Wetlands	1	0*	25	25	50	50
	2	0*	55	55	75	75

*Note that constructed wetlands do not receive runoff reduction credit, but Level 2 extended detention ponds do! (See slide 70)

Virginia Stormwater BMP Clearinghouse

Specification No. 13: Constructed Wetlands (cont.)

Constructed wetland in Fairfax County
Source: Wetland Studies and Solutions, Inc.

Design Criteria

Table 13.2. Constructed Wetland Design Criteria

Level 1 Design (RR:0; TP:50; TN:25)	Level 2 Design (RR:0; TP:75; TN:55)
$T_V = [(R_V)(A)] / 12$ – the volume reduced by an upstream BMP	$Tv = [1.5(R_V)(A)] / 12$ – the volume reduced by an upstream BMP
Single cell (with a forebay)[1,2]	Multiple cells or a multi-cell pond/wetland combination[1,2]
Extended Detention (ED) for T_V (24 hr)[3] or Detention storage (up to 12 inches) above the wetland pool for channel protection (1-year storm event)	No ED. (limited water surface fluctuations allowed during the 1-inch and 1-year storm events – refer to **Section 6)**
Uniform wetland depth [2]	Diverse microtopography with varying depths [2]
Mean wetland depth is *more* than 1 foot	Mean wetland depth is *less* than 1 foot
The surface area of the wetland is *less* than 3% of the contributing drainage area (CDA).	The surface area of the wetland is *more* than 3% of the CDA.
Length/Width ratio *OR* Flow path = 2:1 or more	Length/Width ratio *OR* Flow path = 3:1 or more
Length of shortest flow path/overall length = 0.5 or more [3]	Length of shortest flow path/overall length = 0.8 or more [4]
Emergent wetland design	Mixed wetland design

Stormwater Functions Summary

Table 13.1. Summary of Stormwater Functions Provided by Constructed Wetlands

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.		

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

Constructed wetland in Fairfax County
Source: Wetland Studies and Solutions, Inc.

Virginia Stormwater BMP Clearinghouse

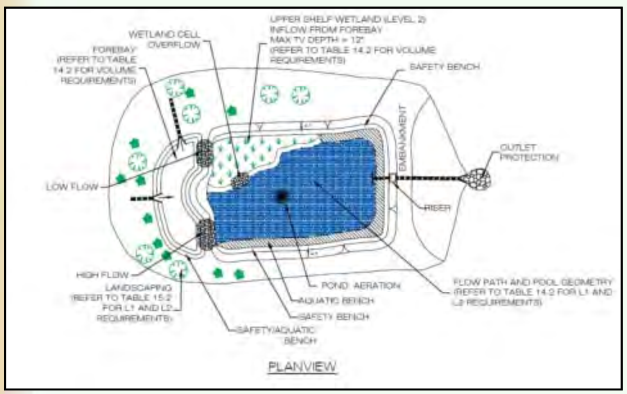
Specification No. 14: Wet Ponds

What is it?

A permanent pool of standing water that promotes settling, biological uptake, and microbial activity. Should be considered only after all other upland runoff reduction options.

May be designed as:

- A single cell;
- Wet extended detention;
- A multi-cell wet pond; or
- A pond/wetland combination.



Wet pond typical plan view
DCR Stormwater Design Spec No. 14

Wet pond in Fairfax County
Source: Wetland Studies and Solutions, Inc.

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Wet Ponds	1	0	30	30	50	50
	2	0	40	40	75	75

Virginia Stormwater BMP Clearinghouse

Specification No. 14: Wet Ponds (cont.)

Wet pond in Fairfax County
Source: Wetland Studies and Solutions, Inc.

Stormwater Functions Summary

Table 14.1. Summary of Stormwater Functions Provided by Wet Ponds

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] Note that EMC removal rate is slightly lower in the coastal plain if the wet pond is influenced by groundwater. See **Section 6.2** of this design specification and CSN Technical Bulletin No. 2. (2009).
Sources: CWP and CSN (2008), CWP (2007)

Design Criteria

Table 14.2. Level 1 and 2 Wet Pond Design Guidance

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 ratio OR Flow path = 2:1 or more	Length/Width ratio OR Flow path = 3:1 or more
Length of shortest flow path / overall length [4] = 0.5 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 or floating islands

[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 Treatment Volume; Refer to Design Specification 15 for ED 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), CWP (2007)

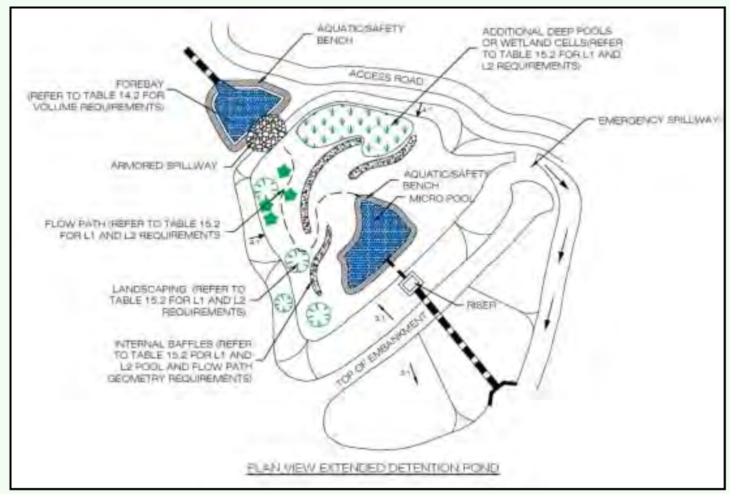
Virginia Stormwater BMP Clearinghouse

Specification No. 15: Extended Detention Ponds

A temporary (12- to 24-hour) pool of standing water that promotes settling after rain events. Should be considered only after all other upland runoff reduction options have been considered.

Typical design applications include:
- Micropool extended detention;
- Wet extended detention; or
- Limited extended detention for constructed wetlands.

Extended detention in Fairfax County
Source: Wetland Studies and Solutions, Inc.



Extended detention pond typical plan view
DCR Stormwater Design Spec No. 15

Practice	Design Level	Runoff Reduction	TN EMC Removal	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal
Extended Detention Ponds	1	0	10	10	15	15
	2	15	10	24	15	31

Virginia Stormwater BMP Clearinghouse

Specification No. 15: Extended Detention Ponds (cont.)

Stormwater Functions Summary

Table 15.1. Summary of Stormwater Functions Provided by ED Ponds

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*).

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

Design Criteria

Table 15.2. Extended Detention (ED) Pond Criteria

Level 1 Design (RR:0; TP:15; TN:10)	Level 2 Design (RR:15; TP:15; TN:10)
T_V = [(1.0) (Rv) (A)] / 12 – the volume reduced by an upstream BMP	T_V = [(1.25) (R_V) (A)] / 12 – the volume reduced by an upstream BMP
A minumum of 15% of the T_V in the permanent pool (forebay, micropool)	A minumum of 40% of T_V in the permanent pool (forebay, micropool, or deep pool, or wetlands)
Length/Width ratio *OR* flow path = 2:1 or more	Length/Width ratio *OR* flow path = 3:1 or more
Length of the shortest flow path / overall length = 0.4 or more	Length of the shortest flow path / overall length = 0.7 or more
Average T_V ED time = 24 hours or less	Average T_V ED time = 36 hours
Vertical T_V ED fluctuation exceeds 4 feet	Maximum vertical T_V ED limit of 4 feet
Turf cover on floor	Trees and wetlands in the planting plan
Forebay and micropool	Incudes additional cells or features (deep pools, wetlands, etc.) Refer to Section 5
CDA is less than 10 acres	CDA is greater than 10 acres

Extended detention in Fairfax County
Source: Wetland Studies and Solutions, Inc.

The Virginia Runoff Reduction Method

Virginia Runoff Reduction Method (VRRM)

Background:

Created by the Center for Watershed Protection and the Chesapeake Stormwater Network with funding from the National Fish and Wildlife Foundation and the Virginia DCR.

Spreadsheets and documentation available at: *http://www.dcr.virginia.gov/lr2f.shtml*
(Most recent revision: March 28, 2011)

4VAC50-60-65.A: "Compliance with the water quality design criteria set out in subdivisions 1 and 2 of 4VAC50-60-63 shall be determined by utilizing the Virginia Runoff Reduction Method or another equivalent methodology that is approved by the board."

What does VRRM do?

- VRRM calculates runoff volume and TP load based on land cover and soils;
- User inputs BMP types and coverage;
- VRRM calculates the runoff volume reduction and TP load reduction from BMP coverage; and
- VRRM calculates the adjusted curve numbers for BMP sizing; however, it does not perform the 1-year storm sizing calculations.

Wetland Studies and Solutions, Inc.®

Virginia Runoff Reduction Method (VRRM)

Process Steps:

1. Enter project and land cover information.
   (“Site Data” tab)
2. Apply BMPs to the site and review phosphorus load reductions. Continue to add additional BMPs until phosphorus load reduction requirements are met.
   (“D.A.” and “Water Quality Compliance” tabs)
3. Determine allowable peak flow using adjusted curve numbers.
   (“Channel and Flood Protection” tab)

Legend for the following VRRM slides:

Data input cells

Constant values (non-editable)

Calculated values

VRRM Overview

Site Data Tab

Virginia Runoff Reduction Method Worksheet -- Revised 03/25/2011

Site Data

Project Name: ESI Class Example (WSSI Office Site)
Date: March 22, 2012

	data input cells
	calculation cells
	constant values

1. Post-Development Project & Land Cover Information

Constants

Annual Rainfall (inches)	43		
Target Rainfall Event (inches)	1.00		
Phosphorus EMC (mg/L)	0.26	Nitrogen EMC (mg/L)	1.86
Target Phosphorus Target Load (lb/acre/yr)	0.41		
Pj	0.90		

Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals
Forest/Open Space (acres) -- undisturbed, protected forest/open space or reforested land	0.00	0.00	0.25	1.86	2.11
Managed Turf (acres) -- disturbed, graded for yards or other turf to be mowed/managed	0.00	0.00	0.00	1.03	1.03
Impervious Cover (acres)	0.00	0.00	0.00	1.94	1.94
				Total	5.08

Rv Coefficients

	A soils	B Soils	C Soils	D Soils
Forest/Open Space	0.02	0.03	0.04	0.05
Managed Turf	0.15	0.20	0.22	0.25
Impervious Cover	0.95	0.95	0.95	0.95

Land Cover Summary

Forest/Open Space Cover (acres)	2.11		
Weighted Rv(forest)	0.05		
% Forest	42%		
Managed Turf Cover (acres)	1.03		
Weighted Rv(turf)	0.25		
% Managed Turf	20%		
Impervious Cover (acres)	1.94		
Rv(impervious)	0.95		
% Impervious	38%		
Total Site Area (acres)	5.08		
Site Rv	0.43		
Post-Development Treatment Volume (acre-ft)	0.18		
Post-Development Treatment Volume (cubic feet)	7,999		
Post_Development Load (TP) (lb/yr)	5.03	Post_Development Load (TN) (lb/yr)	35.95
Total Load (TP) Reduction Required (lb/yr)	2.94		

Data Input:
Enter project name/date

Data Input:
Enter annual rainfall

Data Input:
Enter post-development, pre-BMP land cover data. Note that:

- "Forest/Open Space" includes planted meadow which will not be mowed or maintained;
- "Managed Turf" includes areas to be mowed; and
- "Impervious cover" includes BMPs on surfaces that would otherwise be impervious (e.g., green roof, pervious parking.)

See VRRM documentation, Table 1.

Calculated:
Post-development loads and required reduction

VRRM Overview

D.A. Tabs– Constant Values

Drainage Area A Land Cover (acres)	A soils	B Soils	C Soils	D Soils	Totals
Forest/Open Space (acres) -- undisturbed, protected forest/open space or reforested land	0.00	0.00	0.25	1.86	2.11
Managed Turf (acres) -- disturbed, graded for yards or other turf to be mowed/managed	0.00	0.00	0.00	1.03	1.03
Impervious Cover (acres)	0.00	0.00	0.00	1.94	1.94
				Total	5.08

Apply Runoff Reduction Practices to Reduce Treatment Volume & Post-Development Load in Drainage Area A

Credit	Unit	Description of Credit	Credit	Credit Area (acres)	Volume from Upstream RR Practice (cf)	Runoff Reduction (cf)	Remaining Runoff Volume (cf)	Phosphorus Efficiency (%)	Phosphorus Load from Upstream RR Practices (lbs)	Untreated Phosphorus Load to Practice (lbs.)	Phosphorus Removed By Practice (lbs.)	Remaining Phosphorus Load (lbs.)	Downstream Treatment to be Employed
1. Vegetated Roof													
1.a. Vegetated Roof #1 (Spec #5)	acres of green roof	45% runoff volume reduction	0.45	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
1.b. Vegetated Roof #2 (Spec #5)	acres of green roof	60% runoff volume reduction	0.60	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
2. Rooftop Disconnection													
2.a. Simple Disconnection to A/B Soils (Spec #1)	impervious acres disconnected	50% runoff volume reduction for treated area	0.50	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
2.b. Simple Disconnection to C/D Soils (Spec #1)	impervious acres disconnected	25% runoff volume reduction for treated area	0.25	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
2.c. To Soil Amended Filter Path as per specifications (existing C/D soils) (Spec #4)	impervious acres disconnected	50% runoff volume reduction for treated area	0.50	0.00	[illegible]	[illegible]	0	0	0.00	0.00	0.00	0.00	
2.d. To Dry Well or French Drain #1 (Microinfilration #1) (Spec #8)	impervious acres disconnected	50% runoff volume reduction for treated area	0.50	0.00	[illegible]	[illegible]	0	25	0.00	0.00	0.00	0.00	
2.e. To Dry Well or French Drain #2 (Micro-Infiltration #2) (Spec #8)	impervious acres disconnected	90% runoff volume reduction for treated area	0.90	0.00	[illegible]	[illegible]	0	25	0.00	[illegible]	[illegible]	[illegible]	
2.f. To Rain Garden #1 (Micro-Bioretention #1) (Spec #9)	impervious ac...	...ed	0.40	0.00	[illegible]	[illegible]	0	25	0.00	[illegible]	[illegible]	[illegible]	
2.g. To Rain Garden #2 (Micro-Bioretention #2) (Spec #9)	impervious ac...	...on fo...	0.80	[illegible]	[illegible]	[illegible]	0	50	0.00	[illegible]	[illegible]	[illegible]	
2.h. To Rainwater Harvesting (Spec #6)	impervious...	...esign	0.00	[illegible]	[illegible]	[illegible]	0	0	0.00	[illegible]	[illegible]	[illegible]	
2.i. To Stormwater Planter (Urban Bioretention) (Spec #9, Appendix A)	impervious ac...	...on fo...	0.40	0.00	[illegible]	[illegible]	0	25	0.00	[illegible]	[illegible]	[illegible]	
3. Permeable Pavement													
3.a. Permeable Pavement #1 (Spec #7)	acres of permeable pavement + acres of "external" (upgradient) impervious pavement	45% runoff volume reduction	0.45	0.00	0	0	0	25	0.00	[illegible]	[illegible]	[illegible]	
3.b. Permeable Pavement #2 (Spec #7)	acres of permeable pavement	75% runoff volume reduction	0.75	0.00	0	0	0	25	0.00	[illegible]	[illegible]	[illegible]	
4. Grass Channel													
4.a. Grass Channel A/B Soils (Spec #3)	impervious acres draining to grass channels	20% runoff volume reduction	0.20	0.00	0	0	0	15	0.00	0.00	0.00	0.00	
	turf acres draining to grass channels	20% runoff volume reduction	0.20	0.00	0	0	0	15	0.00	0.00	0.00	0.00	
4.b. Grass Channel C/D Soils (Spec #3)	impervious acres draining to grass channels	10% runoff volume reduction	0.10	0.00	0	0	0	15	0.00	0.00	0.00	0.00	
	turf acres draining to grass channels	10% runoff volume reduction	0.10	0.00	0	0	0	15	0.00	0.00	0.00	0.00	
4.c. Grass Channel with Compost Amended Soils as per specs (see Spec #4)	impervious acres draining to grass channels	30% runoff volume reduction	0.30	0.00	0	0	0	15	0.00	0.00	0.00	0.00	
	turf acres draining to grass channels	30% runoff volume reduction	0.30	0.00	0	0	0	15	0.00	0.00	0.00	0.00	
5. Dry Swale													
5.a. Dry Swale #1 (Spec #10)	impervious acres draining to dry swale	40% runoff volume reduction	0.40	0.00	0	0	0	20	0.00	0.00	0.00	0.00	
	turf acres draining to dry swale	40% runoff volume reduction	0.40	0.00	0	0	0	20	0.00	0.00	0.00	0.00	
5.b. Dry Swale #2 (Spec #10)	impervious acres draining to dry swale	60% runoff volume reduction	0.60	0.00	0	0	0	40	0.00	0.00	0.00	0.00	
	turf acres draining to dry swale	60% runoff volume reduction	0.60	0.00	0	0	0	40	0.00	0.00	0.00	0.00	

Constant:
BMP Type

Constant:
TP Reduction via volume reduction

Constant:
EMC Reduction via chemical processes (reduction taken on remaining volume)

VRRM Overview

D.A. Tabs – User Input

Drainage Area A Land Cover (acres)	A soils	B Soils	C Soils	D Soils	Totals
Forest/Open Space (acres) -- undisturbed, protected forest/open space or reforested land	0.00	0.00	0.25	1.86	2.11
Managed Turf (acres) -- disturbed, graded for yards or other turf to be mowed/managed	0.00	0.00	0.00	1.03	1.03
Impervious Cover (acres)	0.00	0.00	0.00	1.94	1.94
				Total	5.08

Apply Runoff Reduction Practices to Reduce Treatment Volume & Post-Development Load in Drainage Area A

Credit	Unit	Description of Credit	Credit	Credit Area (acres)	olume from Upstream R Practice (cf)	Runoff Reduction (cf)	Remaining Runoff Volume (cf)	Phosphorus Efficiency (%)	Phosphorus Load from Upstream RR Practices (lbs)	Untreated Phosphorus Load to Practice (lbs.)	Phosphorus Removed By Practice (lbs.)	Remaining Phosphorus Load (lbs.)	Downstream Treatment to be Employed
1. Vegetated Roof													
1.a. Vegetated Roof #1 (Spec #5)	acres of green roof	45% runoff volume reduction	0.45	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
1.b. Vegetated Roof #2 (Spec #5)	acres of green roof	60% runoff volume reduction	0.60	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
2. Rooftop Disconnection													
2.a. Simple Disconnection to A/B Soils (Spec #1)	impervious acres disconnected	50% runoff volume reduction for treated area	0.50	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
2.b. Simple Disconnection to C/D Soils (Spec #1)	impervious acres disconnected	25% runoff volume reduction for treated area	0.25	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
2.c. To Soil Amended Filter Path as per specifications (existing C/D soils) (Spec #4)	impervious acres disconnected	50% runoff volume reduction for treated area	0.50	0.00	0					0.00	0.00	0.00	
2.d. To Dry Well or French Drain #1 (Microinfilration #1) (Spec #8)	impervious acres disconnected	50% runoff volume reduction for treated area	0.50	0.00	0					0.00	0.00	0.00	
2.e. To Dry Well or French Drain #2 (Micro-Infiltration #2) (Spec #8)	impervious acres disconnected	90% runoff volume reduction for treated area	0.90	0.00	0					0.00	0.00	0.00	
2.f. To Rain Garden #1 (Micro-Bioretention #1) (Spec #9)	impervious acres disconnected	40% of volume captured	0.40	0.00	0					0.00	0.00	0.00	
2.g. To Rain Garden #2 (Micro-Bioretention #2) (Spec #9)	impervious acres disconnected	80% runoff volume reduction for treated area	0.80	0.00	0					0.00	0.00	0.00	
2.h. To Rainwater Harvesting (Spec #6)	impervious acres captured	based on tank size and design	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
2.i. To Stormwater Planter (Urban Bioretention) (Spec #9, Appendix A)	impervious acres disconnected	40% runoff volume reduction for treated area	0.40	0.00	0	0	0	25	0.00	0.00	0.00	0.00	
3. Permeable Pavement													
3.a. Permeable Pavement #1 (Spec #7)	acres of permeable pavement + acres of "external" (upgradient) impervious pavement	45% runoff volume reduction	0.45	0.00	0	0	0	25	0.00	0.00	0.00	0.00	
3.b. Permeable Pavement #2 (Spec #7)	acres of permeable pavement	75% runoff volume reduction	0.75	0.00	0	0	0	25	0.00	0.00	0.00	0.00	
4. Grass Channel													
4.a. Grass Channel A/B Soils (Spec #3)	impervious acres draining to grass channels	20% runoff volume reduction	0.20	0.00	0	0	0	15	0.00	0.00	0.00	0.00	
	turf acres draining to grass channels	20% runoff volume reduction	0.20	0.00	0					0.00	0.00	0.00	
4.b. Grass Channel C/D Soils (Spec #3)	impervious acres draining to grass channels	10% runoff volume reduction	0.10	0.00	0					0.00	0.00	0.00	
	turf acres draining to grass channels	10% runoff volume reduction	0.10	0.00	0					0.00	0.00	0.00	
4.c. Grass Channel with Compost Amended Soils as per specs (see Spec #4)	impervious acres draining to grass channels	30% runoff volume reduction	0.30	0.00	0					0.00	0.00	0.00	
	turf acres draining to grass channels	30% runoff volume reduction	0.30	0.00	0					0.00	0.00	0.00	
5. Dry Swale													
5.a. Dry Swale #1 (Spec #10)	impervious acres draining to dry swale	40% runoff volume reduction	0.40	0.00	0					0.00	0.00	0.00	
	turf acres draining to dry swale	40% runoff volume reduction	0.40	0.00	0	0	0	20	0.00	0.00	0.00	0.00	
5.b. Dry Swale #2 (Spec #10)	impervious acres draining to dry swale	60% runoff volume reduction	0.60	0.00	0	0	0	40	0.00	0.00	0.00	0.00	
	turf acres draining to dry swale	60% runoff volume reduction	0.60	0.00	0	0	0	40	0.00	0.00	0.00	0.00	

Data Input:
Enter drainage area acreage (which may equal the total project area)

Data Input:
Enter area treated by each BMP type

Data Input:
Enter downstream treatment, if any, via dropdown menu

VRRM Overview

Water Quality Compliance Tab

Site Results	
Phosphorous	
TOTAL TREATMENT VOLUME (cf	7,999
TOTAL PHOSPHOROUS LOAD REDUCTION REQUIRED (LB/YEAR	2.94
RUNOFF REDUCTION (cf	0
PHOSPHOROUS LOAD REDUCTION ACHIEVED (LB/YR	0.00
ADJUSTED POST-DEVELOPMENT PHOSPHOROUS LOAD (TP) (lb/yr	5.03
REMAINING PHOSPHOROUS LOAD REDUCTION (LB/YR) NEEDED	2.94
Nitrogen (for information purposes)	
TOTAL TREATMENT VOLUME (cf)	7,999
RUNOFF REDUCTION (cf)	0
NITROGEN LOAD REDUCTION ACHIEVED (LB/YR)	0.00
ADJUSTED POST-DEVELOPMENT NITROGEN LOAD (TP) (lb/yr)	35.95

Calculated:
Static values based on Land Cover tab

Calculated:
Values will change as BMPs are applied

VRRM Overview

Channel and Flood Protection Tab

		1-year storm	2-year storm	10-year storm
Target Rainfall Event (in)		2.70	3.35	5.15
Drainage Area A				
Drainage Area (acres)	5.08			
Runoff Reduction Volume (cf)	0			
Drainage Area B				
Drainage Area (acres)	0.00			
Runoff Reduction Volume (cf)	0			
Drainage Area C				
Drainage Area (acres)	0.00			
Runoff Reduction Volume (cf)	0			
Drainage Area D				
Drainage Area (acres)	0.00			
Runoff Reduction Volume (cf)	0			
Drainage Area E				
Drainage Area (acres)	0.00			
Runoff Reduction Volume (cf)	0			

Based on the use of Runoff Reduction practices in the various drainage areas, the spreadsheet calculates an adjusted Vdeveloped and adjusted Curve Number.

Drainage Area A		A soils	B Soils	C Soils	D Soils
Forest/Open Space -- undisturbed, protected forest/open space or reforested land	Area (acres)	0.0	0.0	0.3	1.9
	CN	30	55	70	77
Managed Turf -- disturbed, graded for yards or other turf to be mowed/managed	Area (acres)	0.0	0.0	0.0	1.0
	CN	39	61	74	80
Impervious Cover	Area (acres)	0.0	0.0	0.0	1.9
	CN	98	98	98	98
					Weighted CN
					85

	1-year storm	2-year storm	10-year storm
$RV_{Developed}$ (in) with no Runoff Reduction	1.36	1.91	3.54
$RV_{Developed}$ (in) with Runoff Reducti	[illegible]	[illegible]	[illegible]
Adjusted CN	85	85	85

Data Input: Enter rainfall values

Calculated: Values will change as BMPs are applied

Calculated: Adjusted CN

Using the adjusted curve number (CN) for each drainage area, calculate the peak discharge for the 1-, 2-, and 10-year storms. Compare the peak discharge to the allowable rates described in the Virginia Stormwater Management Program permit regulations (4VAC 50-60-66(b) 4VAC 50-60-66(c)).

VRRM Overview

Channel Protection using TR-55 and Energy Balance

To meet the requirements of 4VAC50-60-66.B (Channel Protection), use the adjusted curve numbers from the VRRM to determine the pre- and post-development runoff volume and the pre-development runoff rate.

$RV_{pre/post\text{-}developed}$ = Q x A / 12

Where:

RV = Runoff volume (cf)

A = Drainage area (sf)

Q_{depth} = Runoff (in)

$$= \frac{(P-I_a)^2}{(P-I_a) + S}$$

Where:

P = Precipitation (in)

I_a = Initial abstraction = 0.2S

S = (1000 / CN) – 10

$Q_{pre\text{-}developed} = q_u \times A_m \times Q_{depth} \times F_p$

Where:

$Q_{pre\text{-}developed}$ = Peak discharge (cfs)

q_u = Unit peak discharge (csm/in)

(Determined using the graphical peak discharge method or tabular hydrograph method. See TR-55.)

A_m = Drainage area (mi^2)

Q_{depth} = Runoff (in)

F_p = Pond and swamp adjustment factor

VRRM Overview

Channel Protection using TR-55 and Energy Balance

Solve for the allowable $Q_{developed}$ using the Energy Balance method (4VAC50-60-66.B) and the values calculated on the previous slide.

Allowable 1-yr, 24-hr peak flow rate per 4VAC50-60-66.B:

$Q_{developed} \leq 0.8 \times Q_{pre\text{-}developed} \times RV_{pre\text{-}developed} / RV_{developed}$

$Q_{developed}$ *shall not be required to be less than* $[Q_{forested} \times RV_{forested}] / RV_{developed}$

$Q_{developed}$ *must be* $\leq Q_{pre\text{-}developed}$

VRRM Example

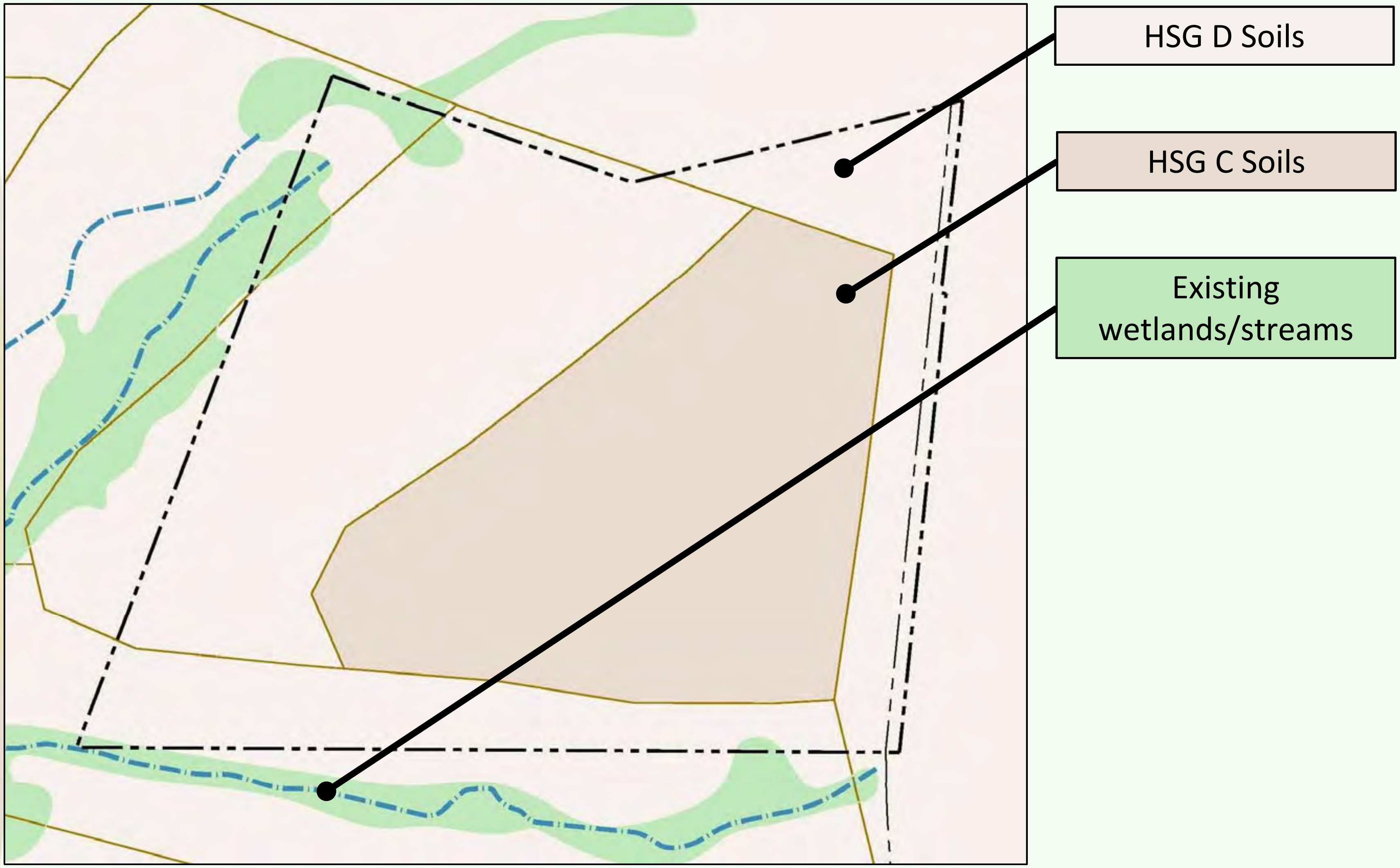
Introduction

This example is based on WSSI's office site. However, this is a simplified analysis for VRRM process illustration purposes only.

Note that the site's drainage areas have been changed, and not all practices currently on the ground at WSSI are represented herein.

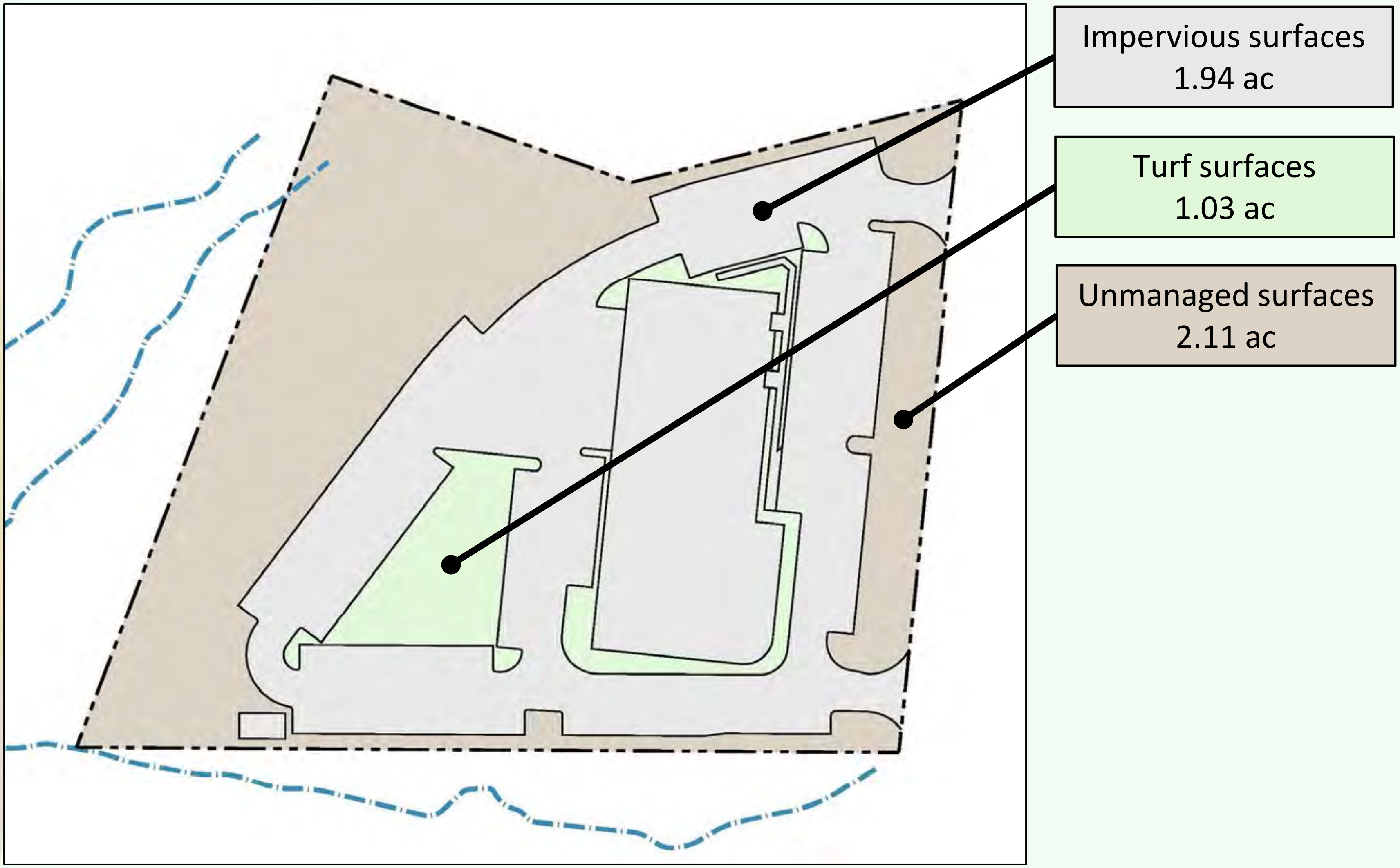
VRRM Example

Initial Design Information: Base Land Cover



VRRM Example

Initial Design Information: Pre-BMP Plan



VRRM Example

Step 1: Enter Project and Land Cover Information

Virginia Runoff Reduction Method Worksheet -- Revised 03/25/2011

Site Data

Project Name: ESI Class Example (WSSI Office Site)

Date: March 22, 2012

(cyan)	data input cells
(gray)	calculation cells
(yellow)	constant values

1. Post-Development Project & Land Cover Information

Constants

Annual Rainfall (inches)	43			
Target Rainfall Event (inches)	1.00			
Phosphorus EMC (mg/L)	0.26		Nitrogen EMC (mg/L)	1.86
Target Phosphorus Target Load (lb/acre/yr)	0.41			
Pj	0.90			

Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals
Forest/Open Space (acres) -- undisturbed, protected forest/open space or reforested land	0.00	0.00	0.15	1.86	2.01
Managed Turf (acres) -- disturbed, graded for yards or other turf to be mowed/managed	0.00	0.00	0.52	0.00	0.52
Impervious Cover (acres)	0.00	0.00	0.00	2.55	2.55
				Total	5.08

Rv Coefficients

	A soils	B Soils	C Soils	D Soils
Forest/Open Space	0.02	0.03	0.04	0.05
Managed Turf	0.15	0.20	0.22	0.25
Impervious Cover	0.95	0.95	0.95	0.95

Land Cover Summary

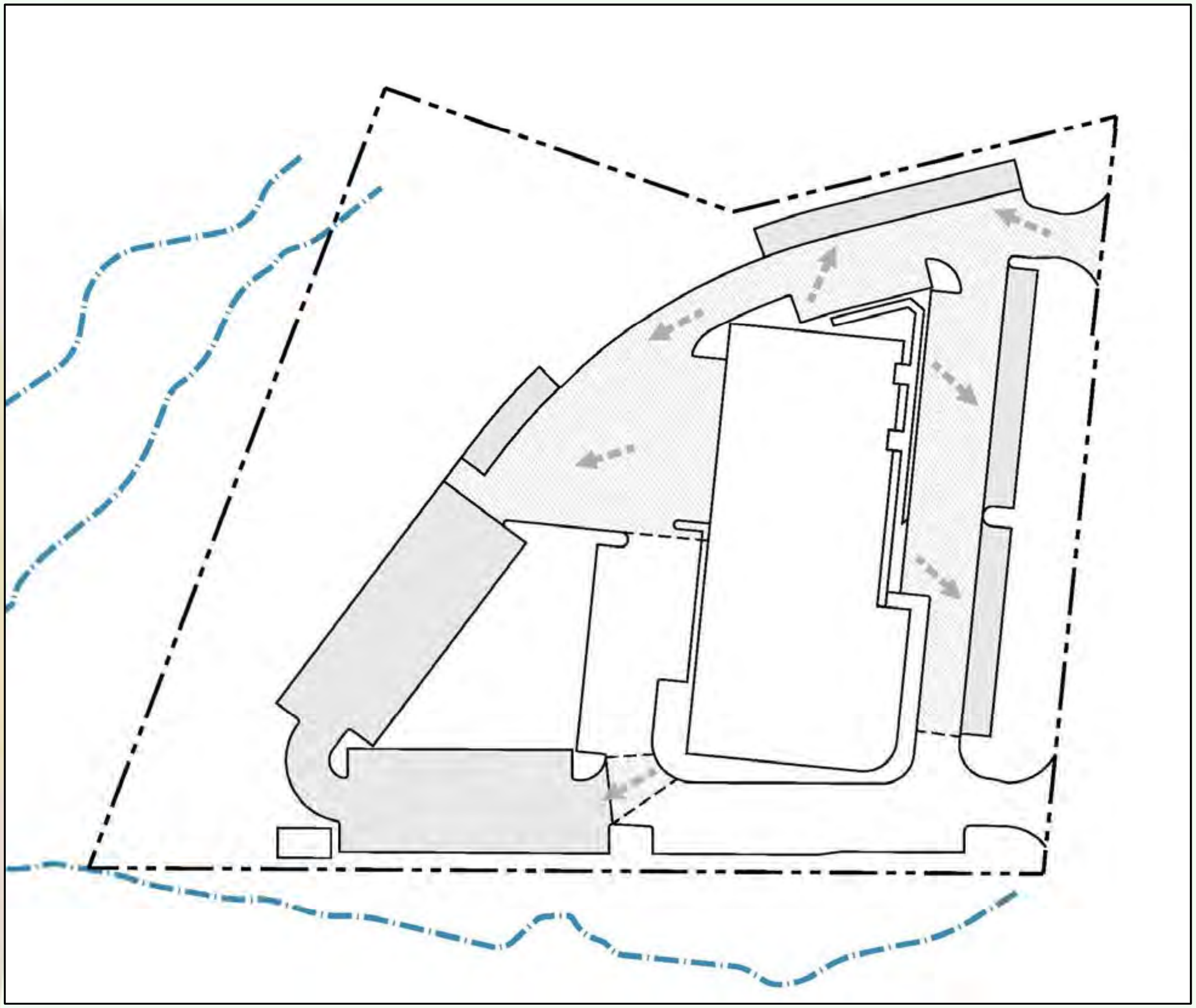
Forest/Open Space Cover (acres)	2.01		
Weighted Rv(forest)	0.05		
% Forest	40%		
Managed Turf Cover (acres)	0.52		
Weighted Rv(turf)	0.22		
% Managed Turf	10%		
Impervious Cover (acres)	2.55		
Rv(impervious)	0.95		
% Impervious	50%		
Total Site Area (acres)	5.08		
Site Rv	0.52		
Post-Development Treatment Volume (acre-ft)	0.22		
Post-Development Treatment Volume (cubic feet)	9,568		
Post_Development Load (TP) (lb/yr)	6.01	Post_Development Load (TN) (lb/yr)	43.01
Total Load (TP) Reduction Required (lb/yr)	3.93		

Enter land cover data

Post-development TP load: 6.01 lb/yr
Required TP reduction: 3.93 lb/yr

VRRM Example

Step 2: Apply BMPs- Level 1 Pervious Pavement



L1 Pervious pavement 0.67 ac
0.85 “up-gradient” impervious acres

VRRM Example

Step 2 (cont): Apply BMPs; Review Phosphorus Reduction

3. Permeable Pavement													
3.a. Permeable Pavement #1 (Spec #7)	acres of permeable pavement + acres of "external" (upgradient) impervious pavement	45% runoff volume reduction	0.45	1.52	0	2359	2883	25	0.00	3.29	1.93	1.36	
3.b. Permeable Pavement #2 (Spec #7)	acres of permeable pavement	75% runoff volume reduction	0.75	0.00	0	0	0	25	0.00	0.00	0.00	0.00	

D.A. Tab:
Enter permeable pavement acreage

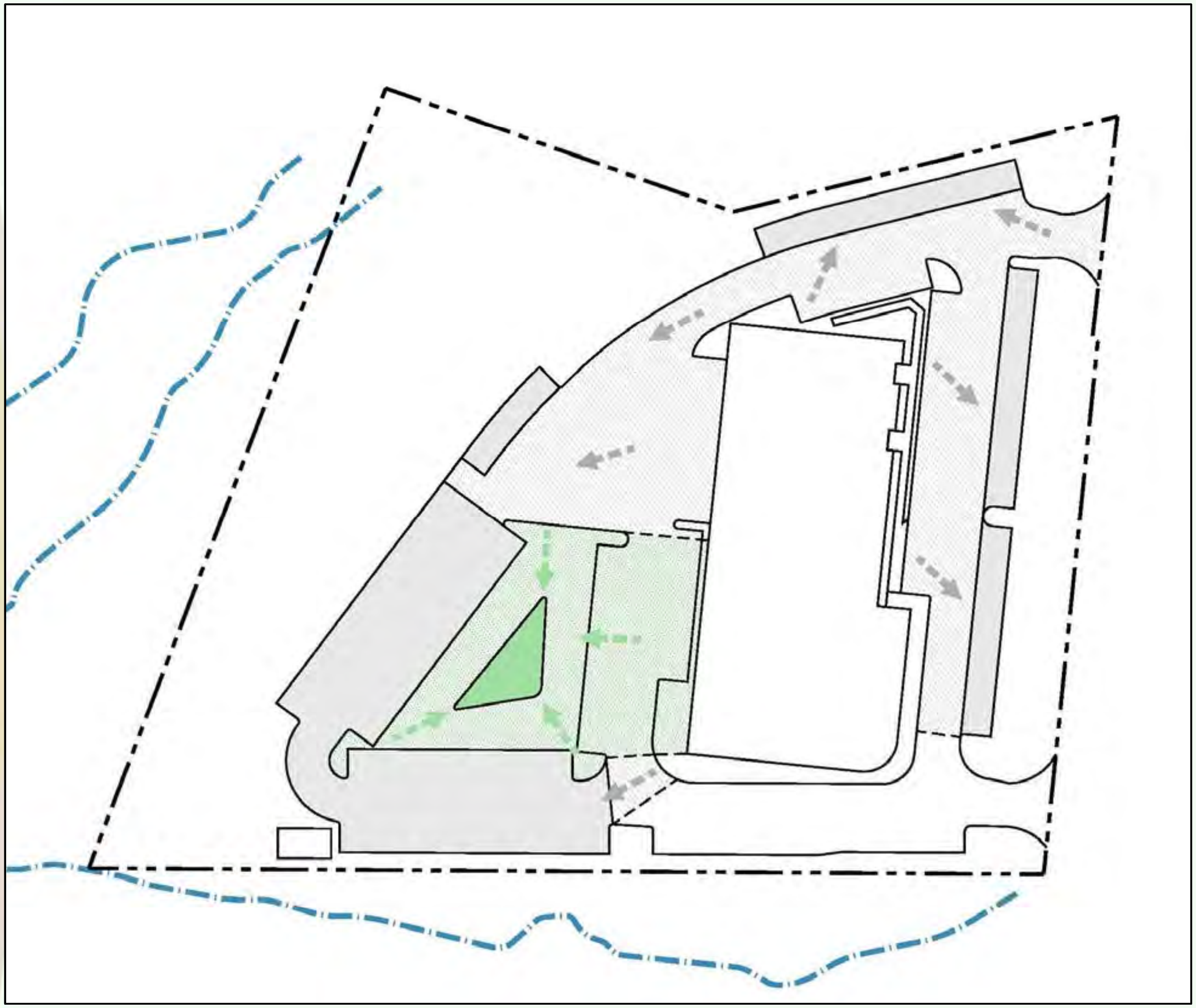
Site Results	
Phosphorous	
TOTAL TREATMENT VOLUME (cf)	9,568
TOTAL PHOSPHOROUS LOAD REDUCTION REQUIRED (LB/YEAR)	3.93
RUNOFF REDUCTION (cf)	2359
PHOSPHOROUS LOAD REDUCTION ACHIEVED (LB/YR)	1.93
ADJUSTED POST-DEVELOPMENT PHOSPHOROUS LOAD (TP) (lb/yr)	4.08
REMAINING PHOSPHOROUS LOAD REDUCTION (LB/YR) NEEDED	2.00
Nitrogen (for information purposes)	
TOTAL TREATMENT VOLUME (cf)	9,568
RUNOFF REDUCTION (cf)	2359
NITROGEN LOAD REDUCTION ACHIEVED (LB/YR)	13.83
ADJUSTED POST-DEVELOPMENT NITROGEN LOAD (TP) (lb/yr)	29.18

Water Quality Compliance Tab:
TP reduction achieved with pervious pavement:
1.93 lb/yr

Remaining required TP reduction:
2.00 lb/yr

VRRM Example

Step 2 (cont): Apply BMPs- Level 1 Bioretention



L1 Pervious pavement
0.67 ac

0.85 “up-gradient” impervious acres

L1 Bioretention
0.17 “up-gradient” impervious acres

0.25 “up-gradient” turf/impervious acres

VRRM Example

Step 2 (cont): Apply BMPs; Review Phosphorus Reduction

6. Bioretention														
6.a. Bioretention #1 or Urban Bioretention (Spec #9)	impervious acres draining to bioretention	40% runoff volume reduction	0.40	0.17	0	234	352	25	0.00	0.37	0.20	0.17	
	turf acres draining to bioretention	40% runoff volume reduction	0.40	0.29	0	93	139	25	0.00	0.15	0.08	0.07	
6.b. Bioretention #2 (Spec #9)	impervious acres draining to bioretention	80% runoff volume reduction	0.80	0.00	0	0	0	50	0.00	0.00	0.00	0.00	
	turf acres draining to bioretention	80% runoff volume reduction	0.80	0.00	0	0	0	50	0.00	0.00	0.00	0.00	

D.A. Tab:
Enter bioretention watershed acreage

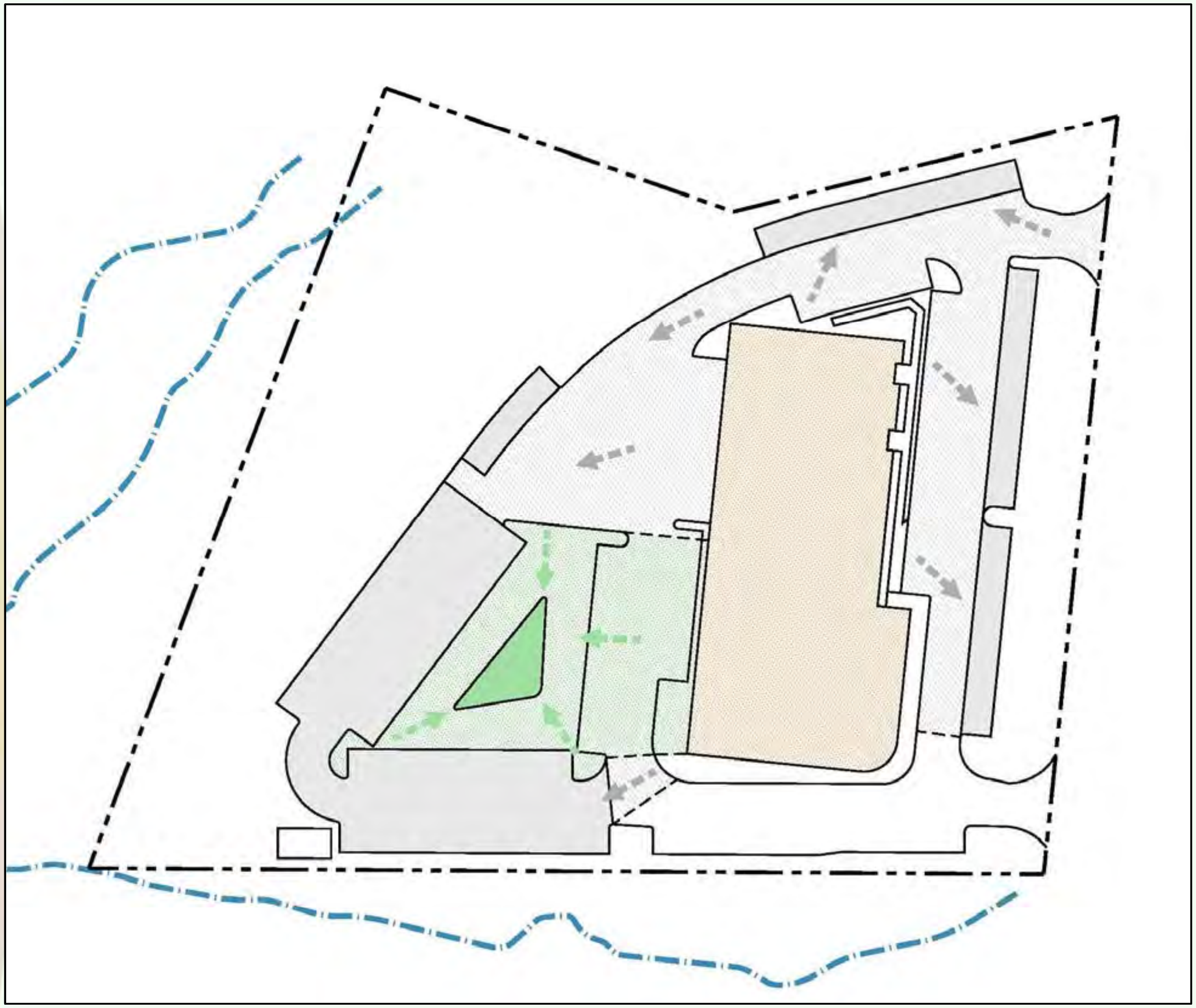
Site Results	
Phosphorous	
TOTAL TREATMENT VOLUME (cf)	9,568
TOTAL PHOSPHOROUS LOAD REDUCTION REQUIRED (LB/YEAR)	3.93
RUNOFF REDUCTION (cf)	2686
PHOSPHOROUS LOAD REDUCTION ACHIEVED (LB/YR)	2.21
ADJUSTED POST-DEVELOPMENT PHOSPHOROUS LOAD (TP) (lb/yr)	3.80
REMAINING PHOSPHOROUS LOAD REDUCTION (LB/YR) NEEDED	1.71
Nitrogen (for information purposes)	
TOTAL TREATMENT VOLUME (cf)	9,568
RUNOFF REDUCTION (cf)	2686
NITROGEN LOAD REDUCTION ACHIEVED (LB/YR)	16.18
ADJUSTED POST-DEVELOPMENT NITROGEN LOAD (TP) (lb/yr)	26.83

Water Quality Compliance Tab:
TP reduction achieved with pervious pavement and bioretention:
2.21 lb/yr

Remaining required TP reduction:
1.71 lb/yr

VRRM Example

Step 2 (cont): Apply BMPs- Rainwater Harvesting



L1 Pervious pavement
0.67 ac

0.85 “up-gradient” impervious acres

L1 Bioretention
0.17 “up-gradient” impervious acres

0.25 “up-gradient” turf/impervious acres

Harvesting
0.59 roof acres

VRRM Example

Apply BMPs- Rainwater Harvesting Spreadsheet

Input	
REGIONAL LOCATION	
What region will the rainwater harvesting system be located closest to?	2
(click drop down menu in green on the right for directions to appear)	
ROOF AREA	
How big is the roof footprint (in sf)?	25,700
IRRIGATION	
What is the daily demand for irrigation in gallons? (if you do not know the daily demand, use the next two questions to generate an estimated demand)	0
How big is the area to irrigate?	30,500
How many inches per week of irrigation are needed?	1.00
What day of the year does irrigation start?	120
What day of the year does irrigation end?	270
Total daily irrigation demand (gallons)	*2,701*
INDOOR DEMAND - FLUSING TOILETS/URINALS	
Water closet and urinal use (if only toilets are used, set urinals = 0)	
How many people will use the building?	120
How much water does each urinal use? (set to 0, if no urinal)	0.00
How much water does each toilet use?	1.10
Calculated daily water closet and urinal demand in gallons (if this has already been calculated, use this instead of the rows above)	0
Start day of the week (Monday=1, etc)	1
End day of the week (Monday=1, etc)	5
Hours per day the building is used (i.e. 8 for a 9-5 office building; 24 for a shift-work factory)	9
Total daily water closet and urinal demand (gallons)	297
INDOOR DEMAND - LAUNDRY	
Laundry use (use either loads per day, pounds per day or calculated demand)	
How many loads of laundry are done each day?	0
How much water does each load of laundry use in gallons?	42
How many pounds of laundry are done per day?	0
Calculated daily laundry demand	
Start day of the week (Monday=1, etc)	1
End day of the week (Monday=1, etc)	5
Total daily laundry demand (gallons)	0
ADDITIONAL DAILY USE	
Additional daily use (bus wash, street sweepers, etc) in gallons	
Daily use in gallons	0
Start day of the week (Monday=1, etc)	1
End day of the week (Monday=1, etc)	7
Total daily additional demand (gallons)	0
CHILLED WATER COOLING TOWERS	
If water is to be used for cooling towers (for large scale projects)	
Start day of the week (Monday=1, etc)	1
End day of the week (Monday=1, etc)	7
Total daily water cooling tower demand (gallons)	0
SECONDARY RUNOFF REDUCTION DRAWDOWN	
How many gallons per day are directed to the secondary practice?	0
What day of the year does secondary practice start?	1
What day of the year does secondary practice end?	366
Total daily additional demand (gallons)	0
FIRST FLUSH FILTER DIVERSION AND EFFICIENCY	
Filter Efficiency must be MIN 95% of 1" storm for Treatment Volume Credit and MIN 95% of 2 year storm for Channel Protection Credit. This value may be modified if higher efficiencies are realized	
Filter Efficiency Associated with the 1" storm	0.05

Enter water usage information

Determine runoff reduction credit based on cistern size

Runoff Reduction Volume Summary: Results using precipitation data <= 1"

Cistern Storage Associated with Treatment Volume Credit (gallons)	Overflow frequency for storms of 1" or less (per year)	Dry Frequency	Mean Overflow of 1" storm volume per year (thousands of gallons)	Runoff Reduction Volume Credit
10,000	47%	28%	165	40%
20,000	43%	25%	153	43%
30,000	41%	22%	147	45%
40,000	40%	21%	142	46%
50,000	38%	20%	136	48%
60,000	37%	19%	130	49%
70,000	36%	18%	125	51%
80,000	34%	17%	119	52%
90,000	33%	16%	114	53%
100,000	31%	15%	109	55%
110,000	30%	14%	104	56%
120,000	29%	13%	98	58%
130,000	27%	12%	92	59%
140,000	25%	11%	86	61%
150,000	23%	10%	82	62%
160,000	22%	10%	78	63%
170,000	20%	9%	73	64%
180,000	19%	8%	69	65%

Total Volume generated by storms of 1" or less (thousands of gallons/ye 410

(Spreadsheet available at *http://vwrrc.vt.edu/swc/NonProprietaryBMPs.html*).

VRRM Example

Step 2 (cont): Apply BMPs; Review Phosphorus Reduction

2. Rooftop Disconnection													
2.a. Simple Disconnection to A/B Soils (Spec #1)	impervious acres disconnected	50% runoff volume reduction for treated area	0.50	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
2.b. Simple Disconnection to C/D Soils (Spec #1)	impervious acres disconnected	25% runoff volume reduction for treated area	0.25	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
2.c. To Soil Amended Filter Path as per specifications (existing C/D soils) (Spec #4)	impervious acres disconnected	50% runoff volume reduction for treated area	0.50	0.00	0	0	0					0.00	
2.d. To Dry Well or French Drain #1 (Microinfiltration #1) (Spec #8)	impervious acres disconnected	50% runoff volume reduction for treated area	0.50	0.00	0	0	0					0.00	
2.e. To Dry Well or French Drain #2 (Micro-Infiltration #2) (Spec #8)	impervious acres disconnected	90% runoff volume reduction for treated area	0.90	0.00	0	0	0					0.00	
2.f. To Rain Garden #1 (Micro-Bioretention #1) (Spec #9)	impervious acres disconnected	40% of volume captured	0.40	0.00	0	0	0					0.00	
2.g. To Rain Garden #2 (Micro-Bioretention #2) (Spec #9)	impervious acres disconnected	80% runoff volume reduction for treated area	0.80	0.00	0	0	0					0.00	
2.h. To Rainwater Harvesting (Spec #6)	impervious acres captured	based on tank size and design	0.41	0.59	0	834	1200					0.75	
2.i. To Stormwater Planter (Urban Bioretention) (Spec #9, Appendix A)	impervious acres disconnected	40% runoff volume reduction for treated area	0.40	0.00	0	0	0	25	0.00	0.00	0.00	0.00	

D.A. Tab:
Enter roof acreage and harvesting credit from harvesting spreadsheet

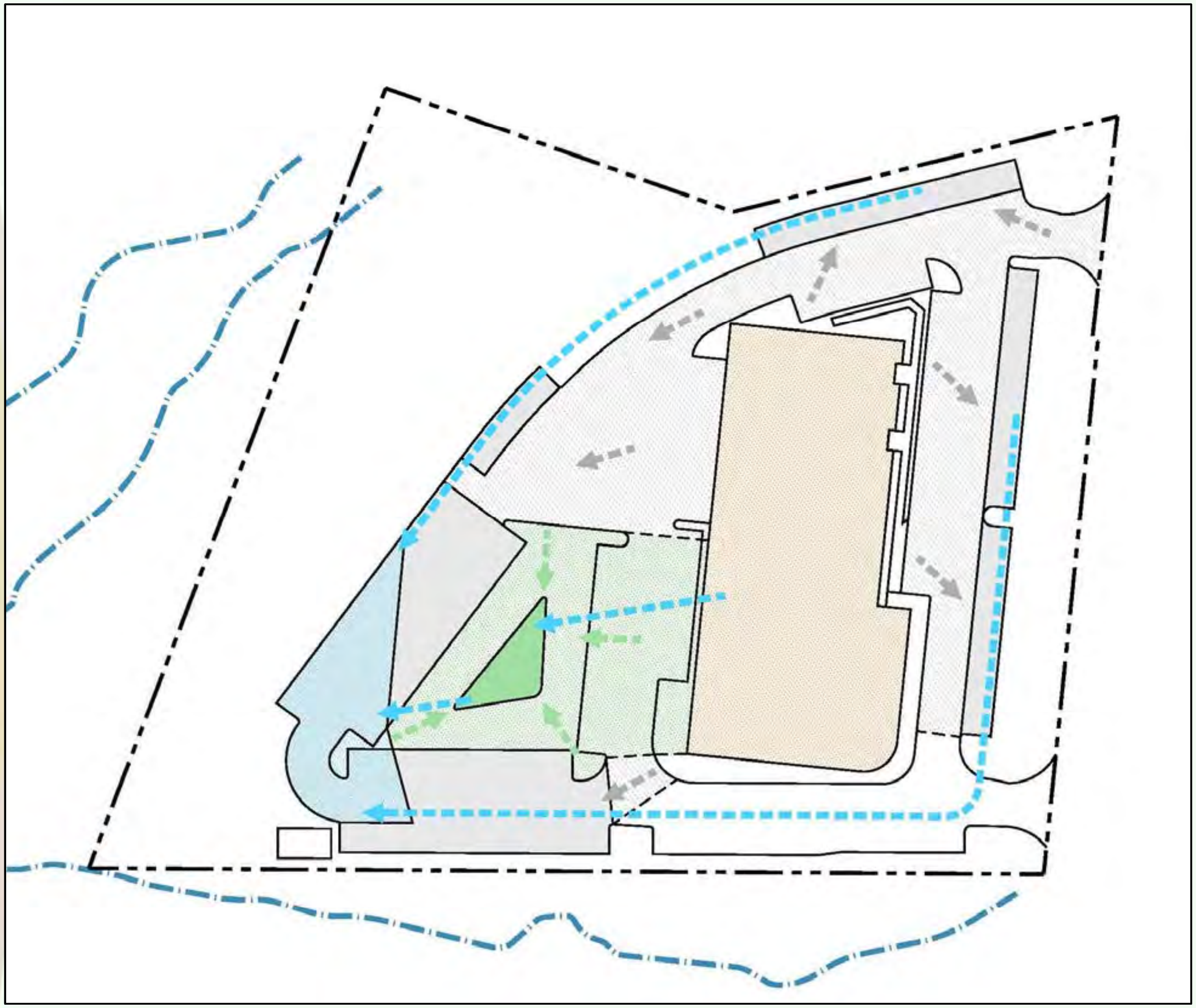
Site Results	
Phosphorous	
TOTAL TREATMENT VOLUME (cf)	9,568
TOTAL PHOSPHOROUS LOAD REDUCTION REQUIRED (LB/YEAR)	3.93
RUNOFF REDUCTION (cf)	3520
PHOSPHOROUS LOAD REDUCTION ACHIEVED (LB/YR)	2.74
ADJUSTED POST-DEVELOPMENT PHOSPHOROUS LOAD (TP) (lb/yr)	3.27
REMAINING PHOSPHOROUS LOAD REDUCTION (LB/YR) NEEDED	1.19
Nitrogen (for information purposes)	
TOTAL TREATMENT VOLUME (cf)	9,568
RUNOFF REDUCTION (cf)	3520
NITROGEN LOAD REDUCTION ACHIEVED (LB/YR)	19.92
ADJUSTED POST-DEVELOPMENT NITROGEN LOAD (TP) (lb/yr)	23.09

Water Quality Compliance Tab:
TP reduction achieved with pervious pavement, bioretention, and harvesting:
2.74 lb/yr

Remaining required TP reduction:
1.19 lb/yr

VRRM Example

Step 2 (cont): Apply BMPs- Downstream Treatment



L1 Pervious pavement
0.67 ac

0.85 “up-gradient” impervious acres

L1 Bioretention
0.17 “up-gradient” impervious acres

0.25 “up-gradient” turf/impervious acres

Harvesting
0.59 roof acres

L1 Extended Detention
Accepts overflow from upstream practices via underdrains

VRRM Example

Step 2 (cont): Apply BMPs; Review Phosphorus Reduction

#1) (Spec #9)	impervious acres disconnected	40% of volume captured	0.40	0.00	0	0	0	[illegible]	[illegible]	[illegible]	[illegible]	0.00	
2.g. To Rain Garden #2 (Micro-Bioretention #2) (Spec #9)	impervious acres disconnected	80% runoff volume reduction for treated area	0.80	0.00	0	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
2.h. To Rainwater Harvesting (Spec #6)	impervious acres captured	based on tank size and design	0.41	0.59	0	834	1200	[illegible]	[illegible]	[illegible]	[illegible]	0.75	6.a. Bioretention #1
2.i. To Stormwater Planter (Urban Bioretention) (Spec #9, Appendix A)	impervious acres disconnected	40% runoff volume reduction for treated area	0.40	0.00	0	0	0	25	0.00	0.00	0.00	0.00	
3. Permeable Pavement													
3.a. Permeable Pavement #1 (Spec #7)	acres of permeable pavement + acres of "external" (upgradient) impervious pavement	45% runoff volume reduction	0.45	1.54	[illegible]	2390	2921	25	0.00	3.33	1.96	1.37	8.a. ED #1
3.b. Permeable Pavement #2 (Spec #7)	acres of permeable pavement	75% runoff volume reduction	0.75	0.00	[illegible]	0	0	[illegible]	[illegible]	[illegible]	[illegible]	0.00	
6. Bioretention													
6.a. Bioretention #1 or Urban Bioretention (Spec #9)	impervious acres draining to bioretention	40% runoff volume reduction	0.40	0.17	1200	715	1072	[illegible]	[illegible]	[illegible]	[illegible]	0.50	8.a. ED #1
	turf acres draining to bioretention	40% runoff volume reduction	0.40	0.29	0	93	139	[illegible]	[illegible]	[illegible]	[illegible]	0.07	8.a. ED #1
6.b. Bioretention #2 (Spec #9)	impervious acres draining to bioretention	80% runoff volume reduction	0.80	0.00	0	0	0	50	0.00	0.00	0.00	0.00	
	turf acres draining to bioretention	80% runoff volume reduction	0.80	0.00	0	0	0	50	0.00	0.00	0.00	0.00	
8. Extended Detention Pond													
8.a. ED #1 (Spec #15)	impervious acres draining to ED	0% runoff volume reduction	0.00	0.00	3993	0	3993	15	1.88	0.00	0.28	1.60	
	turf acres draining to ED	0% runoff volume reduction	0.00	0.00	139	0	139	15	0.07	0.00	0.01	0.06	
8.b. ED #2 (Spec #15)	impervious acres draining to ED	15% runoff volume reduction	0.15	0.00	0	0	0	15	0.00	0.00	0.00	0.00	
	turf acres draining to ED	15% runoff volume reduction	0.15	0.00	0	0	0	15	0.00	0.00	0.00	0.00	

Harvesting overflows to bioretention

Permeable pavement and bioretention overflow to extended detention

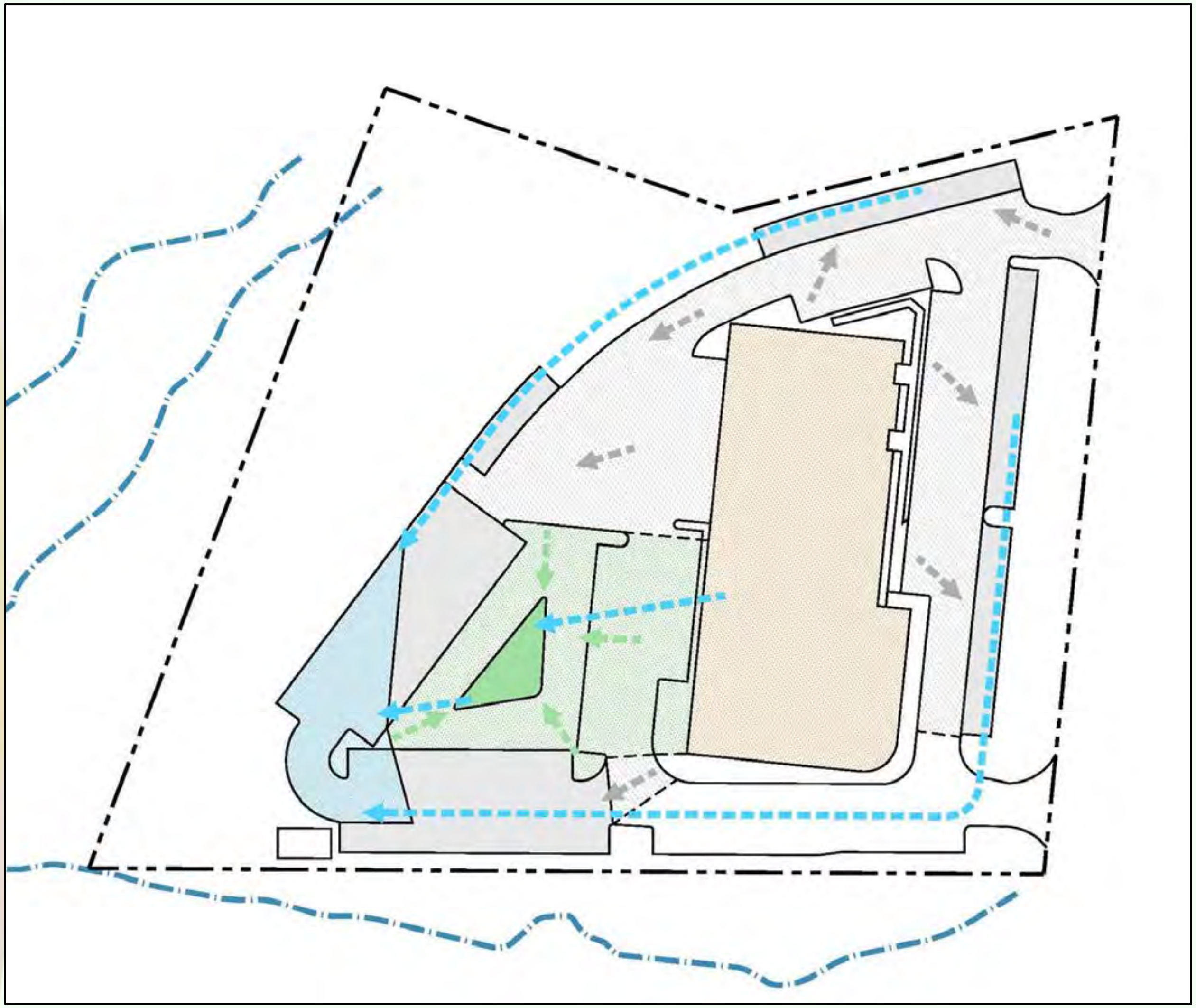
Site Results	
Phosphorous	
TOTAL TREATMENT VOLUME (cf)	9,568
TOTAL PHOSPHOROUS LOAD REDUCTION REQUIRED (LB/YEAR)	3.93
RUNOFF REDUCTION (cf)	4392
PHOSPHOROUS LOAD REDUCTION ACHIEVED (LB/YR)	3.76
ADJUSTED POST-DEVELOPMENT PHOSPHOROUS LOAD (TP) (lb/yr)	2.25
REMAINING PHOSPHOROUS LOAD REDUCTION (LB/YR) NEEDED	0.16
Nitrogen (for information purposes)	
TOTAL TREATMENT VOLUME (cf)	9,568
RUNOFF REDUCTION (cf)	4392
NITROGEN LOAD REDUCTION ACHIEVED (LB/YR)	27.09
ADJUSTED POST-DEVELOPMENT NITROGEN LOAD (TP) (lb/yr)	15.92

TP reduction achieved with pervious pavement, bioretention, harvesting, extended detention, and downstream connections: 3.76 lb/yr

Remaining required TP reduction: 0.16 lb/yr

VRRM Example

Step 2 (cont): Apply BMPs- Re-design Pavement to Level 2



L2 Pervious pavement
0.67 ac

0.85 “up-gradient” impervious acres

L1 Bioretention
0.17 “up-gradient” impervious acres

0.25 “up-gradient” turf/impervious acres

Harvesting
0.59 roof acres

L1 Extended Detention
Accepts overflow from upstream practices via underdrains

VRRM Example

Step 2 (cont): Apply BMPs; Review Phosphorus Reduction

3. Permeable Pavement													
3.a. Permeable Pavement #1 (Spec #7)	acres of permeable pavement + acres of "external" (upgradient) impervious pavement	45% runoff volume reduction	0.45	0.67	0	1040	1271	25	0.00	1.45	0.85	0.60	8.a. ED #1
3.b. Permeable Pavement #2 (Spec #7)	acres of permeable pavement	75% runoff volume reduction	0.75	0.85	0	2198	733	25	0.00	1.84	1.49	0.34	8.a. ED #1

D.A. Tab:
Design permeable pavement to Level 2 specifications

Site Results	
Phosphorous	
TOTAL TREATMENT VOLUME (cf)	9,568
TOTAL PHOSPHOROUS LOAD REDUCTION REQUIRED (LB/YEAR)	3.93
RUNOFF REDUCTION (cf)	5240
PHOSPHOROUS LOAD REDUCTION ACHIEVED (LB/YR)	4.09
ADJUSTED POST-DEVELOPMENT PHOSPHOROUS LOAD (TP) (lb/yr)	1.92
REMAINING PHOSPHOROUS LOAD REDUCTION (LB/YR) NEEDED	CONGRATULATIONS!! YOU EXCEEDED THE TARGET REDUCTION BY 0.2 LB/YEAR!!
Nitrogen (for information purposes)	
TOTAL TREATMENT VOLUME (cf)	9,568
RUNOFF REDUCTION (cf)	5240
NITROGEN LOAD REDUCTION ACHIEVED (LB/YR)	29.56
ADJUSTED POST-DEVELOPMENT NITROGEN LOAD (TP) (lb/yr)	13.45

Water Quality Compliance Tab:
TP reduction achieved with Level 2 pervious pavement, bioretention, harvesting, extended detention, and downstream connections:
4.09 lb/yr

TP Reduction requirement met via:
Level 2 pervious pavement;
Level 1 bioretention;
Harvesting (for irrigation and toilets);
Extended detention; and
Downstream connections.

VRRM Example

Step 3: Determine Allowable Peak Flow

		1-year storm	2-year storm	10-year storm
Target Rainfall Event (in)		3.10	3.50	5.30
Drainage Area A				
Drainage Area (acres)	5.08			
Runoff Reduction Volume (cf)	5,240			
Drainage Area B				
Drainage Area (acres)	0.00			
Runoff Reduction Volume (cf)	0			
Drainage Area C				
Drainage Area (acres)	0.00			
Runoff Reduction Volume (cf)	0			
Drainage Area D				
Drainage Area (acres)	0.00			
Runoff Reduction Volume (cf)	0			
Drainage Area E				
Drainage Area (acres)	0.00			
Runoff Reduction Volume (cf)	0			

Based on the use of Runoff Reduction practices in the various drainage areas, the spreadsheet calculates an adjusted Vdeveloped and adjusted Curve Number.

Drainage Area A		A soils	B Soils	C Soils	D Soils
Forest/Open Space -- undisturbed, protected forest/open space or reforested land	Area (acres)	0.0	0.0	0.2	1.9
	CN	30	55	70	77
Managed Turf -- disturbed, graded for yards or other turf to be mowed/managed	Area (acres)	0.0	0.0	0.5	0.0
	CN	39	61	74	80
Impervious Cover	Area (acres)	0.0	0.0	0.0	2.6
	CN	98	98	98	98

Weighted CN	S
87	1.49

	1-year storm	2-year storm	10-year storm
$RV_{Developed}$ (in) with no Runoff Reduction	1.74	2.18	3.85
$RV_{Developed}$ (in) with Runoff Reduction	1.46	1.90	3.57
Adjusted CN	83	83	84

Enter storm event depths (From VSMH, PFM, FSM, etc.)

Note:
CN (pre-BMP) = 87
Adjusted CN = 83-84

Using the adjusted curve number (CN) for each drainage area, calculate the peak discharge for the 1-, 2-, and 10-year storms. Compare the peak discharge to the allowable rates described in the Virginia Stormwater Management Program permit regulations (4VAC 50-60-66(b) and (c)).

Use adjusted CNs to determine the site's runoff volume and peak discharge. Compare to the requirements of 4VAC50-60-66.B.

VRRM Example

Runoff Volume Estimation Using TR-55

Step 1. Solve for $RV_{pre\text{-}development}$ and $RV_{post\text{-}development}$ for use in the Energy Balance method (4VAC50-60-66.B).

Pre-development Runoff Volume Calculations:

$S = (1000 / CN) - 10$

$= (1000 / 76) - 10 = 3.16$

$Q_{depth} = [(P - 0.2S)^2] / [(P + 0.8S)]$

$= [(3.0 - (0.2 \times 3.16))^2] / [(3.0 + (0.8 \times 3.16))]$

$= 1.0$ in

$RV_{pre\text{-}development} = Q \times A / 12$

$= 1.0'' \times 221{,}284 \text{ sf} / 12''$

$RV_{pre\text{-}development}$ = 18,440 cf

Pre-development condition assumptions for this example:

- Land cover is forest in good condition
- Weighted CN = 76
- 1-year rainfall event = 3.0" (per VSMH Table 4B)

Post-development Runoff Volume Calculations:

$S = (1000 / CN) - 10$

$= (1000 / 83) - 10 = 2.05$

$Q_{depth} = [(P - 0.2S)^2] / [(P + 0.8S)]$

$= [(3.0 - (0.2 \times 2.05))^2] / [(3.0 + (0.8 \times 2.05))]$

$= 1.5$ in *(Note that this is also given in the VRRM spreadsheet)*

$RV_{post\text{-}development} = Q \times A / 12$

$= 1.5'' \times 221{,}284 \text{ sf} / 12''$

$RV_{post\text{-}development}$ = 27,660 cf

Post-development conditions for this example:

- See Slide 97 for adjusted post-development CN
- Adjusted CN = 83 (1-yr storm)
- 1-year storm= 3.0" (per VSMH Table 4B)

Note that $Rv_{post\text{-}development\ pre\text{-}BMP}$ = 32,115 cf
Post-development, Pre-BMP CN = 87

VRRM Example

Pre-Development Peak Flow Estimation Using TR-55

Step 2. Solve for $Q_{pre\text{-}developed}$ for use in the Energy Balance method (4VAC50-60-66.B).

Assumptions for this example:
- T_c = 0.5 hr
- Rainfall distribution = SCS Type II
- 1-year rainfall event = 3.0” (per VSMH Table 4B)
- q_u determined from graphical peak discharge method
- F_p = 1.0

$Q_{pre\text{-}developed} = q_u \times A_m \times Q_{depth} \times F_p$

q_u = 520 csm/in

For graphical peak discharge method:

$I_a = 0.2 \times ((1000/83) - 10) = 0.41$

$I_a / P = 0.41 / 3.0 = 0.14$

A_m = 221,284 sf = 0.008 mi^2

Q_{depth} = 1.0” *(see previous slide)*

F_p = 1.0

$Q_{pre\text{-}developed} = 520 \times 0.008 \times 1.0 \times 1.0$

$Q_{pre\text{-}developed}$ = 4.2 cfs

VRRM Example

Channel and Flood Protection – Allowable Peak Flow

Step 3. Solve for the allowable $Q_{developed}$ using the Energy Balance method (4VAC50-60-66.B).

Allowable 1-yr, 24-hr peak flow rate per 4VAC50-60-66.B:

$Q_{developed} \leq 0.8 \times Q_{pre\text{-}developed} \times RV_{pre\text{-}developed} / RV_{developed}$

$Q_{developed}$ *shall not be required to be less than* $[Q_{forested} \times RV_{forested}] / RV_{developed}$

$Q_{developed}$ *must be* $\leq Q_{pre\text{-}developed}$

$Q_{pre\text{-}developed}$ = 4.2 cfs *(See slide 99. Also equals $Q_{forested}$ in this example.)*

$RV_{pre\text{-}developed}$ = 18,440 cf *(See slide 98. Also equals $RV_{forested}$ in this example)*

$RV_{developed}$ = 27,660 cf *(See slide 98.)*

Applying the Energy Balance Method conditions above:

Condition 1:

$Q_{developed} \leq 0.8 \times Q_{pre\text{-}developed} \times RV_{pre\text{-}developed} / RV_{developed}$

$Q_{developed} \leq 0.8 \times [5.51 \times 18{,}440] / 27{,}660 \leq$ **2.94 cfs**

Condition 2:

$Q_{developed}$ shall not be required to be less than $[Q_{forested} \times RV_{forested}] / Rv_{developed}$

$Q_{developed}$ shall not be required to be less than [5.51 x 18,440] / 27,660

$Q_{developed}$ shall not be required to be less than **3.67 cfs**

Condition3:

$Q_{developed}$ must be $\leq Q_{pre\text{-}developed}$

$Q_{developed}$ must be **$\leq$ 4.2 cfs**

Therefore, $Q_{developed} \leq$ 3.67 cfs

References

Stormwater Regulations

- http://www.dcr.virginia.gov/documents/swmfinregspublishedvareg.pdf
- (Additional information: http://www.dcr.virginia.gov/lr2d.shtml)

Virginia Runoff Reduction Method

- http://www.dcr.virginia.gov/lr2f.shtml

Virginia Stormwater BMP Clearinghouse

- http://vwrrc.vt.edu/swc/

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