Appendix A Compliance Calculations and Design Examples

A.1 General Retention Compliance CalculatorCompliance Calculations

The General Retention Compliance Calculator is an Excel file located on the DDOE website at http://ddoe.dc.gov/swregs.

Each regulated project must use the General Retention Compliance Calculator to demonstrate proper BMP selection and sizing to achieve the required amount of stormwater retention and/or water quality treatment. The completed worksheets from this calculator must be submitted with the Stormwater Management Plan (SWMP). All major regulated projects are required to address the Stormwater Retention Volume (SWRv), and major regulated projects in the Anacostia Waterfront Development Zone (AWDZ) are required to address the Water Quality Treatment Volume (WQTv), as described in Chapter 2.

Section A.2 provides guidance on using the General Retention Compliance Calculator. The resulting worksheets from this Excel program must be submitted with the Stormwater Management Plan (SWMP) for retention approval. The General Retention Compliance Calculator can also be used, in addition to other hydrologic methods and models, to demonstrate compliance with Achieving detention obligations (see may be demonstrated with these worksheets or other hydrologic methods and models as detailed in Chapter Section 2.6 and Appendix H).

A.2 Instructions for Compliance CalculationsDistrict of Columbia Stormwater Compliance Spreadsheet

The following guidance goes through the explains how to use of each of the worksheet tabs in the General Retention Compliance Calculator.

Note: All cells highlighted in blue are user input cells. Cells highlighted in gray are calculation cells, and cells highlighted in yellow are constant values that generally should not be changed.

Site Data Sheet

1. Input the name of the proposed project on **line 9**.
2. Determine if the site is located in the AWDZ and note in **cell E13**.
3. Determine if the site is located in the MS4 and note in **cell E14**.
4. The regulatory rain event for calculation of the SWRv varies depending upon the type of development. For major land-disturbing activities, the SWRv is based upon the 90th percentile depth (1.2 inches). For major substantial improvements, the SWRv is based upon the 80th percentile depth (0.8 inches). If the site is in the AWDZ and undergoing major

Formatted: Font: 11 pt

substantial improvement, the SWRv is based upon the 85th percentile depth (1.0 inches). Choose the type of development on **line 15**. The regulatory rain event for SWRv will be shown on **line 16**, and the regulatory rain event for the WQTv (if applicable) will be shown on **line 17**.

5. For the site, indicate the area (in square feet) of post-development Natural Cover, Compacted Cover, and b~~B~~est m~~M~~anagement p~~P~~ractice (BMP) surface area in **cells D22–D25**. Guidance for various land covers is provided in Table A.1. Efforts to reduce i~~I~~mpervious c~~C~~over on the site and maximize Natural Cover will reduce the required Stormwater Retention Volume (SWRv). Portions of a project located in the p~~P~~ublic r~~R~~ight-of-w~~W~~ay should be considered separately from the rest of the site and surface area by cover type should be indicated in **cells E22–E25**.

   Note: This step will be iterative as BMP sizing is performed, and the area of both BMPs and other land cover types are adjusted.

6. From the land cover input, weighted site-runoff coefficients (*Rv*) will be calculated (**line 33**) for both the site and the public right-of-way based upon the land cover *Rv* values of 0.00 for Natural Cover, 0.25 for Compacted Cover, and 0.95 for Impervious Cover.

$$\%N = AN/SA \times 100$$

$$\%C = AC/SA \times 100$$

$$\%I = AI/SA \times 100$$

$$Rv = (\%N \times RvN + (\%C) \times RvC + (\%I) \times RVI$$

where:

$\%N$	=	percent of site in natural cover
AN	=	area of post-development natural cover (ft^2)
$\%C$	=	percent of site in compacted cover
AC	=	area of post-development compacted cover (ft^2)
$\%I$	=	percent of site in impervious cover
AI	=	area of post-development impervious cover (ft^2)
SA	=	total site area (ft^2)
Rv	=	weighted site runoff coefficient
Rv_N	=	runoff coefficient for natural cover (0.00)
Rv_C	=	runoff coefficient for compacted cover (0.25)
Rv_I	=	runoff coefficient for impervious cover (0.95)

7. The SWRv that must be retained on the site and in the PROW will be calculated on **line 37**.

$$SWRv = P/12 \times Rv \times SA$$

where:

SWRv	=	SstormwaterRretention Vvolume (ft^3)
P	=	regulatory rain event (in.)
12	=	conversion from inches to feet
Rv	=	weighted site runoff coefficient
SA	=	total site area (ac)

8. If the site is in the AWDZ, the WQTv that must be treated on site and in the PROW will be calculated on **line 39**. The regulatory rain event for calculation of the WQTv is based upon the 95th percentile depth (1.7 inches).

$$WQTv = P/12 \times Rv \times SA$$

where:

WQTv	=	stormwater treatment volume (ft^3)
P	=	regulatory rain event (1.7 in.)
12	=	conversion from inches to feet
Rv	=	weighted site runoff coefficient
SA	=	total site area (ac)

Table A.1 Land Cover Guidance for General Retention Compliance Calculator, consult Appendix OAppendix N for more details.

Natural Cover
Land that will remain undisturbed and exhibits hydrologic properties equal to or better than meadow in good condition OR land that will be restored to such a condition. This includes: ▪ Portions of residential yards in forest cover that will NOT be disturbed during construction. ▪ Community open space areas that will not be mowed routinely, but left in a natural vegetated state (can include areas that will be rotary mowed no more than two times per year). ▪ Utility rights-of-way that will be left in a natural vegetated state (can include areas that will be rotary mowed no more than two times per year). ▪ Other areas of existing forest and/or open space that will be protected during construction and that will remain undisturbed. <u>Operational and Management Conditions in Natural Cover Category:</u> ▪ Undisturbed portions of yards, community open space, and other areas that will be considered as forest/open space must be shown outside the Limits of Disturbance (LOD) on an approved Soil Erosion and Sediment Control Plan (SESCP) AND demarcated in the field (e.g., fencing) prior to commencement of construction. ▪ Portions of roadway rights-of-way that will count as natural cover are assumed to be disturbed during construction, and must follow the most recent design specifications for soil restoration and, if applicable, site reforestation, as well as other relevant specifications if the area will be used as a BMP. ▪ All areas that will be considered natural cover for stormwater purposes must have documentation that prescribes that the area will remain in a natural, vegetated state. Appropriate documentation includes: subdivision covenants and restrictions, deeded operation and maintenance agreements and plans, parcel of common ownership with maintenance plan, third-party protective easement, within public right-of-way or easement with maintenance plan, or other documentation approved by DDOE. ▪ While the goal is to have natural cover areas remain undisturbed, some activities may be prescribed in the appropriate documentation, as approved by DDOE: forest management, control of invasive species, replanting and revegetation, passive recreation (e.g., trails), limited bush hogging to maintain desired vegetative community, etc. ▪ Land that will undergo conversion from compacted cover or impervious cover to natural cover must follow the

Formatted: Font: 11 pt

Formatted: Font: 11 pt

guidelines for compost amended soils in Appendix KAppendix J.	
Compacted Cover	
Land disturbed and/or graded for eventual use as managed turf or landscaping. Managed turf comprises of areas that are graded or disturbed, and maintained as turf, including yard areas, septic fields, residential utility connections, and roadway rights of way. Landscaping includes areas that are intended to be maintained in vegetation other than turf within residential, commercial, industrial, and institutional settings.	
Impervious Cover	
Roadways, driveways, rooftops, parking lots, sidewalks, and other areas of impervious cover. While they are noted separately in the spreadsheet, the surface area of all BMPs, except disconnection areas are included with impervious cover in the spreadsheet's calculations.	

Drainage Area Sheets 1–510

If the site has multiple discharge points, or complex treatment sequences, it must be divided into individual drainage areas (DAs). For each DA, a minimum of 50 percent of the SWRv must be retained. In the MS4, if 50 percent of the SWRv cannot be retained, that volume (or equivalent 24-hour storm) must be captured and treated with an accepted TSS treatment practice.

For each DA sheet:

1. Indicate the specific area of post-development Natural Cover, Compacted Cover, Impervious Cover, Vehicular Access, and BMP surface area in **lines 6–10**. The SWRv for the DA will be calculated in **cell G11G12**, and the WQTv (if in the AWDZ) will be calculated in **cell G15G17**.

   Note: This step will be iterative as BMP sizing is performed, and the area of both BMPs and other land cover types is adjusted. Vehicular Access Areas are a sub-category of Impervious Cover. Therefore, the Vehicular Access Areas must be included as a part of the total Impervious Cover area.

2. Apply BMPs to the drainage area to address the required SWRv and WQTv by indicating the area in square feet of compacted cover, impervious cover, and vehicular access areas (see not above) to be treated by a given BMP in **columns B, D,** and **F** (or the number of trees in the case of tree preservation or planting). This will likely be an iterative process. The available BMPs include the following:

   - Green Roofs
   - Rainwater Harvesting
   - Simple Disconnection to a Pervious Area (Compacted Cover)
   - Simple Disconnection to a Conservation Area (Natural Cover)

Formatted: Font: 11 pt

- Simple Disconnection to Amended Soils
- Permeable Pavement Systems - Enhanced
- Permeable Pavement Systems - Standard
- Bioretention - Enhanced
- Bioretention - Standard
- Stormwater Filtering Systems
- Stormwater Infiltration
- Grass Channels
- Grass Channel with Amended Soils
- Dry Swales
- Wet Swales Storage
- Stormwater Ponds
- Stormwater Wetlands
- Grass Channel
- Grass Channel with Amended Soils
- Dry Swale
- Wet Swale Storage Practices
- Proprietary Practices
- Tree Planting
- Tree Preservation

3. Based upon the area input for a given BMP, the spreadsheet will calculate the Maximum Retention Volume Received by BMP in **column H**. Regardless of the Regulatory Rainfall Event that applies to the site, the volume calculated in **column F** is based on a rainfall depth of 1.7 inches. Therefore, the value in **column H** represents the greatest retention volume for which a BMP can be valued, rather than the volume that must be retained to achieve compliance. In other words, it is possible to “oversize” BMPs in one drainage area and “undersize” others to achieve compliance. However, as noted above, in the MS4, a minimum of 50 percent of the SWRv must be retained in each drainage area. Otherwise, treatment of the remaining runoff to reach 50 percent of the SWRv must be provided by an accepted TSS treatment practice.

$$V_{max} = 1.7/12 \times (Rv_N \times A_{NC} + Rv_C \times A_C + Rv_I \times (A_I + A_{BMP}))$$

where:

V_{max} = volume received by the BMP from 1.7-inch rain event (ft^3)

Formatted: Font: 11 pt

Rv_N = runoff coefficient for natural cover (0.00)
A_N = area of post-development natural cover (ft^2)
Rv_C = runoff coefficient for compacted cover (0.25)

A_C = area of post-development compacted cover (ft^2)
Rv_I = runoff coefficient for impervious cover (0.95)

A_I = area of post-development impervious cover (ft^2)
A_{BMP} = area of BMP (ft^2)

4. As noted in Chapter 2, for all vehicular access areas, a minimum of 50% percent of the SWRv must also be retained or treated. This volume is calculated for each BMP in **column G** as follows:

$$V = RRE/12 \times Rv_I \times Av \times 0.5$$

where:

V = volume received by the BMP from vehicular access areas that must be retained or treated (ft^3)
RRE = Regulatory Rain Event for SWRv (in.)
Rv_I = runoff coefficient for impervious cover (0.95)
Av = area of vehicular access area (ft^2)

5. If more than one BMP will be employed in series, any overflow from upstream BMPs will be accounted for in **column L**, and the total volume directed to the BMP will be summed in **column M**.
6. For most BMPs it is necessary to input the surface area of the BMP and/or the storage volume of the BMP in **columns N** and **O**. These should be calculated using the equations provided in Chapter 3.
7. The spreadsheet calculates a retention volume value in **column NP**, based on the value descriptions in **columns I–K**. Regardless of the storage volume of the BMP, the retention volume value cannot be greater than the total volume received by the BMP (**column M**).
8. The Potential Retention Volume Remaining (**column Q**) equals the total volume received by the BMP minus the retention volume value.
9. BMPs that have a less than 100 percent retention value and are accepted TSS treatment practices are assigned additional treatment volume based upon the lesser of the runoff volume received by the BMP and the actual storage volume minus the retention value. This additional treatment volume is indicated in **column R**.
10. Any potential retention volume remaining (**column Q**) can be directed to a downstream BMP in **column S** by selecting from the pull-down menu. Selecting a BMP from the menu will automatically direct the retention volume remaining to **column L** for the appropriate BMP.

Formatted: Font: 11 pt

11. **Column T** calculates whether or not the vehicular access area directed to each BMP is adequately addressed, via retention or treatment. To do this, the required runoff volume from the vehicular access area is compared to the retention and treatment volumes provided by the BMP, as well as from a downstream BMP, if selected. For each BMP that receives vehicular access runoff, "Yes" or "No" will be displayed. It should be noted that while this column does take downstream BMPs into account, it is not a precise enough check to ensure that all possible design variations are accounted for. Sufficient retention or treatment from vehicular access areas must be clearly shown on the design plans.
12. From the selected BMPs, the total volume retained will be summed in **cell P66**. The retention volume remaining will then be calculated as the difference between the SWRv and the total volume retained in **cell P68** (in cubic feet) and **cell P69** (in gallons). **Cell P71** indicates if at least 50 percent of the SWRv has been retained for the DA.
13. **Cell P72** indicates whether or not all of the vehicular access areas have been adequately addressed. This is accomplished with two checks. First, the cell checks that the entire vehicular access area for the drainage area indicated in **cell B9** has been included in **column F**, by comparing **cell F66** to **cell B9**. Second, the cell checks that sufficient retention or treatment volume has been provided in each BMP by searching for "No's" in **column T**. As noted above, this check is not precise enough to ensure that all possible design variations are accounted for. Sufficient retention or treatment from vehicular access areas must be clearly shown on the design plans.
14. If in the MS4, if 50 percent of the SWRv has not been retained, **cell P73** indicates that treatment is required.
15. From the selected BMPs, **cell T66** is the sum of the total volume treated. If treatment is required due to a shortage of retention, **cells T68** (cubic feet) and **T69** (gallons) indicate how much more runoff must be treated. If treatment is required because the site is located in the AWDZ, **cells T71** (cubic feet) and **T72** (gallons) indicate how much runoff must be treated to meet WQTv requirements.
16. **Cell P75** will indicate compliance for the DA with a "Yes" or "No," depending on retention and treatment volume provided in the drainage area.

    Note: Since only 50 percent of the SWRv must be retained in any individual DA, compliance in each drainage area does not automatically mean that compliance for the entire site has been achieved.

Public Right-of-Way Sheet

The Public Right-of-Way sheet is functionally identical to the Drainage Area sheet; therefore, Steps 1–16 should be followed as stated above. If SWRv or WQTv is not met, the site may still comply if it follows the Maximum Extent Practicable (MEP) process as described in Appendix B.

Compliance Worksheet Tab

The Compliance worksheet summarizes the stormwater retention and treatment results for each DA as well as the whole site. For all sites, in order to comply with the stormwater management requirements, each DA must indicate that the vehicular access areas volume has been addressed.

Formatted: Font: 11 pt

In the MS4, each DA must either indicate that 50 percent of the SWRv has been retained, or that there are ~~"~~0 inches of remaining volume to treat 50~~%~~ percent of the SWRv. Key values for each drainage area are described on this worksheet, with s~~S~~ite c~~C~~ompliance and the p~~P~~ublic r~~R~~ight-of-w~~W~~ay summarized at the bottom.

Cell ~~B106~~ B206 indicates the t~~T~~otal v~~V~~olume r~~R~~etained on site. **Cell ~~B108~~ B208** (cubic feet) and **cell ~~B109~~ B209** (gallons) indicate the remaining retention volume (if any) to meet the SWRv. If the SWRv has not been fully met, **cell ~~B115~~ B215** indicates the required Off-site Retention Volume (Offv). The Offv may be addressed through the use of Stormwater Retention Credits (SRCs) and/or payment of an in-lieu fee. If the SWRv has been exceeded, **cell ~~B114~~ B214** indicates the volume that may be available ~~for~~ to generate SRCs

This sheet also summarizes the stormwater retention results from the Public R~~r~~ight-of-W~~w~~ay (PROW) sheet. **Cell ~~B124~~ B224** indicates the Total Volume Retained on site. **Cells ~~B125~~ B225** and **~~B126~~ B226** show the remaining retention volume (if any) in cubic feet and gallons, respectively. **Cells ~~B131~~B232–~~B134~~ B235** show the remaining treatment volume (if any) to meet SWRv and WQTv requirements.

Channel and Flood Protection

This sheet assists with calculation of Adjusted Curve Numbers that can be used to calculate peak flows associated with the 2-year storm, 15-year storm, or other storm events.

1. Indicate the appropriate depths for the 1-year, 2-year, and 100-year 24-hour storms (or other storms as needed) on **line 5**.
2. Each cover type is associated with a Natural Resource Conservation Service (NRCS) curve number. **Cells ~~D34–D38~~D54, D56, and D58** show the curve number for D.A. 1. Using these curve numbers (or other curve numbers if appropriate), a weighted curve number and the total runoff volume for D.A. 1 is calculated (**cell ~~E38~~E58**).
3. **Line ~~41~~ 61** calculates the runoff volume without regard to the BMPs employed in D.A. 1. **Line ~~42~~ 62** subtracts the storage volume provided by the BMPs in D.A. 1 from these totals.
4. The spreadsheet then determines the curve number that results in the calculated runoff volume with the BMPs. This Adjusted Curve Number is reported on **line ~~43~~63**.
5. These steps are repeated for Drainage Areas ~~B~~2–~~E~~10.

Weighted Curve Number

$$CN = [(AN \times 70) + (AC \times 74) + (AI \times 98)]/SA$$

where:

CN = weighted curve number
AN = area of post-development natural cover (ft^2)
AC = area of post-development compacted cover (ft^2)
AI = area of post-development impervious cover (ft^2)
SA = total site area (ft^2)

Formatted: Font: 11 pt

Potential Abstraction

$$S = 1000/(CN\text{-}10)$$

where:

S = potential abstraction (in.)
CN = weighted curve number

Runoff Volume with no Retention

$$Q = (P - 0.2 \times S)2/(P + 0.8 \times S)$$

where:

Q = runoff volume with no BMPs (in.)
P = precipitation depth for a given 24-hour storm (in.)
S = potential abstraction (in.)

Runoff Volume with BMPs

$$Q_{BMP} = Q - Cv_{DA}~~(da)~~ \times 12/~~S~~DA$$

where:

Q_{BMP} = runoff volume with BMPs (in.)
Q = runoff volume with no BMPs (in.)
Cv_{DA}~~(da)~~ = total storage volume provided by BMPs for the drainage area (ft^3)
~~3630~~12 = unit adjustment factor, ~~cubic feet to acre-~~feet to inches
DA = ~~site~~ drainage area (~~ac~~ft^2)

Adjusted Curve Number

The adjusted curve number is calculated using a lookup table of curve number and runoff volumes so that:

$$CN_{adjusted}, so\ (P - 0.2 \times S_{adjusted}) \times 2/(P + 0.8 \times S_{adjusted}) = Q_{BMP}$$

$$S_{adjusted} = 1000/(CN_{adjusted} - 10)$$

where:

$CN_{adjusted}$ = adjusted curve number that will create a runoff volume equal to the drainage area runoff volume including BMPs
P = precipitation depth for a given 24-hour storm (in.)
$S_{adjusted}$ = adjusted potential abstraction based upon adjusted curve number (in.)
Q_{BMP} = runoff volume with BMPs (in.)

Formatted: Font: 11 pt

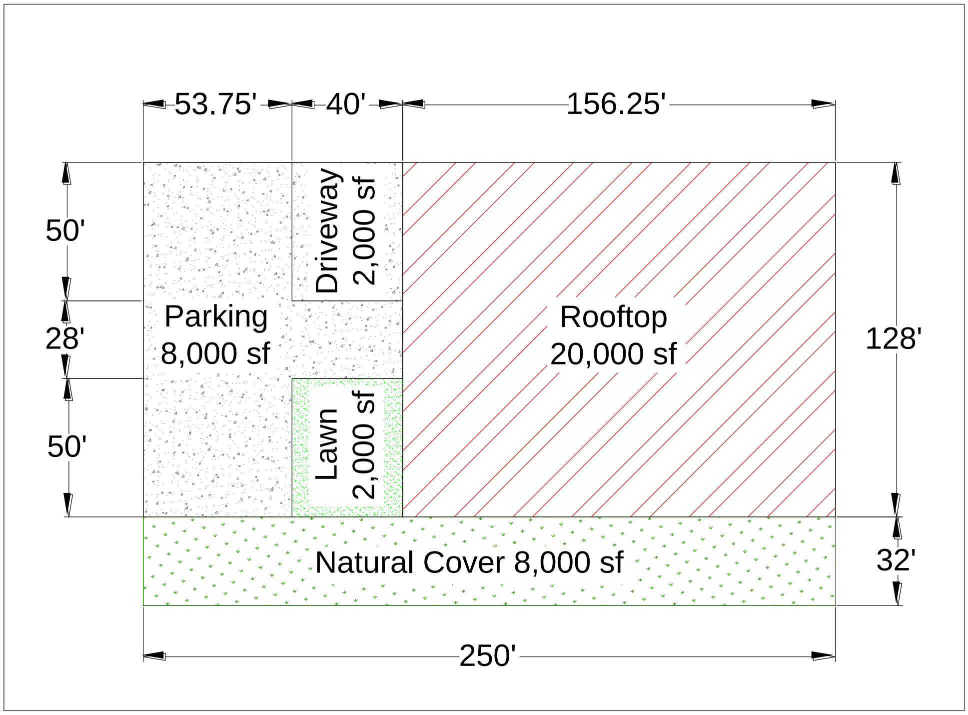
A.3 Design Examples

Design Example 1

Step 1: **Determine Design Criteria.**

Design Example 1 includes the following site characteristics:

Site Name	Anacostia Offices
Total Site Area	40,000 ft^2
Natural Cover Area	8,000 ft^2
Compacted Cover	2,000 ft^2
Impervious Cover	30,000 ft^2
Vehicular Access Areas	10,000 ft^2
Is site located within the AWDZ?	No
Is site located within the MS4?	No
What type of activity is site undergoing?	Major Land Disturbing



Step 2: **Input Design Criteria to Determine the Retention and Treatment Requirements.**

Formatted: Font: 11 pt

The General Retention Compliance Calculator will calculate a Stormwater Retention Volume (SWRv), once the natural cover, compacted cover, and impervious cover areas are put into **cells D22–D25** on the Site Data sheet.

Based on the design criteria above, Anacostia Offices has the following requirements:

$$SWRv = \times \textbf{ cell D37} = 2{,}900 \text{ ft}^3$$

Step 3: **Identify Site Constraints and BMP Restrictions.**

Key considerations for Anacostia Offices include the following:

- Site soils are contaminated, so infiltration is not allowed, and impermeable liners will be required for most BMPs.
- The commercial land use means that most BMPs are otherwise acceptable.

Step 4: **Select BMPs to Meet the Retention and Treatment Requirements.**

While there are numerous options for treatment of this site, two BMPs were selected: rainwater harvesting (R1) for the rooftop and bioretention (B1) for any remaining rooftop runoff and the rest of the site. Since the site is contaminated, a liner is required and the enhanced bioretention option is not available.

The site will ultimately have one outlet point, and the selected treatment train is relatively simple, so the calculations can be performed on one Drainage Area tab – D.A. 1. Therefore, all of the same values from the Site Data tab for the various cover types (plus the vehicle access area) should be put into **cells B6-B10** on the D.A.1tab.

The first BMP selected is rainwater harvesting for runoff from the rooftop. The Cistern Design spreadsheetRainwater Harvesting Retention Calculator should be used to determine the cistern size and the associated retention value. In the Cistern Design SpreadsheetRainwater Harvesting Retention Calculator 20,000 square feet should be put in as the Contributing Drainage Area (CDA) (**cell L7**). For utilization of the rainwater, flushing toilets/urinals is selected as the use, and the appropriate values are entered. In this case, 500 people will use the building per day (**cell L21**), Monday through Friday (**cells L30** and **L32**), 8 hours per day (**cell L34)**. On the Results – Retention Value sheet, the retention values are given for various tank sizes. The tables and graphs show that a 30,000 gallon underground tank (or series of tanks) would meet much of the demand and have a very high retention value—94 percent.

The next step is to return to the D.A. 1 tab and input the 20,000-square foot CDA into **cell D25** for rainwater harvesting and input the efficiency (94%) into **cell K25**. The result is that 2,530 cubic feet of runoff are retained and 162 cubic feet remain. Since Standard Bioretention will be the next BMP in the series, it should be selected from the pull-down menu in **cell S25**. The remaining runoff volume will then be directed to this BMP.

In addition to the overflow from the rainwater harvesting BMP, the bioretention area will receive runoff from the rest of the site. Initially, these land uses can be input into **cells B39–D40**. However, the surface area of the bioretention area must be accounted for as well. Through trial and error, it was determined that a 1,000-square-foot bioretention area would be sufficient to meet the retention requirement. This area will be taken from the compacted cover area and will need to be changed on the Site Data Tab as well as at the top of DA. 1. Compacted cover will now be 1,000 square feet, and BMP will be 1,000 square feet. The 8,000 square feet of natural cover will remain. Impervious cover directed to the bioretention area **(cell D39)** will be 10,000 square feet (the remaining impervious area after 20,000 square feet was removed for rainwater harvesting). 1,000 square feet of compacted cover and 1,000 square feet of BMP surface area will also be directed to the bioretention area (**cells B40** and **D40**). Since thise 10,000 square feet of impervious cover is made up of driveway and parking area, it is all classified as vehicular access area, so 10,000 should be put into **cell F39** as well.

The vehicular access retention/treatment requirement is 475 cubic feet (**cell G39**), and the total volume directed to the bioretention area, including the “overflow” from the rainwater harvesting BMP, will be 1,677 cubic feet (**cell M39**) is more than sufficient to address the vehicular access volume and. Inputting 800 cubic feet for the storage volume in the spreadsheet (**cell O39**) is more than sufficient to address the vehicular access volume and leads to an exceedaence of 300 gallons for the SWRv (**cell Q69**). This information is also summarized on the Compliance worksheet tab.

Step 5: Size the BMPs According to the Design Equations.

The size of the rainwater-harvesting cistern was already determined to be 30,000 gallons, although additional volume may be necessary for dead storage for a pump, and/or freeboard.

To meet the bioretention criteria, the bioretention area is sized with 1.5 feet of filter media, 0.75 feet of gravel, and a 0.5-foot ponding depth. The bioretention cell sizing goal is 800 cubic feet.

Step 5.1: Check the Filter Media Depth.

Ensure that the filter media depth does not exceed the maximum in Table 3.21. The ratio of the surface area of the BMP (1,000 ft^2) to the contributing drainage area (32,000 ft^2) is 3.1%. The Rv for the contributing drainage area to the bioretention practice is 0.93. The maximum filter media depth allowed is 5.0 feet. As the bioretention was sized with 1.5 feet of filter media, it passes this check.

Table 3.21 Determining Maximum Filter Media Depth (feet)

SA:CDA (%)	RvCDA								
	0.25	0.3	0.40	0.50	0.60	0.70	0.80	0.90	0.95
0.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
1.0	5.0	5.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0
1.5	3.5	4.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0
2.0	2.5	3.0	4.0	5.0	5.5	6.0	6.0	6.0	6.0
2.5	2.0	2.5	3.5	4.0	4.5	5.0	5.5	6.0	6.0
3.0	1.5	2.0	3.0	3.5	4.0	4.5	5.0	5.5	5.5
3.5	1.5	1.5	2.5	3.0	3.5	4.0	4.5	5.0	5.0
4.0	1.5	1.5	2.0	2.5	3.0	3.5	4.0	4.5	4.5

Formatted: Font: 11 pt

4.5	1.5	1.5	2.0	2.5	3.0	3.5	3.5	4.0	4.5
5.0	1.5	1.5	1.5	2.0	2.5	3.0	3.5	4.0	4.0
5.5	1.5	1.5	1.5	2.0	2.5	2.5	3.0	3.5	3.5
6.0	1.5	1.5	1.5	1.5	2.0	2.5	3.0	3.0	3.5
6.5	1.5	1.5	1.5	1.5	2.0	2.5	2.5	3.0	3.0
7.0	1.5	1.5	1.5	1.5	1.5	2.0	2.5	3.0	3.0
7.5	1.5	1.5	1.5	1.5	1.5	2.0	2.5	2.5	2.5
8.0	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.5	2.5
8.5	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.5
9.0	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.0
9.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0
10.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0

Step 5.2**: Determine Storage Volume.**

Equation 3.5

$$Sv = SA_{bottom} \times \left[\left(d_{media} \times \eta_{media} \right) + \left(d_{gravel} \times \eta_{gravel} \right) \right] + \left(SA_{average} \times d_{ponding} \right)]$$

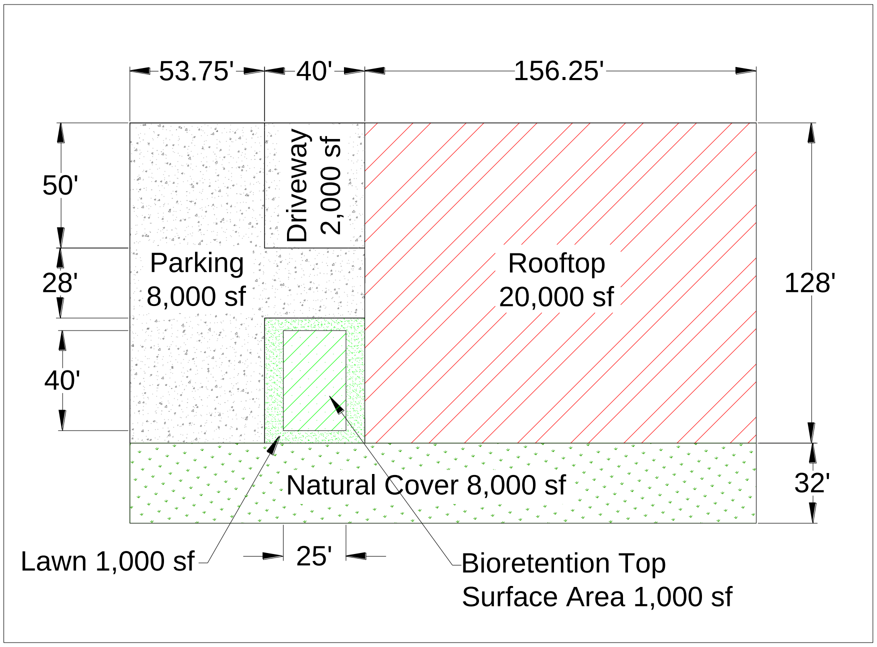
where:

Sv	=	total storage volume of bioretention (ft^3)
SA_{bottom}	=	bottom surface area of bioretention (ft^2)
d_{media}	=	depth of the filter media (ft)
η_{media}	=	effective porosity of the filter media (typically 0.25)
d_{gravel}	=	depth of the underdrain and underground storage gravel layer(ft)
η_{gravel}	=	effective porosity of the gravel layer (typically 0.4)
$SA_{average}$	=	the average surface area of the bioretention (ft^2) ((typically, where SA_{top} is the top surface area of bioretention, = ½ × (top area + SAbottom area) $SA_{average} = \frac{SA_{bottom} + SA_{top}}{2}$
$d_{ponding}$	=	the maximum ponding depth of the bioretention (ft)

Field Code Changed

Solving Equation 3.5 often requires an iterative approach to determine the most appropriate bottom surface area and average surface area to achieve the desired *Sv*. In this case, a bioretention with a 40 foot by 25 foot top area and 3:1 side slopes will provide a SA_{top} of 1,000 square feet, a SA_{bottom} of 814 square feet, a $SA_{average}$ of 907 square feet, and achieve a *Sv* of 1,003 cubic feet. This more than meets the goal of 800 cubic feet. If desired, the surface area of the practice could be reduced accordingly, or more SRCs could be generated with the excess volume.

Formatted: Font: 11 pt



Step 6: **Check Design Assumptions and Requirements.**

Key assumptions and requirements for this site include:

- Based upon the above design, the rainwater harvesting cistern will be 30,000 gallons and the bioretention cell will require at least 1,000 square feet of surface area. The designer would need to ensure that space would be available for these BMPs on the site.
- The contributing drainage area for traditional bioretention must be 2.5 acres or less and this site is less than 1 acre.
- The required head for the above design will be 25 feet, including ponding depth (9 inches), mulch (3 inches), filter media (18 inches), choking layer (about 3inches) , and gravel layer (about 9 inches). (See Figure 3.18). The outlet for the underdrain must be at least this deep.
- The water table must be at least 2 feet below the underdrain, or 5.5 feet below the surface. According to the Soil Survey, Beltsville soils have a 1.5- to 2-foot depth to seasonally high groundwater table, Croom soils have greater than a 5-foot depth, and Sassafras soils have a 4-foot depth. On-site soil investigations will be needed to determine if the 5.5-foot depth to the groundwater table can be met on this site.
- Due to soil contamination and the bioretention area's proximity to the building (less than 10 feet), an impermeable liner is required.

Since all of these assumptions and requirements can be met in this design example (pending groundwater table investigations), this step is complete.

Step 7: Use the Adjusted Curve Number to Address Peak Flow Requirements.

On the Channel and Flood Protection tab, enter values for C soils in **cells ~~D34~~D54, ~~D36~~D56**, and **~~D38~~ D58** (70 for natural areas, 74 for turf, and 98 for impervious cover, respectively). The original site curve number of 92 is reduced for the 2-year, 15-year, and 100-year storms to 79, 82, and 83, respectively, by the retention provided by the cistern and bioretention cell. These values can be used to help determine detention requirements for this site.

Step 8: Determine Detention Requirements.

Detention is required to reduce the peak discharge rate from the 2-year storm event to the predevelopment (meadow conditions or better) peak discharge rate and to reduce the peak discharge rate from the 15-year storm event to the preproject peak discharge rate. Appendix H includes details on the procedure for calculating the detention volume. In this example, the proposed impervious cover and the proposed runoff curve number is less than the preproject conditions, so detention for the 15-year storm is not required. Detention for the 2-year storm will be required.

The peak inflow (q_{i2}) and the peak outflow (q_{o2}) can be calculated using the WinTR-55 Small Watershed Hydrology program, the area of the site, the time of concentration (Tc), assumed to be 10 minutes), and the curve numbers. The reduced curve of 79, determined above, generates a q_{i2} of 1.61 cubic feet per second (cfs). The curve number for meadow in good condition, 71, generates a q_{o2} of 1.07 cfs.

The ratio of 1.07 cfs to 1.61 cfs equals 0.63. Using Figure H.1, the ratio of storage volume (Vs_2) to runoff volume (Vr_2) is 0.22.

The runoff volume (Vr_2) determined from the General Retention Compliance Calculator ~~spreadsheet~~ is 1.33 inches, which equates to 4,333 cubic feet. Using the calculated ratio of Vs_2/Vr_2, the storage volume required for the site (Vs_2) is 1,020 cubic feet.

With appropriate orifice design to ensure that outflows are properly restricted, this detention volume can be incorporated below the proposed bioretention area or located elsewhere on the site as a standalone detention practice.

Design Example 2

Step 1: Determine Design Criteria.

Design Example 2 includes the following proposed design criteria:

Site Name	Downtown Multi-Story Renovation
Total Site Area	15,000 ft^2
Natural Cover Area	0 ft^2
Compacted Cover	0 ft^2
Impervious Cover (Rooftop)	15,000 ft^2
Vehicular Access Areas	0 ft^2

Formatted: Font: 11 pt

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Formatted: Font: 11 pt

Is site located within the AWDZ?	No
Is site located within the MS4?	Yes
What type of activity is the site undergoing?	Major Substantial Improvement

Step 2: **Input Design Criteria to Determine the Retention and Treatment Requirements.**

The Compliance Calculator Spreadsheet will calculate a Stormwater Retention Volume (SWRv), once the above values are put into the Site Data sheet.

Based on the design criteria above, the Multi-Story Renovation project is required to treat 0.8 inches of rainfall for the SWRv:

SWRv = ~~×~~ **cell D37** = 950 ft^3

Step 3: **Identify Site Constraints and BMP Restrictions.**

Key considerations for the Multi-Story Renovation project include the following:

- Since this is a rooftop-only site, very few treatment options are available.
- As a renovation, the structure of the existing roof will be a factor for any rooftop practice.

Step 4: **Select BMPs to Meet the Retention and Treatment Requirements.**

As an initial estimate 75 percent of the rooftop is proposed to be converted to a green roof, with the remaining 25 percent draining to it. Therefore, the land use values need to be changed to account for the green roof: 3,750 square feet should be entered as ~~rooftop~~ impervious cover in **cell D24** on the Site Data sheet, and 11,250 square feet should be entered in **cell D25** as "BMP." As there will be only one drainage area for the site, these same values should be entered into **cells B8** and **B10** on sheet D.A. 1. and as the Green Roof drainage area (**cells D23** and **D24**).

The goal of this design is to capture the entire retention volume (950 ft^3) in the Green Roof. This can be shown on the spreadsheet by entering 950 cubic feet in **cell O23** on sheet D.A. A. **Cell Q69** shows that the SWRv has been met for the site. This information is also summarized on the Compliance worksheet tab.

Step 5: **Size the BMPs According to the Design Equations.**

The green roof needs to be sized according to Equation 3.1. ~~Note:~~ Since green roofs are typically manufactured systems, several of the parameters, such as the drainage layer depth and ~~porosity~~ maximum water retention of all layers, need to be provided by the manufacturer. The values for the roof used in this design are provided in the variable descriptions below Equation 3.1 (with each layer illustrated in Figure 3.1).

Equation 3.1 Storage Volume for Green Roofs

$$Sv = \frac{SA \times [(d \times \eta_1) + (DL \times \eta_2)]}{12}$$

where:

Sv	=	storage volume (ft^3) (goal is 950 ft^3)
SA	=	green roof area (ft^2) (need to determine)
Dd	=	media depth (in.) (6 in.)
$\eta 1$	=	verified media porosity maximum water retention (0.25)
DL	=	drainage layer depth (in.) (1 in.)
$\eta 2$	=	verified drainage layer porosity maximum water retention (0.4)

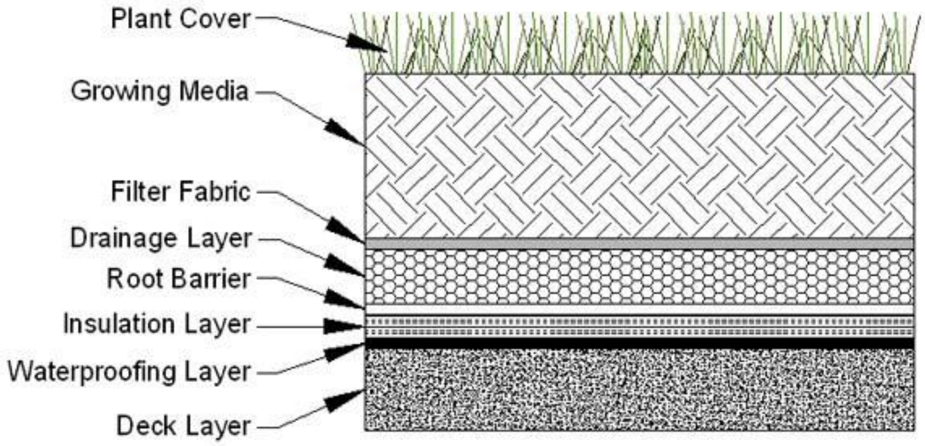


Figure 3.1 Typical layers for a green roof.

Rearranging Equation 3.1 to find the minimum required surface area:

$$SA = Sv/[(d \times \eta\ 1)+(DL \times \eta\ 2)] \times 12$$

or:

$$SA = 950/(6 \times 0.25+1\times 0.4) \times 12$$

$$SA = 6{,}000\ ft^2$$

Therefore, the green roof must be sized to be at least 6,000 square feet, given the proposed depths. The original assumption was that an 11,250-square-foot roof would be used. Since a smaller roof is feasible, the drainage areas in the spreadsheet may be revised accordingly.

Note: The drainage area to the green roof is only 25 percent larger than the green roof itself, so the maximum additional drainage area to a 6,000-square-foot roof is 1,500 square feet. Alternatively, the larger roof may be utilized, and the increased storage volume can be used to reduce peak flow volume requirements (see Step 8) or sold as Stormwater Retention Credits.

Step 6: **Check Design Assumptions and Requirements.**

Formatted: Font: 11 pt

Key assumptions and requirements for this site include:

- A structural analysis of the building is needed to determine that the green roof can be supported by the existing structure.
- Ensure that there is sufficient space on the rooftop (allowing for structures such as vents, steep areas of the roof, and other panels). In this case, the minimum roof area of 6,000 square feet is less than half of the entire roof area and most roofs can accommodate this area.
- At least 1,500 square feet of the rooftop not covered by green roof needs to be designed so that it drains to the green roof without damaging it.

Since all of these assumptions and requirements can be met in this design example, this step is complete.

Step 7: Use the Adjusted Curve Number to Address Peak Flow Requirements.

The initial curve number for this site is 98, but retention provided by the green roof changes this number. The Channel and Flood Protection tab notes the reduced curve numbers for the 2-year, 15-year, and 100-year storms: 90, 91, and 92, respectively. These curve numbers can be used to help determine detention requirements for this site.

Step 8: Determine Detention Requirements.

Detention is required to reduce the peak discharge rate from the 2-year-storm event to the predevelopment (meadow conditions or better) peak discharge rate and to reduce the peak discharge rate from the 15-year storm event to the preproject peak discharge rate. Appendix H includes details on the procedure for calculating the detention volume. In this example, since the proposed land cover is the same as the preproject conditions, detention is not required for the 15-year storm. However, detention is required for the 2-year storm.

The peak inflow, $qi_2$and the peak outflow, q_{o2} can be calculated using the WinTR-55 Small Watershed Hydrology program, the area of the site, the time of concentration (Tc, assumed to be 10 minutes), and the curve numbers. The reduced curve of 90, determined above, generates a qi_2 of 1.00 cubic foot per second (cfs). The curve number for meadow in good condition, 71, generates a q_{o2} of 0.39 cfs.

The ratio of 0.39 cfs to 1.00 cfs equals 0.39. Using Figure H.1, this equates to a ratio of storage volume (Vs_2) to runoff volume (Vr_2) of 0.33.

The runoff volume (Vr_2) determined in the Compliance Calculator spreadsheet is 2.21 inches, which equates to 2,763 cubic feet. Using the calculated ratio of Vs_2/Vr_2, the storage volume required for the site (Vs_2) is912 cubic feet.

Formatted: Subscript
Formatted: Subscript
Formatted: Subscript
Formatted: Subscript
Formatted: Subscript
Formatted: Subscript

Rooftop Storage (see Appendix I) may be the most cost effective method for achieving this detention volume in this example.

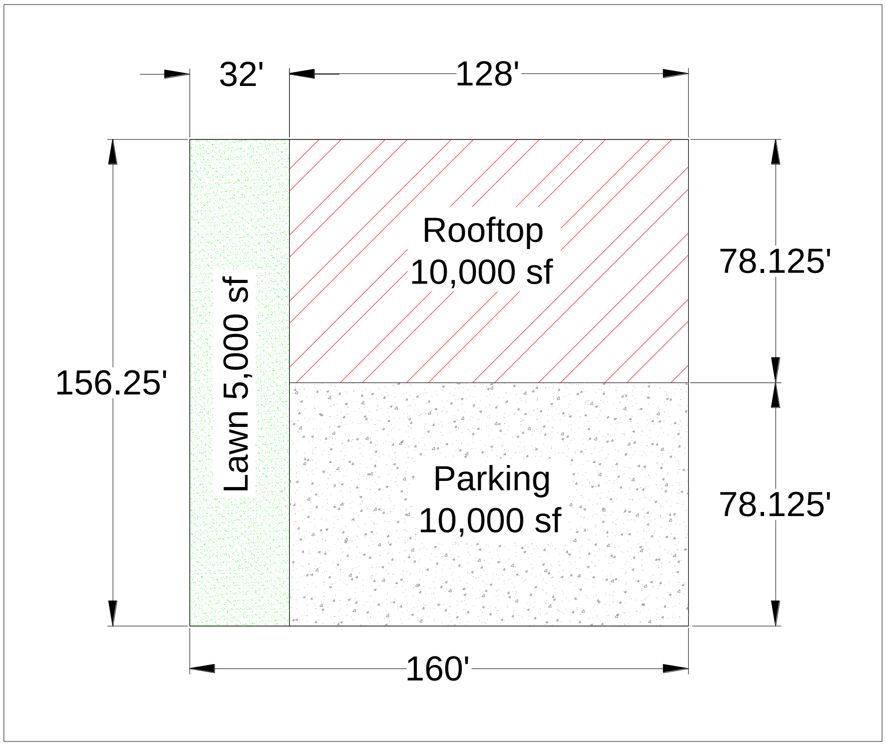
Design Example 3

Step 1: Determine Design Criteria.

Formatted: Font: 11 pt

Design Example 3 includes the following proposed design criteria:

Site Name	Ward 5 Low-Rise Commercial
Total Site Area	25,000 ft^2
Natural Cover Area	0 ft^2
Compacted Cover	5,000 ft^2
Impervious Cover	20,000 ft^2
Vehicular Access Areas	10,000 ft^2
Is site located in the AWDZ?	No
Is site located within the MS4?	Yes
What type of activity is site undergoing?	Major Land Disturbing



Step 2: **Input Design Criteria to Determine the Retention and Treatment Requirements.**

Formatted: Font: 11 pt

The Compliance Calculator Spreadsheet will calculate a Stormwater Retention Volume (SWRv), once the natural cover, compacted cover, and impervious cover areas are put into **cells D22–D25** on the Site Data sheet.

Based on the design criteria above, the project has the following requirement:

SWRv = ~~×~~ **cell D37** = 2,025 ft^3

Step 3: **Identify Site Constraints and BMP Restrictions.**

Key considerations for the project include the following:

- Only a small portion of the compacted cover is available for potential BMPs.
- The Multi-Family Residential site is not restrictive of BMP options.
- The relatively permeable Sunnyside-Sassafras-Muirkirk-Christiana soils on this site allow for infiltration into site soils. ~~However, it is not likely that infiltration rates will be greater than 2 inches per hour.~~

Step 4: **Select BMPs to Meet the Retention and Treatment Requirements.**

An enhanced bioretention with no underdrain is chosen for this site, primarily to minimize cost. Several other options, such as permeable pavers, would have been acceptable at this site.

The site will ultimately have one outlet point, with only one BMP, so the calculations can be performed on one Drainage Area tab—D.A. 1. Therefore, all of the same values from the Site Data tab for the various cover types (plus the vehicle access area) should be put into **cells B6–B10** on the D.A. 1 sheet.

It is assumed that the entire site will be directed to the bioretention area, so the same values from the top of the ~~DAA~~ DA1 sheet may be input into **cells B37–F38** (including the 10,000 square feet of vehicle access area in **cell F3~~8~~7**. However, the surface area of the bioretention area must be accounted for as well. It was determined that only 1,000 square feet of compacted cover would be available for a bioretention area. This area will be taken from the compacted cover area, and will need to be changed on the Site Data Tab as well as the top of D.A. 1. Compacted cover will now be 4,000 square feet, and "BMP" will be 1,000 square feet. The rooftop and parking areas will not change. This approach will lead to a total volume of 2,968 cubic feet directed to the BMP.

Since enhanced bioretention receives100 percent retention value, the required storage volume to meet the SWRv is 2,095 cubic feet (this is the required SWRv after changes in land use were made to account for the bioretention surface area). However, the 1,000 square feet available will not be sufficient to provide the entire required storage volume. Through trial and error (see Step 5 below) it was determined that the maximum storage volume is 1,~~077~~301 cubic feet. This value can be input into **cell O37**. **Cell P68** indicates that there is still ~~1,018~~ 794 cubic feet, or ~~7,615~~ 5,939 gallons (**cell P69**), remaining. This volume will have to be met through the purchase or generation of Stormwater Retention Credits (SRCs) (see Chapter 7 and Step 9 below).

Step 5: **Size the BMPs According to the Design Equations.**

Formatted: Font: 11 pt

Assume a filter media depth of 2 feet, a gravel depth of 0.75 feet, and a ponding depth of 1 foot.

***Step 5.1*: Check the Filter Media Depth.**

Ensure that the filter media depth does not exceed the maximum in Table 3.21. The ratio of the surface area of the bioretention (1,000 ft^2) to the contributing drainage area (25,000 ft^2) is 4%. The *Rv* was previously determined to be 0.~~95~~84. The maximum filter media depth allowed is 4.~~5~~0 feet. As the bioretention was sized with 2 feet of filter media, it passes this check.

Table 3.21 Determining Maximum Filter Media Depth (feet)

SA:CDA (%)	RvCDA								
	0.25	**0.3**	**0.40**	**0.50**	**0.60**	**0.70**	**0.80**	**0.90**	**0.95**
0.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
1.0	5.0	5.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0
1.5	3.5	4.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0
2.0	2.5	3.0	4.0	5.0	5.5	6.0	6.0	6.0	6.0
2.5	2.0	2.5	3.5	4.0	4.5	5.0	5.5	6.0	6.0
3.0	1.5	2.0	3.0	3.5	4.0	4.5	5.0	5.5	5.5
3.5	1.5	1.5	2.5	3.0	3.5	4.0	4.5	5.0	5.0
4.0	1.5	1.5	2.0	2.5	3.0	3.5	4.0	4.5	4.5
4.5	1.5	1.5	2.0	2.5	3.0	3.5	3.5	4.0	4.5
5.0	1.5	1.5	1.5	2.0	2.5	3.0	3.5	4.0	4.0
5.5	1.5	1.5	1.5	2.0	2.5	2.5	3.0	3.5	3.5
6.0	1.5	1.5	1.5	1.5	2.0	2.5	3.0	3.0	3.5
6.5	1.5	1.5	1.5	1.5	2.0	2.5	2.5	3.0	3.0
7.0	1.5	1.5	1.5	1.5	1.5	2.0	2.5	3.0	3.0
7.5	1.5	1.5	1.5	1.5	1.5	2.0	2.5	2.5	2.5
8.0	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.5	2.5
8.5	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.5
9.0	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.0
9.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0
10.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0

***Step 5.2*: Determine the Storage Volume.**

Equation 3.5

$$Sv = SA_{bottom} \times [(d_{media} \times \eta_{media}) + (d_{gravel} \times \eta_{gravel})] + (SA_{average} \times d_{ponding})$$

where:

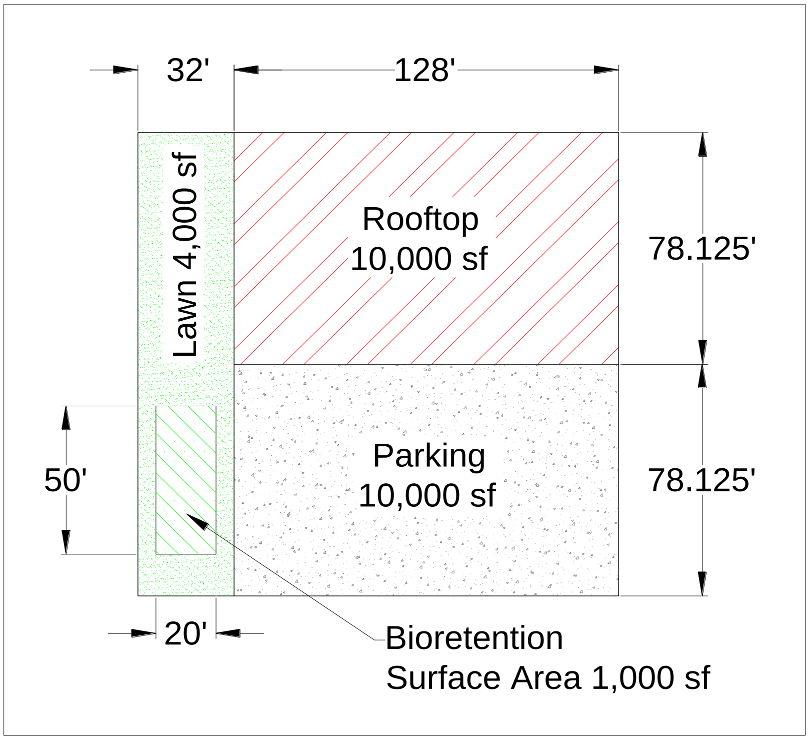
Sv = total storage volume of bioretention (ft^3)
SA_{bottom} = bottom surface area of bioretention (ft^2)

Formatted: Font: 11 pt

d_{media}	=	depth of the filter media (ft)
η_{media}	=	effective porosity of the filter media (typically 0.25)
d_{gravel}	=	depth of the underdrain and underground storage gravel layer(ft)
η_{gravel}	=	effective porosity of the gravel layer (typically 0.4)
$SA_{average}$	=	the average surface area of the bioretention (ft^2) (typically, where SA_{top} is the top surface area of bioretention, = 1/2 × (top area + SA_{bottom} area)) $SA_{average} = \frac{SA_{bottom} + SA_{top}}{2}$
$d_{ponding}$	=	the maximum ponding depth of the bioretention (ft)

Field Code Changed

Solving Equation 3.5 often requires an iterative approach to determine the most appropriate bottom surface area and average surface area to achieve the desired *Sv*. In this case, a long, narrow practice with a 50 foot by 20 foot top area and 3:1 side slopes was all that would fit on the site. This configuration will provide a SA_{top} of 1,000 square feet, a SA_{bottom} of 616 square feet, a $SA_{average}$ of 808 square feet, and will achieve an *Sv* of 1,301 cubic feet.



Step 6: **Check Design Assumptions and Requirements.**

Key assumptions and requirements for this site include:

Formatted: Font: 11 pt

- The design will need at least 1,000 square feet of surface area. The designer would need to ensure that this area is available.
- Contributing drainage area for traditional bioretention must be 2.5 acres are less, and this site has a total drainage area of less than 0.5 acres.
- Vehicle access areas must be addressed. The vehicle access retention/treatment requirement of 475 cubic feet is met by this design.
- Head requirements are not likely to be an issue, since this is an infiltration design.
- The water table must be at least 2 feet below the bottom of the bioretention, or 4.25 feet below the surface.
- The measured permeability of the underlying soils must be at least 0.5 inches/hour.
- Additional SRCs will need to be generated or purchased off-site.

Since all of these assumptions and requirements can be met (pending groundwater table and infiltration rate investigations) in this design example, this step is complete.

Step 7: **Use the Adjusted Curve Number to Address Peak Flow Requirements.**

On the Channel and Flood Protection tab, enter values for B soils in **cells ~~D34~~D54**, **~~D36~~D56**, and **~~D38~~ D58** (55 for natural areas, 61 for turf, and 98 for impervious cover, respectively). The original site curve number of 92 is reduced for the 2-year, 15-year, and 100-year storms to ~~86,~~ 87, 88, and 8~~8~~9, respectively by the retention provided by the bioretention cell. These curve numbers can be used to help determine detention requirements for this site.

Step 8: **Determine the Detention Requirements.**

Detention is required to reduce the peak discharge rate from the 2-year storm event to the predevelopment (meadow conditions or better) peak discharge rate and to reduce the peak discharge rate from the 15-year storm event to the preproject peak discharge rate. Appendix H includes details on the procedure for calculating the detention volume. In this example, the proposed impervious cover and the proposed runoff curve number is less than the preproject conditions, so detention for the 15-year storm is not required. Detention for the 2-year storm will be required.

The peak inflow (qi_2) and the peak outflow (q_{o2}) can be calculated using the WinTR-55 Small Watershed Hydrology program, the area of the site, the time of concentration (Tc, assumed to be 10 minutes), and the curve numbers. The reduced curve of 87, determined above, generates a qi_2 of 1.~~45~~50 cubic feet per second (cfs). The curve number for meadow in good condition, 58, generates a q_{o2} of 0.18 cfs.

The ratio of 0.18 cfs to 1.~~45~~50 cfs equals 0.12. Using Figure H.1, the ratio of storage volume (Vs_2) to runoff volume (Vr_2) is 0.53.

The runoff volume (Vr_2) determined in the Compliance Calculator spreadsheet is 1.84 inches, which equates to 3,833 cubic feet. Using the calculated ratio of Vs_2/Vr_2, the storage volume required for the site (Vs_2) is 2,032 cubic feet.

Formatted: Subscript
Formatted: Subscript
Formatted: Subscript
Formatted: Subscript
Formatted: Subscript
Formatted: Subscript

This detention volume, with appropriate orifice design to ensure that outflows are properly restricted, can be incorporated below the proposed bioretention area or located elsewhere on the site, such as underneath the parking lot as a standalone detention practice.

Step 9: **Identify Stormwater Retention Credits.**

Since the SWRv was short of the requirement by 7,615 gallons, 7,615 SRCs will need to be purchased or generated annually for this site to achieve compliance (see Chapter 7 for more details and example calculations).

Design Example 4

Design Example 4 includes the following proposed design criteria:

Site Name	Green St. and Gold St. Intersection
Total Site Area	13,528 ft^2
Natural Cover Area	0 ft^2
Compacted Cover	185 ft^2
Impervious Cover	13,343 ft^2

The site in this design example is a street reconstruction project. Since it is located in the public right-of-way (PROW), the maximum extent practicable (MEP) design process applies (see Appendix B).

Step 1: **Calculate SWRv.**

This intersection includes four stormwater inlets (one at each corner), so it will be divided into four drainage areas. The MEP Verification checklist requires calculation of the contributing drainage area within the limit of disturbance (LOD) as well as calculation of the contributing drainage area outside the LOD.

Drainage Area (DA 1 - N)	Contributing Area (ft^2)		SWRv (gal)	
	within LOD	outside LOD	within LOD	outside LOD
DA1	3,473	1,138	2,371	809
DA2	2,937	987	2,087	701
DA3	5,285	1,747	3,756	1,241
DA4	1,833	1,931	1,303	1,372
DATOTAL	**13,528**	**5,803**	**9,517**	**4,123**

Formatted: Font: 11 pt

SWRv can be calculated using the Compliance Calculator spreadsheet. In this case, all of the drainage areas were 100 percent impervious, except for DA1, which included 185 square feet of landscaped area within the LOD.

Step 2: **Consider Infiltration.**

This step requires looking at infiltration options by identifying constraints to infiltration, such as a high water table, soil contamination, or poor infiltration rates and locating areas that are well suited for infiltration.

In this example, a high water table and soil contamination were not a concern, The soil had only a moderate to low infiltration rate, making an infiltration sump a possibility as part of another BMP (such as enhanced bioretention) but not feasible as a standalone BMP.

Step 3: **Demonstrate Full Consideration of Land-Cover Conversions and Optimum BMP Placement.**

Opportunities for BMP placement within and adjacent to the PROW include traffic islands, triangle parks, median islands, cul-de-sacs, paper streets, and traffic calming measures, such as median islands, pedestrian curb extensions, bump outs, chicanes, and turning radius reductions.

As this example is a small intersection project, pedestrian curb extensions are the only feasible location for BMP placement. BMP locations in the pedestrian curb extensions will be possible at three of the four corners of the intersection.

Step 4: **Demonstrate Full Consideration of Opportunities Within Existing Infrastructure.**

This step requires the assessment and documentation of utility locations, storm sewer depths, right-of-way widths, and exiting trees to determine potential conflicts.

In this example, the difference in elevation between the storm sewer inlets and the invert of the pipes is approximately 5 feet. Other utilities will constrain the space available for the proposed BMPs but will not eliminate the pedestrian curb extension spaces entirely.

Step 5: **Locate and Choose BMPs.**

Although they may be undersized, enhanced bioretention areas will be selected for 3 of the 4 corners in the space available.

Areas for enhanced bioretention are as follows:

Drainage Area (DA 1 - N)	Contributing Area within LOD (ft^2)	SWRv within LOD (gal)	Available Area for BMP (ft^2)
DA1	3,473	2,371	72
DA2	2,937	2,087	285
DA3	5,285	3,756	190

Formatted: Font: 11 pt

DA4	1,833	1,303	0
DATOTAL	**13,528**	**9,517**	**N/A**

Step 6: **Siz~~eing~~ BMPs.**

Each bioretention area will be designed with a similar cross section: vertical side slopes for the ponding area, a ponding depth of 0.75 feet, a filter media depth of 2 feet, and a gravel depth (including the infiltration sump) of 1.25 feet.

The storage volume is determined with Equation 3.5

Equation 3.5

$$Sv = SA_{bottom} \times \left[\left(d_{media} \times \eta_{media} \right) + \left(d_{gravel} \times \eta_{gravel} \right) \right] + \left(SA_{average} \times d_{ponding} \right) \Big]$$

where:

Sv = total storage volume of bioretention (ft^3)
SA_{bottom} = bottom surface area of bioretention (ft^2)
d_{media} = depth of the filter media (ft)
η_{media} = effective porosity of the filter media (typically 0.25)
d_{gravel} = depth of the underdrain and underground storage gravel layer(ft)
η_{gravel} = effective porosity of the gravel layer (typically 0.4)
$SA_{average}$ = the average surface area of the bioretention (ft^2) ~~(~~typically, where SA_{top} is the top surface area of bioretention, ~~= ½ × (top area + SAbottom area)~~ $SA_{average} = \frac{SA_{bottom} + SA_{top}}{2}$
$d_{ponding}$ = the maximum ponding depth of the bioretention (ft)

Field Code Changed

With the cross section dimensions provided above, Equation 3.5 yields the following results:

Drainage Area (DA1–N)	Available Area for BMP (ft^2)	Sv (gal)	Sv (ft^3)
DA1	72	942	126
DA2	285	3,731	499
DA3	190	2,487	332
DA4	0	0	0

The table below indicates that there is a retention deficiency for 3 of the 4 drainage areas with the proposed BMPs.

Formatted: Font: 11 pt

Drainage Area (DA 1 - N)	Regulated SWRv within LOD (gal)	SWRv Achieved (gal)	Retention Deficiency (gal)	Altered Drainage Profile	
				Y	N
DA1	2,371	942	1,429		X
DA2	2,087	3,731	N/A		X
DA3	3,756	2,487	1,269		X
DA4	1,303	-	1,303		X
DATOTAL	**9,517**	**7,160**			

If there is a retention volume deficiency, the MEP design process notes that the designer should consider sizing BMPs to manage the comingled volume on-site, and/or revisit Design Steps 1 through 6 to increase land conversion areas and BMP facilities.

In this case, the proposed bioretention areas in DA2 could treat additional volume, but the proposed bioretention areas in DA1 and DA3 are at capacity. At this point, the designer should review Steps 1 through 6 to ensure that all opportunities for land conversion and BMP facilities have been maximized. If so, this step is complete.

Step 7: **Identify Drainage Areas Where Zero-Retention BMPs are Installed.**

Drainage areas that do not include a retention BMP will require installation of a water-quality catch basin to treat stormwater runoff. This requirement applies only to DA4 in this example.

Design Example 5

Step 1: **Determine Design Criteria.**

Design Example 5 includes the following proposed design criteria:

Site Name	NoMa Office Tower
Total Site Area	65,340 ft^2
Natural Cover Area	0 ft^2
Compacted Cover	0 ft^2
Impervious Cover (Rooftop)	65,340 ft^2
Vehicular Access Areas	0 ft^2
Is site located within the AWDZ?	No
Is site located within the MS4?	Yes
What type of activity is the site undergoing?	Major Land Disturbing

Step 2: **Input Design Criteria to Determine the Retention and Treatment Requirements.**

The Compliance Calculator Spreadsheet will calculate a Stormwater Retention Volume (SWRv), once the impervious cover area is put into **cell D24** on the Site Data sheet.

Based on the design criteria above, the NoMa Office Tower project is required to treat 1.2 inches of rainfall for the SWRv:

SWRv (**cell D37**) = 6,207 ft^3

Identify Site Constraints and BMP Restrictions.

Limitation of space is the key considerations for the NoMa Office tower project. The lot line to lot line construction means there are limited retention and treatment options. A rooftop approach is selected.

Step 3: **Select BMPs to Meet the Retention and Treatment Requirements.**

As an initial estimate 60 percent of the rooftop is proposed to be converted to a green roof, with an additional 15 percent of the remaining rooftop draining to it. Therefore, the land use values need to be changed to account for the green roof: 26,136 square feet should be entered as rooftop in **cell D24** on the Site Data sheet, and 39,204 square feet should be entered in **cell D25** as "BMP." As there will be only one drainage area for the site, these same values should be entered into **cells B8** and **B10** on sheet DA A. For the Green Roof drainage area (**cells D23** and **D24**), 9801 square feet should be entered as impervious cover, and 39,204 should be entered as BMP surface area.

The goal of this design is to capture the entire retention volume (6,207 ft^3) in the Green Roof. This can be shown on the spreadsheet by entering 6,208 cubic feet (1 extra cubic foot to ensure that any rounding losses are covered) in **cell O23** on sheet DA A. **Cell P68** shows that the SWRv has been met for the site. This information is also summarized on the Compliance worksheet tab.

Step 4: **Size the BMPs According to the Design Equations.**

The green roof needs to be sized according to Equation 3.1. Note that, since green roofs are typically manufactured systems, several of the parameters, such as the drainage layer depth and maximum water retention of all layers, need to be provided by the manufacturer. In this example, a media depth of 6 inches with a maximum water retention of 0.40 was chosen. The drainage layer has a depth of 1 inch and a maximum water retention of 0.15. These values are indicated in the variable descriptions below Equation 3.1 (with each layer illustrated in Figure 3.1).

Equation 3.1 Storage Volume for Green Roofs

$$Sv = \frac{SA \times [(d \times \eta_1) + (DL \times \eta_2)]}{12}$$

where:

Sv = storage volume (ft^3)
SA = green roof area (ft^2)
d = media depth (in.) (minimum 3 in.)
η_1 = verified media maximum water retention
DL = drainage layer depth (in.)

Formatted: Font: 11 pt

Field Code Changed

Field Code Changed

η_2 = verified drainage layer maximum water retention

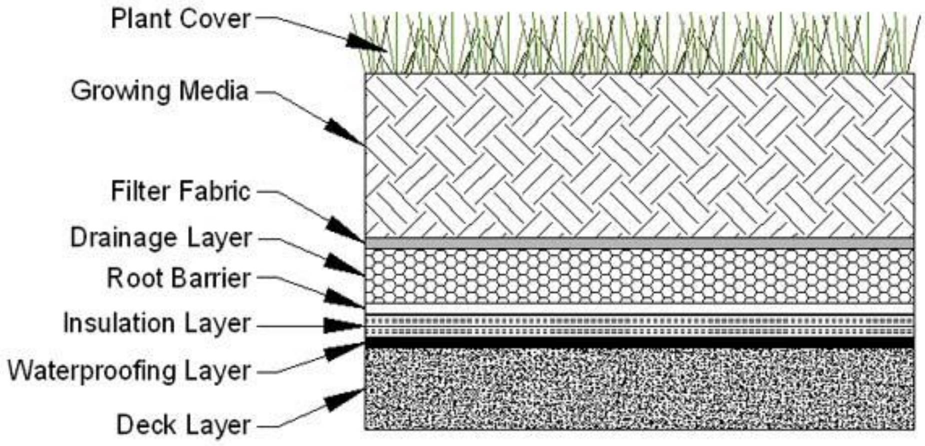


Figure 3.1 Typical layers for a green roof.

Rearranging Equation 3.1 to find the minimum required surface area:

$$SA = Sv/[(d \times \eta_1)+(DL \times \eta_2)] \times 12$$

or:

$$SA = 6{,}208/(6 \times 0.40 + 1 \times 0.15) \times 12$$

$$SA = 29{,}214 \text{ ft}^2$$

Therefore, the green roof must be sized to be at least 29,214 square feet (45% of the rooftop surface area), given the proposed depths. The original assumption was that a 39,204-square-foot roof would be used. Since a smaller roof is feasible, the drainage areas in the spreadsheet may be revised accordingly. However, the maximum drainage area to a green roof is only 25% more than the green roof itself. If a smaller roof is used, the design must indicate that the water can be conveyed onto the green roof in a non-erosive manner. If the larger green roof area is used, it could be designed with a lower media depth or the increased storage volume could be used to reduce peak flow volume requirements (see Step 8) and/or sold as Stormwater Retention Credits.

Step 5: **Check Design Assumptions and Requirements.**

Key assumptions and requirements for this site include:

Formatted: Font: 11 pt

Field Code Changed

Formatted: Font: 11 pt

- Ensure that there is sufficient space on the rooftop (allowing for structures such as vents, steep areas of the roof, and other panels). In this case, the green roof area of 29,214 square feet is less than half of the entire roof area.
- At least 19,791 square feet of the rooftop not covered by green roof needs to be designed so that it drains to the green roof without damaging it. This may require level spreaders or other devices.

Since all of these assumptions and requirements can be met in this design example, this step is complete.

Step 6: Use the Adjusted Curve Number to Address Peak Flow Requirements.

The initial curve number for this site is 98, but retention provided by the green roof change this number. The Channel and Flood Protection tab notes the reduced curve numbers for the 2-year, 15-year, and 100-year storms: 86, 88, and 88, respectively. These curve numbers can be used to help determine detention requirements for this site.

Step 7: Determine Detention Requirements.

Detention is required to reduce the peak discharge rate from the 2-year-storm event to the predevelopment (meadow conditions or better) peak discharge rate and to reduce the peak discharge rate from the 15-year storm event to the preproject peak discharge rate. Appendix H includes details on the procedure for calculating the detention volume. In this example, the proposed land cover is the same as the preproject conditions, so detention is not required for the 15-year storm. However, detention is required for the 2-year storm.

The peak inflow, qi_2 and the peak outflow, q_{o2} can be calculated using the WinTR-55 Small Watershed Hydrology program, the area of the site, the time of concentration (Tc, assumed to be 10 minutes), and the curve numbers. The reduced curve of 90, determined above, generates a $qi_2$of 3.80 cubic foot per second (cfs). The curve number for meadow in good condition, 71, generates a q_{o2} of 1.74 cfs.

The ratio of 0.39 cfs to 1.00 cfs equals 0.46. Using Figure H.1, this equates to a ratio of storage volume (Vs_2) to runoff volume (Vr_2) of approximately 0.29.

The runoff volume (Vr_2) determined in the Compliance Calculator spreadsheet is 1.83 inches, which equates to 9,964 cubic feet. Using the calculated ratio of Vs_2/Vr_2, the storage volume required for the site (Vs_2) is 2,890 cubic feet.

Rooftop Storage (see Appendix I) may be the most cost effective method for achieving this detention volume in this example, if space is available, and the design configuration can be created that routes the green roof to the rooftop storage. Alternatively, the required storage could be achieved via a tank located somewhere in the building

Design Example 6

Step 1: Determine Design Criteria

Design Example 6 includes the following proposed design criteria:

Site Name	Connecticut Ave. Complex
Total Site Area	65,340 ft^2
Natural Cover Area	0 ft^2
Compacted Cover	0 ft^2
Impervious Cover (Rooftop)	65,340 ft^2
Vehicular Access Areas	0 ft^2
Is site located within the AWDZ?	No
Is site located within the MS4?	Yes
What type of activity is the site undergoing?	Major Land Disturbing

Step 2: Input Design Criteria to Determine the Retention and Treatment Requirements.

The General Retention Compliance Calculator will calculate a stormwater retention volume (SWRv) once the impervious cover area is entered in **cell D24** on the Site Data sheet.

Based on the design criteria above, the Connecticut Ave. Complex project is required to treat 1.2 inches of rainfall for the SWRv:

SWRv (**cell D37**) = 6,207 ft^3

Step 3: Identify Site Constraints and BMP Restrictions.

Key considerations for the Connecticut Ave. Complex project include the following:

- Since this is a rooftop-only site, very few treatment options are available.

Step 4: Select BMPs to Meet the Retention and Treatment Requirements.

Rainwater harvesting (R-1) is selected as the most appropriate BMP for this site.

The site will ultimately have one outlet point, so the calculations can be performed on one Drainage Area sheet – D.A. 1. Therefore, the impervious cover value from the Site Data tab should be put into **cell B8** on the D.A.1 sheet.

The Rainwater Harvesting Retention Calculator should be used to determine the cistern size and the associated retention value. In the Rainwater Harvesting Retention Calculator 65,340 square feet should be put in as the Contributing Drainage Area (CDA) (**cell L7**). For utilization of the rainwater, flushing toilets/urinals is selected as the use, and the appropriate values are entered. In this case, 1,600 people will use the building per day (**cell L21**), Monday through Friday (**cells L30** and **L32**), 8 hours per day (**cell L34)**. On the Results – Retention Value sheet, the retention values are given for various tank sizes. The tables and graphs show that an 80,000 gallon tank would have a 74% retention value. Coincidentally, it would also meet 74% of the annual demand.

The next step is to return to the D.A. 1 tab and input the 65,340-square foot CDA into **cell D25** for rainwater harvesting and input the efficiency (74%) into **cell K25**. The result is that 6,507 cubic feet of runoff are retained and 2,286 cubic feet remain. **Cell P68** shows that the SWRv has been met for the site, and **cell Q69** shows that the SWRv exceedance of 2,244 gallons may be available to generate SRCs.

Step 5: Size the BMPs According to the Design Equations.

The size of the rainwater-harvesting cistern was already determined to be 80,000 gallons, although additional volume may be necessary for detention, as described in Step 8 below, as well as for dead storage for a pump, and/or freeboard.

Step 6: Check Design Assumptions and Requirements.

Key assumptions and requirements for this site include:

- The rainwater harvesting cistern will be at least 80,000 gallons. The designer would need to ensure that space would be available for these BMPs on the site.
- Demand for the water from toilet flushing should be verified.

Since all of these assumptions and requirements can be met in this design example, this step is complete.

Step 7: Use the Adjusted Curve Number to Address Peak Flow Requirements.

The initial curve number for this site is 98, but retention provided by rainwater harvesting changes this number. The Channel and Flood Protection tab notes the reduced curve numbers for the 2-year, 15-year, and 100-year storms: 85, 87, and 88, respectively. These curve numbers can be used to help determine detention requirements for this site.

Step 8: Determine Detention Requirements.

Detention is required to reduce the peak discharge rate from the 2-year-storm event to the pre-development (meadow conditions or better) peak discharge rate and to reduce the peak discharge rate from the 15-year storm event to the pre-project peak discharge rate. Appendix H includes details on the procedure for calculating the detention volume. In this example, the proposed land cover is the same as the pre-project conditions, so detention is not required for the 15-year storm. However, detention is required for the 2-year storm.

The peak inflow, qi_2 and the peak outflow, q_{o2} can be calculated using the WinTR-55 Small Watershed Hydrology program, the area of the site, the time of concentration (Tc, assumed to be 10 minutes), and the curve numbers. The reduced curve of 85, determined above, generates a qi_2 of 3.64 cubic foot per second (cfs). The curve number for meadow in good condition, 71, generates a q_{o2} of 1.74 cfs.

The ratio of 1.74 cfs to 3.64 cfs equals 0.48. Using Appendix H this equates to a ratio of storage volume (Vs_2) to runoff volume (Vr_2) of approximately 0.29.

Formatted: Font: 11 pt

The runoff volume (Vr_2) determined in the Compliance Calculator spreadsheet is 1.77 inches, which equates to 9,938 cubic feet. Using the calculated ratio of Vs_2/Vr_2, the storage volume required for the site (Vs_2) is 2,795 cubic feet.

Since rainwater harvesting is the selected BMP on this project, the most appropriate means for detaining the 2,795 cubic feet (20,907 gallons) may be to increase the size of the cistern to 13,500 cubic feet (101,000 gallons). Alternatively, if stage-storage routing is performed on the tank for a 2-year storm event, beginning with the average daily volume in the tank, the detention volume may be decreased significantly.

Appendix B Maximum Extent Practicable Process for Existing Public Right-of-Way

B.1 Maximum Extent Practicable: Overview

Maximum extent practicable, or "MEP,"~~,~~ is the language of the Clean Water Act that sets the standards to evaluate efforts pursued to achieve pollution reduction to ~~US~~ United States water bodies. ~~The~~ MEP refers to management practices~~,~~; control techniques~~,~~; and system, design, and engineering methods for the control of pollutants. It allows for considerations of public health risks, societal concerns, and social benefits, along with the gravity of the problem~~,~~ and the technical feasibility of solutions.

~~The~~ MEP is achieved, in part, ~~by~~ through a process of selecting and implementing different design options with various ~~effective~~ structural and non-structural stormwater best management practices (BMPs)~~ and~~, ~~rejecting~~ where ineffective ~~BMPs~~BMP options may be rejected, ~~and replacing them with~~ and replaced when more effective ~~management practices (~~BMP~~s)~~ options are found. MEP is an iterative standard~~, which~~ that evolves over time as urban runoff management knowledge increases. As such, it must ~~continually~~ be assessed continually and modified to incorporate improved programs, control measures, and BMPs~~, etc.,~~ to attain compliance with water quality standards. ~~Because~~ As a result of this evolution, some end-of-pipe strategies~~, which~~ that were considered to meet the MEP standard ten years ago~~,~~ are no longer accepted as such. Similarly, in cases where just one BMP may have gained project approval in the past, today there are many cases where multiple BMPs will be required ~~in order~~ to achieve treatment to the MEP.

Many jurisdictions have said of the MEP standard that there "must be a serious attempt to comply, and practical solutions may not be lightly rejected." If project applicants implement only a few of the least expensive BMPs, and the regulated volume has not been retained, it is likely that the MEP standard has not been met. If, on the other hand, a project applicant implements all applicable and effective BMPs except those shown to be technically infeasible, then the project applicant would have achieved retention to the MEP.

B.2 Public Right-of-Way Projects

Public right-of-way (PROW) projects within the District of Columbia are owned and operated by the District Government. They are linear in orientation and are distinct from parcel or lot development~~ within the District of Columbia. These projects are linear in orientation. They~~. ~~may consist of bridges, highways, commercial and residential streets, alleyways, pedestrian walkways, bicycle trails, tunnels and railway tracks. They are owned and operated by the Government.~~

~~The~~ PROW is defined as the surface, ~~and~~ the air space above the surface (including air space immediately adjacent to a private structure located on public space or in a PROW), and the area

Formatted: Font: 11 pt

below the surface of any public street, bridge, tunnel, highway, railway track, lane, path, alley, sidewalk, or boulevard, where a property line is the line delineating the boundaries of public space and private property.

~~Important for the following discussion is the definition of T~~the Public Parking Area or “Public Parking,” ~~.~~ is important for the following discussion. It ~~This~~ is defined as that area of public space devoted to open space, greenery, parks, or parking that lies between the property line~~,~~ (which may or may not coincide with the building restriction line~~,~~) and the edge of the actual or planned sidewalk that is nearer to the property line, as the property line and sidewalk are shown on the records of the District. This area often includes spaces that appear to be front yards with private landscaping, which ~~that~~ create park-like settings on residential streets.

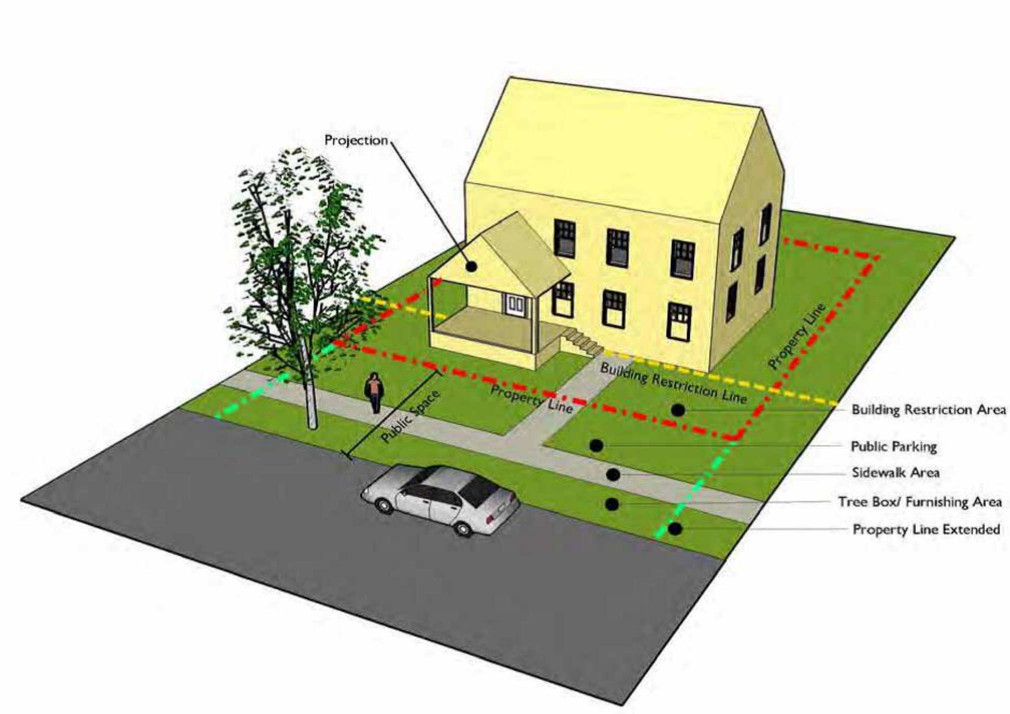


Figure B.1~~B.1~~ Diagram of typical residential public right-of-way in the District of Columbia (DDOT Public Realm Design Manual 2011).

Public Space is defined as all the publicly owned property between the property lines on a street, park, or other public property, as such property lines are shown on the records of the District, and includes any roadway, tree space, sidewalk, or parking between such property lines.

Other important terms are the tree box area or planter area and the sidewalk area. These are defined as the area of the roadside that provides a buffer between the pedestrians and vehicles,

Formatted: Font: 11 pt

which primarily contains landscaping such as a continuous planting strip in residential areas. The sidewalk area is sometimes known as the "pedestrian clear zone", this is the walking zone adjacent to the tree box that must remain clear, both horizontally and vertically.

In the MEP discussion that follows, a PROW project means a land-disturbing activity conducted in the existing PROW and the existing public space associated with the project. The MEP discussion applies only to those PROW projects required for the operation and maintenance of existing commercial and residential streets, existing alleyways, and other existing transportation infrastructure designed and maintained for the safe conveyance of people and commerce. Private subdivision roads or streets shall not be considered PROW projects.

Construction projects to maintain and upgrade the District's PROW are faced with a multitude of unique site constraints that vary widely. Limited space outside of the roadway restricts opportunities for infiltration and evapotranspiration, and in many cases the width of the roadway cannot be reduced to create additional space. In the roadway itself, the structural integrity of the pavement is the prime concern. The weight and volume of traffic loads may limit the use of permeable pavements.

The PROW occupy approximately 25 percent of the impervious area of the District of Columbia, making the PROW one of the most significant sources of stormwater runoff impacting District water~~-~~bodies. Stormwater runoff from roadways can present high pollutant loading. Despite the challenges to stormwater management faced by PROW projects, it is essential for the protection of District water~~-~~bodies to strive to achieve full retention of the regulated stormwater volume through the use of BMPs to the MEP on all PROW projects. This means the design process of all PROW projects shall evaluate and implement all applicable and effective BMPs except those shown to be technically infeasible.

The aim for full retention on-site of a PROW project's regulated stormwater volume is consistent with the District of Columbia~~'s~~ Department of Transportation's (DDOT's) "Complete Streets" policy which states, "improvements to the right-of-way shall consider… environmental enhancements including, reducing right-of-way stormwater run-off, improving water quality, prioritizing and allocating sustainable tree space and planting areas (both surface and subsurface), … wherever possible". It is also an effort consistent with the District's 2012 Municipal Separated Storm Sewer System (MS4) permit which requires the retrofit for on-site stormwater retention of 1,500,000 ~~s~~ft^2 of PROW by 2016, which might translate to 35.5 miles of 8 foot wide pervious parking lanes or 4.7 miles of 60 foot wide full PROW cross section where the runoff is captured and managed from sidewalks, tree boxes, parking lanes, and the roadway.

The sections that follow, Design Considerations and Decision Process, are intended to provide structure for planners, designers and reviewers to evaluate whether or not a PROW project has exhausted every opportunity to achieve the full retention of the regulated stormwater volume. Achieving the regulated S~~s~~tormwater R~~r~~etention V~~v~~olume (SWRv) in the PROW projects will be technically infeasible on many occasions, even after going through the MEP process. Given this and the compelling interest of the ongoing reconstruction of the PROW for the maintenance of public safety and well-being, PROW projects can be excluded from the requirement to use Stormwater Retention Credits (SRCs) or pay an in-lieu fee to satisfy any shortfall in attaining the

Formatted: Font: 11 pt

SWRv if the MEP is demonstrated. These PROW projects are the only type of projects that are excluded from this requirement.

DDOE’s MEP process applies to two types of projects. ~~One project type, MEP~~ T~~t~~ype 1~~, is~~ projects ~~where~~ solely involve ~~the~~ reconstruction of the existing PROW ~~constitutes the entirety of a project~~, such as when the District of Columbia Department of Transportation reconstructs multiple blocks of a roadway. ~~The second project type, MEP~~ T~~t~~ype 2 designates ~~, is a~~ parcel-based development projects that ~~the~~ reconstruct~~s~~ the adjacent, existing PROW as portion of the project~~part of the development process~~. ~~Under this project type the PROW reconstruction constitutes a portion of the project.~~ Under the MEP process for Type 2 ~~scenario~~projects, the parcel portion of the application will be reviewed under the full stormwater management performance standards defined in Chapter 2, while the PROW portion of the application will be reviewed under the MEP Type 2 approach defined in this appendix.

The General Retention Compliance Calculator has a separate PROW worksheet that allows ~~MEP~~ Type 2 applicants to ~~keep~~ separate parcel drainage area obligations from PROW obligations. The ~~final~~ compliance ~~worksheet~~ tab also presents these drainage areas separately to simplify t~~keep t~~he review process and make it transparent ~~and simple~~. To request a~~A~~n MEP Type 2 review, an applicant ~~wishing to use MEP Type 2 review~~ will follow the format used to the request “relief for extraordinarily difficult site conditions” described in Appendix E, which ~~includes~~ requires a request memo with supporting evidence in addition to the completed worksheets from the General Retention Compliance Calculator ~~worksheets~~.

The memo must address the six designs steps ~~spelled out~~described in ~~this appendix~~Section B.5. Type 2 applicants can ~~choice~~ choose to follow the same table, plan view, and narrative approach identified for Type 1 applicants without the multiple~~-~~stage review process for the ~~(~~30 percent ~~/~~65 percent, and ~~/~~90 percent design phases~~)~~. Type 1 projects will use a stormwater report that contains information in spreadsheet, plan view, and narrative formats for the submission and review of the 30 percent, 65 percent, and 90 percent design stages, typically of ~~District of Columbia Department of Transportation (~~DDOT~~)~~ projects. ~~A sample chart is provided at the end of this appendix to~~Table B.3 indicates the information and submission format expected at each review stage ~~and in which format~~.

B.3 Codes

DDOT uses a “functional street classification” system that is defined in Chapter 30 of the Transportation Design and Engineering Manual. There are five functional categories including Freeways, Principal arterials, Minor arterials, Collector streets and Local streets. Table B.1 shows relative distribution of roadway classifications in the District. Each type has design criteria that are governed by traffic volumes, land use, and expected growth. These design criteria set the acceptable ranges for geometric design elements that will govern roadway geometry. The MEP process assumes transportation design criteria govern when conflicting demands exist.

Table B.1 Roadway Classification and Extent Relative to Total Roadway System

Type	Approximate Miles	% of District Roadway System

Freeways	46	4
Principal Arterials	92	8
Minor Arterials	178	15
Collectors	152	13
Local Roads	682	60

The MEP process assumes BMP designs will comply with the District of Columbia Department of Transportation Design and Engineering Manual Chapter 33, Chapter 47, and the Design and Engineering Manual supplements for Low Impact Development and Green Infrastructure Standards and Specifications as well as Chapter 3 in this guidebook.

B.4 PROW Design Considerations

~~B.4.1 Looking Ahead~~

B.4.1 Considerations in the Planning Process (limited to Type 1). The local capital authority for PROW projects is defined in the District of Columbia's Capital Improvement Program (CIP), a six-year-plan that is updated annually. Federally funded projects are listed in the Transportation Improvement Program (TIP), which is updated every other year according to the Metropolitan Washington Council of Government National Capital Region Transportation Planning Board's (MWCOG TPB) schedule and is also coordinated with the Constrained Long-Range Transportation Plan (CLRP). Each planning stage has an amendment process. Planners shall incorporate the MEP process into all future PROW projects and shall review and revisit, as needed, existing PROW plans for MEP analysis, revisions, and amendments. The TIP and CLRP are able to be amended and modified as allowed by the MWCOG TPB. As projects move from study to design and construction, DDOT will include necessary measures to include MEP analysis and implementation.

B.4.2 Site Assessment Considerations for the Retention Standard in ~~Public Right-of-Way (~~PROW~~)~~ Projects

1. **Level of Disturbance (Type 1 and Type 2).** If a PROW project includes major land-disturbing activity required for the operation and maintenance of existing commercial and residential streets, existing alleyways, and other existing transportation infrastructure designed and maintained for the safe conveyance of people and commerce, it is captured by the stormwater regulatory obligations of Chapter 5 of Title 21, of the District of Columbia Municipal Regulations, Water Quality and Pollution (2012). Routine maintenance such as surface asphalt milling of roadways, where the roadway base is not disturbed, is not considered a level of disturbance that will require compliance with the regulation.
2. **Available Space (Type 1 and Type 2).** A PROW project must first and foremost seek to maximize landscape areas, maximize available space for stormwater retention, and minimize impervious surface, while coordinating with transportation, access, safety, and other applicable -requirements, such as the American Disability Act (ADA) requirements and emergency vehicle needs. Street widths should be reduced to the appropriate minimum width

Formatted: Font: 11 pt

while maintaining~~-~~ multi-modal transportation needs, parking, ~~traffic flow~~ and public safety. A ~~common~~ rule of thumb used in some cities (e.g. Los Angeles, Portland, Seattle, and Philadelphia) ~~is to~~ equates the expected landscape space to ~~be~~ a minimum ~~of ten~~ percentage of the imperviousness within each drainage area within the PROW project limits of disturbance. This percentage ranges from 4 percent to 10 percent.

In the District of Columbia several hundred triangular islands, less than one acre in area, are created by diagonal street intersections. A PROW project must consider the opportunity for stormwater retention within traffic islands, or triangle parks, that fall within, or adjacent to, the project limits of disturbance. Streets that end as cul-de-sacs, are less prevalent in the District, however, when present cul-de-sacs within, or adjacent to, the limits of disturbance of a PROW project must be evaluated for stormwater retention opportunities. In the District "paper streets" exist throughout, as areas of the City dedicated as streets but not useable as transportation passageways. These areas, under the control of the DDOT, may be created by the intersection of streets with parks and streams, and are often mowed grass areas. "Paper streets" within, or adjacent to, the limits of disturbance of a PROW project must be evaluated for stormwater retention opportunities.

3. **Impervious Cover Removal (Type 1 and~~&~~ Type 2).** The elimination of impervious surface may be accomplished by closing diagonal roadways adjacent to triangle parks to create larger parks. Diagonal roadways that are adjacent to triangle parks and fall within, or are adjacent to, a PROW project must be evaluated for stormwater retention opportunities. PROW projects must evaluate the opportunity to integrate traffic calming measures including but not limited to, median islands, pedestrian curb extensions, bump outs and chicanes, and turning radius reductions that may double as areas for impervious surface removal and BMPs.

   Replacing impervious cover with landscape area in the contributing drainage area converts the runoff coefficient from 95 percent to 25 percent in essence decreasing that area's contribution to stormwater runoff by 70 percent without the use of an active stormwater facility. If an area can be converted to "natural cover" through conservation and reforestation strategies that area's contribution to stormwater runoff is reduced to zero. Consult ~~Appendix O~~Appendix N for minimum thresholds and other required for each land cover designation. Further opportunities to reduce stormwater runoff in these drainage areas should be explored with adjacent property both public and private as source control may be the most cost effective approach to managing stormwater runoff, see Section 3.4 Impervious Surface Disconnection.

4. **Drainage Areas (Type 1 and Type 2).** Overall conceptual drainage plans for PROW projects should identify drainage areas outside of the project's limits of disturbance that generate runoff that may comingle with on-site runoff. The project is not required to consider off-site runoff in the calculation for the regulated S~~s~~tormwater R~~r~~etention V~~v~~olume (SWRv); however BMPs sized for retention of comingled off-site runoff can be used to off-set the inability to capture and retain the SWRv in areas within the project for which significant constraints prevent retention.

   For example, a typical city block will have at least two distinct drainage areas created by the crown in the center of the road. While one side of the road may have significant obstacles to the implementation of retention practices the other may not. If the limits of disturbance are defined by the boundaries of the sidewalks on either side of the roadway this is the area that

Formatted: Font: 11 pt

is used to calculate the SWRv. However, in many circumstances stormwater runoff is entering the sidewalk and roadway from adjacent properties, both public and private, creating a comingled stormwater runoff. Under these conditions the side of the street that has the greater opportunity to implement retention strategies shall be designed to manage that comingled volume up to the full SWRv.

Type 1 and Type 2 projects must prioritize capturing roadway runoff. For Type 2 projects, where limits of disturbance do not extend into the roadway, the capture of roadway runoff from adjacent roadway drainage areas may be accomplished with curb cuts or sidewalk trenches used to direct roadway runoff from the curb line into sidewalk BMPs within the project's limits of disturbance. This must be the first consideration to satisfy the SWRv calculated for the project's PROW portion.

5. **Ownership of Land Adjacent to Right-of-Ways (limited to Type 1).** The opportunity to incorporate stormwater retention may depend on the ownership of land adjacent to the right-of-way. Acquisition of additional right-of-way and/or access easements may only be feasible if land bordering the project is publicly owned. PROW project must identify public lands and public rights of way adjacent to the project's limit of disturbance. PROW project planners and managers may need to consult with adjacent public property owners and managers to evaluate opportunities to direct stormwater runoff from the project drainage area to adjacent public lands.

6. **Location of Existing Utilities (Type 1 and Type 2).** The location of existing storm drainage utilities (grey infrastructure) can influence the opportunities for stormwater retention in PROW projects. Utilizing the existing grey infrastructure for the conveyance of large events with under drain connections and curb line overflows can reduce costs. Using existing grey infrastructure where possible frees funds for drainage areas within the project limits of disturbance where grey infrastructure does not exist or is more challenging to utilize. Standard peak-flow curb inlets, such as catch basins, should be located downstream of areas with potential for stormwater retention practices so that water can first flow into the BMP, and then overflow to the downstream inlet if capacity of the BMP is exceeded. It is more difficult to apply retention practices after water has entered the storm drain. The location of other utilities will influence the ability connect BMPs to storm drains, and may limit the allowable placement of BMPs to only those areas where a clear pathway to the storm drain exists.

   The f~~F~~ollowing outlines an approach to take~~ these steps~~ when considering the design and location of BMPs in the existing PROW relative to existing utilities: 1) avoidance; 2) mitigation; 3) relocation; and 4) acceptance.

   ~~*The first step is a*~~**Avoidance**. Whenever possible, locate BMPs to avoid a conflict that either jeopardizes the functionality and longevity of the utility or complicates future utility maintenance. Consult with each utility company on their recommended offsets which will allow utility maintenance work with minimal disturbance to the BMP. A consolidated presentation of the various utility offset recommendations can be found in Chapter 33.14.5 of the District of Columbia Department of Transportation Design and Engineering Manual, latest edition. Consult the District of Columbia Water and Sewer Authority (DC Water) Green Infrastructure Utility Protection Guidelines, latest edition, for water and sewer line recommendations. Avoidance of utility conflicts may mean one BMP type is selected over another. It may mean the sizing of a BMP is altered.

*The second step is m*__M__**itigation.** Under the mitigation approach the BMP design is adjusted to mitigate utility concerns. A BMP design may need to be resized or otherwise altered to satisfy utility offsets. This may include moving, adding, or deleting a key design feature of the BMP such as check dams, inlets, outlets and trees.

The third step is **Rrelocation.** Under the relocation approach an attempt is made to coordinate with utility companies to allow them to replace or relocate their aging infrastructure while BMPs are being implemented. Where the capital budget and priorities of the utility can be aligned with the larger construction in the PROW, there are potential benefits, including cost savings, for both the utility and the entity undertaking the reconstruction of the PROW. The age of the utility line is a factor in selecting this solution. While a utility relocation during a street re-construction project may be advantageous to the utility provider, it is understood that the utility may not be able to align its capital budget or may be otherwise unable or unwilling to take advantage of the relocation opportunity.

The fourth step is aAcceptance. When the first three steps approaches are inadequate to achieve the required stormwater retention, consider a the fourth step is approach, acceptance of conflicts that do not jeopardize the functionality, longevity and vehicular access to manholes and other key points of utility maintenance. This does not preclude the typical public right-of-way PROW BMP such as street trees, bioretention, or permeable pavement which the utility would be expected to replace if maintenance in those areas was required. In this scenario, a BMP location and design that complicates utility maintenance should be considered acceptable if it does not compromise the utility function, longevity, and major access points. When accepting utility conflict into the BMP location and design, it is understood the BMP will be temporarily impacted during utility work but the utility will replace the BMP or, alternatively, install a functionally comparable BMP according to the specifications in the current version of this Stormwater Management Guidebook and the District of Columbia Department of Transportation Design and Engineering Manual with special attention to Chapter 33, Chapter 47, and the Design and Engineering Manual supplements for Low Impact Development and Green Infrastructure Standards and Specifications. To clarify whether a conflict jeopardizes the functionality, longevity and access to a utility consider the latest editions of the District of Columbia Department of Transportation Design and Engineering Manual and the District of Columbia Water and Sewer Authority (DC Water) Green Infrastructure Utility Protection Guidelines.

7. **Grade Differential Between Road Surface and Storm Drain System (Type 1 and Type 2).** Some BMPs require more head from inlet to outlet than others; therefore, allowable head drop may be an important consideration in BMP selection. Storm drain elevations may be constrained by a variety of factors in a roadway project (utility crossings, outfall elevations, etc.) that cannot be overcome and may override SStormwater RRetention VVolume considerations.

8. **Longitudinal Slope (limited to Type 1).** The suite of BMPs which may be installed on steeper road sections is more limited. Specifically, permeable pavement and swales are more suitable for gentle grades. Other BMPs may be more readily terraced to be used on steeper slopes. Check dams and weirs should be incorporated into BMP designs on steeper slopes.

Formatted: Font: 11 pt

9. **Potential Access Opportunities (limited to Type 1).** A significant concern with the installation of BMPs in high speed, high volume PROW is the ability to safely access the BMPs for maintenance considering traffic hazards. A PROW project involving high speed, high volume PROW should include a site assessment to identify vehicle travel lanes and areas of specific safety hazards for maintenance crews. Subsequent steps in the preparation of the stormwater management plan (SWMP) for the PROW project should attempt to avoid placing BMPs in these areas.

10. **Tree Canopy and Vegetation (Type 1 and Type 2).** Concern for the preservation of existing mature trees is a reasonable consideration when determining where and how to direct stormwater runoff from the curb line for retention goals in a PROW project. In general, stormwater retention practices should be installed outside the drip line of existing trees (more specific guidance is provided in Section 3.14). A guiding principal for PROW projects should be the improvement and maintenance of the most robust tree canopy possible along the PROW. The planting of trees and the preservation of trees should look to the latest science on the soil volume requirements, spacing needs and methods to connect stormwater runoff to tree roots to support healthy vigorous tree growth. PROW projects should clearly identify existing healthy trees and detail how to prevent tree losses during construction. Additionally, diseased and dead trees should be removed. Soils in tree planting areas should be amended and volumes expanded whenever trees are replaced or new trees are planted.

11. **Infiltration (Type 1 and Type 2).** Infiltration practices have very high storage and retention capabilities when sited and designed appropriately. Designers should evaluate the range of soil properties during initial site layout and seek to configure the site to conserve and protect the soils with the greatest recharge and infiltration rates. In particular, areas of Hydrologic Soil Group A or B soils shown on NRCS soil surveys should be considered as primary locations for infiltration practices. When designing a PROW project consult ~~Appendix P~~Appendix O, Geotechnical, and Chapter 3.7, Infiltration, as well as chapters on specific BMPs under consideration in this Stormwater Management Guidebook (SWMG) for specific design details and constraints.

    In areas where a qualified professional engineer, soils scientist or geologist determines during an initial feasibility test the presence of soil characteristics which support the categorization as D soils, no further investigation is required. A designer of a PROW project should first consider reducing the impervious surface area draining to these poor soil areas. Other soil types may require further analysis to determine infiltration feasibility. ~~Note: A~~It is important to understand that areas with poor soils may still be sites for BMPs that are designed with underdrains.

    If the seasonally high water table is determined to be less than two feet from the bottom of the proposed BMP, infiltration may not be appropriate. This may be determined through a comparison of historic and actual elevations. If the site is one of known soil contamination or receiving uncontrolled stormwater runoff from a land use hotspot, as determined by guidance in ~~Appendix Q~~Appendix P. Stormwater Hotspots, infiltration must not be used.

12. **Street Profile (limited to Type 1).** The profile of an impervious surface such as a street or an alleyway determines how stormwater runoff flows off the surface. District streets follow a crowned design with the high point in the center draining to both sides, alleyways are typically reverse crowned, draining to the center and sidewalks side shed, draining to one

Formatted: Font: 11 pt

side. Flat drainage is a term used to denote vertical drainage through a permeable paving profile. A PROW project should consider all variations of drainage patterns when the standard drainage design does not provide retention for the full regulated Sstormwater Rretention Vvolume (SWRv). The drainage patterns of the project should be developed so that drainage can be routed to areas with BMP opportunities before entering storm drains. For example, if a median strip is present, a reverse crown should be considered, so that stormwater can drain to a median swale.

13. **Pedestrian Circulation (Type 1 and Type 2).** The design of stormwater retention facilities should harmonize with effective pedestrian circulation in PROW projects. PROW project BMPs commonly integrate the goals of stormwater retention and pedestrian safety by reducing pedestrian crossing distances, providing more space against vehicular traffic, and improving site angles at intersections. While pedestrian circulation and stormwater retention should not be at odds, conflicts can arise with on street parking. Considerations should be given to provide adequate egress for parking adjacent to a BMP (typically 23 feet). In addition, frequent walkways across BMPs can give pedestrians sufficient access to parking zones.

    Retention facilities with vertical drops of greater than six inches in a PROW projects should provide pedestrians with visual or physical signals that denote a significant drop in grade, such as a raised curb edge, a detectable warning strip or a raised railing. Railings maybe designed to perform additional functions such as seating or bicycle racks. In areas with the potential for high pedestrian volume railings may be needed to prevent pedestrians from cutting through landscaped areas, trampling vegetation and compacting soils.

B.4.3 Fundamental Tenets of MEP for PROW

A PROW project shall demonstrate a design approach that indicates stormwater retention opportunities were evaluated to the MEP, which includes the following:

a. Selecting BMPs based on site opportunities to reduce stormwater runoff volumes.

b. Sizing BMPs opportunistically to provide the maximum stormwater retention while accounting for the many competing considerations in PROW projects.

c. Prioritizing capturing roadway runoff. By managing comingled stormwater runoff within some project drainage areas to offset minimum retention achieved in other project drainage areas.

d. Developing innovative stormwater management configurations integrating "green" with "grey" infrastructure,

e. Minimizing street width to the appropriate minimum width for maintaining traffic flow and public safety.

f. Maximizing tree canopy by planting or preserving trees/shrubs, amending soils, increasing soil volumes and connecting tree roots with stormwater runoff.

g. Using porous pavement or pavers for low traffic roadways, on-street parking, shoulders or sidewalks.

Formatted: Font: 11 pt

h. Integrating traffic calming measures that serve as stormwater retention BMPs.

i. Reducing stormwater runoff volume by converting impervious surfaces to land cover types that generate little or zero stormwater runoff.

j. Reducing stormwater runoff volume by employing impervious surface disconnection strategies within and adjacent to the project's limits of disturbance.

B.5 Design Process for PROW

Step 1: Identify Drainage Areas and Calculate SWRv.

a. Define the limits of disturbance for the PROW project.

b. Delineate all drainage areas both within, and contributing to, the limits of disturbance for the PROW project. Prioritize drainage areas conveying roadway runoff.

c. Identify proposed land covers within the limits of disturbance for the PROW project, including impervious cover, compacted cover, and natural cover. Area under proposed BMPs counts as impervious cover. A continuous planter strip may be consider compacted cover, or natural cover; consult ~~Appendix O~~Appendix N for the minimum thresholds an area needs to qualify for each designation. Individual street trees may count as compacted cover or as a BMP. Use the General Retention Compliance Calculator PROW worksheet to determine which approach provides the greatest SWRv reduction.

d. Calculate the regulated S~~s~~tormwater R~~r~~etention V~~v~~olume (SWRv) based on land cover and area within the limits of disturbance for the entire PROW project. Calculate the portion of the SWRv for each drainage area within the limits of disturbance of the PROW project. Calculate any "unregulated" off-site stormwater retention volume contributing to the project limits of disturbance.

~~d.~~ Note: When off-site stormwater runoff volumes are managed their reduction will count toward a reduction in the SWRv. Off-site stormwater runoff volumes may be managed at the source or within the project's limits of disturbance. Prioritize drainage areas conveying roadway runoff.

Formatted: Indent: Left: 0.25", No bullets or numbering

e. Consider land conversion and BMP designations in adjacent public lands. While these volumes are not counted in the calculation of the site's SWRv, if controlled they will count towards the reduction of the site's SWRv. Identify opportunities for land cover conversions or other source control measures that would reduce these off-site volumes.

f. Consider altering the drainage profile if that alteration would increase runoff capture opportunities. This consideration will typically be set aside until all other considerations have been exhausted (limited to Type 1).

Step 2: ~~Consider~~ Evaluate Infiltration.

a. Determine historical and actual water table elevations to evaluate opportunities and restrictions for locating infiltration practices.

b. Consult a qualified professional engineer, soil scientist or geologist using initial infiltration feasibility tests, to identify the areas within the limits of disturbance with Hydrologic Soil groups that should be preserved and targeted for infiltration BMPs, and areas where infiltration BMPs will require amended soils and under drains.

c. Identify any areas within the limits of disturbance where there is a known issue of soil contamination. Infiltration BMPs in these areas are not allowed. Use the guidance in Appendix QAppendix P. Stormwater Hotspots to evaluate adjacent land use hotspots that may be a source of uncontrolled contaminates in stormwater runoff.

Step 3: **Demonstrate Full Consideration of Opportunities with Existing Infrastructure.**

a. Review substructure maps and utility plans; delineate areas of potential conflict as well as areas without conflict.

b. Identify the location and elevation of the existing the storm drainage system (grey infrastructure), including catch basins, drain inlets, and manholes in both the drainage areas within, and those drainage areas contributing stormwater runoff to, the limits of disturbance for the PROW project.

c. Identify all existing trees to be preserved. Identify and record tree species, size and preservation status.

Step 4: **Demonstrate Full Consideration of Land Cover Conversions and Optimum BMP Placement.**

a. Identify traffic islands, triangle parks, median islands, cul-de-sacs, and paper streets within and adjacent to the PROW project's limits of disturbance. These areas can be the focus of land cover conversions and BMP locations (unless within LOD of Type 2 this is limited Type 1).

b. Evaluate the opportunity to integrate traffic calming measures including but not limited to, median islands, pedestrian curb extensions, bump outs and chicanes, and turning radius reductions. Delineate these areas out for consideration for impervious surface removal and BMP facilities. Delineate areas available for additional tree planting. Note whether soil volume increases and amended soils are required (unless within LOD of Type 2 this is limited Type 1).

c. Evaluate right-of-way widths; identify minimum requirements for trails, alleys, roadways and sidewalks. Delineate sections where existing conditions exceed minimum requirements. These areas can be the focus of land cover conversions and BMP locations (limited to Type 1).

d. Select areas delineated as optimum opportunities for land conversion or BMP location.

d. Note: Land conversions can significantly reduce the project's SWRv without the use of an active stormwater facility. Designate land conversions and recalculate SWRv at the full project scale and the scale of the individual drainage areas within the project area.

e. Select most appropriate BMP types for each area delineated as optimum opportunities for BMP locations. Consult Table B.2 for potential BMPs recommended by US EPA for "Green Streets", DDOT's AWI Chapter 5 LID, DDOT's LID Action Plan, DDOT's LID Standards and Specifications, and Chapters 3.1 through 3.12 in this Guidance Manual.

Formatted: Font: 11 pt

Step 5: **Size BMPs.**

a. The following~~ steps~~ process are used to size BMPs for PROW projects:

1. Delineate drainage areas to BMP locations including any area outside the limits of disturbance contributing off-site stormwater runoff volume; prioritize roadway runoff; consider the land covers to compute optimum S~~s~~tormwater R~~r~~etention V~~v~~olume. Consider designing to the over control retention volume, above the regulated requirement of 1.2 inches, up to the regulated ceiling of 1.7 inches.

2. Look up the recommended sizing methodology for the BMP selected in each drainage area and using the appropriate BMP chapter of this guidance manual to calculate target sizing criteria.

3. Design BMPs per the appropriate chapter of this guidance manual and the District of Columbia Department of Transportation Design and Engineering Manual.

4. Attempt to provide the calculated sizing criteria for the selected BMPs.

5. If sizing criteria cannot be achieved, document the constraints that override the application of BMPs, and provide the largest portion of the sizing criteria that can be reasonably provided given constraints.

Note: If BMPs cannot be sized to provide the calculated volume for the drainage area, it is still essential to design the BMP inlet, energy dissipation, and overflow capacity for the full drainage area, including any area contributing off-site stormwater runoff volume, to ensure that flooding and scour is avoided. It is strongly recommended that BMPs which are designed to less than their target design volume be designed to bypass peak flows.

b. Aggregate the retention values achieved with the BMPs ~~designed in Step 5~~ and compare with the regulated Stormwater Retention Volume (SWRv) for PROW project. If the aggregate retention value meets or exceeds the SWRv the project has meet its regulatory obligation.

c. If there is a retention volume deficiency, consider sizing BMPs to manage the comingled volume on-site.

d. If there is a retention volume deficiency, revisit Design Steps 1~~ through ~~–4. Increase land conversion areas and BMP facilities. Depending on the extent and complexity of the PROW project this may require several iterations.

Step 6: **Address Drainage Areas where Zero-Retention Practices are Installed.**

It is possible, despite following the design considerations, fundamental tenants, and the iterative Steps 1~~through ~~–5 of the design process, that drainage areas within the proposed limits of disturbance may emerge without any retention practices. If these cases occur in the Municipal Separate Storm Sewer System (MS4)~~In these cases~~, those drainage areas ~~will~~ must incorporate water quality catch basins~~,~~ or other emergent ~~technology~~technologies~~,~~ that provide~~s~~ water quality treatment for the SWRv of those drainage areas~~, if the project is in the Municipal Separate Storm Sewer System (MS4)~~.

Formatted: Font: 11 pt

Table B.2 Potential BMPs for Green Streets Projects (modified US EPA)

BMP Type	Opportunity Criteria for PROW Projects
Street Trees, Canopy Interception	▪ Access roads, residential streets, local roads and minor arterials ▪ Drainage infrastructure, sea walls/break water ▪ Effective for projects with any slope ▪ Trees may be prohibited along high speed roads for safety reasons or must be setback behind the clear zone or protected with guard rails and barriers; planting setbacks may also be required for traffic and pedestrian lines of sight.
Stormwater Curb Extensions / Stormwater Planters	▪ Access roads, residential streets, and local roads with parallel or angle parking and sidewalks ▪ Can be designed to overflow back to curb line and to standard inlet ▪ Shape is not important and can be integrated wherever unused space exists ▪ Can be installed on relatively steep grades with terracing
Bioretention Areas	▪ Low density residential streets without sidewalks; along roadways adjacent to park space; well suited for the DCistrict''s triangle parks; ramp, slipways and road closings can make good conversion-sites ▪ May require more space than curb extensions/ planters, consider combing with minimized road widths to maximize bioretention area.
Permeable Pavement	▪ Parking and sidewalk areas of residential streets, and local roads If significant run-on from major roads is a possibility ensure deign and maintenance protocols to accommodate potential TSS loads ▪ Should not be subject to heavy truck/ equipment traffic ▪ Light vehicle access roads and alleyways
Permeable Friction Course Overlays	▪ High speed roadways unsuitable for full depth permeable pavement ▪ Suitable for parking lots and all roadway types
Vegetated Swales (compost amended were possible)	▪ Roadways with low to moderate slope or terraced systems ▪ Residential streets with minimal driveway access ▪ Minor to major arterials with medians or mandatory sidewalk set-backs Access roads ▪ Swales running parallel to storm drain can have intermittent discharge points to reduce required flow capacity
Filter strips (amended road shoulder)	▪ Access roads ▪ Major roadways with excess PROW ▪ Not practicable in most PROWs because of width requirements
Proprietary Biotreatment	▪ Constrained PROWs ▪ Typically have small footprint to drainage area ratio ▪ Simple install and maintenance ▪ Can be installed on roadways of any slope ▪ Can be designed to overflow back to curb line and to standard inlet
Infiltration Trench	▪ Constrained PROWs ▪ Can require small footprint where soils are suitable ▪ Low to moderate traffic roadways ▪ Infiltration trenches are not suitable for high traffic roadways ▪ Requires robust pretreatment

Formatted: Font: 11 pt

B.6 ~~Supporting Forms~~Summary of MEP Type 1 Submission Process

B.1 MEP Type 1Submission Elements and Review Points

	Stormwater Report Design Phases								
	30%			65%			90%		
Process Steps	Table	Plan	Narrative	Table	Plan	Narrative	Table	Plan	Narrative
Step 1: Identify Drainage Areas and Calculate SWRv									
DA count	I		I	R		R	F		F
DA list and SWRv per DA	I			R			F		
Project LOD		I			R			F	
DAs within LOD		I			R			F	
DAs outside LOD		I			R			F	
Land cover in LOD	I			R			F		
Volume calculated per DA inside LOD	I			R			F		
Volume calculated per DA outside LOD	I			R			F		
Will altered drainage profile increase SWRV?		I	I		R	R			F
Consider adjacent public lands		I			R	R			F
Step 2: Evaluate Infiltration									
Water table conflict per DA (Y/N)	I		I	R		R	F		F
Bedrock conflict per DA (Y/N)	I		I	R		R	F		F
Hydro soil group per DA (Y/N)	I		I	R		R	F		F
Hotspot concern noted (Y/N)	I		I	R		R	F		F
Water table impact (Y/N)					R	R	F	F	
Initial infiltration feasibility tests–opportunities and restrictions? (Y/N)					R	R		F	
Identify adjacent land use hotspots (Y/N)		I			R	R		F	
Step 3: Demonstrate Full Consideration of Existing Infrastructure									
Utility plans		I			R			F	
Utility conflicts		I			R			F	
Existing sewer infrastructure elevations		I			R			F	
Existing Trees	I	I			R			F	
Step 4: Demonstrate Full Consideration of Land Cover Conversions and Optimum BMP Placement									
Land conversion and BMP placement		I	I		R	R		F	F
Count of BMPs and land conversions	I			R			F		
Step 5: Size BMPs									

Formatted: Font: 11 pt

	Stormwater Report Design Phases								
	30%			65%			90%		
Process Steps	Table	Plan	Narrative	Table	Plan	Narrative	Table	Plan	Narrative
BMP drainage areas within LOD and outside LOD (Y/N)					I			R	
Consider overcontrol of SWRV (Y/N)						I			R
Achieve BMP sizing criteria (Y/N)						I			R
Design sizing achieved (under/over)				I			R		
Sizing constraints						I			R
Step 6: Address DAs with Zero-Retention Practices Installed									
SWRv achieved per DA				I		I	F		F

Notes:
I = Initial findings and presentation; this should define known facts and best opportunities.
R = Revisions based on further investigations and review comments; this will include some firm commitments.
F = Final design decisions based on initial commitments, interim reviews and final findings.
The process outlined in this table leads to a final submission of 100 percent design SWMP as required for the building permit.
DA = drainage area, LOD = limits of disturbance, SWRv = stormwater retention volume

Formatted: Note-Table, Don't keep with next

B.7 References

District of Columbia Department of the EnvironmentTransportation, 2010, Anacostia Waterfront Transportation Architecture Design Guidelines, Chapter 5: Low Impact Development (LID). Washington D.C. http://www.scribd.com/doc/83991242/Anacostia-Waterfront-Transportation-Architecture-Design-Guidelines

City Council for Montgomery County, Maryland. 2007. Streets and Roads—comprehensive revision. enacted July 3, 2007. Montgomery County, MD. http://www.montgomerycountymd.gov/content/council/pdf/bill/2007/48-06e.pdf

District of Columbia Department of Transportation (DDOT). Public Realm Design Manual 2011. http://dc.gov/DC/DDOT/Projects+and+Planning/Standards+and+Guidelines/Public+Realm+Design+Manual

Environmental Services City of Portland, 2008, Green Streets Construction Guide. Portland, OR. http://www.portlandoregon.gov/bes/article/228860

Philadelphia Water Department, Office of Watersheds, 2009, Stormwater Manual v2.0 Chapter 6.1 Street Design. Philadelphia, PA. http://www.scribd.com/doc/13322624/Stormwater-Management-Guidance-Manual-Ver-20

Environmental Services City of Portland, 2008, Green Streets Construction Guide. Portland, OR. http://www.portlandonline.com/bes/index.cfm?c=34602&

City of Los Angeles, 2009, Green Streets & Green Alleys: design guidelines standards. Los Angeles, CA. http://www.lastormwater.org/wp-content/files_mf/greenstreetguidelines.pdf

Santa Ana Regional Water Quality Control Board, May 19, 2011. Exhibit 7.III Technical guidance document for the preparation of conceptual/preliminary and/or project water quality management plans (WQMPs); Santa Ana County, CA. http://www.cityoforange.org/civicax/filebank/blobdload.aspx?blobid=9653

San Francisco Planning Department, 2010, San Francisco Better Streets Plan, Final Draft, 2010, http://www.sf-planning.org/ftp/BetterStreets/proposals.htm#Final_Plan

San Mateo Countywide Water Pollution Prevention Program, San Mateo County Sustainable Green Streets and Parking Lots Guide, 2009; San Mateo, CA. http://www.flowstobay.org/ms_sustainable_guidebook.php

U.S. Environmental Protection Agency, Managing Wet Weather with Green Infrastructure Municipal Handbook, Green Streets, EPA Publication 833-F-08-009, 2008; http://water.epa.gov/infrastructure/greeninfrastructure/upload/gi_munichandbook_green_streets.pdf

Appendix C Off-Site Retention Forms for Regulated Sites

This appendix includes the following off-site retention forms for regulated sites:

- Application to Use Stormwater Retention Credits for Off-Site Retention Volume
- Notification of In-Lieu Fee Payment to Meet Off-Site Retention Volume

Formatted: Font: 11 pt

GOVERNMENT OF THE DISTRICT OF COLUMBIA
District Department of the Environment
1200 First Street NE, Fifth Floor, Washington, DC 20002

Application to Use Stormwater Retention Credits
for Off-Site Retention Volume

Acronyms

AWDZ	Anacostia Waterfront Development Zone
CSS	Combined Sewer System
DDOE	District Department of the Environment
ILF	In-Lieu Fee
MS4	Municipal Separate Storm Sewer System
Offv	Off-Site Retention Volume
SRC	Stormwater Retention Credit
SWMP	Stormwater Management Plan
SWRv	Stormwater Retention Volume

Application date: ______________________

Address of regulated site for which SRC use is proposed:

____

Lot: ______Square: ______Ward: ______Storm Sewer System (CSS or MS4): ____________

Is the site an AWDZ site (Yes or No)? ________

Name of site owner: _______________________________________

Address: _______________________________________

E-Mail: ______________________ Phone: ______________________

Name of owner's agent (if applicable): ______________________________

Address: _______________________________________

E-Mail:______________________ Phone: ______________________

Information from DDOE-Approved SWMP for Regulated Site	
SWMP tracking number	
SWRv	
On-site retention volume achieved	
Offv	

1

Figure C.1~~C.1~~ Application to Use Stormwater Retention Credits for Off-Site Retention Volume.

Formatted: Font: 11 pt

Offv to be met with SRCs (number of gallons): ______________________________

For an AWDZ site, how much of the Offv will be met with SRCs from outside the Anacostia River watershed? ______________________________

Offv to be met with payment of ILF (number of gallons): ______________________________

SRCs proposed for use (Attach additional sheet if necessary):

Starting date for use (Indicate date or "as of final inspection." Multiple dates may be listed.)	**Serial numbers** (May indicate as range, where appropriate)

Applicant's Signature

A. Owner of regulated property: I hereby certify that I am the owner of the regulated property and of the SRCs proposed for use herein and that this application is correct to the best of my knowledge.

Signature of Owner: Date:

B. Agent: I hereby certify that I have the authority of the regulated property owner to make this application. The owner has assured me that he/she owns the SRCs proposed for use herein. I declare that this application is correct to the best of my knowledge.

Signature of Agent: Date:

FOR DEPARTMENT USE ONLY		
Approved:	Approved in part:	Disapproved:
Signature:		Date:
Notes:		

2

Figure C.1 (continued)

Formatted: Font: 11 pt

GOVERNMENT OF THE DISTRICT OF COLUMBIA
District Department of the Environment
1200 First Street NE, Fifth Floor, Washington, DC 20002

Instructions for Application to Use Stormwater Retention Credits for Off-Site Retention Volume

Purpose of form: This form provides DDOE with the necessary information to track compliance with an Offv by use of SRCs.

NOTE: Buyers, sellers, or their agents must complete an Application for Transfer of Stormwater Retention Credit Ownership before SRCs may be used to satisfy an Offv requirement.

Instructions

Application date: Enter the date that the applicant completes the application.

Address of regulated site for which SRC use is proposed: Enter the street address for the regulated site that seeks to use SRCs to meet an Offv requirement. Lot, square, and ward information is available from the building permit and the approved SWMP for the site.

Is the site an AWDZ site (Yes or No)? Select "yes" or "no". AWDZ sites must purchase SRCs generated outside of the Anacostia River watershed at a 1.25:1 ratio.

Name of site owner: Enter the name of the site owner. Also provide the site owner's contact information.

Name of owner's agent: If applicable, enter the name of a representative whom the owner has charged with achieving the Offv.

Information from DDOE-approved SWMP for regulated site: Enter information from the SWMP including the Plan's tracking number, total required stormwater retention volume in gallons, on-site volume achieved, and required Offv.

Offv to be met with SRCs: Enter the number of gallons of the Offv requirement that a site owner seeks to achieve through SRCs.

For an AWDZ site, how much of the Offv will be met with SRCs from outside the Anacostia River watershed? AWDZ sites must purchase SRCs generated outside of the Anacostia River watershed at a 1.25:1 ratio. This information assists DDOE in calculating the correct number of SRCs for the regulated site to achieve its Offv requirement.

Offv to be met with payment of ILF: Enter the number of gallons of the Offv to be achieved through payment of the ILF. To use an ILF payment for compliance, sites must also submit a Notification of In-Lieu Fee Payment to Meet Off-Site Retention Volume.

SRCs proposed for use: Enter the effective date when SRCs will be used to satisfy an Offv requirement. Also list the serial numbers of purchased SRCs.

3

Figure C.1 (continued)

Formatted: Font: 11 pt

GOVERNMENT OF THE DISTRICT OF COLUMBIA
District Department of the Environment
1200 First Street NE, Fifth Floor, Washington, DC 20002

Notification of In-Lieu Fee Payment to Meet Off-Site Retention Volume

Acronyms

AWDZ Anacostia Waterfront Development Zone
CSS Combined Sewer System
DDOE District Department of the Environment
ILF In-Lieu Fee
MS4 Municipal Separate Storm Sewer System
Offv Off-Site Retention Volume
SRC Stormwater Retention Credit
SWMP Stormwater Management Plan
SWRv Stormwater Retention Volume

Application date: ____________________________

Address of regulated site for which ILF use is proposed:

____

Lot: _______Square: ______Ward: _______Storm Sewer System (CSS or MS4): ______________

Is the site an AWDZ site (Yes or No)? __________

Name of site owner: ____

Address: ____

E-Mail: ____________________________ Phone: _____________________________________

Name of owner's agent (if applicable): ____

Address: ____

E-Mail: ____________________________ Phone: _____________________________________

Information from DDOE-Approved SWMP for Regulated Site	
SWMP tracking number	
SWRv	
On-site retention volume achieved	
Offv	

1

Figure C.2C.2 Notification of In-Lieu Fee Payment to Meet Off-Site Retention Volume.

Formatted: Font: 11 pt

Offv to be met with SRCs (number of gallons): __________________

Offv to be met with payment of ILF (number of gallons): __________________

Proposed use of ILF (attach additional sheet if necessary).

Starting Date For Use (Indicate date or "as of final inspection." Multiple years may be listed.)	**Total Payment**

Applicant's Signature

A. Owner of regulated property: I hereby certify that I am the owner of the regulated property and that this application is correct to the best of my knowledge.

Signature of Owner: Date:

B. Agent: I hereby certify that I have the authority of the regulated property owner to make this application. I declare that this application is correct to the best of my knowledge.

Signature of Agent: Date:

FOR DEPARTMENT USE ONLY		
Payment Received:	Payment Received in Part:	Payment Not Received:
Signature:		Date:
Notes:		

2

Figure C.2 (continued)

Formatted: Font: 11 pt

GOVERNMENT OF THE DISTRICT OF COLUMBIA
District Department of the Environment
1200 First Street NE, Fifth Floor, Washington, DC 20002

Instructions for Notification of In-Lieu Fee Payment to Meet Off-Site Retention Volume

Purpose of form: This form provides DDOE with the necessary information to track compliance with an Offv by use of ILF

Instructions

Application date: Enter the date that the applicant completes the application.

Address of regulated site for which ILF is proposed: Enter the street address for the regulated site that seeks to make an ILF payment to meet an Offv. Lot, Square, Ward, and Storm Sewer System information is available from the building permit and the approved SWMP for the site.

Is the site an AWDZ site (Yes or No)? Select "yes" or "no". AWDZ sites must purchase SRCs generated outside of the Anacostia River watershed at a 1.25:1 ratio.

Name of site owner: Enter the name of the site owner. Also provide the site owner's contact information.

Name of owner's agent: If applicable, enter the name of a representative whom the owner has charged with achieving the Offv.

Information from DDOE-Approved SWMP for regulated site: Enter information from the SWMP including the Plan's tracking number, total required stormwater retention volume in gallons, on-site volume achieved, and required Offv.

Offv to be met with SRCs: Enter the number of gallons of the Offv requirement that a site owner seeks to achieve through SRCs.

Offv to be met with payment of in-lieu fee: Enter the number of gallons of the Offv that a site owner seeks to achieve through payment of the ILF. To use an ILF payment for compliance, sites must also submit a Notification of In-Lieu Fee Payment to Meet Off-Site Retention Volume.

Proposed use of in-lieu fee: Enter the effective date when in-lieu fee will be used to satisfy an Offv requirement.

3

Figure C.2 (continued)

Appendix D Stormwater Retention Credit Forms (Certification, Trading, and Retirement)

This appendix includes the following Stormwater Retention Credit forms:

- Application for Certification of Stormwater Retention Credits
- Application for Transfer of Stormwater Retention Credit Ownership
- Application to Retire Stormwater Retention Credits

Formatted: Font: 11 pt

GOVERNMENT OF THE DISTRICT OF COLUMBIA
District Department of the Environment
1200 First Street NE, Fifth Floor, Washington, DC 20002

Application for Certification of Stormwater Retention Credits

Acronyms

BMP	Best Management Practice	**MS4**	Municipal Separate Storm Sewer System
CSS	Combined Sewer System	**SRC**	Stormwater Retention Credit
DDOE	District Department of the Environment	**SWMP**	Stormwater Management Plan

Application date: ______________________________

Address of site with eligible retention capacity:

____

Lot: ______Square: _____Ward: ______Storm Sewer System (CSS or MS4): _____________

Name of owner of proposed SRCs: ____

Address: ____

E-Mail:_________________________ Phone: _________________________________

Name of site owner (if different from proposed SRC owner):

____

Address: ____

E-Mail:_________________________ Phone: _________________________________

Name of owner of retention capacity (if different from site owner):

____

Address: ____

E-Mail:_________________________ Phone: _________________________________

1

Figure D.1~~D.1~~ Application for Certification of Stormwater Retention Credits.

Formatted: Font: 11 pt

Name of agent for owner of proposed SRCs (if applicable): _____________________________

Address: ____

E-Mail:____________________________ Phone: ____________________________________

Should the agent be listed as the contact person for interested SRC buyers in DDOE's SRC registry (Yes or No)? ________________________

DDOE tracking number for SWMP: _____________________________

Identification number(s) for each BMP for which SRCs are requested:

____

SRC-eligible retention capacity for each BMP or land cover for which SRCs are requested:

____

Has DDOE previously certified SRCs for the retention capacity (Yes or No) _____________

If no, attach the following:

- ☐ As-built SWMP, including site plan showing pre-project site conditions and retention.
- ☐ Signed maintenance contract or documentation of capacity and expertise to conduct maintenance for the time period for which SRCs are requested.
- ☐ Documentation of the legal right to the SRCs applied for, if the proposed SRC owner is not the property owner.
- ☐ Completed DDOE SRC calculator spreadsheet.

If yes, attach the following:

- ☐ Signed maintenance contract or documentation of capacity and expertise to conduct maintenance for the time period for which SRCs are requested.
- ☐ Documentation of the legal right to the SRCs applied for, if the proposed SRC owner is not the property owner.

Is this application for SRCs for the maximum three-year period (Yes or No)? ____________

If no, what is the period for which SRCs are requested? _______________________________

What is the listing price for each SRC (optional)? _____________________________________

Should DDOE list these SRCs and corresponding name and contact information in DDOE's SRC registry (Indicate Yes or No and, if yes, who should be listed):

____

2

Figure D.1 (continued)

Formatted: Font: 11 pt

GOVERNMENT OF THE DISTRICT OF COLUMBIA
District Department of the Environment
1200 First Street NE, Fifth Floor, Washington, DC 20002

Applicant's Signature

A. Proposed SRC Owner: I hereby certify that I have the legal right to the SRCs proposed for certification above; that the application, including supporting documentation, is complete and correct to the best of my knowledge; that access will be provided for DDOE inspections; that the retention capacity will be maintained in accordance with the maintenance plan for the period for which SRCs are requested; that, if the retention capacity is not maintained, I will, for the volume from the period of failed maintenance, forfeit the SRCs, purchase replacement SRCs, or pay in-lieu fee to DDOE. ; and that, if during the period of time for which an SRC is certified, the property is sold or otherwise transferred to another person, the owner of the property on which the BMP or land cover is located will notify DDOE.

Signature of Proposed SRC Owner: Date:

B. Agent: I hereby certify that I have the authority of the proposed SRC owner to make this application and that the application and plans are complete and correct to the best of my knowledge. The owner has assured me that access will be provided for DDOE inspections and that the retention capacity will be maintained in accordance with the maintenance plan for the period for which SRCs are requested. If the retention capacity is not maintained in good working order, the proposed SRC owner has assured me that, for the volume from the period of failed maintenance, he will forfeit the SRCs, purchase replacement SRCs, or pay in-lieu fee to DDOE. Finally, the proposed SRC owner has assured me that, if during the period of time for which an SRC is certified, the property is sold or otherwise transferred to another person, the owner of the property on which the BMP or land cover is located will notify the Department.

Signature of Agent: Date:

FOR DEPARTMENT USE ONLY		
Approved:	Approved in part:	Disapproved:
Signature:		Date:
Total SRCs certified:	Total time period for which SRCs are certified:	
SRCs certified year 1:	Serial numbers:	
SRCs certified year 2:	Serial numbers:	
SRCs certified year 3	Serial numbers:	
Notes:		

3

Figure D.1 (continued)

Formatted: Font: 11 pt

Instructions for Application for Certification of Stormwater Retention Credits

Purpose of form: This form provides DDOE with the necessary information to certify SRCs.

NOTE: Buyers, sellers, or their agents must complete an Application for Transfer of Stormwater Retention Credit Ownership before an SRC transaction may occur.

Instructions

Application date: Enter the date that the applicant completes the application.

Address of site with eligible retention capacity: Enter the street address for the site with retention capacity that complies with the eligibility requirements for SRC certification. Lot, square, and ward information is available from the building permit and the approved SWMP for the site.

Name of owner of proposed SRCs: Enter the name and contact information for the person proposed as the owner of the SRCs. Once DDOE certifies the SRCs, this person will become the original SRC owner, with associated maintenance obligation. This person or their agent signs the application form. Once SRCs are certified or the agent signs the application, DDOE will notify the proposed SRC owner of its determination for the application. DDOE will list the original SRC owner (or the owner's agent) and contact information in a public registry posted to the DDOE website.

Name of site owner: If different from the proposed SRC owner, enter the name and contact information for the person who owns the site where practices are installed to generate SRCs. DDOE recognizes that a site owner could assign the right to the SRCs to an SRC aggregator or other person. In such a case, the SRC aggregator or other person would presumably be the proposed SRC owner.

Name of owner of retention capacity: If different from site owner, enter the name and contact information for the owner of the retention capacity generating SRCs on a site. DDOE expects that typically the site owner would also be the owner of the retention capacity, but this may not always be the case.

Name of agent for owner of proposed SRCs (if applicable): Enter the name and contact information for a person who is authorized to represent the proposed SRC owner in applying for certification of SRCs. If the agent is also authorized to represent (and take the place of) the proposed SRC owner in DDOE's SRC registry as the contact for interested SRC buyers, that should be indicated.

4

Figure D.1 (continued)

Formatted: Font: 11 pt

GOVERNMENT OF THE DISTRICT OF COLUMBIA
District Department of the Environment
1200 First Street NE, Fifth Floor, Washington, DC 20002

DDOE tracking number for SWMP: Enter the tracking number assigned to the SWMP by DDOE.

Identification number(s) for each BMP for which SRCs are requested: Enter the tracking number for the BMP, as identified in the SWMP. This will allow DDOE to identify the specific BMP on a site for which SRCs are being requested and for which maintenance will be required. Some sites may have multiple BMPs.

SRC-eligible retention capacity for each BMP or land cover for which SRCs are requested: Enter the SRC-eligible volume, as identified in the as-built SWMP for a site. For a site with one SRC-eligible BMP or land cover, this will typically correspond to cell B:50 of the SRC calculator.

Has DDOE previously certified SRCs for the retention capacity? Select "yes" or "no". DDOE certifies SRCs for three-year periods. If the retention capacity continues to be maintained and function properly, applicants may apply for an additional three years of SRCs.

Is this application for SRCs for the maximum three-year period? Select "yes" or "no". DDOE certifies SRCs for three year periods, but applicants should apply for fewer years if they do not intend to maintain the retention capacity for the entire three-year time period.

If no, what is the period for which SRCs are requested? Enter the period of time for which the applicant requests SRCs.

What is the listing price for for each SRC (optional)? If the applicant would like DDOE to include an SRC price in the SRC registry, indicate that here. This is not binding, and the final price will be determined by the SRC seller and buyer.

Should DDOE list these SRCs and corresponding name and contact information in DDOE's SRC registry? Indicate whether the proposed SRC owner or the owner's agent would like the SRCs to be listed in DDOE's SRC registry. Also indicate whether contact information for the owner or agent should be listed.

5

Figure D.1 (continued)

Formatted: Font: 11 pt

GOVERNMENT OF THE DISTRICT OF COLUMBIA
District Department of the Environment
1200 First Street NE, Fifth Floor, Washington, DC 20002

DISTRICT DEPARTMENT OF THE ENVIRONMENT green forward

Application for Transfer
of Stormwater Retention Credit Ownership

Acronyms

DDOE District Department of the Environment   **SRC** Stormwater Retention Credit

Application date: ______________________

Number of SRCs to transfer: ______________________

Serial numbers of SRCs (may be listed as a range):

Purchase price for SRCs: ______________________

Name of current owner of SRCs: ______________________

Address______________________

E-Mail:______________________ Phone: ______________________

Name of new owner of SRCs: ______________________

Address: ______________________

E-Mail: ______________________ Phone: ______________________

Name of agent for new owner of SRCs (if applicable):

____

Address: ______________________

E-Mail: ______________________ Phone: ______________________

1

Figure D.2~~D.2~~ Application for Transfer of Stormwater Retention Credit Ownership.

Formatted: Font: 11 pt

Should DDOE list these SRCs and the name and contact information for the owner or owner's agent in DDOE's SRC registry? (Indicate Yes or No and, if yes, who should be listed)

Signature of Current Owner

I hereby certify that I am the owner of the above SRCs; that I request the ownership of these SRCs to be transferred as stated above; and that this application is complete and correct to the best of my knowledge.

Signature: Date:

Signature of New Owner (or Owner's Agent)

I hereby certify that this application is complete and correct to the best of my knowledge.

Signature: Date:

FOR DEPARTMENT USE ONLY		
Approved:	Approved in part:	Disapproved:
Signature:		Date:
Notes:		

2

Figure D.2 (continued)

Formatted: Font: 11 pt

GOVERNMENT OF THE DISTRICT OF COLUMBIA
District Department of the Environment
1200 First Street NE, Fifth Floor, Washington, DC 20002

Instructions for Application for Transfer of Stormwater Retention Credit Ownership

Purpose of form: This form provides DDOE with the necessary information to verify and track ownership of SRCs and the price at which SRCs are traded.

Instructions

Application date: Enter the date that the applicant completes the application.

Number of SRCs to transfer: Enter the number of SRCs that are proposed for transfer from a seller to buyer.

Serial numbers of SRCs (may be listed as a range): Enter the serial numbers for SRCs to be transferred. Individually list serial numbers for SRCs that are not in sequential order. Use a range for sequential SRCs.

Purchase price for SRCs: Enter the price for each SRC to be transferred. If prices vary for different SRCs being transferred, enter each of the prices and the corresponding SRCs. DDOE will share price information on its website.

Name of current owner of SRCs: Enter the name and contact information for the current owner of SRCs to be transferred to the new owner.

Name of new owner of SRCs: Enter the name and contact information for the person to whom the SRCs will be transferred. DDOE will list the new owner on its SRC registry, unless the new owner requests not to be listed.

Name of agent for new owner: If applicable, enter the name and contact information for the agent of the new owner.

Should DDOE list these SRCs and the new owner's name and contact information in DDOE's SRC registry? Indicate whether the new SRC owner or the owner's agent would like the SRCs to be listed in DDOE's SRC registry. Also indicate whether the listed contact information should be for the new owner or the agent.

3

Figure D.2 (continued)

Formatted: Font: 11 pt

GOVERNMENT OF THE DISTRICT OF COLUMBIA
District Department of the Environment
1200 First Street NE, Fifth Floor, Washington, DC 20002

Application to Retire Stormwater Retention Credits

Acronyms

DDOE District Department of the Environment **SRC** Stormwater Retention Credit

Application date: ______________________

Number of SRCs to retire: __________________________

Serial numbers of SRCs (may be listed as a range):

Name of current owner of SRCs: ____

Address: ____

E-Mail:_______________________ Phone: ______________________________

Signature of SRC Owner

I hereby certify that I am the owner of the above SRCs; that I request these SRCs to be retired; and that this application is complete and correct to the best of my knowledge.

Signature: Date:

FOR DEPARTMENT USE ONLY		
Approved:	Approved in part:	Disapproved:
Signature:		Date:
Notes:		

1

Figure D.3~~D.3~~ Application to Retire Stormwater Retention Credits.

Formatted: Font: 11 pt

GOVERNMENT OF THE DISTRICT OF COLUMBIA
District Department of the Environment
1200 First Street NE, Fifth Floor, Washington, DC 20002

Instructions for Application to Retire Stormwater Retention Credits

Purpose of form: This form provides DDOE with the necessary information to retire SRCs and track accordingly.

Instructions

Application date: Enter the date that the applicant completes the application.

Number of SRCs to retire: Enter the number of SRCs that are proposed for retirement.

Serial numbers of SRCs (may be listed as a range): Enter the serial numbers for SRCs to be retired. Individually list serial numbers for SRCs that are not in sequential order. Use a range for sequential SRCs.

Name of current owner of SRCs: Enter the name and contact information for the owner of the SRCs.

2

Figure D.3 (continued)

Appendix E Relief for Extraordinarily Difficult Site Conditions

E.1 Relief from Extraordinarily Difficult Site Conditions

Note that major land-disturbing activity in the existing public right-of-way (PROW) uses the maximum extent practicable process detailed in Appendix B to determine sizing criteria used to achieve the stormwater management performance requirements for regulated activity. These projects are not required to apply for relief from extraordinarily difficult site conditions. Regulated activity located in the Anacostia Waterfront Development Zone (AWDZ) that are governed by the Anacostia Waterfront Environmental Standards Amendment Act of 2012 (see D.C. Official Code §§ 2-1226.36(c)(1)) must have all off-site retention and all off-site water quality treatment volume approved by DDOE through the process defined in this appendix, even if the District-wide minimum 50 percent on-site retention requirement is met. All development sites are required to address the Stormwater Retention Volume (SWRv), as described in Chapter 2. All development sites in the Anacostia Waterfront Development Zone (AWDZ), governed by the Anacostia Waterfront Environmental Standards Amendment Act of 2012, are required to address the Water Quality Treatment Volume (WQTv), as described in Chapter 2. If compliance with the minimum on-site retention requirement or on-site water quality treatment requirement is technically infeasible or environmentally harmful, the applicant may apply for relief from extraordinarily difficult site conditions. Additionally, if the regulated activity is in the Anacostia Waterfront Development Zone (AWDZ), governed by the Anacostia Waterfront Environmental Standards Amendment Act of 2012, consideration for a request for relief will include the limited appropriateness of on-site compliance in terms of impact on surrounding landowners or overall benefit to District waterbodies. In cases where an applicant claims extraordinarily difficult site conditions, it is the responsibility of the applicant to provide sufficient evidence to support the claim.

Once granted relief from extraordinarily difficult site conditions, an applicant is allowed to provide less than the minimum compliance requirements on site by managing a greater retention volume or water quality treatment volume through off-site mitigation. This process does not relieve the applicant from the obligation to manage the full SWRv or the WQTv determined through compliance calculations. Additionally, stormwater runoff not receiving the minimum on-site retention must receive treatment to remove 80 percent of total suspended solids based on the treatment practices, as defined in Chapter 3 of this guidance manual. When DDOE finds the evidence presented is sufficient and compelling to grant relief, the Stormwater Management Plan (SWMP) for the project must the two conditions for relief have been satisfied: (1) removing 80 percent of total suspended solids from 50~~%~~ percent of the SWRv and (2) identifying the requirement for the use of off-site retention to offset the entire on-site retention deficit.

Formatted: Font: 11 pt

E.2 Submission requirements for Relief from Extraordinarily Difficult Site Conditions

A request for relief is made through a "relief request memo." The memo is submitted in advance of a final SWMP, but not before the 65 percent design stage of the SWMP, as part of the SWMP with supporting evidence to demonstrate the claim of technical infeasibility or environmental harm. The memo shall provide a detailed explanation of each opportunity for on-site installation of retention BMPs that was considered and rejected, and the reasons for each rejection. The applicant shall address each retention practice specified in this guidance manual in BMP groups 1 through 13, specifically,

BMP Group 1 Green Roofs

BMP Group 2 Rainwater Harvesting

BMP Group 3 Impermeable Surface Disconnection

BMP Group 4 Permeable Pavement Systems

BMP Group 5 Bioretention

BMP Group 7 Infiltration

BMP Group 8 Open Channel Systems

BMP Group 13 Tree Planting

Evidence of site conditions limiting each opportunity for a retention BMP include the following:

1. Data on soil and groundwater contamination;
2. Data from soils testing consistent with the geotechnical requirements in Appendix PAppendix O;
3. Documentation of the presence of utilities requiring impermeable protection or a setback;
4. Evidence of the applicability of a statute, regulation, court order, preexisting covenant, or other restriction having the force of law;
5. Evidence that the installation of a retention BMP would conflict with the terms of a non-expired approval, applied for prior to the end of Transition Period Two A for a major land-disturbing activity or before the end of Transition Period Two B for a major substantial improvement activity, of a:
   (a) Concept review by the Historic Preservation Review Board;
   (b) Concept review by the Commission on Fine Arts;
   (c) Preliminary or final design submission by the National Capital Planning Commission;
   (d) Variance or special exception from the Board of Zoning Adjustment; or
   (e) Large Tract Review by the District Office of Planning; and
6. For a utility, evidence that a property owner on or under whose land the utility is conducting work objects to the installation of a BMP; and

7. For a major substantial improvement activity, evidence that the structure cannot accommodate a BMP without significant alteration, because of a lack of available interior or exterior space or limited load-bearing capacity.

Projects in the AWDZ, governed by the Anacostia Waterfront Environmental Standards Amendment Act of 2012, may also discuss the limited appropriateness of on-site compliance verses a combination of off-site and on-site retention and or water quality treatment in terms of the impact on surrounding landowners or the overall benefit to District waterbodies.

E.3 Review of Requests for Relief from Extraordinarily Difficult Site Conditions

In an application for Relief from Extraordinarily Difficult Site Conditions, a completed application and proof of payment of the applicable fee are required to begin the review of the request. DDOE cannot render a final decision until an application for relief is considered complete. However, if an application is substantially complete, DDOE may begin consideration of the request for relief. Upon accepting an application, DDOE will review and determine whether the application meets the requirements of this section, including the following:

a. Require additional information;

b. Grant relief;

c. Grant relief, with conditions;

d. Deny relief; or

e. Deny relief in part.

In determining whether to grant relief, DDOE may consider the following:

a. The applicant's submittal;

b. Other site-related information;

c. An alternative design;

d. DDOE's Stormwater Management Guidebook (SWMG);

e. Another BMP that meets the SWMG's approval requirements; and

f. Relevant scientific and technical literature, reports, guidance, and standards.

Appendix F Stormwater Conveyance System Design

F.1 Introduction

The focus of this SWMG is to define standards and specifications for design, construction and maintenance of BMPs required to meet stormwater performance objectives. The components and considerations of the accompanying stormwater conveyance system are outlined in this appendix.

F.2 Clearance with Other Utilities

- All proposed and existing utilities crossing or parallel to designed storm sewer systems must be shown on the plan and profile.
- Storm drain and utility crossings must not have be less than a 45-degree angle between them.
- ~~A minimum~~ Minimum vertical and horizontal clearances ~~of one foot and a minimum horizontal clearance of five feet~~, wall to wall, must be provided between storm drainage lines and other utilities as defined by the District of Columbia Water and Sewer Authority (DC Water). Consult DC Water's Project Design Manual and Green Infrastructure Utility Protection Guidelines, latest additions, for details. Exceptions may be granted by the ~~District of Columbia Water and Sewer Authority (~~DC Water~~)~~ on a case-by-case basis when justified. ~~Consult DC Water's Project Design Manual, latest addition, for details.~~

~~F.1~~F.3 Design of Stormwater Conveyance Systems

The Chezy-Manning formula is to be used to compute the system's transport capacities:

$$Q = \frac{1.486}{n} \times A \times R^{2/3} \times S^{1/2}$$

where:

Q	=	channel flow (cfs)
n	=	Manning's roughness coefficient (Table F.1)
A	=	cross-sectional area of flow (ft^2)
R	=	hydraulic radius (ft)
S	=	channel slope (ft/ft)
Wp	=	wetland perimeter
R	=	A/W_P

Table F.1 Manning's Roughness Coefficient (*n*) Values for Various Channel Materials

Channel Materials	Roughness Coefficient

Formatted: Font: 12 pt, Not Bold

Formatted: Font: 12 pt, Not Bold, Font color: Auto

Channel Materials	Roughness Coefficient
Concrete pipe and precast culverts	
24 inches and smaller	0.015
27 inches and larger	0.013
Monolithic concrete in boxes, channels	0.015
Corrugated metal	0.022
PVC pipes	0.011
Sodded channel with water depth < 1.5 feet'	0.050
Sodded channel with water depth >1.5 feet'	0.035
Smooth earth channel or bottom of wide channels with sodded slopes	0.025
Rip-rap channels	0.035

Note: Where drainage systems are composed of more than one of the above channel materials, a composite roughness coefficient must be computed in proportion to the wetted perimeter of the different materials.

Also, the computation for the flow velocity of the channel must use the continuity equation as follows:

$$Q = A \times V$$

where:

V = velocity (ft/s)
A = cross-sectional area of the flow (ft^2)

F.1.1F.4 Gutters

With uniform cross slope and composite gutter section use the following equation:

$$Q = \frac{0.50}{n} \times S_x^{1.67} \times S^{0.5} \times T^{2.67}$$

where:

Q = flow rate (cfs)
n = Manning's roughness coefficient (Table F.1)
S_x = cross slope (ft/ft)
S = longitudinal slope (ft/ft)
T = width of flow (spread) (ft)

F.1.2F.5 Inlets

Formatted: Font: 11 pt

In accordance with the current requirements of the District of Columbia Plumbing Code, all inlets on private or public parcels, but outside the public right-of-way (PROW), must be sized to ensure safe conveyance of stormwater flows exceeding the capacity of the approved on-site stormwater management practices and the designated pervious land cover areas. These stormwater flows must not flow over property lines onto adjacent lots unless these flows run into an existing natural water course. Stormwater inlets in the PROW must be designed in accordance with the current requirements in Chapter 33 of the District of Columbia Department of Transportation Design and Engineering Manual and be approved for use by the District of Columbia Water and Sewer Authority.

~~F.1.3~~F.6 Street Capacity (Spread)

Formatted: Heading 7

Design of the conveyance of stormwater runoff within the public right-of-way must follow the current requirements in the Design and Engineering Manual of the District of Columbia Department of Transportation. The roadway drainage design criteria for existing streets is a 15-year storm, 5-minute duration, and a maximum spread of 6 feet from the face of the curb (32.3.13 DDOT Design and Engineering Manual 2009). Proposed streets must use AASHTO Chapter VI for their design criteria.

~~F.1.4~~F.7 Manhole and Inlet Energy Losses

Formatted: Heading 7

The following formulas must be used to calculate headloss:

$$HL = \frac{V_{outlet}^2 - V_r^2}{2g} + SL$$

$$V_r = \frac{Q(V\cos\frac{a}{2})(inlet1) + Q(V\cos\frac{a}{2}(inlet2) + ...}{Q(outlet)}$$

where:

HL	=	headloss in the structure
V_r	=	resultant velocity
g	=	gravitational acceleration (32.2 ft/s^2)
SL	=	minimum structure loss
a	=	angle between the inlet and outlet pipes (180°)

Table F.2 provides the minimum structure loss for inlets, manholes, and other inlet structures for use in the headloss calculation.

Table F.2 Minimum Structure Loss to Use in Hydraulic Grade Line Calculation

Velocity, V_{outlet} (ft/s)*	Structure Loss, SL
2	0.00

Formatted: Font: 11 pt

3	0.05
4	0.10
5	0.15
6	0.20
6	0.25

* Velocities leaving the structure.

Headloss at the field connection is to be calculated like those structures, eliminating the structure loss. For the angular loss coefficient, cos a/2 is assumed to be 1.

F.1.5F.8 Open Channels

Formatted: Heading 7

- Calculations must be provided for all channels, streams, ditches, swales and etc., including a typical section of each reach and a plan view with reach locations. In the case of existing natural streams/swales, a field survey of the stream (swale) cross sections may be required prior to the final approval.
- The final designed channel must provide a 6-inch minimum freeboard above the designated water surface profile of the channel.
- If the base flow exists for a long period of time or velocities are more than five feet per second in earth and sodded channel linings, gabion or rip-rap protection must be provided at the intersection of the inverts and side slopes of the channels unless it can be demonstrated that the final bank and vegetation are sufficiently erosion-resistant to withstand the designed flows, and the channel will stay within the floodplain easement throughout the project life.
- Channel inverts and tops of bank are to be shown in plan and profile views.
- For a designed channel, a cross section view of each configuration must be shown.
- For proposed channels, a final grading plan must be provided.
- The limits of a recorded 100-year floodplain easement or surface water easement sufficient to convey the 100 year flow must be shown.
- The minimum 25-foot horizontal clearance between a residential structure and 100 year floodplain must be indicated in the plan.
- For designed channels, transition at the entrance and outfall is to be clearly shown on the site plan and profile views.

F.1.6F.9 Pipe Systems

Formatted: Heading 7

- Individual stormwater traps must be installed on the storm drain branch serving each structural best management practice, or a single trap must be installed in the main storm drain after it leaves the structural best management practice and before it connects with the city’'s combined sewer. Such traps must be provided with an accessible cleanout. The traps must not be required for storm drains which are connected to a separate storm sewer system.

- The pipe sizes used for any part of the storm drainage system within the public right-of-way must follow District of Columbia Water and Sewer Authority Standard and Specifications. The minimum pipe size to be used for any part of a private storm drainage system must follow the current requirements of the District of Columbia Plumbing Code.
- The material and installation of the storm drain for any part of public storm sewer must follow District of Columbia Water and Sewer Authority Standard and Specifications.
- An alternative overflow path for the 100-year storm is to be shown on the plan view if the path is not directly over the pipe. Where applicable, proposed grading must ensure that overflow will be into attenuation facilities designed to control the 100-year storm.
- A pipe schedule tabulating pipe lengths by diameter and class is to be included on the drawings. Public and private systems must be shown separately.
- Profiles of the proposed storm drains must indicate size, type, and class of pipe, percent grade, existing ground and proposed ground over the proposed system, and invert elevations at both ends of each pipe run. Pipe elevations and grades must be set to avoid hydrostatic surcharge during design conditions. Where hydrostatic surcharge greater than one foot of head cannot be avoided, a rubber gasket pipe is to be specified.

F.1.7F.10 Culverts

Culverts must be built at the lowest point to pass the water across embankment of pond or highway. Inlet structure must be designed to resist long term erosion and increased hydraulic capacities of culverts. Outlet structures must be designed to protect outlets from future scouring. The following formulas are to be used in computing the culvert:

If the outlet is submerged then the culvert discharge is controlled by the tail water elevation:

$$h = h_e + h_f + h_v$$

where:

h	=	head required to pass given quantity of water through culvert flowing in outlet control with barrel flowing full throughout its length
h_e	=	entrance loss
h_f	=	friction loss
h_v	=	velocity head

and

$$h = k_e\left(\frac{V^2}{2g}\right) + \frac{n^2V^2L}{2.21R^{4/3}} + \frac{V^2}{2g}$$

$$h = \left[k_e + \frac{n^2L}{2.21R^{4/3}} \times 2g + 1\right] \times \left(\frac{V^2}{2g}\right)$$

Formatted: Font: 11 pt

$$h = \left[k_e + \frac{n^2 L}{2.21 R^{4/3}} \times 2g + 1 \right] \times \left(\frac{8Q^2}{9.87 g D^4} \right)$$

where:

k_e	=	entrance loss coefficient = 0.5 for a square-edged entrance
		entrance loss coefficient = 0.1 for a well-rounded entrance
V	=	mean or average velocity in the culvert barrel (ft/s)
g	=	32.2ft/s^2 (gravitational acceleration)
n	=	Manning's roughness coefficient = 0.012 for concrete pipe
L	=	length of culvert barrel (ft)
R	=	0.25D = hydraulic radius (ft)
Q	=	flow (cfs)
D	=	diameter (ft)

If the normal depth of the culvert is larger than the barrel height, the culvert will flow into a full or partially full pipe. The culvert discharge is controlled by the entrance conditions or entrance control.

$$Q = C_d A (2gh)^{0.5}$$

where:

Q	=	discharge (cfs)
Cd	=	discharge coefficient = 0.62 for square-edged entrance
		discharge coefficient = 0.1 for well-rounded entrance
A	=	cross sectional area (ft^2)
g	=	32.2ft/s^2 (gravitational acceleration)
h	=	hydrostatic head above the center of the orifice (ft)

If the hydrostatic head is less than 1.2D, the culvert will flow under no pressure as an open channel system.

If the flows are submerged at both ends of the culvert, use Figure F.1.

F.1.8F.11 Hydraulic Grade Line

Formatted: Heading 7

A hydraulic grade line (HGL) must be clearly indicated on the system profiles and identified with the initials HGL on the line and identified in the legend key. This grade line must take into consideration pipe and channel friction losses, computing structures losses, tail water conditions and entrance losses. All pipe systems must be designed so that they will operate without building up a surcharged hydrostatic head under design flow conditions. It is recommended that the HGL be no more than 1 foot above the pipe crown. If pipes have a HGL more than 1 foot above the pipe crown, rubber gaskets -are required.

If the structural best management practice discharges into a storm sewer or a combined sewer system, a detailed HGL analysis of the system including the receiving system must be submitted

Formatted: Font: 11 pt

with the final stormwater management plans for the 15- and 100-year flow frequencies. If the time characteristics of the HGL are unknown, the designed structural best management practice must be functional under expected minimum and maximum grade lines.

F.1.9F.12 Manholes and Inlets

Formatted: Heading 7

- District of Columbia Water and Sewer Authority Standards and Specifications must be used. All structures are to be numbered and listed in the structure schedule and must include type, standard detail number, size, top elevation, slot elevation and locations, and modification notes.
- Access structures must be spaced -according to the District of Columbia Water and Sewer Authority Standards and Specifications and the Design and Engineering Manual of the District of Columbia Department of Transportation.
- Where two or more pipes enter a structure maintain a minimum of 9 inches of undisturbed concrete between holes in precast concrete is required to ensure sufficient steel. Consult the District of Columbia Water and Sewer Authority (DC Water) for more specifics.
- A minimum drop of 0.1 foot must be provided through the structure invert.
- Drainage boundary and contours must be shown around each inlet to ensure that positive drainage to the proposed inlet is provided.
- Invert elevations of the pipes entering and leaving the structures must be shown in the profile view.
- Yard or grate inlets must show the 15-year and 100-year ponding limits (if applicable). A depth of not more than two feet is allowed from the throat or grate to the 100-year storm elevation.
- Public street inlets must follow District of Columbia Water and Sewer Authority and District of Columbia Department of Transportation criteria.
- Additional structures are recommended and may be required on steep slopes to reduce excessive pipe depths and/or to provide deliberate drops in the main line to facilitate safe conveyance to a proper outfall discharge point. In order to provide an outfall at a suitable slope (i.e., less than 5 percent slope), drop structures may need to be used to reduce the velocity before discharging on a rip-rap area.
- Curb inlets located on private cul-de-sacs must have a maximum 10 linear feet opening.
- For commercial/industrial areas, inlets must be kept at least five feet away from the driveway aprons.Where two or more pipes enter a structure, a minimum of two feet horizontal clearance must be maintained between the pipes connected to the structure at the same elevation.

Formatted: Font: 11 pt

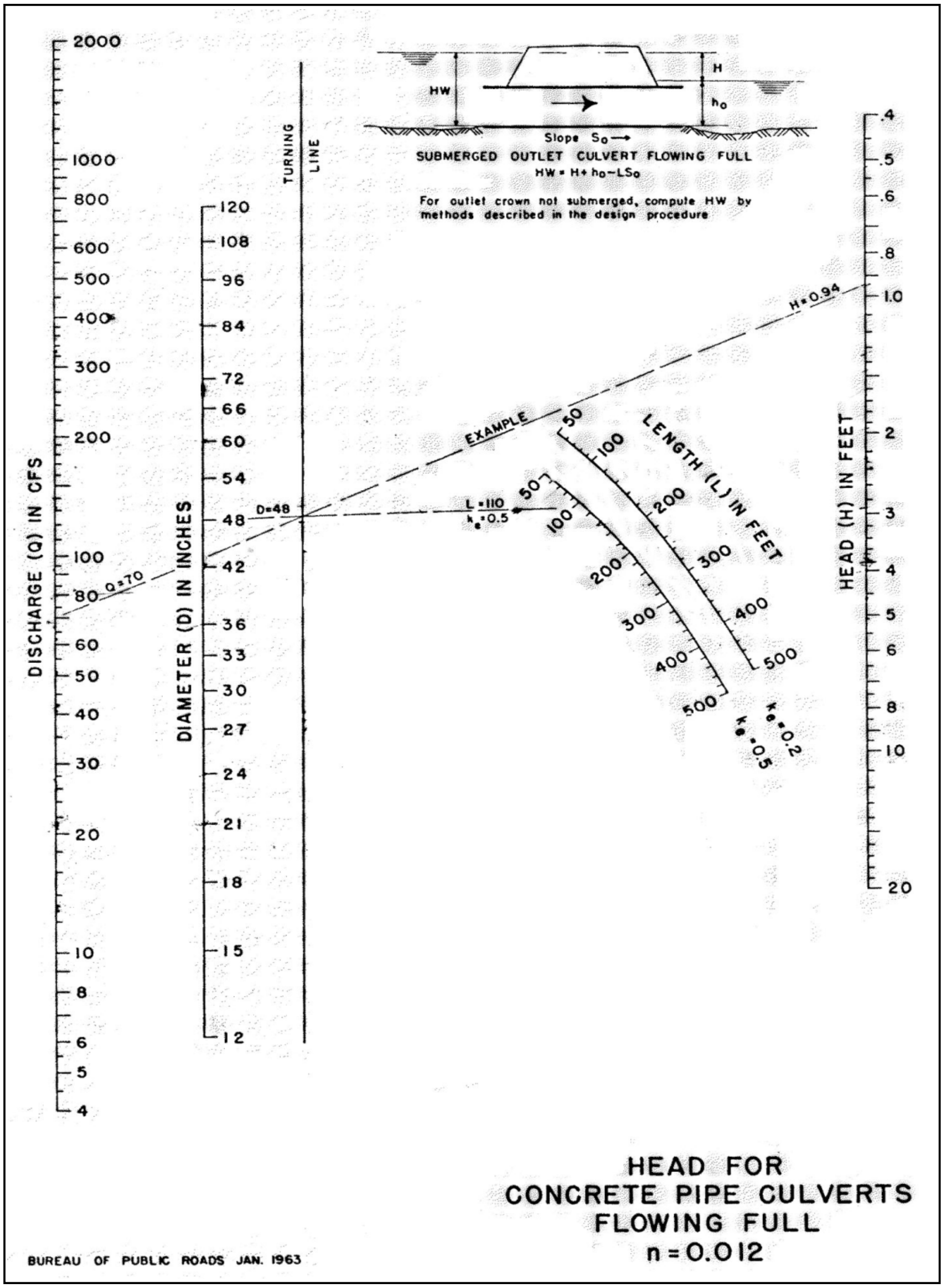


Figure F.1F.1 Typical nomograph for culverts under outlet control.

Formatted: Font: 11 pt

- For commercial/industrial areas, inlets must be kept at least five feet away from the driveway aprons.

The determination of the minimum width of a structure based on incoming pipes is based on the following formula:

$$W = \frac{D}{\sin\theta} + \frac{T}{\tan\theta}$$

where:

D	=	pipe diameter (outside)
T	=	inlet wall thickness
W	=	minimum structure width (inside)
θ	=	angle of pipe entering structure

F.1.10 Clearance with Other Utilities

Formatted: Heading 7

- All proposed and existing utilities crossing or parallel to designed storm sewer systems must be shown on the plan and profile.
- Storm drain and utility crossings must not have be less than a 45-degree angle between them.
- A minimum vertical clearance of one foot and a minimum horizontal clearance of five feet, wall to wall, must be provided between storm drainage lines and other utilities. Exceptions may be granted by the District of Columbia Water and Sewer Authority (DC Water) on a case-by-case basis when justified. Consult DC Water's Project Design Manual, latest addition, for details.

Appendix G Design of Flow Control Structures

G.1 Design of Flow Control Structures

Flow control devices are orifices and weirs. The following formulas shall be used in computing maximum release rates from the designed ~~stormwater management facility~~structural BMP.

G.1.1 Circular Orifices

$$Q = CA(2gh)^{0.5}$$

where:

Q	=	orifice discharge (cfs)
C	=	discharge coefficient = 0.6
A	=	orifice cross-sectional area (ft^2) = 3.1416(D2/4)
g	=	gravitational acceleration (ft/s^2) = 32.2
h	=	hydraulic head above the center of the orifice (ft)

When h < D, the orifice shall be treated as a weir:

$$Q = CLH^{3/2}$$

where:

Q	=	flow through the weir (cfs)
C	=	3
L	=	diameter of orifice (ft)
H	=	hydraulic head above bottom of weir opening (ft)

G.1.2 Flow Under Gates

Flow under a vertical gate can be treated as a square orifice. For submerged conditions:

When outflow is not influenced by downstream water level:

$$Q = b \times a \times C \times \left[2g \times \left(\frac{H_0}{H_0 + H_i} \right) \right]^{0.5}$$

where:

Q	=	flow through the gate (cfs)
b	=	width of gate (ft)
a	=	gate opening height (ft)

Formatted: Font: 11 pt

C = discharge coefficient
G = 32.2 ft/s^2 (gravitational acceleration)

When outflow is influenced by downstream water level:

$$Q' = KQ$$

where:

Q = flow through the gate (cfs)
K = coefficient found in Figure G.1

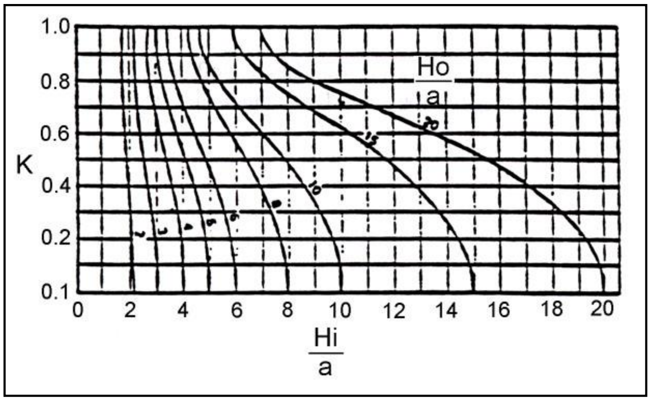


Figure G.1G.1 Absolute downstream control of flow under gate.

G.1.3 Weirs

Rectangular:

$$Q = 3.33H^{1.5}(L - 0.2H)$$

60o V-notch:

$$Q = 1.43H^{2.5}$$

90o V-notch:

$$Q = 2.49H^{2.48}$$

where:

Q	=	low through the weir (cfs)
H	=	hydraulic head above the bottom of the weir (ft)
L	=	length of the weir crest (ft)

Appendix H Acceptable Hydrological Methods and Models

H.1 Acceptable Hydrologic Methods and Models

The following are the acceptable methodologies and computer models for estimating runoff hydrographs before and after development. These methods are used to predict the runoff response from given rainfall information and site surface characteristic conditions. The design storm frequencies used in all of the hydrologic engineering calculations will be based on design storms required in this guidebook unless circumstances make consideration of another storm intensity criterion appropriate:

- Urban Hydrology for Small Watersheds TR-55 (TR-55)
- Storage-Indication Routing
- HEC-1, WinTR-55, TR-20, and SWMM Computer Models
- Rational Method (limited to sites under five acres)

These methods are given as valid in principle, and are applicable to most stormwater management design situations in the District. Other methods may be used when the District reviewing authority approves their application.

Note: Of the above methods, TR-55 and SWMM allow for the easiest correlation of the benefits of retention BMPs used to meet the SWRv with peak flow detention requirements, and are therefore strongly recommended. Appendix A includes more information on using the General Retention Compliance Calculator~~Stormwater Compliance Spreadsheet~~ to account for retention BMPs in calculating peak flow detention requirements.

The following conditions should be assumed when developing predevelopment, preproject, and post-development hydrology, as applicable:

- Predevelopment runoff conditions (used for the 2-year storm) shall be computed independent of existing developed land uses and conditions and shall be based on “Meadow in good condition” or better, assuming good hydrologic conditions and land with grass cover.
- Preproject runoff conditions (used for the 15-year storm) shall be based on the existing condition of the site
- Post-development shall be computed for future land use assuming good hydrologic and appropriate land use conditions. If a NRCS CN Method-based approach, such as TR-55, is used, this curve number may be reduced based upon the application of retention BMPs, as indicated in the General Retention Compliance Calculator~~Stormwater Compliance Spreadsheet~~ (see Appendix A). This curve number reduction will reduce the required

Formatted: Font: 11 pt

detention volume for a site, but it should not be used to reduce the size of conveyance infrastructure.

- The rainfall intensity - duration - frequency curve should be determined from the most recent version of the Hydrometeorological Design Studies Center's Precipitation Frequency Data Server (NOAA Atlas 14, Volume 2). ~~http://hdsc.nws.noaa.gov/hdsc/pfds/index.html~~
- Predevelopment time of concentration shall be based on the sum total of computed or estimated overland flow time and travel in natural swales, streams, creeks and rivers, but never less than six minutes.
- Post-development time of concentration shall be based on the sum total of the inlet time and travel time in improved channels or storm drains, but shall not be less than six minutes.
- Drainage areas exceeding 25 acres that are heterogeneous with respect to land use, soils, RCN or Time of Concentration (Tc) shall require a separate hydrological analysis for each sub-area ~~including Tc, RCN, soils and land use~~.
- Hydrologic Soil Groups approved for use in the District are contained in the Soil Survey of the District of Columbia Handbook. Where the Hydrologic Soil Group is not available through the Soil Survey due to the listed soil type being "Urban Soils" or similar, a Hydrologic Soil Group of C shall be used.

H.2 Urban Hydrology for Small Watersheds TR-55

Chapter 6 of Urban Hydrology for Small Watersheds TR-55, Storage Volume for Detention Basins, or TR-55 shortcut procedure, is based on average storage and routing effects for many structures, and can be used for multistage outflow devices. Refer to TR-55 for more detailed discussions and limitations.

Information Needed

To calculate the required storage volume using TR-55, the predevelopment hydrology for the 2-year storm, and the preproject hydrology for the 15-year storm are needed, along with post-development hydrology for both the 2-year and 15-year storms. The predevelopment hydrology for the 2-year storm is based on natural conditions (meadow), and will determine the site's predevelopment peak rate of discharge, or allowable release rate, qo_2, for the 2-year storm, where~~-~~as the preproject hydrology for the 15-year storm is based on existing conditions, and will determine the site's preproject peak rate of discharge, or allowable release rate, qo_{15}, for the 15-year storm.

The post-development hydrology may be determined using the reduced curve numbers calculated in the General Retention Compliance Calculator~~Stormwater Compliance Spreadsheet~~ (See Appendix A) or more detailed routing calculations. This will determine the site's post-development peak rate of discharge, or inflow for both the 2-year and 15-year storms, qi_2 and qi_{15}, respectively, and the site's post-developed runoff, Q_2 and Q_{15}, in inches. (Note that this method does not require a hydrograph.) Once the above parameters are known, the TR-55 Manual can be used to approximate the storage volume required for each design storm. The following procedure summarizes the TR-55 shortcut method.

Procedure

1. Determine the peak development inflows, qi_2 and qi_{15}, and the allowable release rates, $q_{o2}$and qo_{15}, from the hydrology for the appropriate design storm.

   Using the ratio of the allowable release rate, qo , to the peak developed inflow, qi , or qo/qi , for both the 2-year and 15-year design storms, use Figure H.1 (or Figure 6.1 in TR-55) to obtain the ratio of storage volume, Vs , to runoff volume, Vr , or Vs_2 /Vr_2 and Vs_{15} /Vr_{15} for Type II storms.

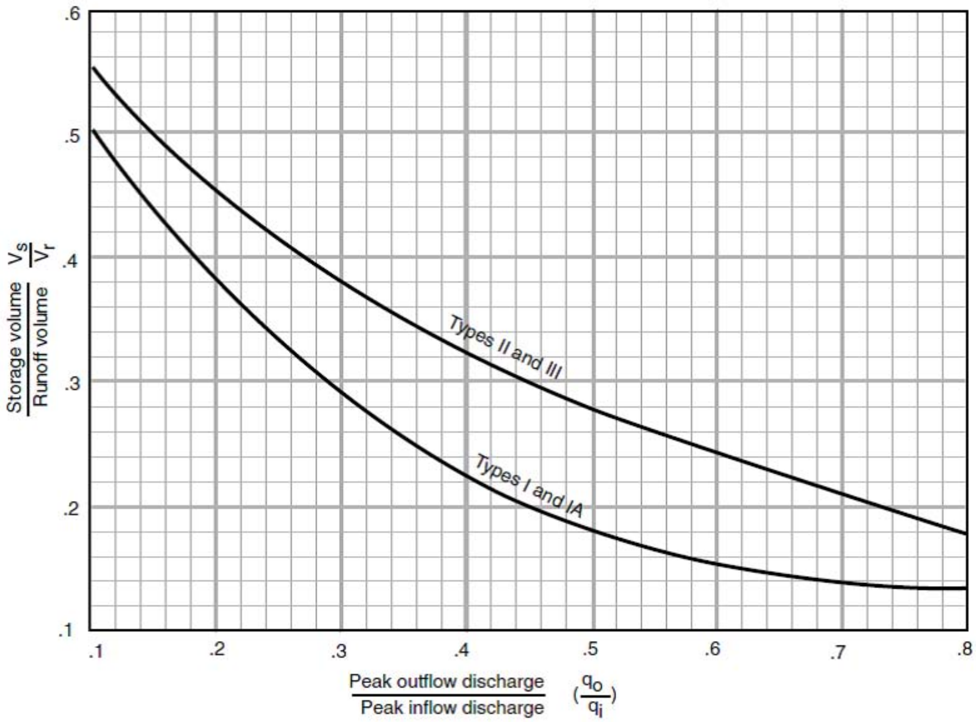


Figure H.1H.1 Approximate detention basin routing for rainfall types I, IA, II and III.

Formatted: Font: 11 pt

2. Determine the runoff volumes, Vr_2 and Vr_{15}.

$$Vr_2 = 53.33 \text{ x } Q_2 \times Am$$

where:

53.33	=	conversion factor from in-mi^2 to acre-feet
Q_2	=	post-development runoff, in inches for the 2-year storm
Am	=	drainage area, in square miles

$$Vr15 = 53.33 \text{ x } Q_{15} \times Am$$

where:

53.33	=	conversion factor from in-mi^2 to acre-feet
Q_{15}	=	post-development runoff for the 15-year storm (in.)
Am	=	drainage area (mi^2)

3. Multiply the Vs /Vr ratios from Step 1 by the runoff volumes, Vr_2 and Vr_{15}, from Step 2, to determine the required storage volumes, Vs_2 and $Vs_{15,}$ in acre-feet.

$$(\frac{Vs_2}{Vr_2})Vr_2 = Vs_2$$

$$(\frac{Vs_{15}}{Vr_{15}})Vr_{15} = Vs_{15}$$

Note: In most cases, Vs_{15} represents the total storage required for the 2-year storm and the 15-year storm, and the outflow, qo_{15}, includes the outflow q_{o2}. In some cases, Vs_{15} may be less than Vs_2. In these cases, the storage volume provided for the 2-year storm (Vs_2) may or may not be sufficient to meet the 15-year requirements, and must be checked via stage-storage curve analysis.

The design procedure presented above may be used with Urban Hydrology for Small Watersheds TR-55 Worksheet 6a. The worksheet includes an area to plot the stage-storage curve, from which actual elevations corresponding to the required storage volumes can be derived. The characteristics of the stage-storage curve are dependent upon the topography of the proposed storage practice and the outlet structure design (see Appendix G), and may be best developed using a spreadsheet or appropriate hydraulics software.

Limitations

This routing method is less accurate as the q_o/q_i ratio approaches the limits shown in Figure H.1. The curves in Figure H.1 depend on the relationship between available storage, outflow device, inflow volume, and shape of the inflow hydrograph. When storage volume (V_s) required is small, the shape of the outflow hydrograph is sensitive to the rate of the inflow hydrograph. Conversely, when V_s is large, the inflow hydrograph shape has little effect on the outflow hydrograph. In such instances, the outflow hydrograph is controlled by the hydraulics of the outflow device and the procedure therefore yields consistent results. When the peak outflow discharge (q_o) approaches the peak inflow discharge (q_i) parameters that affect the rate of rise of a hydrograph, such as rainfall volume, curve number, and time of concentration, become especially significant.

The procedure should not be used to perform final design if an error in storage of 25 percent cannot be tolerated. Figure H.1 is biased to prevent undersizing of outflow devices, but it may significantly overestimate the required storage capacity. More detailed hydrograph development and storage indication routing will often pay for itself through reduced construction costs.

H.3 Storage-Indication Routing

Storage-Indication Routing may be used to analyze storage detention practices. This approach requires that the inflow hydrograph be developed through one of the methods listed in this appendix (TR-55, WinTR-55, SWMM, etc.), as well as the required maximum outflows, q_{o2} and q_{o15}. Using the stage-discharge relationship for a given combination outlet devices, the detention volume necessary to achieve the maximum outflows can be determined.

H.4 HEC-1, WinTR-55, TR-20, and SWMM Computer Models

If the application of the above computer models is needed, the complete input data file and printout will be submitted with the stormwater management plans at the 85 percent submittal stage. Submission of stormwater management plans shall include the following computer model documentation:

- For all computer models, supporting computations prepared for the data input file shall be submitted with the stormwater management plans.
- Inflow-outflow hydrographs shall be computed for each design storm presented graphically, and submitted for all plans.
- Schematic (node) diagrams must be provided for all routings.

H.5 Rational Method

While this method is not recommended, as it cannot account for the retention/detention benefits of the BMPs applied on a site, this method will be permitted for use in a development of five acres or less. When applying this method, the following steps must be taken in the design consideration:

- In the case of more than one sub-drainage area, the longest time of concentration shall be selected.

Formatted: Font: 11 pt

- Individual sub-drainage flows shall not be summed to get the total flow for the watershed.
- The runoff coefficient, C, shall be a composite of the future site development conditions for all contributing areas to the discharge point. Runoff coefficient factors for typical District land uses are provided in Table H.1.
- The flow time in storm sewers shall be taken into account in computing the watershed time of concentration.
- The storm duration shall be dependent upon the watershed time of concentration.
- The storm intensity can be selected from the selected storm duration.

Table H.1 Runoff Coefficient Factors for Typical District of Columbia Land Uses

Zone	Predominant Use	Minimum Lot Dimensions		Runoff Coefficient C
		Width (ft)	Area (ft^2)	
R-1-A	One-family detached dwelling	75	7,500	0.60
R-1-B	One-family detached dwelling	50	5,000	0.65
R-2	One-family semi-detached dwelling	30	3,000	0.65
R-3	Row dwelling	20	2,000	0.70
R-4	Row dwelling	18	1,800	0.75
R-5-A	Low density apartment	–	–	0.70
R-5-B	Medium density apartment house	–	–	0.75
R-5-C	Medium high density apartment house	–	–	0.80
R-5-D	High density building	–	–	0.80
C	Commercial	–	–	0.85–0.95
M	General Industry	–	–	0.80–0.90
Park	Open green space	–	–	0.35

H.6 Stormwater Retention Volume Peak Discharge

The peak rate of discharge for individual design storms may be required for several different components of water quality BMP design. While the primary design and sizing factor for most stormwater retention BMPs is the design Stormwater Retention Volume (SWRv), several design elements will require a peak rate of discharge for specified design storms. The design and sizing of pretreatment cells, level spreaders, by-pass diversion structures, overflow riser structures, grass swales and water quality swale geometry, etc., all require a peak rate of discharge in order to ensure non-erosive conditions and flow capacity.

Formatted: Font: 11 pt

The peak rate of discharge from a drainage area can be calculated from any one of several calculation methods discussed in this appendix. The two most commonly used methods of computing peak discharges for peak runoff calculations and drainage system design are NRCS TR-55 Curve Number (CN) methods (NRCS TR-55, 1986) and the Rational Formula. The Rational Formula is highly sensitive to the time of concentration and rainfall intensity, and therefore should only be used with reliable Intensity-Duration-Frequency (IDF) curves or tables for the rainfall depth and region of interest (Claytor and Schueler, 1996). Unfortunately, there are no IDF curves available at this time for the 1.2-inch rainfall depth.

The NRCS CN methods are very useful for characterizing complex sub-watersheds and drainage areas and estimating the peak discharge from large storms (greater than two inches), but can significantly under estimate the discharge from small storm events (Claytor and Schueler, 1996). Since the Tv is based on a one-inch rainfall, this underestimation of peak discharge can lead to undersized diversion and overflow structures, potentially bypassing a significant volume of the design SWRv around the retention practice. Undersized overflow structures and outlet channels can cause erosion of the BMP conveyance features which can lead to costly and frequent maintenance.

In order to maintain consistency and accuracy, the following Modified CN Method is recommended to calculate the peak discharge for the SWRv 1.2-inch rain event. The method utilizes the Small Storm Hydrology Method (Pitt, 1994) and NRCS Graphical Peak Discharge Method (USDA 1986) to provide an adjusted curve number that is more reflective of the runoff volume from impervious areas within the drainage area. The design rainfall is a NRCS type II distribution so the method incorporates the peak rainfall intensities common in the eastern United States, and the time of concentration is computed using the method outlined in TR-55.

The following provides a step-by-step procedure for calculating the Stormwater Retention Volume peak rate of discharge (q_{pSWRv}):

Step 1: Calculate the adjusted curve number for the site or contributing drainage area.

The following equation is derived from the NRCS CN Method and is described in detail in the National Engineering Handbook Chapter 4: Hydrology (NEH-4), and NRCS TR-55 Chapter 2: Estimating Runoff:

$$CN = \frac{100_0}{\left[10 + 5P + 1_0 Q_a - 1_0 \left(Q_a^2 + 1.2_5 Q_a P\right)^{0.5}\right]}$$

where:

C	=	adjusted curve number
P	=	rainfall (in.), (1.2 in.)
Q_a	=	runoff volume (watershed inches), equal to SWRv divided by drainage area

Note: When using hydraulic/hydrologic model for sizing a retention BMP or calculating the SWRv peak discharge (), designers must use this modified CN for the drainage area to generate runoff equal to the SWRv for the 1.2-inch rainfall event.

Formatted: Font: 11 pt

Step 2: Compute the site or drainage area Time of Concentration (Tc).

TR-55 Chapter 3: Time of Concentration and Travel Time provides a detailed procedure for computing the Tc.

Step 3: Calculate the Stormwater Retention Volume peak discharge (qp_{SWRv})

Step 4: The qp_{SWRv} is computed using the following equation and the procedures outlined in TR-55, Chapter 4: Graphical Peak Discharge Method. Designers can also use WinTR-55 or an equivalent TR-55 spreadsheet to compute qp_{SWRv}:

- Read initial abstraction (I_a) from TR-55 Table 4.1 or calculate using $I_a = 200/CN - 2$
- Compute I_a/P (P = 1.0)
- Read the Unit Peak Discharge (q_u) from exhibit 4-II using Tc and I_a/P
- Compute the qp_{SWRv} peak discharge:

$$qp_{SWRv} = q_u \times A \times Qa$$

where:

qp_{SWRv} = Stormwater Retention Volume peak discharge (cfs)
q_u = unit peak discharge (cfs/mi^2/in.)
A = drainage area (mi^2)
Q_a = runoff volume (watershed inches = SWRv/A)

This procedure is for computing the peak flow rate for the 1.2-inch rainfall event. All other calculations of peak discharge from larger storm events for the design of drainage systems, culverts, etc., should use published curve numbers and computational procedures.

H.7 References

Claytor, R. and T. Schueler. 1996. Design of Stormwater Filtering Systems. Chesapeake Research Consortium and the Center for Watershed Protection. Ellicott City, MD. http://www.cwp.org/online-watershed-library?view=docman

Pitt, R., 1994, Small Storm Hydrology. University of Alabama - Birmingham. Unpublished manuscript. Presented at design of stormwater quality management practices. Madison, WI, May 17-19 1994.

"Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 2, Version 3.0, G. M. Bonnin, D. Martin, B. Lin, T. Parzybok, M. Yekta, and D. Riley, NOAA, National Weather Service, Silver Spring, Maryland, 2006. http://hdsc.nws.noaa.gov/hdsc/pfds/

United States Department of Agriculture Natural Resources Conservation Service Urban Hydrology for Small Watersheds TR-55. June 1986.

Formatted: Font: 11 pt

Virginia Department of Conservation and Recreation DRAFT 2009 Virginia Stormwater Management Handbook. September 2009.

Appendix I Rooftop Storage Design Guidance and Criteria

I.1 Rooftop Storage Design Guidance and Criteria

~~Note:~~ Rooftop storage, as described in this Appendix, is intended as a detention practice only. The rules and guidelines presented in this Appendix do not apply to green roofs (Section 3.2).

1. Rooftop storage may be used to provide detention for the 2-year and 15-year storms, as applicable. Detention calculations must follow the procedures identified in Chapter 2 and Appendix H.
2. Rainfall from the 2-year, 24-hour storm results in an accumulated rainfall of approximately 3.2 inches, and rainfall from the 15-year, 24-hour storm results in an accumulated rainfall of approximately 5.2 inches. Peak flow detention calculations for either of these storms will require less than these depths (assuming there is no run-on from other rooftop areas.
   (a) Based on a snow load of 30 pounds per square foot or 5.8 inches of water, properly designed roofs must be structurally capable of holding the required detention volume with a reasonable factor of safety.
   (b) Roofs calculated to store depths greater than three inches shall be required to show structural adequacy of the roof design.
3. No less than two roof drains shall be installed in roof areas of 10,000 square feet or less, and at least four drains shall be installed in roof areas over 10,000 square feet in area. Roof areas exceeding 40,000 square feet shall have one drain for each 10,000 square foot area.
4. Emergency overflow measures adequate to discharge the 100-year, 45-minute storm must be provided.
   (a) If parapet walls exceed 5 inches in height, the designer shall provide openings (scuppers) in the parapet wall sufficient to discharge the design storm flow at a water level not exceeding 5 inches.
   (b) One scupper shall be provided for every 20,000 square feet of roof area, and the invert of the scupper shall not be more than 5 inches above the roof level. (If such openings are not practical, then detention rings shall be sized accordingly).
5. Detention rings shall be placed around all roof drains that do not have controlled flow.
   (a) The number of holes or size of openings in the rings shall be computed based on the area of roof drained and run-off criteria.
   (b) The minimum spacing of sets of holes is 2 inches center-to-center.
   (c) The height of the ring is determined by the roof slope and detention requirements, and shall be 5 inches maximum.

(d) The diameter of the rings shall be sized to accommodate the required openings and, if scuppers are not provided, to allow the 100-year design storm to overtop the ring (overflow design is based on weir computations with the weir length equal to the circumference of the detention ring).

(e) Conductors and leaders shall also be sized to pass the expected flow from the 100-year design storm.

6. The maximum time of drawdown on the roof shall not exceed 17 hours.
7. Josam Manufacturing Company and Zurn Industries, Inc. market “controlled-flow” roof drains. These products, or their equivalent, are acceptable.
8. Computations required on plans:

(a) Roof area in square feet.

(b) Storage provided at design depth.

(c) Maximum allowable discharge rate.

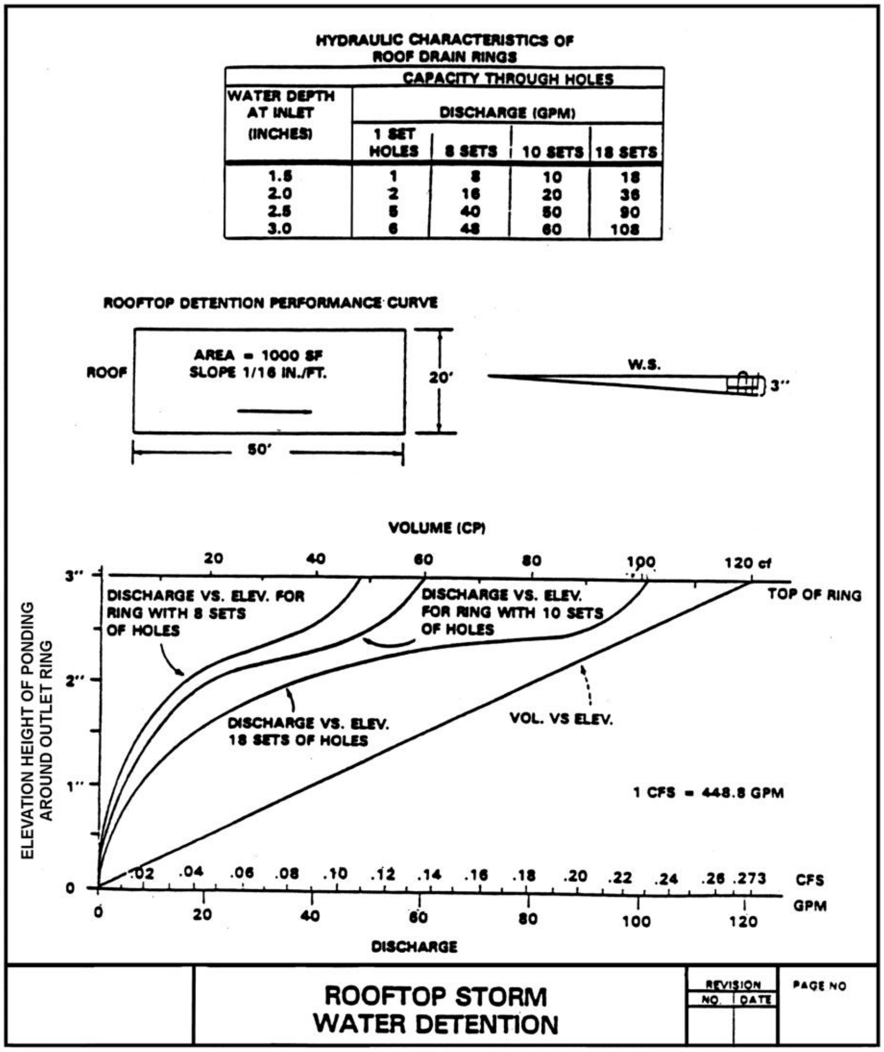
(d) Inflow-outflow hydrograph analysis or acceptable charts (for Josam Manufacturing Company and Zurn Industries, Inc. standard drains, the peak discharge rates as given in their charts are acceptable for drainage calculation purposes without requiring full inflow-outflow hydrograph analysis).

(e) Number of drains required.

(f) Sizing of openings required in detention rings.

(g) Sizing of ring to accept openings and to pass 100-year design storm.

Formatted: Font: 11 pt



HYDRAULIC CHARACTERISTICS OF ROOF DRAIN RINGS

WATER DEPTH AT INLET (INCHES)	CAPACITY THROUGH HOLES — DISCHARGE (GPM)			
	1 SET HOLES	8 SETS	10 SETS	18 SETS
1.5	1	8	10	18
2.0	2	16	20	36
2.5	5	40	50	90
3.0	6	48	60	108

Figure I.1I.1 Rooftop stormwater detention.

Formatted: Font: 11 pt

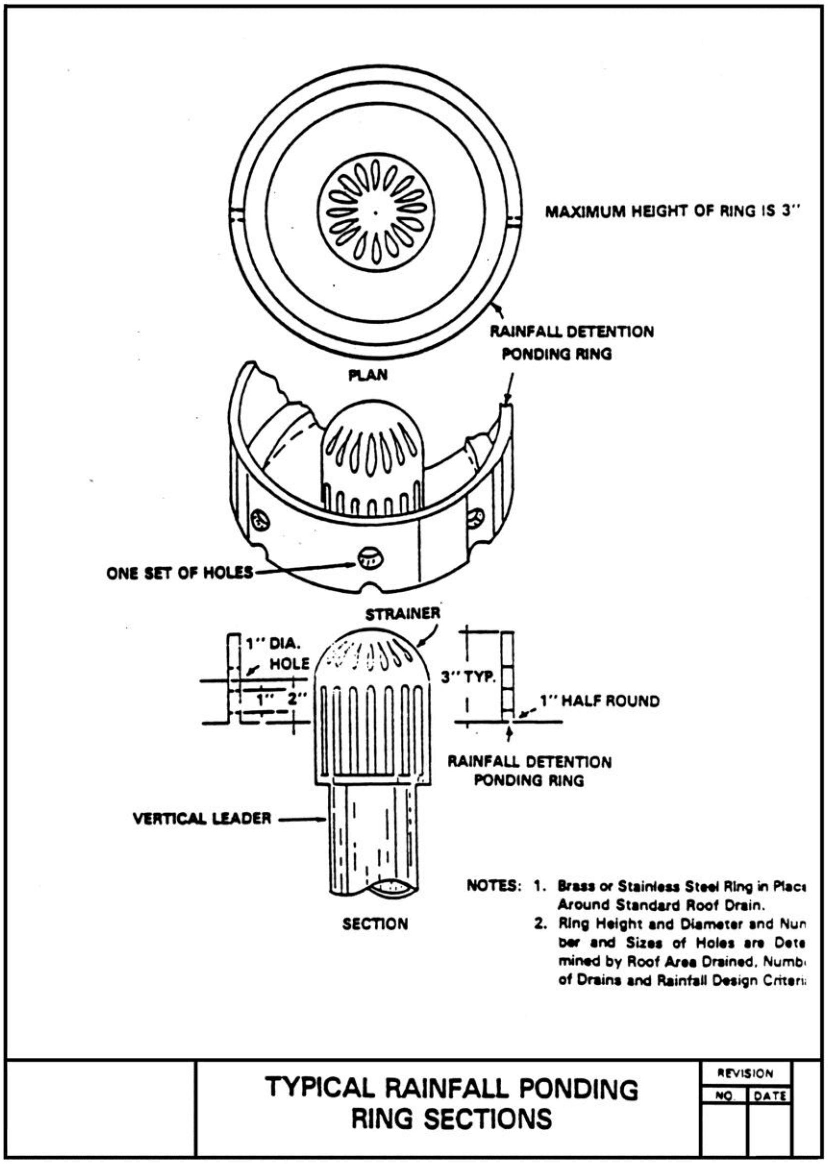


Figure I.2I.2 Typical rainfall ponding ring sections.

Appendix J Reserved

The appendix on the Green Area Ratio (GAR) was removed. Guidance on the GAR will be through separate guidance documents available on DDOE's website when the GAR Rule is finalized.

Appendix K Appendix J Soil Compost Amendment Requirements

J.1 Introduction

Soil amendment (also called soil restoration) is a technique applied after construction to deeply till compacted soils and restore their porosity by amending them with compost. These soil amendments can be used to enhance the performance of impervious cover disconnections and grass channels.

K.1 J.2 Physical Feasibility and Design Applications

Amended soils are suitable for any pervious area where soils have been or will be compacted by the grading and construction process. They are particularly well suited when existing soils have low infiltration rates (HSG C and D) and when the pervious area will be used to filter runoff (downspout disconnections and grass channels). The area or strip of amended soils should be hydraulically connected to the stormwater conveyance system. Soil restoration is recommended for sites that will experience mass grading of more than a foot of cut and fill across the site.

Compost amendments are not recommended where:

- Existing soils have high infiltration rates (e.g., HSG A and B), although compost amendments may be needed at mass-graded B soils in order to maintain infiltration rates.
- The water table or bedrock is located within 1.5 feet of the soil surface.
- Slopes exceed 10 percent (compost can be used on slopes exceeding 10 percent as long as proper soil erosion and sediment control measures are included in the plan).
- Existing soils are saturated or seasonally wet.
- They would harm roots of existing trees (keep amendments outside the tree drip line).
- The downhill slope runs toward an existing or proposed building foundation.
- Areas that will be used for snow storage.

K.2 J.3 Design Criteria

Performance. When Used in Conjunction with Other Practices. As referenced in several of the Chapter 3 specifications, soil compost amendments can be used to enhance the performance of allied practices by improving runoff infiltration. The specifications for each of these practices contain design criteria for how compost amendments can be incorporated into those designs:

- Impermeable Surface Disconnection – See Section 3.4 Impervious Surface Disconnection.
- Grass Channels –See Section 3.9 Open Channel Systems.

Soil Testing. Soil tests are required during two stages of the compost amendment process. The first testing is done to ascertain preconstruction soil properties at proposed amendment areas. The initial testing is used to determine soil properties to a depth 1 foot below the proposed amendment area, with respect to bulk density, pH, salts, and soil nutrients. These tests should be conducted every 5000 square feet, and are used to characterize potential drainage problems and determine what, if any, further soil amendments are needed.

The second soil test is taken at least one week after the compost has been incorporated into the soils. This soil analysis should be conducted by a reputable laboratory to determine whether any further nutritional requirements, pH adjustment, and organic matter adjustments are necessary for plant growth. This soil analysis must be done in conjunction with the final construction inspection to ensure tilling or subsoiling has achieved design depths.

Determining Depth of Compost Incorporation. The depth of compost amendment is based on the relationship of the surface area of the soil amendment to the contributing area of impervious cover that it receives. Table J~~K~~.1 presents some general guidance derived from soil modeling by Holman-Dodds (2004) that evaluates the required depth to which compost must be incorporated. Some adjustments to the recommended incorporation depth were made to reflect alternative recommendations of Roa Espinosa (2006), Balousek (2003), Chollak and Rosenfeld (1998) and others.

Table J.1 Method to Determine Compost and Incorporation Depths

Ratio of Area of Contributing Impervious Cover to Soil Amendment[a] (IC/SA)	Compost Depth[b] (in.)	Incorporation Depth (in.)	Incorporation Method
0.5	3–6[c]	8–12[c]	Tiller
0.75	4–8[c]	15–18[c]	Subsoiler
1.0[d]	6–10[c]	18–24[c]	Subsoiler

[a] IC = contrib. impervious cover (ft^2) and SA = surface area of compost amendment (ft^2)
[b] Average depth of compost added
[c] Lower end for B soils, higher end for C/D soils
[d] In general, IC/SA ratios greater than 1 should be avoided

Once the area and depth of the compost amendments are known, the designer can estimate the total amount of compost needed, using an estimator developed by TCC, (1997):

$$C = A \times D \times 0.0031$$

where:

C = compost needed (yd^3)
A = area of soil amended (ft^2)
D = depth of compost added (in.)

Compost Specifications. The basic material specifications for compost amendments are outlined below:

- Compost shall be derived from plant material and provided by a member of the U.S. Composting Seal of Testing Assurance (STA) program. See www.compostingcouncil.org for a list of local providers.
- Alternative specifications and/or certifications, such as those administered by the Maryland Department of Agriculture or other agencies, may be substituted, as authorized by DDOE. In all cases, compost material must meet standards for chemical contamination and pathogen limits pertaining to source materials, as well as reasonable limits on phosphorus and nitrogen content to avoid excessive leaching of nutrients.
- The compost shall be the result of the biological degradation and transformation of plant-derived materials under conditions that promote anaerobic decomposition. The material shall be well composted, free of viable weed seeds, and stable with regard to oxygen consumption and carbon dioxide generation. The compost shall have a moisture content that has no visible free water or dust produced when handling the material. It shall meet the following criteria, as reported by the U.S. Composting Council STA Compost Technical Data Sheet provided by the vendor:

  (a) 100 percent of the material must pass through a half-inch screen

  (b) The pH of the material shall be between 6 and 8

  (c) Manufactured inert material (plastic, concrete, ceramics, metal, etc.) shall be less than 1.0 percent by weight

  (d) The organic matter content shall be between 35 and 65 percent

  (e) Soluble salt content shall be less than 6.0 mmhos/cm

  (f) Maturity must be greater than 80 percent

  (g) Stability shall be 7 or less

  (h) Carbon/nitrogen ratio shall be less than 25:1

  (i) Trace metal test result = “pass”

  (j) The compost must have a dry bulk density ranging from 40 to 50 lb/ft^3

~~K.3~~J.4 Construction Sequence

The construction sequence for compost amendments differs depending whether the practice will be applied to a large area or a narrow filter strip, such as in a rooftop disconnection or grass channel. For larger areas, a typical construction sequence is as follows:

Step 1: **Soil Erosion and Sediment Control.** When areas of compost amendments exceed 2500 square feet install soil erosion and sediment control measures, such as silt fences, are required to secure the area until the surface is stabilized by vegetation.

~~***Step 1:***~~***Step 2:*****Deep Till.** D~~A d~~eep till~~ing~~ to a depth of 12 to 18 inches after the final building lots have been graded ~~is recommended~~ prior to the addition of compost.

~~***Step 2:***~~***Step 3:*****Dry Conditions.** ~~It is important to have~~Wait for dry conditions at the site prior to incorporating compost.

~~*Step 3:*~~*Step 4:* **Compost.** ~~The~~ Incorporate the required ~~depth of~~ compost depth (as indicated in Table J~~K~~.1) ~~is then incorporated~~ into the tilled soil ~~to the required depth~~ using the appropriate equipment.

Level t~~T~~he site ~~should be leveled.~~ ~~and s~~Seeds or sod ~~used~~ are required to establish a vigorous grass cover. To help the grass grow quickly l~~L~~ime or irrigation ~~may initially be needed~~is recommended. ~~to help the grass grow quickly~~.

~~***Step 4:*** Areas of compost amendments exceeding 2500 square feet should employ simple erosion control measures, such as silt fence, to reduce the potential for erosion and trap sediment.~~

Step 5: **Vegetation.** Ensure surface area is stabilized with vegetation.

Construction Inspection. Construction inspection by a qualified professional involves digging a test pit to verify the depth of amended soil and scarification. A rod penetrometer should be used to establish the depth of uncompacted soil at a minimum of one location per 10,000 square feet.

~~K.4~~J.5 Maintenance

First-Year Maintenance Operations. In order to ensure the success of soil compost amendments, the following tasks must be undertaken in the first year following soil restoration:

- **Initial inspections.** For the first six months following the incorporation of soil amendments, the site should be inspected by a qualified professional at least once after each storm event that exceeds 1/2-inch of rainfall.
- **Spot Reseeding.** Inspectors should look for bare or eroding areas in the contributing drainage area or around the soil restoration area and make sure they are immediately stabilized with grass cover.
- **Fertilization.** Depending on the amended soils test, a one-time, spot fertilization may be needed in the fall after the first growing season to increase plant vigor.
- **Watering.** Water once every three days for the first month, and then weekly during the first year (April-October), depending on rainfall.

Ongoing Maintenance. There are no major ongoing maintenance needs associated with soil compost amendments, although the owners may want to de-thatch the turf every few years to increase permeability. The owner should also be aware that there are maintenance tasks needed for filter strips, grass channels, and reforestation areas. DDOE's maintenance inspection checklist for an area of Soil Compost Amendments can be accessed in ~~Appendix M~~Appendix L.

Declaration of Covenants. A maintenance covenant is required for all stormwater management practices. The covenant specifies the property owner's primary maintenance responsibilities, and authorizes DDOE staff to access the property for inspection or corrective action in the event the proper maintenance is not performed. The covenant is attached to the deed of the property (see standard form, variations exist for scenarios where stormwater crosses property lines). The covenant is between the property and the ~~District~~ Government of the District of Columbia. It is submitted through the Office of the Attorney General. All SWMPs have a maintenance agreement stamp that must be signed for a building permit to proceed. There may be a maintenance schedule on the drawings themselves or the plans may refer to the maintenance schedule (~~schedule c~~Exhibit C in the covenant).

Covenants are not required on government properties, but maintenance responsibilities must be defined through a partnership agreement or a memorandum of understanding.

~~K.5~~J.6 References

Balusek. 2003. Quantifying decreases in stormwater runoff from deep-tilling, chisel-planting and compost amendments. Dane County Land Conservation Department. Madison, Wisconsin.

Chollak, T. and P. Rosenfeld. 1998. Guidelines for Landscaping with Compost-Amended Soils. City of Redmond Public Works. Redmond, WA. Available online at: www.redmond.gov/common/pages/UserFile.aspx?fileId=14766

The Composting Council (TCC). 1997. Development of a Landscape Architect Specification for Compost Utilization. Alexandria, VA. http://www.cwc.org/organics/org972rpt.pdf

Holman-Dodds, L. 2004. Chapter 6. Assessing Infiltration-Based Stormwater Practices. PhD Dissertation. Department of Hydroscience and Engineering. University of Iowa. Iowa City, IA.

Low Impact Development Center. 2003. Guideline for Soil Amendments. Available online at: http://www.lowimpactdevelopment.org/epa03/soilamend.htm

Roa-Espinosa. 2006. An Introduction to Soil Compaction and the Subsoiling Practice. Technical Note. Dane County Land Conservation Department. Madison, Wisconsin