Appendix A

Compliance Calculations and Design Examples

A.1 Compliance Calculations

All major regulated projects are required to address the Stormwater Retention Volume (SWRv), as described in Chapter 2. Section A.2 provides guidance on using the standard Stormwater Compliance Spreadsheet. This spreadsheet or alternative calculations must be submitted with the Stormwater Management Plan (SWMP) for approval.

A.2 District of Columbia Stormwater Compliance Spreadsheet

The guidance below goes through the use of each of the tabs in the Stormwater Compliance Spreadsheet.

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. For the site, indicate the specific types of post-development Natural Cover, Compacted Cover, and Impervious Cover in **lines 16-29**. Guidance for various land covers is provided in Table 1. Efforts to reduce Impervious Cover on the site and maximize Natural Cover will reduce the required Stormwater Retention Volume (SWRv).

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

Table 1. Land Cover Guidance for Stormwater Compliance Spreadsheet
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. Operational & Management Conditions in Natural Cover Category: • 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 guidelines for compost amended soils in Appendix K.	
COMPACTED COVER	
Land disturbed and/or graded for eventual use as managed turf or landscaping:	
Lawn	• Portions of residential yards that are graded or disturbed, and maintained as turf, including yard areas, septic fields, residential utility connections, and roadway rights of way.
Landscaping	• Areas 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. This category also includes the surface area of all BMPs.	
Rooftop	• All rooftops
Res/Comm Parking Lot	• Parking lots in residential or commercially zoned areas.
Industrial Parking Lot	• Parking lots in industrially zoned areas.
Driveway/Sidewalk/Street	• All driveways, sidewalks, and residential streets
Commercial Street	• Streets in commercial or industrially zoned areas.
BMP	• BMP surface area <u>except</u> disconnection areas.

3. From the land cover input, a weighted site runoff coefficient (Rv) will be calculated (**line 39**) based upon the land cover Rv values of 0.00 for Natural Cover, 0.25 for Compacted Cover, and 0.95 for Impervious Cover

%Natural Cover = A_{NC}/SA x 100
%Compacted Cover = A_{CC}/SA x 100
%Impervious Cover = A_I/SA x 100
Rv = (%Natural Cover) x Rv_{NC} + (%Compacted Cover) x RV_{CC} + (%Impervious Cover) x RV_I

Where:
A_{NC} = area of post-development natural cover (square feet)
A_{CC} = area of post-development compacted cover (square feet)
A_I = area of post-development impervious cover (square feet)
SA = total site area (square feet)

Rv = weighted site runoff coefficient
Rv_{NC} = runoff coefficient for natural cover (0.00)
Rv_{CC} = runoff coefficient for compacted cover (0.25)
Rv_{I} = runoff coefficient for impervious cover (0.95)

4. Determine the SWRv that must be retained on the site (**line 43**). The regulatory rain event for calculation of the SWRv varies depending upon the type of development. For most sites, the SWRv is based upon the 90^{th} percentile depth (1.2 inches). If the site is undergoing substantial improvement as part of a redevelopment project, the SWRv is based upon the 80^{th} percentile depth (0.8 inches).

   SWRv = P/12 x Rv x SA

   Where:
   SWRv = Stormwater Retention Volume (cubic feet)
   P = Regulatory Rain Event (inches)
   12 = conversion from inches to feet
   Rv = weighted site runoff coefficient
   SA = total site area (acres)

5. Determine if the site is located in the MS4 and note in **Cell C47**.

6. The total TSS load for the site is calculated on line 45 based on the event mean concentrations of TSS for each land cover type (C**olumn C**).

$$\text{TSS Load} = P/12 \times (Rv_{NC} \times A_{NC} \times TSS_{NC} + Rv_{CC} \times (A_{lawn} \times TSS_{lawn} + A_{ls} \times TSS_{ls}) + Rv_{I} \times (A_{roof} \times TSS_{roof} + A_{rcpl} \times TSS_{rcpl} + A_{ipl} \times TSS_{ipl} + A_{dss} \times TSS_{dss} + A_{cs} \times TSS_{cs} + A_{BMP} \times TSS_{BMP})) \times 2.72/43560$$

Where:
TSS Load = total TSS load for the site (pounds)
P = Regulatory Rain Event (inches)
12 = conversion from inches to feet
Rv_{NC} = runoff coefficient for natural cover (0.00)
A_{NC} = area of post-development natural cover (square feet)
TSS_{NC} = TSS event mean concentration for natural cover (49 mg/L)
Rv_{CC} = runoff coefficient for compacted cover (0.25)
A_{lawn} = area of post-development lawn cover (square feet)
TSS_{lawn} = TSS event mean concentration for lawn cover (602 mg/L)
A_{ls} = area of post-development landscaping cover (square feet)
TSS_{ls} = TSS event mean concentration for landscaping cover (37 mg/L)
Rv_{I} = runoff coefficient for impervious cover (0.95)
A_{roof} = area of post-development rooftop cover (square feet)
TSS_{roof} = TSS event mean concentration for rooftop cover (15 mg/L)
A_{rcpl} = area of post-development residential/commercial parking lot cover (square feet)
TSS_{rcpl} = TSS event mean concentration for residential/commercial parking lot cover (27 mg/L)
A_{ipl} = area of post-development industrial parking lot cover (square feet)
TSS_{ipl} = TSS event mean concentration for industrial parking lot cover (228 mg/L)

A_{dss} = area of post-development driveways, sidewalks, and residential streets (square feet)
TSS_{dss} = TSS event mean concentration for driveways, sidewalks, and residential streets (173 mg/L)
A_{cs} = area of post-development commercial and industrial streets (square feet)
TSS_{cs} = TSS event mean concentration for commercial and industrial streets (468 mg/L)
A_{BMP} = area of BMP (square feet)
TSS_{BMP} = TSS event mean concentration BMPs (0 mg/L)
2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters
43,560 = conversion from square feet to acres

Drainage Area Sheets A-E

If the site has multiple discharge points, or complex treatment sequences, it must be divided into individual drainage areas (D.A.s). For each D.A., a minimum of 50% of the SWRv must be retained. In the MS4, if 50% of the SWRv cannot be retained, 60% of the Total Suspended Solids (TSS) must be removed from the drainage area's runoff through the application of BMPs.

For each D.A. sheet:

1. Indicate the specific types of post-development Natural Cover, Compacted Cover, and Impervious Cover in **lines 6-19.** The SWRv for the D.A. will be calculated in **Cell G17**, and the TSS Load will be calculated in **Cell G20**.

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

2. Apply BMPs to the drainage area to address the required SWRv by indicating the area in square feet of impervious cover and compacted cover to be treated by a given BMP in **Columns B and D** (or number of trees in the case of tree preservation or planting). This will likely be an iterative process. The available practices include:

- Green Roof
- Rainwater Harvesting
- Simple Disconnection to a Pervious Area
- Simple Disconnection to a Conservation Area
- Simple Disconnection to Amended Soils
- Permeable Pavement - Enhanced
- Permeable Pavement - Standard
- Bioretention - Enhanced
- Bioretention - Standard
- Stormwater Filtering Systems
- Stormwater Infiltration
- Storage
- Stormwater Ponds
- Wetlands

- Grass Channel
- Grass Channel with Amended Soils
- Dry Swale
- Wet Swale
- Proprietary Practice
- Tree Planting or Preservation

3. Based upon the area input for a given practice, the spreadsheet will calculate the Maximum Retention Volume Received by Practice in **column F**. 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 F 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" practices in one drainage area and "undersize" others to achieve compliance. However, as noted above, in the MS4, a minimum of 50% of the SWRv must be retained, or 60% TSS removal must be achieved.

$$Vmax = 1.7/12 \times (Rv_{NC} \times A_{NC} + Rv_{CC} \times (A_{lawn} + A_{ls}) + Rv_{I} \times (A_{roof} + A_{rcpl} + A_{ipl} + A_{dss} + A_{cs} + A_{BMP})$$

Where:

Vmax = volume received by practice from 1.7" rain event (cubic feet)
Rv_{NC} = runoff coefficient for natural cover (0.00)
A_{NC} = area of post-development natural cover (square feet)
Rv_{CC} = runoff coefficient for compacted cover (0.25)
A_{lawn} = area of post-development lawn cover (square feet)
A_{ls} = area of post-development landscaping cover (square feet)
Rv_{I} = runoff coefficient for impervious cover (0.95)
A_{roof} = area of post-development rooftop cover (square feet)
A_{rcpl} = area of post-development residential/commercial parking lot cover (square feet)
A_{ipl} = area of post-development industrial parking lot cover (square feet)
A_{dss} = area of post-development driveways, sidewalks, and residential streets (square feet)
A_{cs} = area of post-development commercial and industrial streets (square feet)
A_{BMP}= area of BMP (square feet)

4. If more than one BMP will be employed in series, any overflow from upstream BMPs will be accounted for in **column J**, and the total volume directed to the BMP will be summed in **column K**.

5. For most practices it is necessary to input the surface area of the practice and/or the storage volume of the practice in **columns L and M**. These should be calculated using the equations provided in Chapter 3.

6. The spreadsheet calculates a retention volume value in **column N**, based on the value descriptions in **columns G-I**. Regardless of the storage volume of the BMP, the retention

volume value cannot be greater than the total volume received by the practice (**column K**).

7. The Potential Retention Volume Remaining (**column O**) equals the total volume received by the practice minus the retention volume value.

8. Practices that have a less than 100% retention value may have a TSS removal efficiency as well, meaning that the practice includes filtering or other processes that remove TSS from the runoff that flows through them. This efficiency is indicated in **column P**. The TSS load to the practice is calculated in **column R**.

$$TSS\ Load_{practice} = P/12 \times (Rv_{NC} \times A_{NC} \times TSS_{NC} + Rv_{CC} \times (A_{lawn} \times TSS_{lawn} + A_{ls} \times TSS_{ls}) + Rv_{I} \times (A_{roof} \times TSS_{roof} + A_{rcpl} \times TSS_{rcpl} + A_{ipl} \times TSS_{ipl} + A_{dss} \times TSS_{dss} + A_{cs} \times TSS_{cs} + A_{BMP} \times TSS_{BMP})) \times 2.72/43560 + TSS_{upstream}$$

Where:

$TSS\ Load_{practice}$ = TSS load directed to a practice (pounds)
P_1 = 95% rain event (1.7 inches)
12 = conversion from inches to feet
Rv_{NC} = runoff coefficient for natural cover (0.00)
A_{NC} = area of post-development natural cover (square feet)
TSS_{NC} = TSS event mean concentration for natural cover (49 mg/L)
Rv_{CC} = runoff coefficient for compacted cover (0.25)
A_{lawn} = area of post-development lawn cover (square feet)
TSS_{lawn} = TSS event mean concentration for lawn cover (602 mg/L)
A_{ls} = area of post-development landscaping cover (square feet)
TSS_{ls} = TSS event mean concentration for landscaping cover (37 mg/L)
Rv_{I} = runoff coefficient for impervious cover (0.95)
A_{roof} = area of post-development rooftop cover (square feet)
TSS_{roof} = TSS event mean concentration for rooftop cover (15 mg/L)
A_{rcpl} = area of post-development residential/commercial parking lot cover (square feet)
TSS_{rcpl} = TSS event mean concentration for residential/commercial parking lot cover (27 mg/L)
A_{ipl} = area of post-development industrial parking lot cover (square feet)
TSS_{ipl} = TSS event mean concentration for industrial parking lot cover (228 mg/L)
A_{dss} = area of post-development driveways, sidewalks, and residential streets (square feet)
TSS_{dss} = TSS event mean concentration for driveways, sidewalks, and residential streets (173 mg/L)
A_{cs} = area of post-development commercial and industrial streets (square feet)
TSS_{cs} = TSS event mean concentration for commercial and industrial streets (468 mg/L)
A_{BMP} = area of BMP (square feet)
TSS_{BMP} = TSS event mean concentration BMPs (0 mg/L)
2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters
43,560 = conversion from square feet to acres
$TSS_{upstream}$ = TSS load directed to practice from upstream sources

9. **Column S** indicates the TSS load removed by the practice, based on both the volume retained (for which 100% TSS removal is valued) plus the TSS removal efficiency from column P applied to any remaining TSS. As with the retention volume value, the TSS removed by the

practice cannot be greater than the TSS received by the practice.

10. The Remaining TSS Load (**column T**) equals the TSS load received by the practice minus the TSS load removed.

11 Any potential retention volume or TSS load remaining (**column O and T**) can be directed to a downstream practice in **column U** by selecting from the pull-down menu. Selecting a BMP from the menu will automatically direct the treatable volume and TSS load remaining to **column J and Q**, respectively, for the appropriate BMP.

12. From the selected BMPs, the total volume retained will be summed in **cell N152**. The retention volume remaining will then be calculated as the difference between the SWRv and the total volume retained in **cell N154** (in cubic feet) and **cell N155** (in gallons). **Cell N157** indicates if at least 50% of the SWRv has been retained for the D.A.

13. **Cell S156** sums the total TSS removed for the D.A. In the MS4, if 50% of the SWRv has not been retained, **Cell S158** indicates if at least 60% of the TSS has been removed for the D.A. Either **Cell N156** or **Cell S158** must state "Yes" for the D.A. to comply with the stormwater management requirements.

<u>Compliance</u>

The Compliance sheet summarizes the stormwater retention and TSS removal results for each D.A. as well as the whole site. In order to comply with the stormwater management requirements, each D.A. must have a "Yes" for either SWRv Retention or TSS Removal.

Cell B76 indicates the Total Volume Retained on site. **Cell B77** (cubic feet) and **cell B78** (gallons) indicate the remaining retention volume (if any) to meet the SWRv. If the SWRv has not been fully met, **cell B80** indicates the retention volume credit (RVC) that must be obtained off-site. The RVC is calculated by multiplying the Retention Volume Remaining x 7.48 gallons per cubic foot x an offset multiplier of 1.5.

Alternatively, an annual fee in lieu can be selected. The annual fee in lieu is calculated in **cell B81** as the Retention Volume Remaining x 7.48 gallons per cubic foot x $3.50 per gallon x an offset multiplier of 2.

<u>Channel and Flood Protection</u>

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 2**.

Each cover type is associated with a Natural Resource Conservation Service (NRCS) curve number for in cells **D25-30.** Using these curve numbers (or other curve numbers if appropriate), a weighted curve number and the total runoff volume for D.A. A is calculated. **Line 33** calculates the runoff volume without regard to the BMPs employed in D.A. A. **Line 34** subtracts the storage volume provided by the BMPs in D.A. A from these totals. 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 35.**

These steps are repeated for Drainage Areas B – E.

<u>Weighted Curve Number</u>

$CN = [(A(NC) \times 70) + (A(CC) \times 74) + (A(I) \times 98)]/SA$

Where:
- CN = weighted curve number
- A(NC) = area of post-development natural cover (square feet)
- A(CC) = area of post-development compacted cover (square feet)
- A(I) = area of post-development impervious cover (square feet)
- SA = total site area (square feet)

<u>Potential Abstraction</u>

$S = 1000/(CN-10)$

Where:
- S = Potential Abstraction (inches)
- CN = weighted curve number

<u>Runoff Volume with no Runoff Reduction</u>

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

Where:
- Q = Runoff volume with no BMPs (inches)
- P = Precipitation depth for a given 24-hour storm (inches)
- S = Potential Abstraction (inches)

<u>Runoff Volume with BMPs</u>

$Q_{BMP} = Q - (Cv(da) \times 12 / SA$

Where:
- Q_{BMP} = Runoff volume with BMPs (inches)
- Q = Runoff volume with no BMPs (inches)
- Cv(da) = total storage volume provided by BMPs for the drainage area (cubic ft)
- 3630 = unit adjustment factor, cubic feet to acre-inches
- DA = site area (acres)

<u>Adjusted Curve Number:</u>

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

$CN_{adjusted}$, so $(P-0.2 \times S_{adjusted})^2 / (P + 0.8 \times S_{adjusted}) = Q_{BMP}$
$S_{adjusted} = 1000/(CN_{adjusted} - 10)$

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 (inches)
$S_{adjusted}$ = Adjusted potential abstraction based upon adjusted curve number (inches)
Q_{BMP} = Runoff volume with BMPs (inches)

A.3 Design Examples

Design Example 1

Step 1: Determine Design Criteria

Design Example 1 includes the following site characteristics:

<table>
<tr><td colspan="2">Site Name</td><td>Anacostia Offices</td></tr>
<tr><td colspan="2">Total Site Area</td><td>40,000 sf</td></tr>
<tr><td colspan="2">Natural Cover Area</td><td>8,000 sf</td></tr>
<tr><td rowspan="2">Compacted Cover</td><td>Lawn Area</td><td>2,000 sf</td></tr>
<tr><td>Landscaping Area</td><td>0 sf</td></tr>
<tr><td rowspan="5">Impervious Cover</td><td>Rooftop</td><td>20,000 sf</td></tr>
<tr><td>Res/Comm Parking Lot</td><td>8,000 sf</td></tr>
<tr><td>Industrial Parking Lot</td><td>0 sf</td></tr>
<tr><td>Driveway/Sidewalk/Street</td><td>2,000 sf</td></tr>
<tr><td>Commercial Street</td><td>0 sf</td></tr>
<tr><td colspan="2">Is site a Substantial Improvement?*</td><td>No</td></tr>
</table>

*"Substantial Improvement" is any repair, alteration, addition, or improvement of a building or structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the improvement or repair is started. (If a building is undergoing substantial improvement, without associated land disturbance, the SWRv is reduced to 0.8".)

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 Cells B16 – B29 on the Site Data sheet.

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

SWRv (cell C43) = 2,900 cf

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 practices.
- 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 practices 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. A. Therefore, all of the same values from the Site Data tab for the various cover types should be put into Cells B6-19 on the D.A. A tab.

The first practice selected is rainwater harvesting for runoff from the rooftop. The Cistern Design spreadsheet should be used to determine the cistern size and the associated retention value. In the Cistern Design Spreadsheet 20,000 square feet should be put in as the Contributing Drainage Area (CDA). For utilization of the rainwater, flushing toilets/urinals is selected as the use, and the appropriate values are input. In this case, 500 people will use the building per day (Cell B23), Monday through Friday (Cells B31 & 33), 8 hours per day (Cell B35). On the Results – Retention Value sheet, the retention values are given for various tank sizes. The tables and graphs show that 20,000 gallon underground tank (or series of tanks) would meet much of the demand, and have a very high retention value – 95%.

The next step is to return to the D.A. A tab and input the 20,000 square foot CDA into cell D22 for rainwater harvesting and input the efficiency – 95% into Cell I33. The result is that 2,557 cubic feet of runoff are retained, and 135 cubic feet remain. Since Standard Bioretention will be the next practice in series, it should be selected from the pull-down menu in Cell U33. The remaining runoff volume and TSS loads will then be directed to this practice.

In addition to the overflow from the rainwater harvesting practice, the bioretention area will receive runoff from the rest of the site. Initially, these land uses can be input into Cells B75 – D80. However, the size of 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 the top of D.A. A. Compacted cover will now be 1,000 square feet, and "BMP" will be 1,000 square feet. The 8,000 square feet of parking lot and 2,000 square feet of sidewalk/driveway will not change.

The total volume directed to the bioretention area will therefore be 1,650 cubic feet. Inputting 800 cubic feet for the storage volume in the spreadsheet leads to an exceedence of 67 cubic feet for the SWRv (Cell N154). This information is also summarized on the Compliance sheet.

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

The size of the rainwater harvesting cistern was already determined to be 20,000 gallons.

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

Step 5.1: Determine storage volume:

Equation 3.5.1

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

Where:

$Sv_{practice}$	=	total storage volume of practice (cu. ft.)
SA_{bottom}	=	bottom surface area of practice (sq. ft.)
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 practice (sq. ft.) typically = ½ x (top area plus the bottom (SA_{bottom}) area)
$d_{ponding}$	=	the maximum ponding depth of the practice (ft).

Solving Equation 5.1 often requires an iterative approach to determine the most appropriate bottom surface area and average surface area to achieve the desired $Sv_{practice}$. In this case, a practice with a 40’ by 25’ 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 an $Sv_{practice}$ of 1,003 cubic feet.

Step 5.2: Check the ponding volume.

The ponding volume must be at least 75% of the design volume in order to receive full retention value for the storage volume of the practice. The ponding volume in this case, ($SA_{average}$ x $d_{ponding}$) equals 454 cubic feet in this case, which is only 45% of the design volume for the practice. Based on this percentage, Equation 3.5.2 would apply for calculation of the storage volume.

Equation 3.5.2

$$\text{If } V_{ponding} < 0.75 \; Design\ Volume, \; Sv = (V_{ponding}) / 0.75$$

Where:

$Sv_{practice}$ = total storage volume of practice (cu. ft.)
Sv = storage volume credited toward compliance (cu. ft.)

Equation 3.5.2 indicates that the retention value for the practice will be 605 cubic feet, which is not enough to meet the retention goal for this practice. Therefore, it will be necessary to make the ponding volume larger, either by expanding the surface area or increasing the depth of the ponding.

Increasing the ponding depth to 0.75 feet while retaining the same SA_{top} will increase the $Sv_{practice}$ to 1,139 cubic feet, and, using Equation 3.5.2, Sv is 864 cubic feet – more than enough to meet the retention requirements.

Note: Since the 1,139 cubic foot design volume is not fully credited due to the low percentage of ponding volume, it may be possible to reduce the footprint of the filter media and gravel layer to reduce costs. However, the top surface area of the ponding volume cannot be more than twice the surface area of filter media. In other words, the filter media surface area must be at least half the size of the top surface area of the practice.

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 20,000 gallons and the bioretention cell will require at least 1,000 square feet of surface area. The designer would need to ensure that space is available for these practices on the site.
- Contributing drainage area for traditional bioretention must be 2.5 acres or less, and this site is less than 1 acre.
- Required head for the above design will be 3.5 feet, including ponding depth (9”), mulch (3”), filter media (18”), choking layer (about 3”) , and gravel layer (about 9”). (See Figure 3.5.2). The outlet for the underdrain must be at least this deep.
- 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 1.5-2’ depth to seasonally high GW table, Croom soils have greater than a 5’ depth, and Sassafras have a 4’ 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.

Since all of these assumptions and requirements can be met (pending groundwater table 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 C soils in cells D12, D14, and D16 (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 78, 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 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 impervious cover and the proposed runoff curve number is less than the pre-project conditions, so detention for the 15-year storm is not required. Detention for the 2-year storm will be required.

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 peak inflow, qi_2 and the peak outflow, qo_2 can be calculated. The reduced curve of 78, determined above, generates a qi_2 of 1.61 cubic feet per second (cfs). The curve number for meadow in good condition, 71, generates a qo_2 of 1.07 cfs.

The ratio of 1.07 cfs to 1.61 cfs equals 0.67. Using Figure H.1, this equates to a ratio of storage volume (Vs_2) to runoff volume (Vr_2) of 0.22.

The runoff volume (Vr_2) determined in the Compliance Calculator spreadsheet is 1.31 inches, which equates to 4,367 cubic feet. Using the calculated ratio of Vs_2/Vr_2, the storage volume required for the site, Vs_2 = 961 cubic feet.

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 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 sf
Natural Cover Area	0 sf
Compacted Cover	0 sf
Impervious Cover (Rooftop)	15,000 sf
Is site a Substantial Improvement?*	Yes

*"Substantial Improvement" is any repair, alteration, addition, or improvement of a building or structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the improvement or repair is started. (If a building is undergoing substantial improvement, without associated land disturbance, the SWRv is reduced to 0.8".)

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 Cells B16 – B29 on the Site Data sheet.

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

SWRv (cell C43) = 950 cf

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.

The design for this site will incorporate an extensive green roof that will capture the entire retention volume within the green roof soil medium.

As an initial estimate 75% of the rooftop is proposed to be converted to a green roof, with the remaining 25% draining to it. Therefore, the land use values need to be changed to account for the green roof: 11,250 square feet should be entered as rooftop in Cell B24 on the Site Data sheet, and 3,750 square feet should be entered in Cell B29 as “BMP.” As there will be only one drainage area for the site, these same values should be entered into Cells B14 and B19 on sheet D.A. A., and as the Green Roof drainage area (Cells D27 and D32.

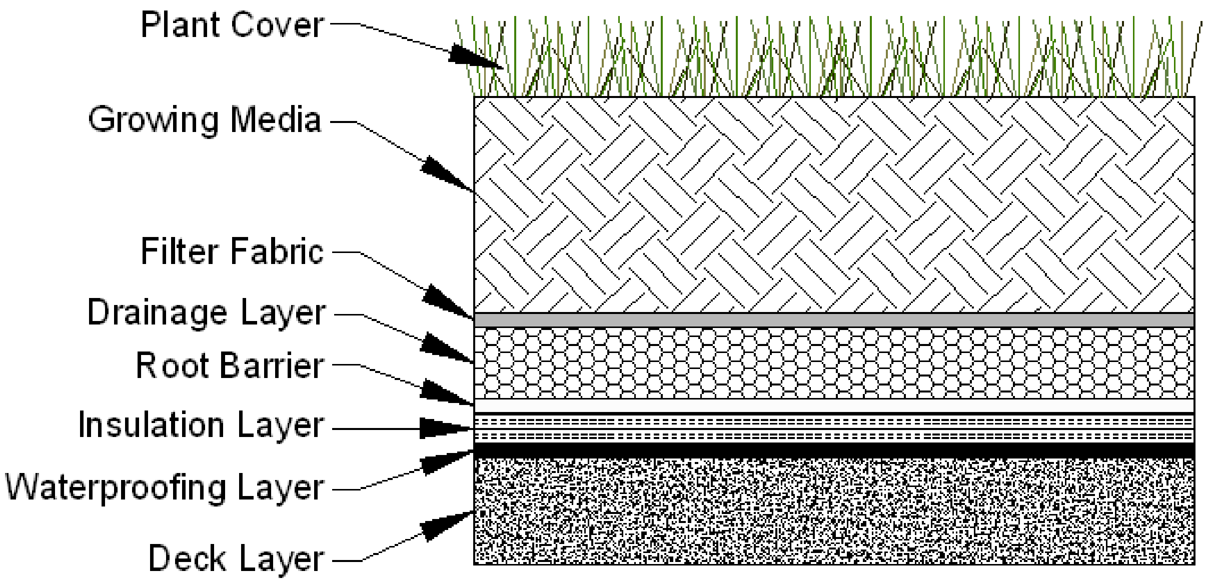
The goal of this design is to capture the entire retention volume (950 cf) in the Green Roof. This can be shown on the spreadsheet by entering 950 cubic feet in Cell M27 on sheet D.A. A. Cell N154 shows that the SWRv has been met for the site. This information is also summarized on the Compliance sheet.

Step 5: Size the Practices According to the Design Equations.
The green roof needs to be sized according to Equation 3.11 in the Design Guidebook. Note that, since green roofs are typically manufactured systems, several of the parameters, such as the drainage layer depth and porosity 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 3.11 (with each layer illustrated in Figure 3.1.1).

Equation 3.1.1. Storage Volume for Green Roofs

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

Where,
- Sv = storage volume (cu. ft.). (Goal is 950 cf)
- SA = green roof area (sq. ft.) (need to determine)
- d = media depth (in.) (6”)
- η_1 =media porosity (0.25)
- DL = drainage layer depth (in.) (1”)
- η_2 =drainage layer porosity (0.4)



Rearranging Equation 3.1.1 to find the minimum required surface area:

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

Or:

$$SA = 950/(6^*.25+1^*.4)^*12$$

$$= 6{,}000 \text{ sf}$$

Therefore, the green roof must be sized to be at least 6,000 sf, given the proposed depths. The original assumption was that a 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 that the drainage area to the green roof can only be 25% 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

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 sf 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.

<u>Step 7: Use the Adjusted Curve Number to Address Peak Flow Requirements</u>

The initial curve number for this site is 98, but with the retention provided by the green roof, the values, as calculated on 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 can be used to help determine detention requirements for this site.

<u>Step 8: Determine Detention Requirements</u>

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, since the proposed land cover is the same as the pre-project conditions, detention for the 15-year storm is not required. Detention for the 2-year storm will be required, however.

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 peak inflow, qi_2 and the peak outflow, qo_2 can be calculated. 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 qo_2 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 = 912 cubic feet.

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

Design Example 3 includes the following proposed design criteria:

Site Name		Ward 5 Low-Rise Commercial
Total Site Area		25,000 sf
Natural Cover Area		0 sf
Compacted Cover	Lawn Area	5,000 sf
	Landscaping Area	0 sf
Impervious Cover	Rooftop	10,000 sf
	Res/Comm Parking Lot	10,000 sf
	Industrial Parking Lot	0 sf
	Driveway/Sidewalk/Street	0 sf
	Commercial Street	0 sf
Is site a Substantial Improvement?*		No

*"Substantial Improvement" is any repair, alteration, addition, or improvement of a building or structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the improvement or repair is started. (If a building is undergoing substantial improvement, without associated land disturbance, the SWRv is reduced to 0.8".)

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 Cells B16 – B29 on the Site Data sheet.

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

SWRv (Cell C43) = 2,025 cf

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 practice options.
- The relatively permeable Sunnyside-Sassafras-Muirkirk-Christiana soils on this site allow for infiltration into site soils.

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. A. Therefore, all of the same values from the Site Data tab for the various cover types should be put into Cells B6-19 on the D.A. A sheet.

It is assumed that the entire site will be directed to the bioretention area, so the same values from the top of the D.A.A sheet may be input into Cells B69 – D74. However, the 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. A. 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 will lead to a total volume directed to the practice of 2,968 cubic feet.

Since enhanced bioretention is credited with 100% retention, 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 cubic feet. This value can be input into Cell M69. Cell N154 indicates that there is still 1,018 cubic feet, or 7,615 gallons (Cell N155) 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 Practices According to the Design Equations.
Assume a filter media depth of 2’, a gravel depth of 0.75’, and a ponding depth of 1’.

Step 5.1: Determine storage volume:

Equation 3.5.1

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

Where:

$Sv_{practice}$ = total storage volume of practice (cu. ft.)
SA_{bottom} = bottom surface area of practice (sq. ft.)
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 practice (sq. ft.) typically = ½ x (top area plus the bottom (SA_{bottom}) area)
$d_{ponding}$ = the maximum ponding depth of the practice (ft).

Solving Equation 5.1 often requires an iterative approach to determine the most appropriate bottom surface area and average surface area to achieve the desired $Sv_{practice}$. In this case, a long narrow practice with a 50' by 20' 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, SA_{bottom} of 616 square feet, a $SA_{average}$ of 808 square feet, and achieve an $Sv_{practice}$ of 1,301 cubic feet.

Step 5.2: Determine ponding volume:

The ponding volume must be at least 75% of the design volume in order to receive full retention value for the storage volume of the practice. The ponding volume ($SA_{average}$ x $d_{ponding}$) equals 808cubic feet in this case, which is 62% of the 1,301 cubic feet design volume. Therefore, Equation 3.5.2 applies:

Equation 3.5.2

$$\text{If } V_{ponding} < 0.75 \text{ } Design\ Volume,\ Sv = (V_{ponding}) / 0.75$$

Where:

$Sv_{practice}$ = total storage volume of practice (cu. ft.)
Sv = storage volume credited toward compliance (cu. ft.)

Equation 3.5.2 indicates that the retention value for the practice will be 1,077 cubic feet.

Note: Since the 1,301 cubic foot design volume is not fully credited due to the low percentage of ponding volume, it may be possible to reduce the footprint of the filter media and gravel layer to reduce costs. However, the top surface area of the ponding volume cannot be more than twice the surface area of filter media. In other words, the filter media surface area must be at least half the size of the top surface area of the practice.

Step 6: Check Design Assumptions and Requirements

Key assumptions and requirements for this site include:

- The design will need at least 1,000 sf 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.
- 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 practice, or 4.25' below the surface.
- The measured permeability of the underlying soils must be at least 0.5"/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.

<u>Step 7: Use the Adjusted Curve Number to Address Peak Flow Requirements</u>

On the Channel and Flood Protection tab, enter values for B soils in cells D26, D28, and D30 (55 for natural areas, 61 for turf and 98 for impervious cover, respectively). The original site curve number of 92 is reduced to for the 2-year, 15-year, and 100-year storms to 86, 87, and 88, respectively by the retention provided by the bioretention cell. These can be used to help determine detention requirements for this site.

<u>Step 8: Determine Detention Requirements</u>

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 impervious cover and the proposed runoff curve number is less than the pre-project conditions, so detention for the 15-year storm is not required. Detention for the 2-year storm will be required.

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 peak inflow, qi_2 and the peak outflow, qo_2 can be calculated. The reduced curve of 86, determined above, generates a qi_2 of 1.45 cubic feet per second (cfs). The curve number for meadow in good condition, 58, generates a qo_2 of 0.18 cfs.

The ratio of 0.18 cfs to 1.45 cfs equals 0.12. Using Figure H.1, this equates to a ratio of storage volume (Vs_2) to runoff volume (Vr_2) of 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 = 2,032 cubic feet.

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 sf
Natural Cover Area		0 sf
Compacted Cover	Lawn Area	185 sf
	Landscaping Area	0 sf
Impervious Cover	Rooftop	0 sf
	Res/Comm Parking Lot	0 sf
	Industrial Parking Lot	0 sf
	Driveway/Sidewalk/Street	13,343 sf
	Commercial Street	0 sf

The site in this design example is a street re-construction 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 4 stormwater inlets (one at each corner), so it will be divided into 4 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		SWRv	
	within LOD	outside LOD	within LOD	outside LOD
	ft^2	ft^2	gallons	gallons
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

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

Step 2: Consider Infiltration.

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

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

Step 3: Demonstrate full consideration of land cover conversions and optimum BMP placement.

Traffic islands, triangle parks, median islands, cul-de-sacs, and paper streets within and adjacent to the PROW, as well as traffic calming measures, like median islands, pedestrian curb extensions, bump outs and chicanes, and turning radius reductions, all represent opportunities for BMP placement.

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 3 of the 4 corners of the intersection.

Step 4: Demonstrate full consideration of opportunities with 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	SWRv	Available Area for BMP
	within LOD	within LOD	
	ft^2	gallons	ft^2
DA1	3,473	2,371	72
DA2	2,937	2,087	285
DA3	5,285	3,756	190
DA4	1,833	1,303	0
DATOTAL	13,528	9,517	N/A

Step 6: Sizing BMPs

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

The storage volume is determined with Equation 3.5.1

Equation 3.5.1

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

Where:

$Sv_{practice}$ = total storage volume of practice (cu. ft.)
SA_{bottom} = bottom surface area of practice (sq. ft.)
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 practice (sq. ft.) typically = ½ x (top area plus the bottom (SA_{bottom}) area)
$d_{ponding}$ = the maximum ponding depth of the practice (ft).

With the cross section dimensions provided above, equation 3.5.1 yields the following results:

Drainage Area (DA $_{1-N}$)	Available Area for BMP	$Sv_{practice}$
	ft^2	gallons
DA1	72	942
DA2	285	3,731
DA3	190	2,487
DA4	0	0

The ponding volume must be at least 75% of the total storage volume in order to receive full retention value for the storage volume of the practice. In each of these cases, the ponding volume ($SA_{average}$ x $d_{ponding}$) equals only 43% of the storage volume. Therefore, Equation 3.5.2 applies:

Equation 3.5.2

$$\text{If } V_{ponding} < 0.75\ Design\ Volume,\ Sv = (V_{ponding}) / 0.75$$

Where:

$Sv_{practice}$ = total storage volume of practice (cu. ft.)

Sv = storage volume credited toward compliance (cu. ft.)

Equation 3.5.2 indicates that the retention value for each practice will be:

Drainage Area (DA $_{1-N}$)	Available Area for BMP	Sv
	ft^2	gallons
DA1	72	539
DA2	285	2,132
DA3	190	1,421

DA4	0	0

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

Drainage Area	**Regulated** SWRv	SWRv		Altered Drainage Profile	
(DA $_{1-N}$)	within LOD	Achieved	Retention Deficiency		
	gallons	gallons	gallons	**Y**	**N**
DA1	2,371	539	1,832		X
DA2	2,087	2,132	N/A		X
DA3	3,756	1,421	2,335		X
DA4	1,303	-	1,303		X
DATOTAL	9,517	4,092			

The MEP design process notes that if there is a retention volume deficiency, 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 are at or near capacity, so treating comingled volume (from outside the LOD) will not increase the SWRv achieved. At this point, the designer should review steps 1 through 6 to ensure that all opportunites for land conversion and BMP facilities have been maximized. If so, this step is complete.

STEP 7: Drainage Areas where zero retention practices are installed

Drainage areas that do not have a retention BMP included in them will require installation of a water quality catch basin to treat stormwater runoff.

This requirement applies only to DA4 in this example.