A Guide to Credits for Commonly Used Storm Water Management Practices

This guide discusses the most commonly used storm water management practices and the credits they can earn. The primary application of this guide is to non-residential sites, although some of the basic concepts included in this guide also apply to residential credits. The guide includes discussions of disconnected imperviousness, bioretention, permeable pavement, detention systems and green roofs.

Contents

Introduction

This guide discusses the most commonly used storm water practices and the credits that customers can earn for implementing them. The primary application of the practices outlined in this guide is to non-residential sites, although some of the basic concepts included in this guide also apply to residential sites. This guide also identifies critical design features of the storm water practices that are necessary in order for customers to earn the credits described. These critical features directly relate to the hydrologic performance of the practice that determines the credit.

“Minimum design standards” as used in this guide are intended ONLY to address those design elements that are directly related to the credit. These should not be interpreted as instructions for engineering design nor be interpreted as minimum standards to satisfy permitting requirements.

The *Southeast Michigan Council of Governments (SEMCOG) Low Impact Development Manual (LID) for Michigan: A Design Guide for Implementers and Reviewers (2008)* provides guidance on how to apply storm water practices to new, existing, and redevelopment sites and contains technical guidance and variations for the storm water practices eligible for credits. The LID Manual can be used to assist customers in designing their storm water practice and should not be construed as requirements. An electronic copy of the Michigan LID Manual can be found on the SEMCOG website: www.semcog.org.

The Detroit Water and Sewerage Department (DWSD) has developed simplified methodologies for quantifying credits that are intended to assist in the evaluation and implementation of storm water management systems. These methods simplify calculations for the designer. They also streamline review of the projects and associated calculations by DWSD.

More sophisticated hydrologic evaluation may be needed or desired for complex sites. DWSD accepts a wide variety of hydrologic/hydraulic design models and tools common in the engineering industry. Sites with complex configurations and storm water practices in series may need to use these more complex tools.

Important notes:

Permits: Projects described in this guide may require permits for construction. For example, a plumbing permit is required for site piping that later connects to the City sewer. A DWSD permit is required for connections to the DWSD sewer. Modifications to site parking require a zoning review to confirm that they meet parking standards. The property owner will need to ensure that all required permits are applied for and received prior to construction. Design drawings submitted for review will require a design professional's seal as confirmation that they were appropriately prepared.

Application of the Credit: Credits are only applied to the 'Managed' area of a site. The drainage charge credits are based on the site's ability to manage the average annual runoff volume and the peak flows from large rain events.

General Quantitative Principles

There are a series of general principles that are used in this guide that apply to the credit calculations. Those common items are described below.

Usable Void Ratio in Soil and Aggregate Layers

The void ratio that is available in soil and aggregate layers is a determinant of the performance of the storm water practice. Many storm water practices rely on the temporary storage of storm water in these layers. The usable void ratio is dependent on the specific media.

In soil, the usable void ratio is the porosity less the field capacity. This is the difference between the total void space and the water that is held in the soil particles due to capillary action. In aggregate, the void ratio is the same as the porosity.

The property owner and their designer will need to identify the material used for soil and aggregate and their actual void ratio in order to quantify performance.

Equivalent Water Depth

Many storm water practices rely on the temporary storage of storm water in designed surface and subsurface storage. This storage occurs on the surface of a practice (such as temporarily ponded water on a bioretention system), and below the surface in layers of soil and aggregate. The performance of the storm water practice is directly related to this storage volume. The Equivalent Water Depth defines the depth of water that can be stored in the mix of surface and subsurface storage.

The Equivalent Water Depth is defined as:

$$\begin{aligned}&\text{Equivalent Water Depth (in)}\\&= \text{surface storage (in)} + \text{soil depth(in)} * \text{usable void ratio} + \text{aggregate depth (in)} * \text{usable void ratio}\end{aligned}$$

Figure 1 illustrates two storm water practice cross sections. The aggregate has a usable void ration of 0.30, the soil has a usable void ratio of 0.20, and surface storage is fully used. Therefore, the Equivalent Water Depth = surface storage depth + soil depth*0.20 + aggregate depth * 0.30.

Equivalent Water Depth (in) Cross Section A
*=3+16*0.20+20*0.30=12.2 inches*

Equivalent Water Depth (in) Cross Section B
*=6+24*0.20+4.7*0.30=12.2 inches*

In general, all surface water must be able to drain below ground within 24 hours and subsurface storage in a storm water practice must be able to infiltrate in a 72-hour period. The maximum equivalent water depth in the retention zone of a practice is therefore dependent on the infiltration rate.

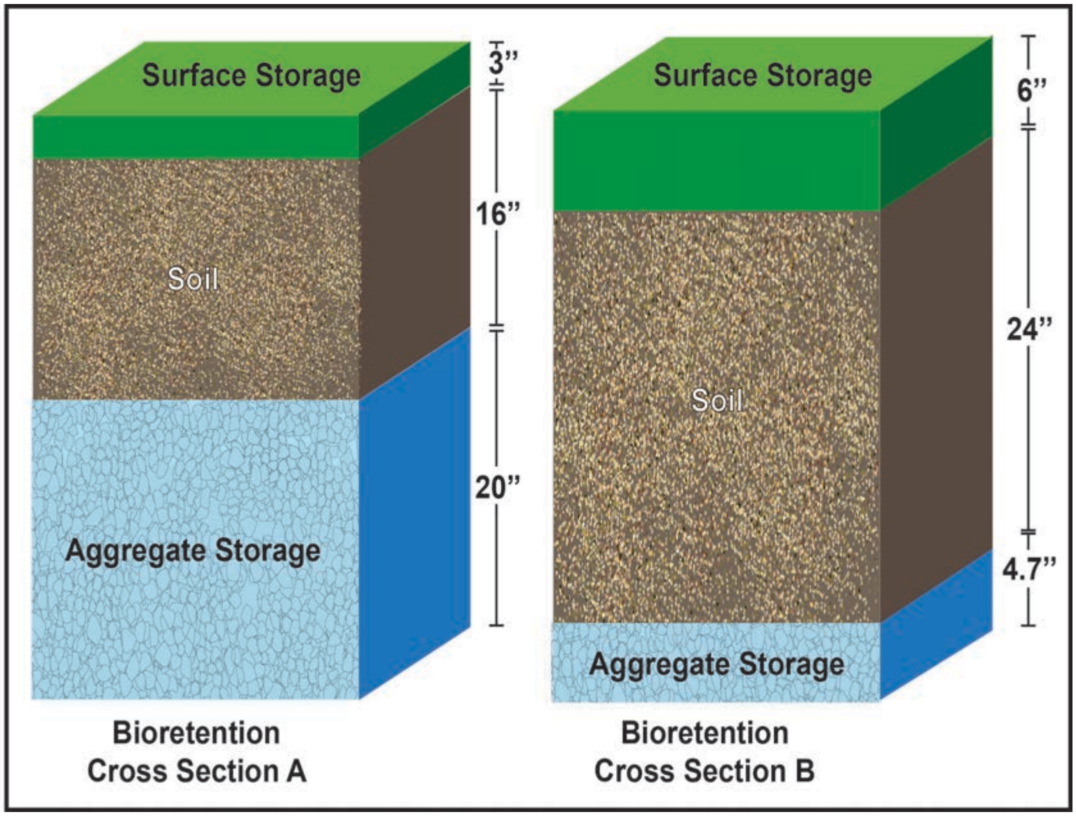

Figure 1: Equivalent Water Depth in Storm Water Practice Cross Section

TABLE 1 - Maximum Equivalent Water Depths in Retention Zone of a Storm Water Practice

Infiltration Rate	Equivalent Water Depth
0.1 inches/hour	7.2 inches
0.2 inches/hour	14.4 inches
0.3 inches/hour	21.6 inches
0.4 inches/hour	28.8 inches

Retention and Detention Concepts

Storm water practices may provide retention, detention or both functions. Some practice types are better at controlling volume, while others may be better suited to peak flow rate control. For example, bioretention is generally sized for small storm events, and has a primary function of promoting infiltration. Therefore, bioretention systems typically are better suited to reducing the volume of runoff. In contrast, detention ponds generally don't have a mechanism to reduce volume and would earn only a peak flow credit.

Storm water practices can be intentionally designed to provide both volume and peak flow management and include both a retention and detention capability. In storm water management, the following terms are used:

Retention: The ability to permanently remove storm water volume. This function results in volume credits.

Detention: The ability to temporarily store storm water volume. This function results in peak flow credits.

Figure 2 shows how the water storage area in a bioretention practice can include both a retention and detention zone. The volume provided in the retention zone determines the volume credit. The volume provided in the detention zone determines the peak flow credit, provided that the flow rate through the outlet is controlled. In both instances, the volume provided is the equivalent water depth times the area of the storm water practice.

There are many ways that dual retention and detention can be accomplished. This may require a larger practice or more complex design. Dual purpose volume and peak flow control can also be accomplished by installing practices in series, such as a bioretention followed by a detention practice.

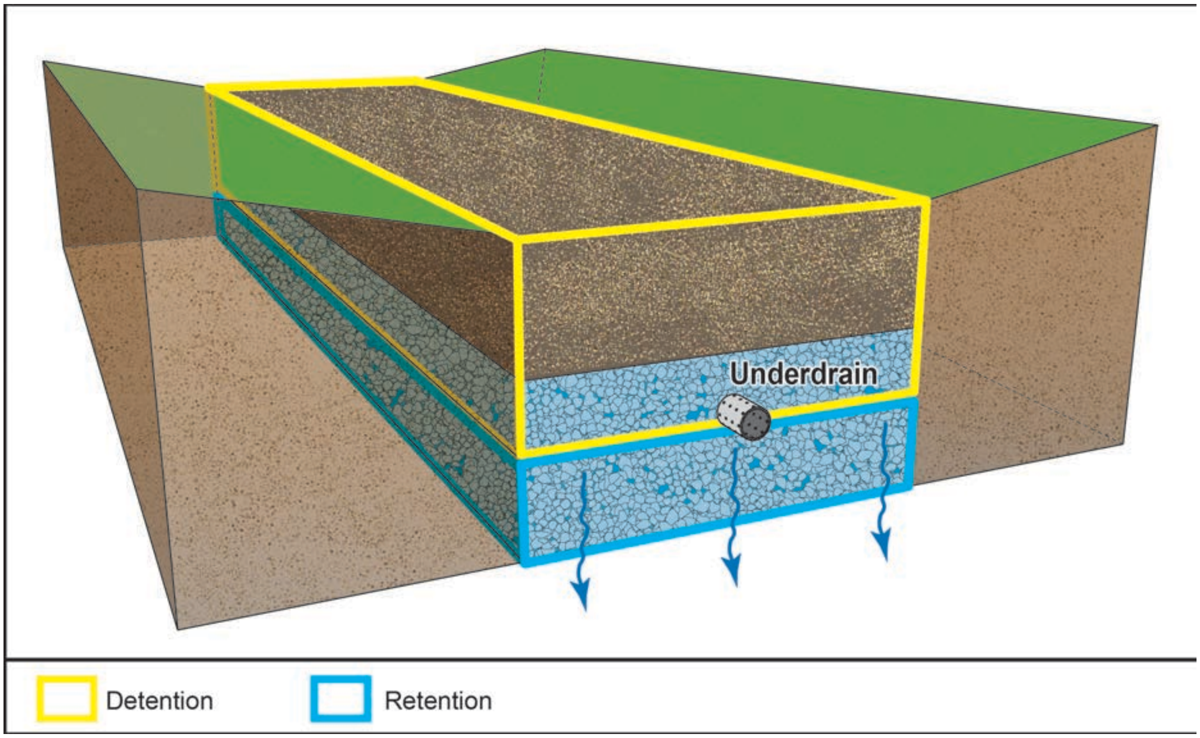

Figure 2: Retention Versus Detention Components of Bioretention Practices

Retention and Detention Determined by Underdrain Outlet Elevation

Most storm water practices include an underdrain to ensure satisfactory performance. The outlet elevation of the underdrain determines the portion of the practice that is in the retention and detention zones. The retention zone is below the underdrain outlet elevation, and the detention zone is above it.

Examples of underdrain outlet designs are shown in Figures 3 and 4.

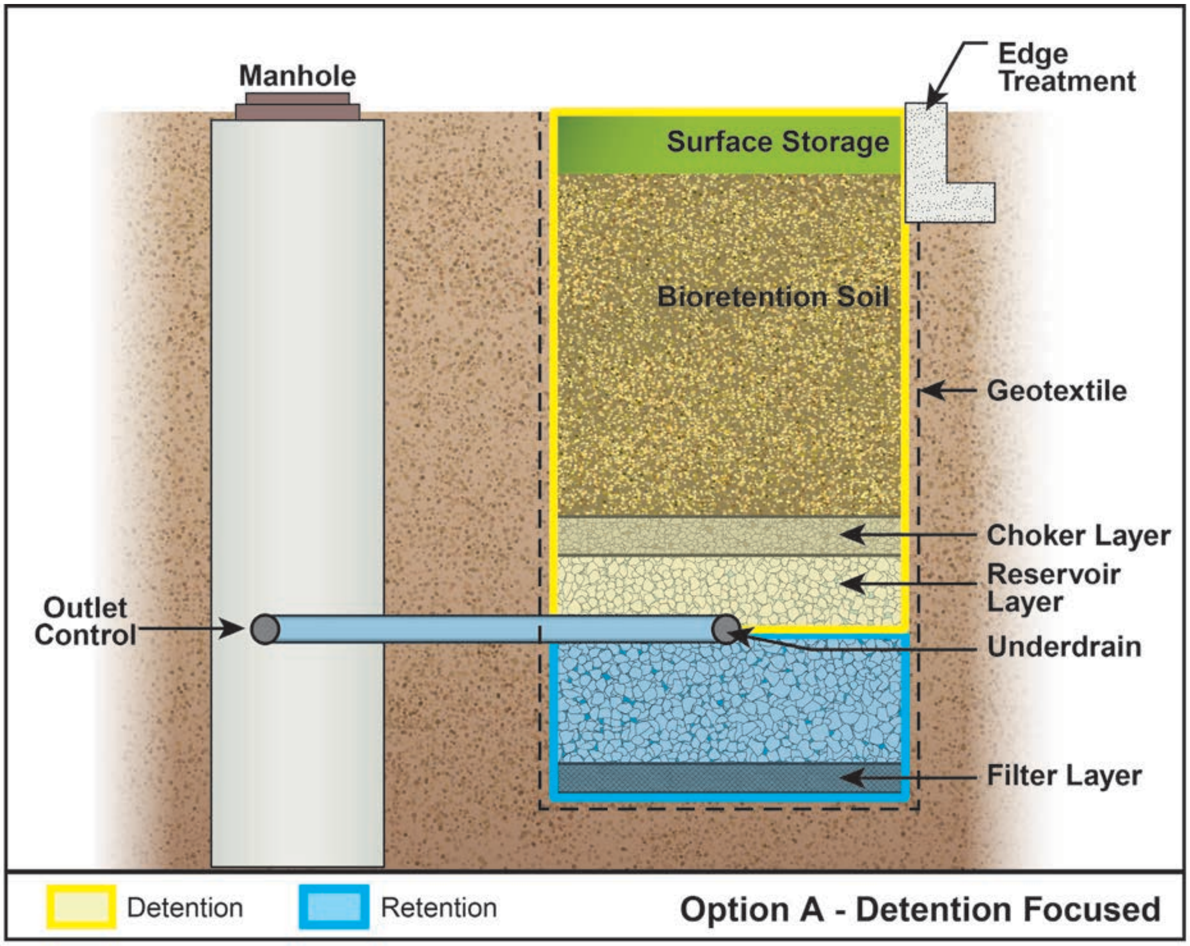

Figure 3: Standard Outlet Underdrain: Majority of Equivalent Water Depth Used for Detention

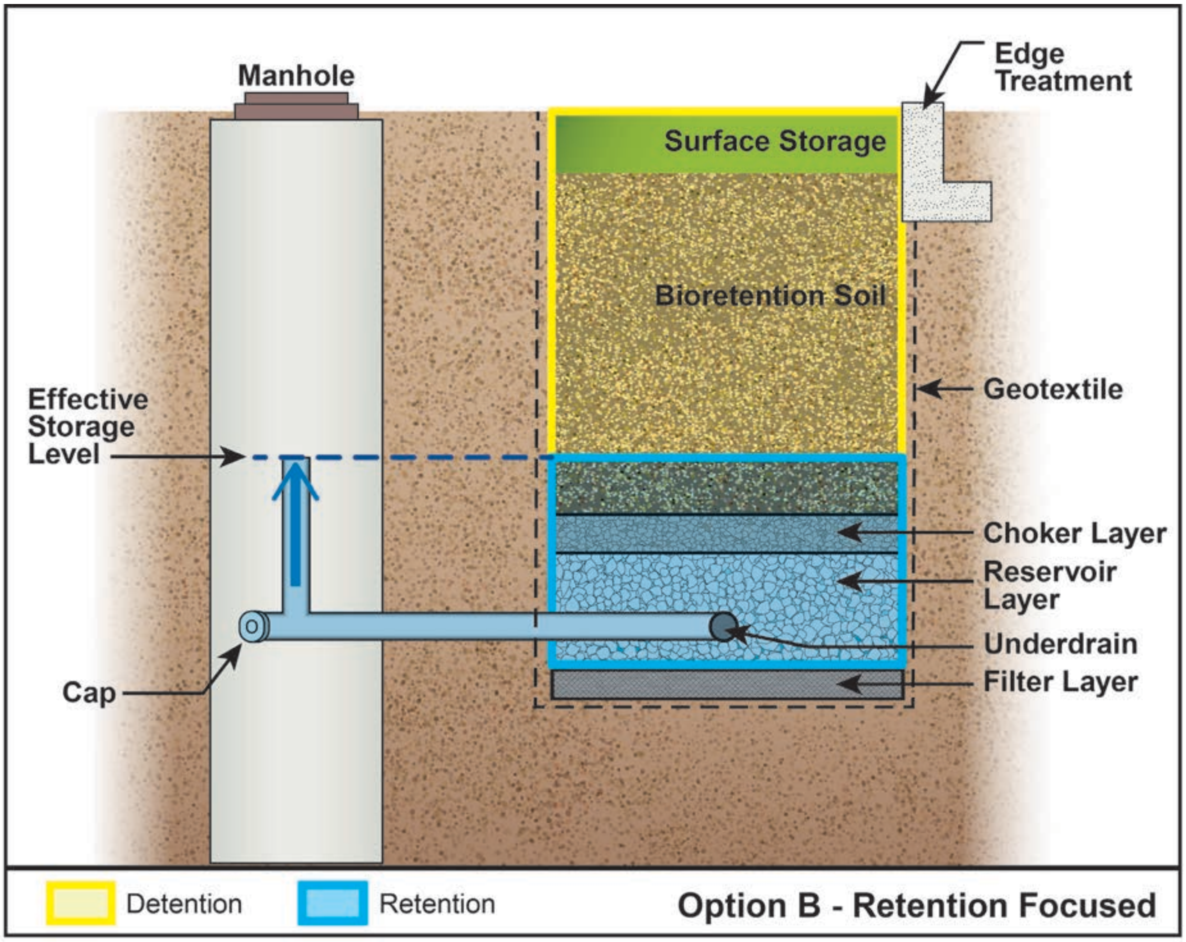

Figure 4: Upturned Elbow Outlet Underdrains: More Equivalent Water Depth Used for Retention

Determining Outlet Capacity

Outlet capacity for detention practices is a critical data element for determining the credit value. Outlet capacity is based on the hydraulic capacity of the outlet when the storage elevation is full, but below any emergency overflow elevation.

Outlet capacity will most typically be determined using an orifice equation.

Groundwater and Infiltration Rates

The simplified calculation methodologies for bioretention and permeable pavement are based on certain assumptions for conditions related to groundwater and infiltration. If these conditions are not present, a more extensive engineering analysis is required.

The lowest elevation of an infiltrating storm water practice must be two feet above the seasonal groundwater table.

Infiltration rates used in calculating credits should be based on measured values wherever geotechnical testing can be performed. Multiple measurements of infiltration rate at the location of the proposed storm water practice(s) are needed to define infiltration rate. The infiltration rate should be tested at a depth consistent with the anticipated depth of excavation for the storm water practice. Geotechnical investigations should also determine the depth to groundwater and the depth to the impervious clay soils that are common in Detroit. The infiltration value used in calculations should have a safety factor of two applied to the measured values. Refer to the appendix in the *Michigan LID Manual* for acceptable procedures and methodologies for measuring infiltration rates.

For instances where the infiltration rates are not measured at the practice location, a maximum value of 0.1 inch/hour infiltration rate is permitted.

Storm Water Practice Ratio

Preliminary sizing of storm water practices can be performed using a simplified credit calculation. This approach is suggested when performing a site assessment or evaluating general options for storm water management relative to available space on a site. These simple calculation methods can also be used for final design performance assessment, although oftentimes the specific conditions on a site will preclude the use of the "idealized" storm water practice cross section.

The practice ratio method uses the concept of a storm water practice area. The "practice ratio" can be used to calculate drainage charge credits based on a comparison of the storm water practice area to the drainage area. The definition of the storm water practice area is specific to each practice type (see Table 2). The drainage area is the area draining to the storm water practice. The general formula for the storm water practice ratio is:

Equation 1

$$Practice\ Ratio = \frac{Storm\ Water\ Practice\ Area}{Drainage\ Area}$$

CONSIDER THIS: One way to think about the storm water practice ratio is as a percentage. Consider a bioretention example. If the storm water practice ratio is 0.10 that's equivalent to the bioretention area sized at 10% of the size of the impervious drainage area.

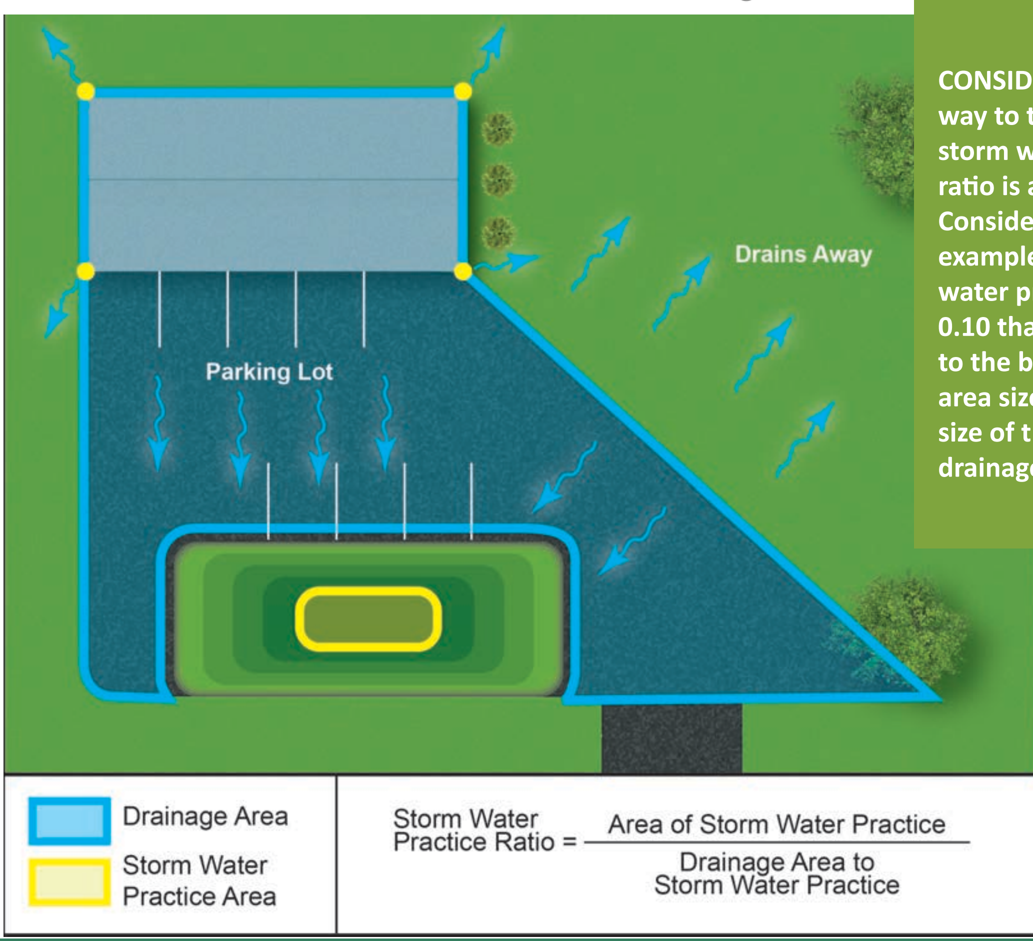

Figure 5: Storm Water Practice Ratio

Storm Water Practice Area

The storm water practice area determines the ability of the practice to infiltrate into the underlying soil. It is the effective area from which infiltration can occur. The practice area needs to be identified properly in order to use the tables, equations and charts that are associated with the practice area calculation methods.

TABLE 2 - Storm Water Practice Area Definitions

Practice Type	Storm Water Practice Area
Downspout Disconnection	Length from the end of the downspout to the edge of the property measured along the path that water will flow multiplied by an assumed width equal to 5 feet.
Other disconnected impervious surfaces	The surface area over which infiltration will naturally occur. This is based on the width of the sheet flow when it leaves the impervious surface multiplied by the length of the flow path in the pervious area.
Bioretention	Surface area of the bioretention not including the side slopes.
Permeable pavement	The surface area of the aggregate reservoir layer if the equivalent water depth for retention is provided in the aggregate reservoir.

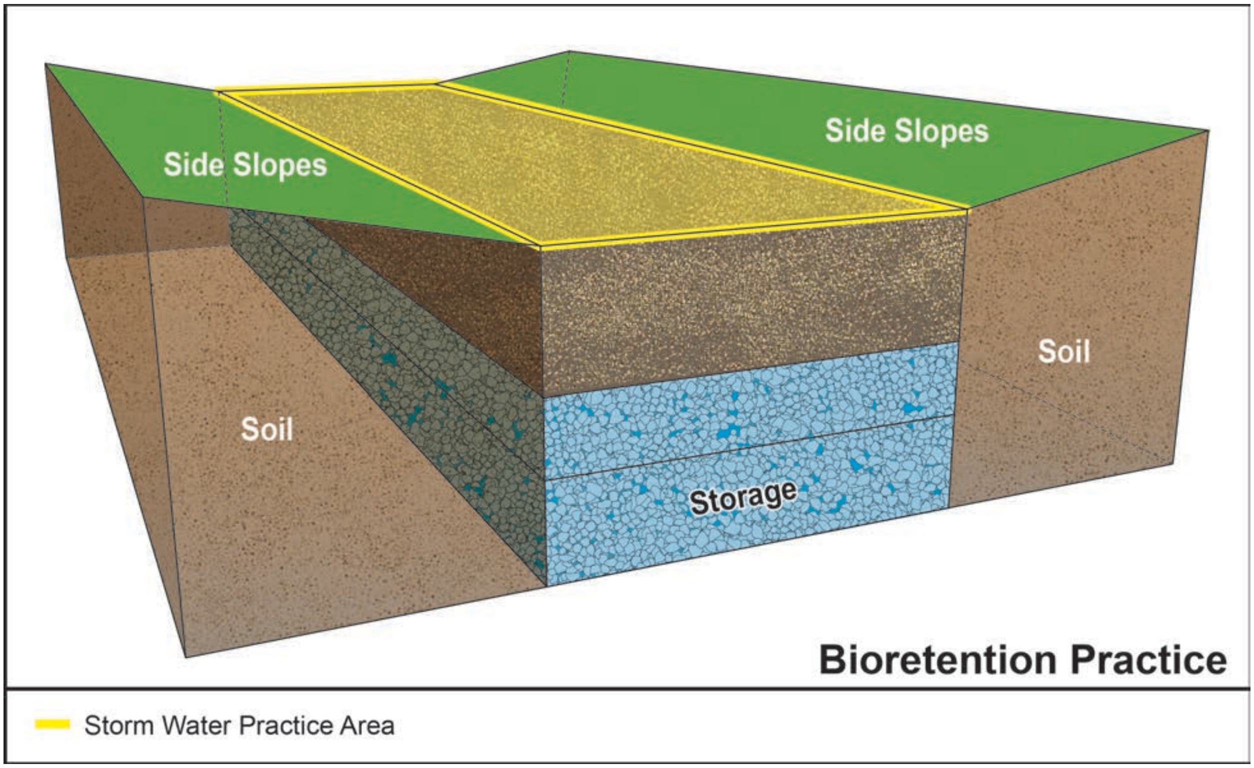

Figure 6: Bioretention Systems Practice Area

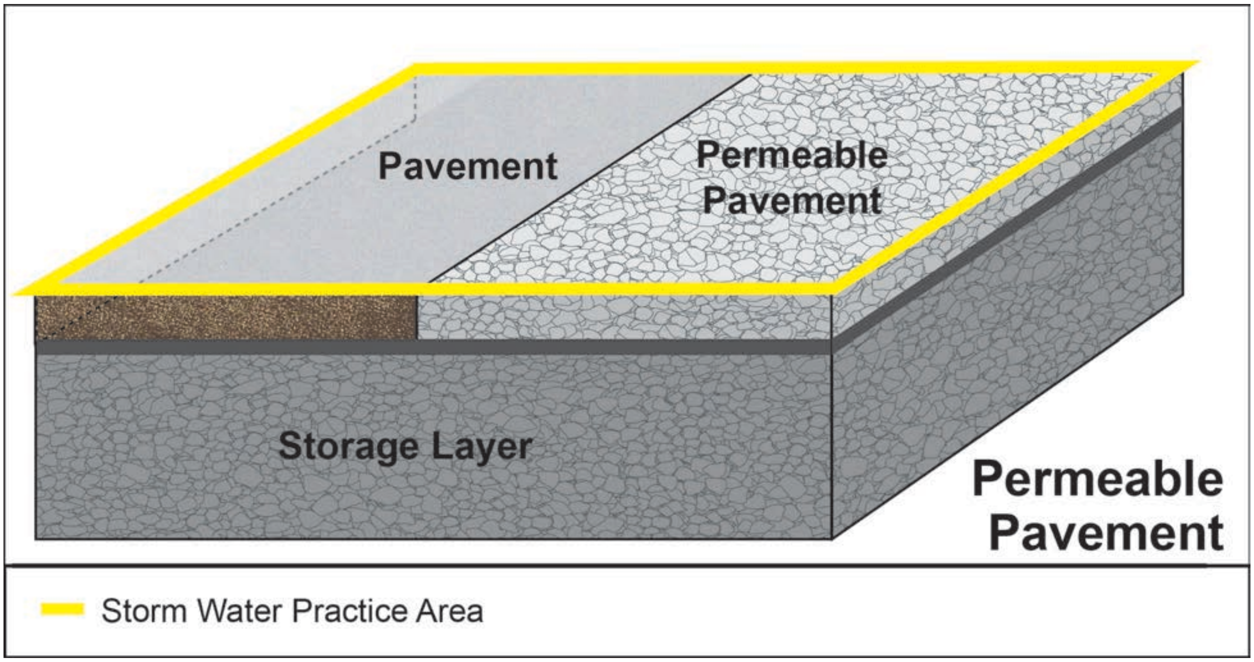

Figure 7: Permeable Pavement Practice Area

Drainage Area to the Storm Water Practice

The *Drainage Area*, in Equation 1 is the area that is tributary to the storm water practice. For example:

- For a roof drain disconnection, it is the portion of the roof draining to the downspout that is being disconnected.
- For a bioretention practice located next to a parking lot, the drainage area is that portion of the parking lot sloped to the bioretention.
- The drainage area may include area draining to the practice through a storm sewer.

Impervious and Pervious Drainage Areas

DWSD will accept calculations that ignore the pervious tributary area if the drainage area is predominately impervious. DWSD considers this to be >75% of the drainage area. When calculations ignore the pervious area, 100% of rainfall is assumed to generate runoff from impervious area.

In cases where the drainage area tributary to the practice is <75% impervious, the amount of pervious surface impacts the design. In this case, engineering calculation methods described later in this guide should be used.

An example of drainage area calculation is shown in Figure 8. For this site, a portion of the parking lot is tributary to a bioretention at the edge of the lot. The drainage area used in calculations is the impervious portion of the lot (e.g., pavement). The grassed parking lot islands would be ignored in the drainage area calculation. The storm water practice area for bioretention is the surface area of the bioretention not including the side slopes.

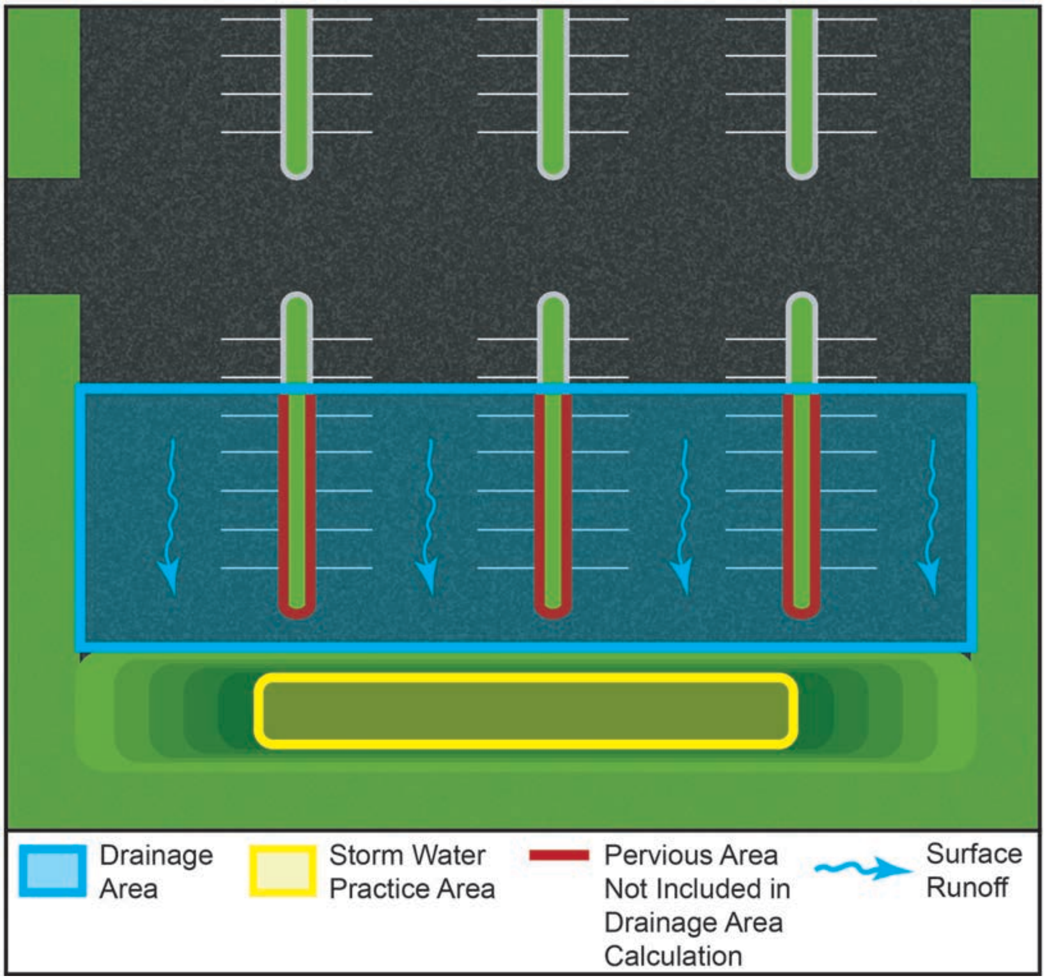

Figure 8: Drainage Area to the Storm Water Practice

Credit Calculation Methods

A wide variety of options are available to quantify credits for the most commonly used storm water practices and techniques. In addition to standard engineering methods, DWSD has developed a series of simplified calculation methods which can be applied. These methods were developed based on a variety of robust hydrologic modeling evaluations that have been summarized into a regression equation.

Simplified methods developed by DWSD include:

- **Practice Ratio Method:** This method determines **volumetric credits** based on the size of the storm water practice relative to the drainage area. This approach assumes that the storm water practice is specifically sized to retain and infiltrate runoff over a 72-hour period. This method should be used for initial assessments and some simple designs. It is most appropriate for bioretention.
- **Disconnected Impervious Method:** This method determines **volumetric credits** based on the relative size of the impervious area and the pervious area onto which it discharges. It should be used for all disconnected impervious area analysis.
- **Equivalent Rainfall Depth Method:** This methodology defines **volumetric credits** based on the equivalent rainfall that can be contained in the retention zone of a practice. This approach is more flexible to varying cross section designs than the practice ratio method. This method works well for bioretention and permeable pavement.
- **Water Balance for Water Reuse Systems:** A water balance methodology is provided for those systems that are using various forms of water reuse to limit the annual volume of storm water discharged to the sewer system.

The standard detention calculation methods are based on the methodology used in a number of southeast Michigan municipalities for sizing of detention facilities:

- **Standard Detention Calculations:** This methodology defines **peak flow credits** based on available detention capacity and standard calculations. This is the preferred methodology for sizing detention basins or detention elements of other practices.

The following methods are standard engineering techniques that are may be used to quantify credits:

- **EPA National Stormwater Calculator:** The EPA National Stormwater Calculator can be used for determining the volumetric capture for any storm water practice. It is the preferred quantification method for green roofs.
- **Hydrologic and Hydraulic Models:** A variety of engineering calculations can be used for quantifying credits. Such tools include hydrologic and hydraulic models that enable consideration of storm water practices in series or complex routing techniques. These may be used for sites where desired by the design professional.

Practice Ratio Method: Volume Credit

The *practice ratio method* provides the option of using either an equation or a chart for determining the corresponding volume credits. Each of these formats provides the same result. The selection of the tool is up to the user.

The method was developed through post processing of long term continuous simulation results for storm water practices that reduce volume through infiltration. The performance of the storm water practice is based on the infiltration capacity of the soil. The result of the regression analysis is shown in Equation 2. This equation can be applied to any infiltrating practice where the constructed equivalent water depth is set at the value identified in Table 1. The most common practices in this category are bioretention and permeable pavement.

The practice ratio method is generally applied to infiltrating systems with an underdrain. In this scenario, where the entire retention zone is below the surface, the analysis should be based on a 72-hour drain time. Storm water practices (such as rain gardens) without an underdrain should be sized to infiltrate within 24 hours.

The information required to use this methodology includes:

- Drainage Area [A] (if > 75% impervious, include impervious area only)
- Practice Area (reference Table 2 for how this is defined for each practice type)

Units for drainage area and practice area must be the same. Typical units are either acres or square feet.

Volumetric credits for these systems are determined using Equation 2.

Equation 2

$$Volume\ Credit\ (\%) = a * \frac{Practice\ Ratio}{b + Practice\ Ratio} * 100$$

The terms a and b are constants and will vary depending on the infiltration rate used in the calculation. Values for coefficients a and b are identified in Table 3.

TABLE 3 - Coefficients for Equation 2

Infiltration Rate	a	b	Drain Time (hours)
0.1 in/hr	1.151	0.123	24
0.2 in/hr	1.096	0.052	24
0.3 in/hr	1.075	0.031	24
0.4 in/hr	1.063	0.022	24
0.5 in/hr	1.055	0.017	24
0.1 in/hr	1.075	0.031	72
0.2 in/hr	1.048	0.014	72
0.3 in/hr	1.036	0.008	72
0.4 in/hr	1.028	0.006	72
0.5 in/hr	1.022	0.004	72

Figure 9 presents results of Equation 2 in graphical format.

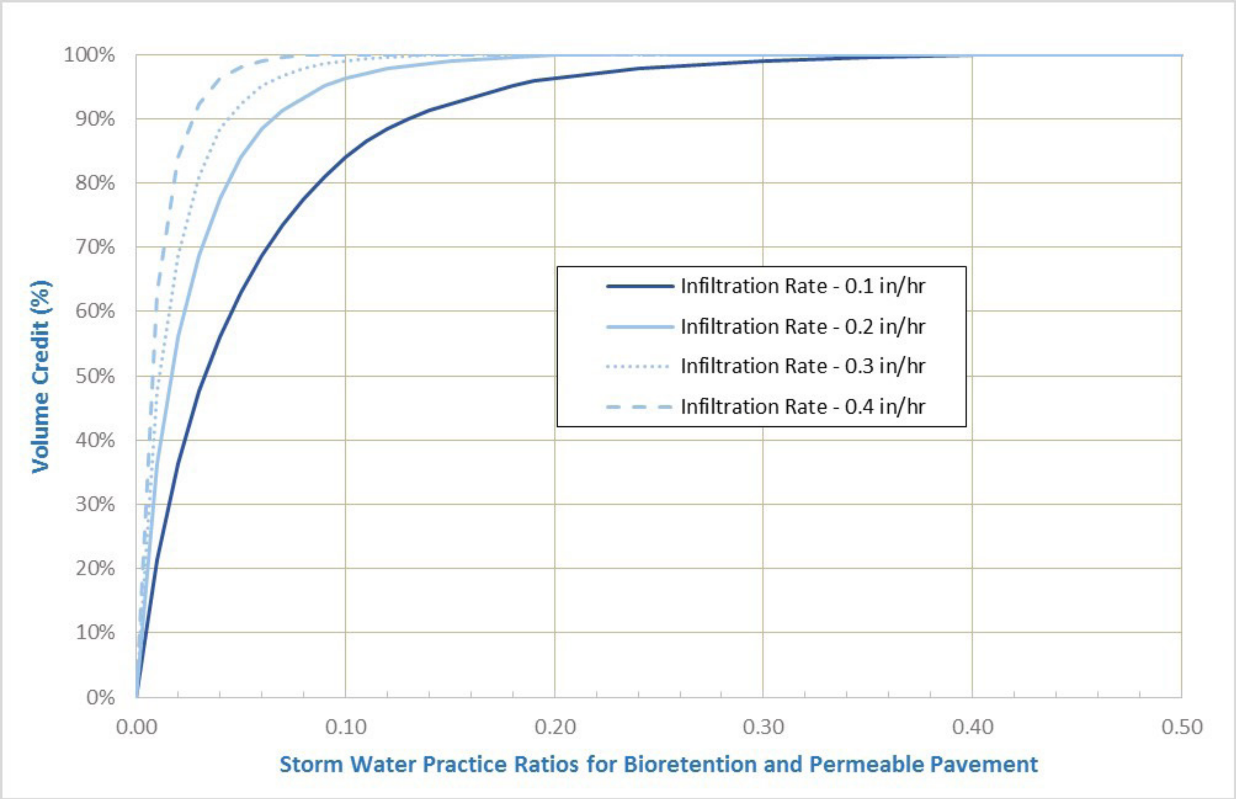

Figure 9: Volume Credits for 72-hour Drain Time from Equation 2

APPLICATION OF THE PRACTICE RATIO METHOD FOR VOLUME CREDIT

STEP 1 Determine the equivalent water depth to be stored in the retention zone of the practice based on the soil infiltration rate (Table 1).

STEP 2 Design the practice to provide the equivalent water depth determined in Step 1. All equivalent water depth must be contained in the retention zone of the storm water practice (i.e., below the underdrain outlet elevation).

STEP 3 Determine the practice area size and the drainage area size using consistent units (e.g., square feet or acres).

STEP 4 Using the coefficients associated with 72-hour drain (Table 3) **OR** the graph in Figure 9, identify the volume credit associated with the practice.

$$\text{Volume Credit (\%)} = a * \frac{\text{Practice Ratio}}{b + \text{Practice Ratio}} * 100$$

STEP 5 Calculate the volume credit associated with the practice. The volume credit applies to 40% of the bill. Therefore multiply the value in Step 4 by 0.4.

$$\text{Practice Credit (\%)} = \text{Volume Credit (\%)} * 0.4$$

STEP 6 Prorate the volume credit to the fraction of impervious area managed versus total site impervious area.

$$\text{Site Credit (\%)} = \text{Practice Credit (\%)} * \frac{\text{impervious area to practice}}{\text{total site impervious area}}$$

Disconnected Impervious Area: Volume Credit

Disconnected impervious areas are eligible for a volume credit based on the ratio of impervious to pervious area. In this case the practice is the pervious area onto which the runoff drains. The practice area must be as defined in Table 2.

The disconnected impervious area credit was based on the presumption that the pervious area includes top soil and vegetation that can absorb up to 0.8 inches of water column. The runoff from the impervious area is distributed over the practice area until its capacity is exceeded. The ratio of pervious to impervious area determines the performance. A continuous simulation provided the net performance of disconnected impervious on an annualized basis.

The results of this analysis are shown in Equation 3. As an alternate to the equation, the corresponding graph may be used. In the simplified methodologies, disconnected imperviousness does not qualify for a peak flow credit, as modeling results do not indicate peak flow rate attenuation during larger storm events.

Equation 3

$$Volume\ Credit\ (\%) = 0.94 * \frac{Practice\ Ratio}{0.25 + Practice\ Ratio}$$

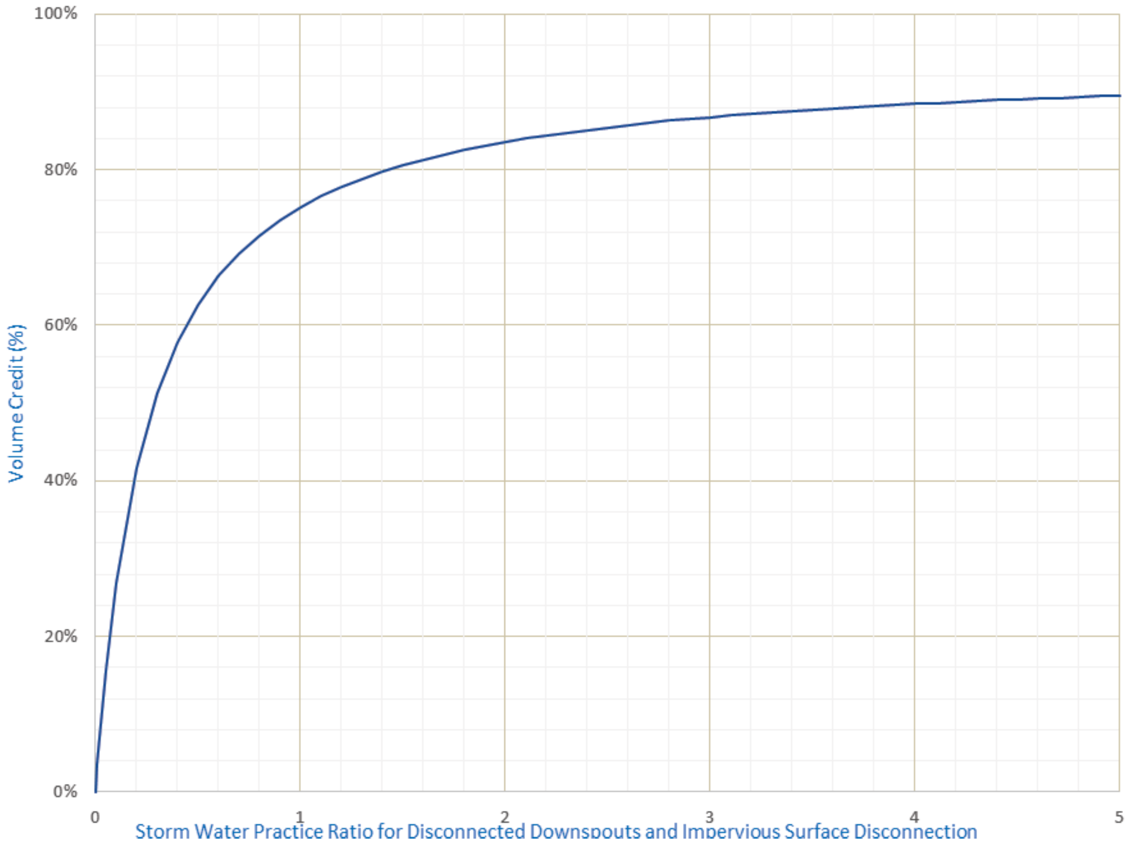

Figure 10: Disconnected Imperviousness Credit

For example, if the practice ratio is 2, then the corresponding volume credit is 84%. A storm water practice ratio of 2 indicates that the pervious area is twice the size of the impervious area draining to it.

Equivalent Rainfall Depth Method: Volume Credit

The Equivalent Rainfall Depth method was developed based on the same principles as described for the Practice Ratio Method. Similar to that approach, the anticipated performance is based on ability of the retained volume to infiltrate into the soil. The Equivalent Rainfall Depth method is different in that it works for a wide range of equivalent water depths. Due to ground water elevations, construction feasibility, hydraulic constraints or other site specific issues, the equivalent water depth installed will often be different than the values shown in Table 1. It is in those instances where this becomes the preferred method.

The volumetric credit is then determined from the equation:

Equation 4

$$Volume\ Credit\ (\%) = (1 - 2.5^{-2.5r}) * 100$$

r = equivalent rainfall depth

where x is the equivalent rainfall depth (in)

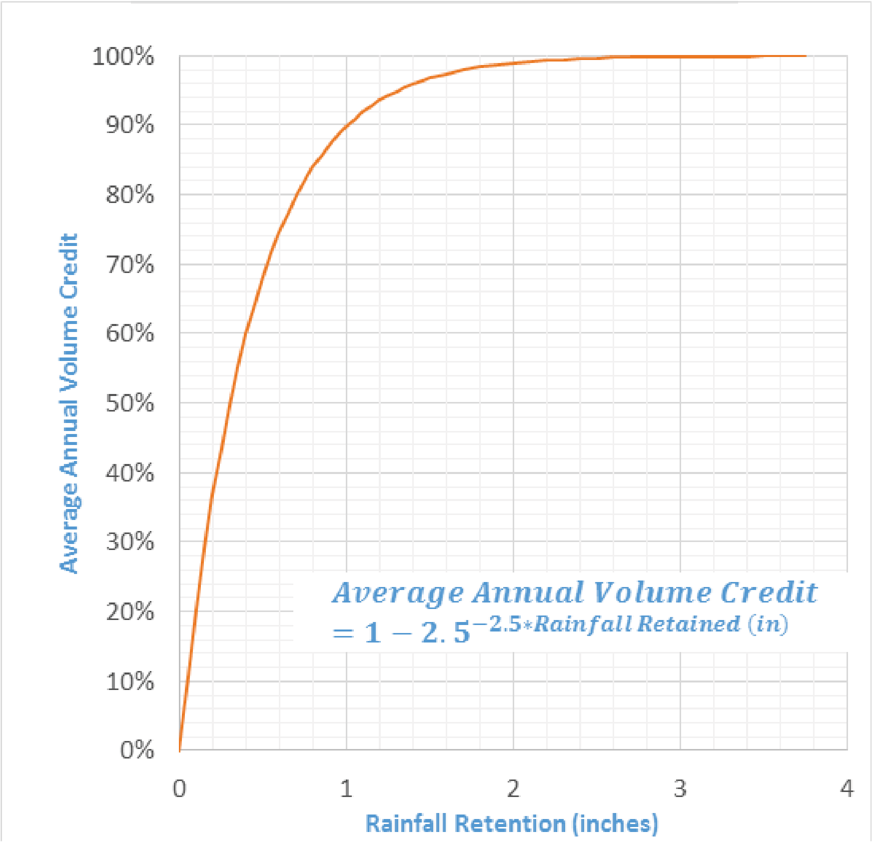

Figure 11: Equivalent Rainfall Depth Credit

The information required to use this methodology includes:

- Drainage Area (if > 75% impervious, include impervious area only);
- Practice Area (reference Table 2 for how this is defined for each practice type);
- Measured infiltration rate in the location of the practice;
- Equivalent Water Depth (EWD) in the practice.

With this information, the volumetric credit can be determined.

The method can also be used to calculate a practice area for a target volumetric credit.

APPLICATION OF THE EQUIVALENT RAINFALL DEPTH METHOD TO CALCULATE A VOLUME CREDIT

This example assumes that the size of the storm water practice is already determined. See the following example for sizing of a practice to achieve a desired credit.

STEP 1 Identify the drainage area and determine the amount of impervious area. Identify the practice area size, infiltration rate, and equivalent water depth (EWD) in the retention zone.

STEP 2 Confirm that the infiltration rate is greater than or equal to the minimum required infiltration rate based on the equation below.

$$Minimum\ Required\ Infiltration\ Rate\left(\frac{in}{hr}\right) = \frac{EWD\ Provided\ (in)}{Allowable\ Drain\ Time\ (hrs)}$$

STEP 3 Quantify the retention volume provided based on the practice area and the EWD:

$$Retention\ Volume\ (cf) = Practice\ Area\ (sf) * \frac{EWD\ (in)}{12}$$

STEP 4 Determine the equivalent rainfall depth that corresponds to the retention volume identified in Step 3:

$$Equivalent\ Rainfall\ Depth\ (in) = \frac{Retention\ Volume\ (cf)}{Impervious\ Drainage\ Area\ (sf)} * 12$$

Note: The method shown simplifies runoff as equal to 100% of rainfall on impervious areas and 0% of rainfall on pervious areas. The designer may substitute an alternate method for the denominator to account for a variety of surface types.

STEP 5 Determine the volume credit from the regression equation.

$$Volume\ Credit\ (\%) = (1 - 2.5^{-2.5r}) * 100$$

where r is the equivalent rainfall depth (in)

STEP 6 Calculate the practice credit. The volume credit applies to 40% of the bill. Therefore multiply the value in Step 5 by 0.4 to identify the practice credit.

STEP 7 Prorate the practice credit to the fraction of impervious area managed versus total site impervious area.

$$Site\ Credit\ (\%) = Practice\ Credit\ (\%) * \frac{Impervious\ Area\ to\ Practice}{Total\ Site\ Impervious\ Area}$$

APPLICATION OF THE EQUIVALENT RAINFALL DEPTH METHOD TO CALCULATE A PRACTICE AREA

This example assumes that the designer is working to size the storm water practice based on a desired credit. See the preceding example to determine a credit if the size of the storm water practice is already determined.

STEP 1 Identify the drainage area and determine the amount of impervious area. Identify the infiltration rate, and EWD in the retention zone. Identify the target volume credit.

STEP 2 Confirm that the infiltration rate is greater than or equal to the minimum required infiltration rate for the EWD provided.

$$\text{Minimum Required Infiltration Rate}\left(\frac{in}{hr}\right) = \frac{\text{EWD Provided (in)}}{\text{Allowable Drain Time (hrs)}}$$

STEP 3 Based on the target volume credit, solve for *r* in the credit equation.

$$\text{Volume Credit (\%)} = (1 - 2.5^{-2.5r}) * 100$$

where r is the equivalent rainfall depth (in)

STEP 4 Determine the necessary retention volume.

$$\text{Retention Volume (cf)} = \frac{r}{12} * \text{Impervious Drainage Area (sf)}$$

STEP 5 Determine the required practice area to accomplish the retention volume.

$$\text{Practice Area (sf)} = \frac{\text{Retention Volume (cf)}}{\text{EWD (in)/12}}$$

Standard Detention Calculations: Peak Flow Credit

The standard detention methodology is used to determine peak flow credits for detention ponds and detention components of other storm water practices. This methodology is based on a process in widespread use in southeastern Michigan for detention pond sizing. As a simplification step, the designer has the option to modify the equations to essentially ignore pervious areas. This should only be used if the drainage area is 75% or more impervious.

The information required to use this methodology includes:

- Tributary Area to the detention practice
- Rational Coefficient (can be ignored if >75% impervious)
- Allowable discharge rate for the 100-year storm event (presumed to be 0.15 cfs/acre)

The outlet rate for the practice must be limited to 0.15 cfs/acre at times of discharge to qualify for a peak flow credit.

Nomenclature used in this method includes:

- A, tributary area to the detention practice (acres)
- C, Rational Coefficient (dimensionless)
- Q_R, peak allowable discharge rate for the 100-year storm event (cfs/acre)
- D, storm duration (minutes)
- I, rainfall intensity (inches per hour)
- t, recurrence interval (years)
- Vn, required detention volume for the n-year event (ft3)

Basic calculations are as follows:

The critical storm duration is based on Equation 5:

Equation 5: Critical Storm Duration

$$D = 49.988 \left(\frac{Q_R}{C}\right)^{-0.984}$$

Simplified calculation (considering impervious areas only): Q_R = 0.15 and C = 1, D = 323 minutes.

The rainfall intensity is calculated from Equation 6:

Equation 6: Average Rainfall Intensity for Critical Duration Event

$$I = \frac{38.0708t^{0.2081}}{(12.1177 + D)^{0.8395}}$$

For the simplified calculation, the following values are determined:

100 year event, I = 0.75
2 year event, I = 0.33

The required detention storage volume for a given recurrence interval event is based on Equation 7:

Equation 7: Volume Required for Selected Event

$$V_n = 60.5 * D * C * A * I - 60 * D * Q_R * A$$

For simplified calculation:

V_{100} = 11,750 cf/impervious acre
V_2 = 3,541 cf/impervious acre

The peak flow credit for the practice is then:

Equation 8: Detention Peak Flow Credit

$$Peak\ Flow\ Credit = \frac{V_{provided}}{V_{100}}$$

APPLICATION OF THE STANDARD DETENTION CALCULATION

STEP 1 Identify the following information: drainage area to the detention practice and rational coefficient for that area; OR impervious area to the detention practice.

STEP 2 Confirm that the outlet rate of the detention practice is less than or equal to 0.15 cfs/acre. This applies ONLY to the practice drainage area.

STEP 3 Identify the volume required for the 100-year event, either through the use of Equation 5 through Equation 7, or by using the standard volume for impervious area of V_{100} = 11,750 cf/impervious acre.

STEP 4 Either a) design the practice for the identified 100-year event volume; or b) design for a lesser volume. The minimum volume that qualifies for a peak flow credit is the 2-year volume (V_2 = 3,541 cf/ impervious acre). The peak flow credit is determined by Equation 8.

$$\textit{Peak Flow Credit} = \frac{V_{provided}}{V_{100}}$$

STEP 5 Calculate the practice credit. The peak flow credit applies to 40% of the bill. Therefore multiply the value in Step 4 by 0.4.

$$\textit{Practice Credit (\%)} = \textit{Peak Flow Credit (\%)} * 0.4$$

STEP 6 Determine the site credit by prorating the practice credit by the fraction of impervious area managed versus total site impervious area.

$$\textit{Site Credit (\%)} = \textit{Practice (\%)} * \frac{\textit{Impervious Area to Practice}}{\textit{Total Site Impervious Area}}$$

Minimum Design Criteria for Credit Quantification

Minimum design criteria are identified for each commonly used storm water practice. Design criteria are specifically related to credit quantification and are not intended to serve as an engineering design standard. **Important Note:** Conditions which constitute a hazard or nuisance are not eligible for credits.

Disconnected Impervious Surfaces

Disconnected impervious surfaces are a storm water management practice that directs runoff from impervious surfaces onto properly sized, sloped and vegetated surfaces. Both roofs and paved surfaces can be disconnected with slightly differing designs. Disconnected impervious surfaces may already exist on many sites. This is a relatively low cost measure that can be implemented if there is pervious area that can accept runoff. Because there is no control of peak storms, the credit is a volume credit.

Disconnected Downspouts

Customers can disconnect downspouts and allow storm runoff to flow over landscaped areas or lawns. Disconnection can be a low-cost option that allows storm water to infiltrate into the soil.

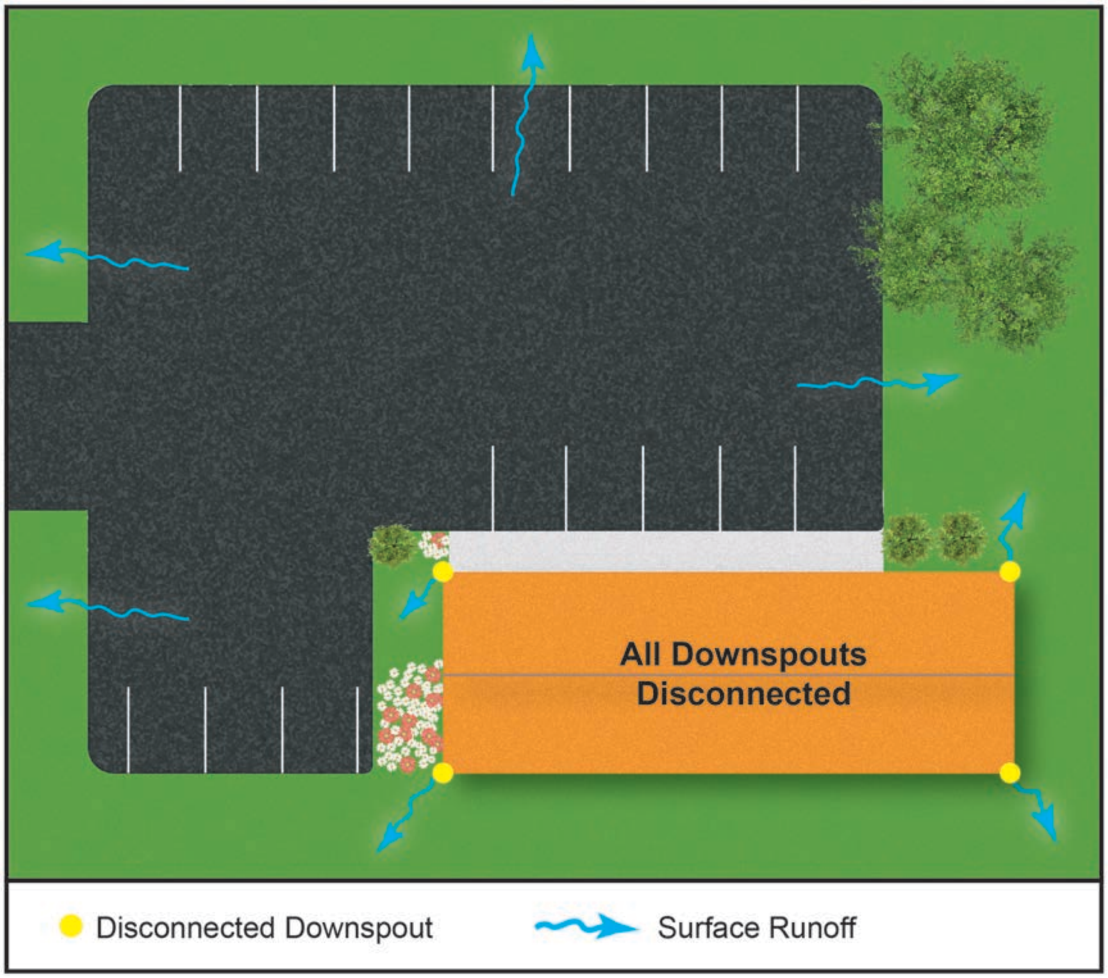

Figure 11: Disconnected Downspouts Draining to Pervious Area

The drainage credit related criteria for design involves the proper size, slope, and vegetation of the area receiving flow from the impervious surface.

The following criteria must be met to be eligible for a downspout disconnection credit:

- Size:
    - **Maximum Drainage Area:** The maximum area tributary to any one individual downspout that may receive credit is 500 sf. If the area is greater than 500 sf, 500 sf must be used in calculations. Special cases may be evaluated by DWSD.
    - **Minimum Flow Path:** The minimum flow path from the end of the downspout to the property line or other impervious surface is 15 feet.
    - **Minimum Practice Ratio:** The minimum practice ratio eligible for credit is 0.1.
    - **Determination of Practice Area:** As noted in Table 2, the standard practice area for the disconnected downspout is the length of the flow path times a width of five feet.
    - **Minimum Distance from Building:** The minimum distance from the structure at which the downspout can discharge is 5 feet. The grade at the point of discharge must be sloped away from the structure.
    - **Nuisance Conditions:** Flow discharged from a downspout cannot lead to nuisance or hazardous conditions.
- Slope: The slope of the pervious area onto which flow is discharged should be less than 5%.
- Vegetation/ Soil Characteristics:
    - **Cover Type:** Downspouts must be directed to a pervious area consisting of well-established vegetation. No credit will be given if downspouts are directed to other impervious areas (i.e., driveway, walkway). No credit will be provided for downspouts directed onto bare soil or poorly vegetated surfaces. Soil in the discharge area should not be compacted. Areas which have evidence of vehicular traffic do not qualify as pervious areas.

Properties which cannot achieve the minimum design standards for disconnected imperviousness may be able to install bioretention systems or other practices that can manage roof runoff in a smaller footprint.

The following example calculation is for a commercial site with multiple downspouts. The site meets the minimum criteria for disconnected downspouts in that:

- The drainage area to each downspout is less than 500 square feet.
- The minimum flow path from each downspout is 15 feet or greater.
- The practice ratio is greater than 0.1.

The pervious area to which the downspout is directed must have well established vegetated cover and soils that are not compacted.

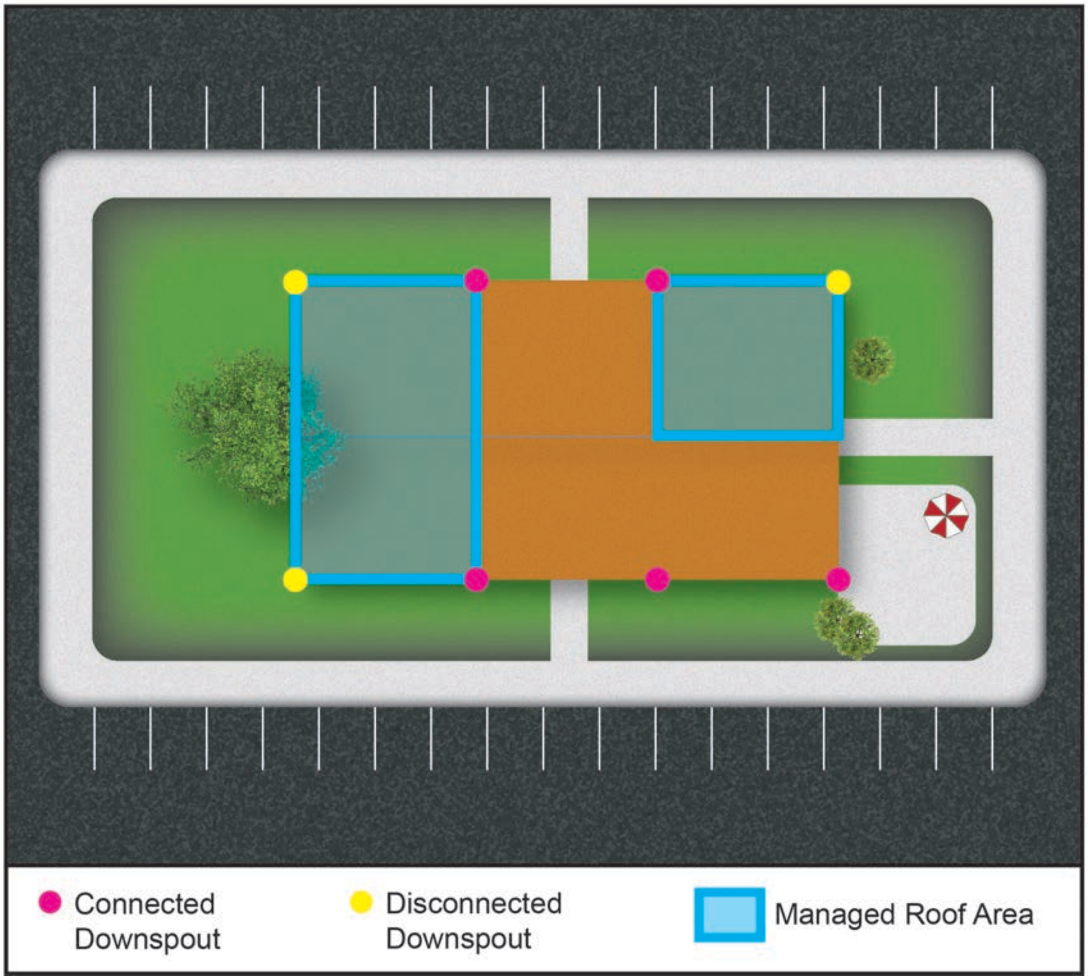

Figure 12: Schematic for Downspout Disconnected Example

DOWNSPOUT DISCONNECTION EXAMPLE

A small commercial property owner is applying for a downspout disconnection credit for a property with the following characteristics:

Total Site Impervious Area: 5,300 square feet (roof and parking lot and sidewalk)
Roof Area: 2,800 square feet, assumed evenly divided to each downspout
Total Number of Downspouts: 8
Number of Disconnected Downspouts: 3

STEP 1 Define the individual drainage areas and practice areas:

Length of each disconnection: See Figure 8.6 (varies from 20-25 feet).

- Downspout 1: Drainage area = 350 square feet, Practice area = 25*5 = 125 square feet
- Downspout 2: Drainage area = 350 square feet, Practice area = 25*5 = 125 square feet
- Downspout 3: Drainage area = 350 square feet, Practice area = 20*5 = 100 square feet

STEP 2 Calculate the individual storm water practice ratios:

$$\textit{Practice Ratio} = \frac{\textit{Practice Area}}{\textit{Managed Impervious Area}}$$

- Downspouts 1 and 2: Practice Ratio = 125/350 = 0.36
- Downspout 3: Practice Ratio = 100/350 = 0.29

STEP 3 Calculate the volume credit:

$$\textit{Volume Credit (\%)} = 0.94 * \frac{\textit{Practice Ratio}}{0.25 + \textit{Practice Ratio}} * 100$$

- Downspouts 1 and 2: Volume Credit = 0.94 * (0.36/(0.25+0.36)) * 100 = 55%
- Downspout 3: Volume Credit = 0.94 * (0.29/(0.25+0.29)) * 100 = 50%

STEP 4 Determine the practice credit for the managed impervious area:

$$\textit{Practice Credit (\%)} = \textit{Volume Credit} * 0.4$$

- Downspouts 1 and 2: Practice Credit = 55% * 0.4 = 22%
- Downspout 3: Practice Credit = 50% * 0.4 = 20%

DOWNSPOUT DISCONNECTION EXAMPLE (continued)

STEP 5 Calculate the site credit:

$$Site\ Credit\ (\%) = \frac{\sum Impervious\ Area\ Managed * Practice\ Credit}{Impervious\ Area}$$

$$Site\ Credit\ (\%) = \frac{350 * 22\% + 350 * 22\% + 350 * 20\%}{5{,}300} = 4.2\%$$

Impervious Surface Disconnection

Customers are eligible to receive an impervious disconnection credit by directing storm water from impervious surfaces to pervious surface areas. Examples include driveways, impervious walkways and parking areas. Impervious surface disconnection allows storm water to drain onto a vegetated area and infiltrate into the ground.

Impervious surface disconnection is comparable to downspout disconnection discussed previously. The major difference between impervious surface disconnection and downspout disconnection is that the flows may be distributed (e.g., sheet flow established) allowing for a greater area of pervious surface to be credited as the practice area.

Drainage credit related criteria for impervious surface disconnection design involves proper sizing, slope and vegetation of the area receiving flow from the impervious surface. It also requires the drainage entering the pervious area to be established as sheet flow.

The following criteria must be met to receive a credit for impervious area disconnection:

- Size:
  - **Maximum Drainage Area:** The maximum drainage area is defined as a contributing flow path of impervious area not longer than 75 feet. With a gravel verge or other transition, this can be increased to 100 feet. For areas longer than this, a special determination will be required.
  - **Minimum Flow Path:** The minimum flow path across the pervious surface is equal to the length of the tributary impervious surface or 25 feet, whichever is less. With a gravel verge at the transition from impervious to pervious area, the length of the pervious area may be reduced to 15 feet. The flow path must be on parcels, not right-of-way.
  - **Minimum Practice Ratio:** The minimum practice ratio eligible for credit is 0.33 without a gravel verge or other transition and is 0.15 with a gravel verge or other transition.

- **Sheet Flow Required:** The overland flow to the pervious area must be sheet flow. For example, flow through a swale does not count as disconnected impervious area. Any flow which enters the pervious area as concentrated flow must first be distributed with a level spreader. The level spreader is not considered part of the disconnected impervious practice area.

- **Determination of Practice Area:** As noted in Table 2, the standard practice area for the disconnected impervious area is the width of the sheet flow multiplied by the length of the flow path across the pervious area.

- **Nuisance Conditions:** Use of disconnected impervious practices must not lead to a nuisance or hazardous conditions.

- Slope: The slope of the both the contributing impervious area and the pervious area onto which flow is discharged should be less than 5%.

- Vegetation/ Soil Characteristics:

  - **Cover Type:** Drainage from the impervious area must be directed to a pervious area consisting of well-established vegetation. No credit will be given if the impervious area is directed to other impervious areas (i.e., driveway, walkway). No credit will be provided for impervious areas that are directed onto bare soil or poorly vegetated surfaces. Soil in the discharge area should not be compacted. Areas which have evidence of vehicular traffic do not qualify as pervious areas.

Figure 13 depicts an example calculation for a parking area that flows onto a pervious area.

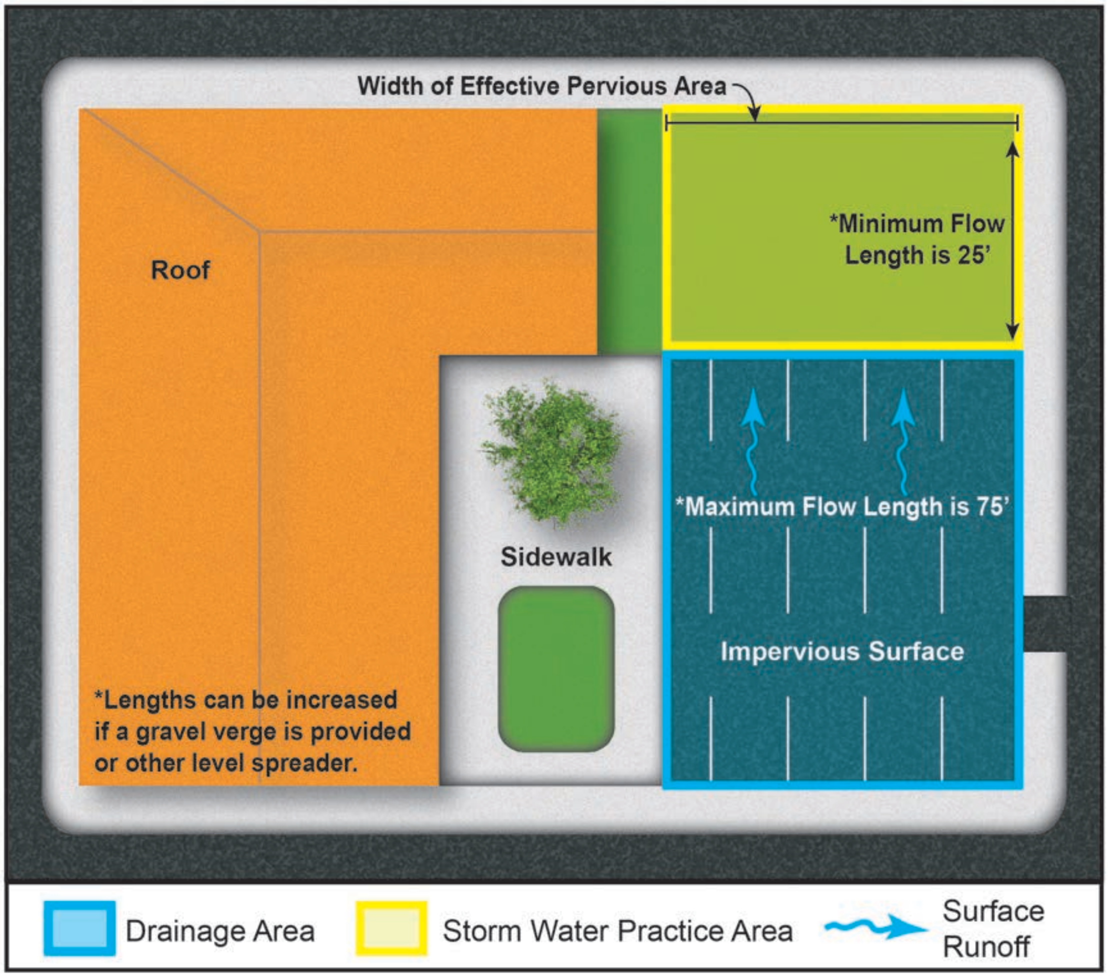

Figure 13: Schematic for Impervious Surface Disconnection Example

IMPERVIOUS SURFACE DISCONNECTION EXAMPLE

The owner of a medium-sized commercial lot is applying for a volume credit for disconnecting a portion of the parking lot.

The property has the following characteristics:

Managed Impervious Area: 3,000 square feet
Total Impervious Area: 12,000 square feet
Practice Area: 2,500 square feet

STEP 1 Calculate the Practice Ratio:

$$\textit{Practice Ratio} = \frac{\textit{Storm Water Practice Area}}{\textit{Managed Impervious Area}} = \frac{2{,}500\ sf}{3{,}000\ sf} = 0.83$$

STEP 2 Calculate the Volume Credit:

$$\textit{Volume Credit (\%)} = 0.94 * \frac{\textit{Practice Ratio}}{0.25 + \textit{Practice Ratio}} * 100 = 0.94 * \frac{0.83}{0.25 + 0.83} * 100 = 72\%$$

STEP 3 Calculate the practice credit:

$$\textit{Practice Credit (\%)} = \textit{Volume Credit (\%)} * 0.4 = 72\% * 0.4 = 28.8\%$$

STEP 4 Prorate the practice credit to the site:

$$\textit{Site Credit (\%)} = \textit{Practice Credit (\%)} * \frac{\textit{Managed Impervious}}{\textit{Total Impervious}} = 28.8\% * \frac{3{,}000\ sf}{12{,}000\ sf} = 7.2\%$$

6.4.2 Bioretention

Bioretention storm water practices include a number of different configurations that temporarily store runoff in an engineered system that will later infiltrate into the soil. The type of bioretention systems most commonly constructed include:

TABLE 4 - Bioretention Types and Application		
Bioretention Type	**Where Used**	**Comments**
Rain garden	**Homes and small buildings**	**Generally less than 1,000 square feet of impervious area, not engineered**
Bioretention	**Nonresidential sites**	**Installed in lawn areas to manage runoff from impervious areas, typically with engineered underdrain**
Parking lots	**Parking lots**	**Generally located in rights-of-way**
Curb extension	**Road rights of way or along private driveways**	**Structural walls, highly compact foot print**
Planter boxes	**Highly urban areas, sites without lawn**	**Structural walls, suspended pavement systems**
Tree trenches	**Highly urban areas, parking lots, sidewalks**	**Structural walls, suspended pavement systems**

Other than rain gardens, bioretention systems are engineered storm water practices that include such elements as aggregate storage, filter layers, and special planting soils that are specifically designed to manage, treat and store storm water prior to infiltration into the soil.

Figure 14: Bioretention Illustration

Bioretention systems are typically designed to control annual volume, but they may also be sized for peak flow credits.

Credit related design criteria includes:

- **Retention Volume:** The retention volume provided must be consistent with the credit quantification methodology selected. Retention volume occurs below the underdrain outlet elevation in the constructed soil and aggregate layers, not in the subgrade.
- **Detention Volume:** Detention volume occurs above the underdrain outlet. The detention volume should be determined based on the geometry of the bioretention system.
- **Groundwater Table:** The bottom of the bioretention media (aggregate and engineered soil) should be two feet above the seasonal high groundwater table for best performance and health of the plants used. More advanced design techniques should be used in high groundwater situations.
- **Dewatering:** Bioretention systems in non-residential applications must have a physical outlet that will allow for drainage. This will ensure satisfactory performance if infiltration capacities are significantly reduced due to seasonal conditions or system failure. The Detroit area experiences frozen ground conditions and a seasonally high water table. Bioretention systems therefore should be equipped with an underdrain at an elevation to drain all water that is stored above the ground surface within 24 hours.
- **Overflow or Bypass:** The practice must have a planned overflow or bypass for when the storage volume is full.

Required design elements when bioretention systems are intended to provide detention and customers want to apply for peak flow credits.

- **Outlet Control:** The outlet capacity from the bioretention (generally the underdrain) must be controlled to 0.15 cfs/acre.
- **Minimum Detention Volume:** The detention volume provided in the bioretention must be sufficient for at least the two year storm event to qualify for a credit.

Bioretention Sample Calculations

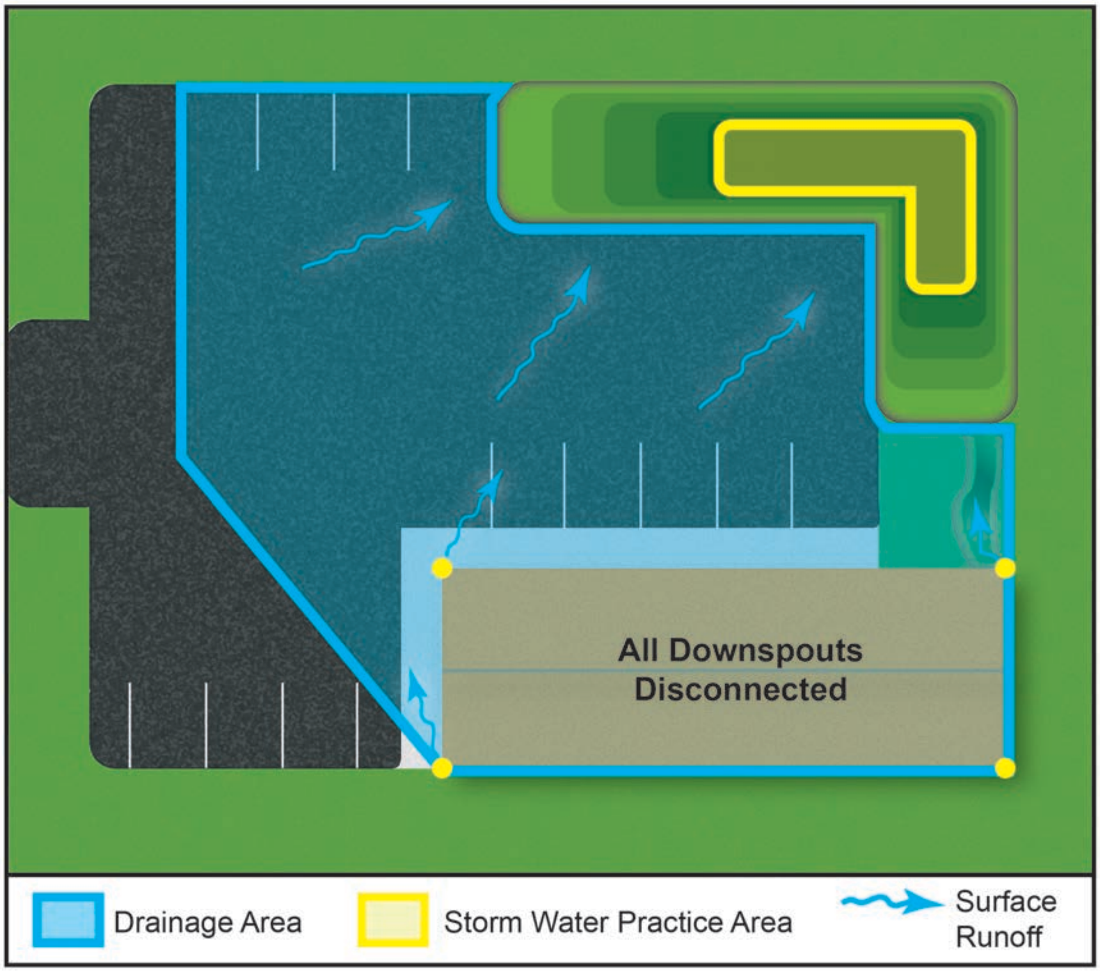

Figure 15: Bioretention Calculation Example

BIORETENTION CALCULATION EXAMPLE – RETENTION ONLY

A small business owner is applying for a volume credit for a bioretention practice; the property has the following characteristics:

Managed Impervious Area: 5,000 square feet
Total Impervious Area: 6,500 square feet
Storm Water Practice Area: 750 square feet
Measured Soil Infiltration Rate: 0.4 in/hr

The calculation methodology selected is the practice ratio method.

STEP 1 Determine the Equivalent Water Depth (EWD) required for the practice area ratio method to apply:

The soil has been tested on site and has a 0.4 inch/hour infiltration rate. A safety factor of 2 should be used in design. The allowable rate in calculations is (0.4 inch/hour)/2 = 0.2 inch/hour.

$$EWD\ Required\ (in) = Infiltration\ Rate \left(allowable\ \frac{in}{hr}\right) * Duration\ (hrs) = 0.2 * 72 = 14.4\ in$$

STEP 2 Select the desired mix of aggregate and soil and place the position of the underdrain outlet to ensure that it provides the required depth of water storage:

Many options are available for the cross section. One example would be:

24” of aggregate with a usable void ratio of 0.4 = 9.6 inches
20” of soil with a usable void ration of 0.25 = 5 inches
Total = 14.6” equivalent water depth, which is slightly greater than required.

The elevation of the underdrain outlet must correspond to the desired water storage elevation.

STEP 3 Calculate the storm water practice ratio:

$$Practice\ Ratio = \frac{Storm\ Water\ Practice\ Area}{Managed\ Impervious\ Area} = \frac{750\ sf}{5{,}000\ sf} = 0.15$$

STEP 4 Calculate the volume credit (Equation 3):

$$Volume\ Credit\ (\%) = 1.09 * \frac{Practice\ Ratio}{0.05 + Practice\ Ratio} * 100 = 1.09 * \frac{0.15}{0.05 + 0.15} * 100 = 82\%$$

BIORETENTION CALCULATION EXAMPLE – RETENTION ONLY (continued)

STEP 5 Calculate the practice credit:

$$\textit{Practice Credit (\%)} = \textit{Volume Credit (\%)} * 0.4 = 82\% * 0.4 = 32.8\%$$

STEP 6 Calculate the site credit:

$$\textit{Site Credit (\%)} = \textit{Practice Credit (\%)} * \frac{\textit{Managed Impervious}}{\textit{Total Impervious}} = 32.8\% * \frac{5{,}000\ sf}{6{,}500\ sf} = 25.2\%$$

BIORETENTION CALCULATION EXAMPLE – RETENTION AND DETENTION

The same site as in the prior example is being constructed to provide both retention and detention.
Data from prior example:
Managed Impervious Area: 5,000 sf (0.11 acre)
Total Impervious Area: 6,500 square feet
Storm Water Practice Area: 750 square feet
Measured Soil Infiltration Rate: 0.4 in/hr

As determined in the prior example, the necessary equivalent water depth for the retention zone is 14.4 inches.

STEP 1 Determine the minimum volume required to obtain a detention credit: The detention credit requires adequate volume to store the 2-year event. Refer to Equation7.

$$V_2 = 3{,}541 \frac{cf}{Impervious\ Acre} * 0.11\ acre = 390\ cf$$

STEP 2 Determine the EWD necessary in the detention zone of the practice: The necessary EWD to achieve a detention credit is:

$$EWD_{detention} = \frac{390\ cf}{750\ sf} = 0.52\ ft = 6.2\ inches$$

STEP 3 Consider the potential EWD based on site constraints:

As part of the practice design, the designer determines that the depth of water on the surface of the practice would be 4 inches, and that there are 18 inches of soil above the underdrain elevation. The EWD provided (void ratio of the soil is assumed to be 0.2 in this example) is:

$$EWD_{provided} = 4.0 + 18.0 * 0.2 = 7.6\ inches$$

STEP 4 Determine the actual detention volume:

$$V_{provided} = \frac{7.6\ inches}{12\ inches/ft} * 750\ sf = 475\ cf$$

STEP 5 Determine the peak flow credit: Using Equation 8, calculate the percentage of the 100-year volume that is provided.

$$Peak\ Flow\ Credit = \frac{V_{provided}}{V_{100}} * 100 = \frac{475}{0.11 * 11{,}750} * 100 = 36.7\%$$

BIORETENTION CALCULATION EXAMPLE – RETENTION AND DETENTION (continued)

STEP 6 Calculate the practice credit.

$$Practice\ Credit = Volume\ Credit * 0.4 + Peak\ Flow\ Credit * 0.4 = 82 * 0.4 + 36.7 * 0.4 = 47.5\%$$

STEP 7 Calculate the site credit:

$$Site\ Credit\ (\%) = Practice\ Credit\ (\%) * \frac{Managed\ Impervious}{Total\ Impervious} = 47.5\% * \frac{5{,}000\ sf}{6{,}500\ sf} = 36.5\%$$

6.4.3 Permeable Pavement

Several design options are available for using permeable pavements to intercept, contain, filter, and where appropriate infiltrate storm water on site. Permeable pavements can be installed across an entire street width or an entire parking area. In some cases, permeable and standard pavements are used in the same parking area. For example, a parking lot (see Figure 16) may use permeable pavement in parking stalls to treat runoff from adjacent standard pavements in drive lanes. The aggregate layer may extend under both the permeable and standard pavements.

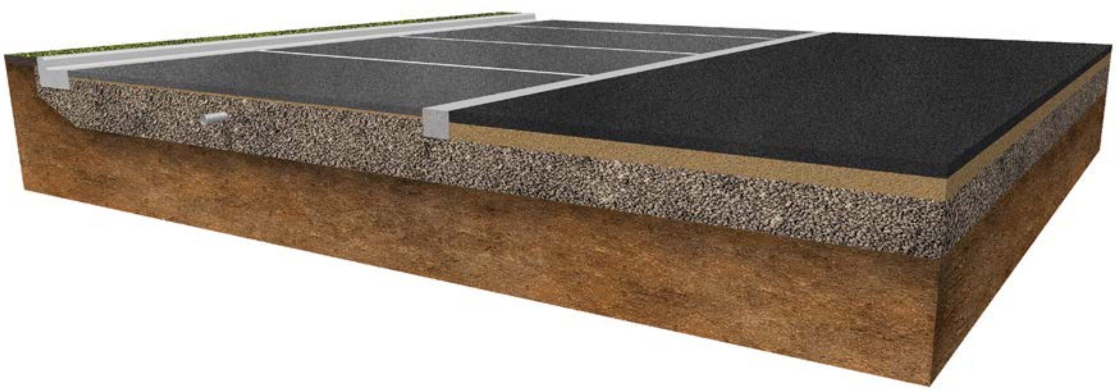

Figure 16: Permeable Pavement Configuration

Similar to bioretention, the placement of the underdrain in the permeable pavement cross section determines the function of the volume provided. As shown in Figure 17, the volume below the underdrain acts as retention while the volume above the underdrain acts as detention (assuming the outlet is controlled).

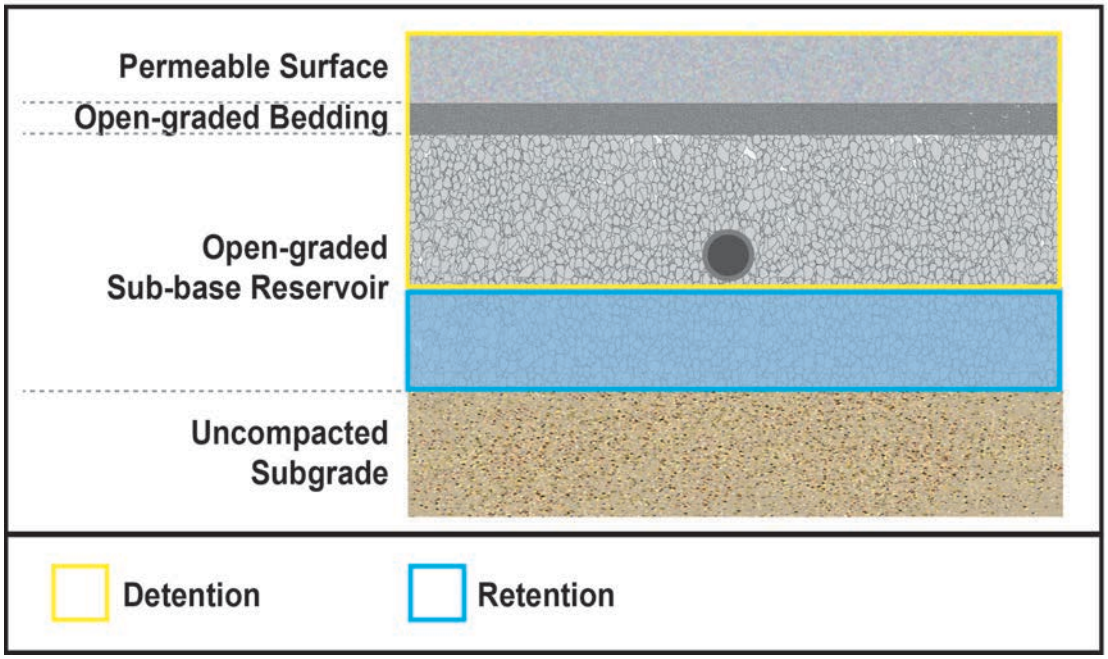

Figure 17: Retention and Detention in Permeable Pavements

Permeable pavement systems result in credits based on their hydrologic performance. The fundamental hydrologic performance is calculated using the same methodology as is used for bioretention. The critical factors include:

- Practice area
- Infiltration rates into the soil
- Available retention volume
- Available detention volume
- **Practice Area:** Practice areas for permeable pavement systems are based on the size of the aggregate storage provided under pavement and not the pavement surface characteristics. To the extent that the aggregate layer receives flows from surfaces other than pervious pavement, the flows need to be well distributed within the aggregate. Generally the ratio of standard to permeable pavement in a parking area should be limited. Dirt and debris from the standard pavement can result in clogging of the permeable surface. A maximum standard to permeable pavement ratio of 4:1 is permitted.
- **Available Retention Volume:** The available retention volume is the equivalent water depth in the aggregate layer below the underdrain. Underdrains in permeable pavement generally do not contain upturned elbows. The maximum retention volume is based on infiltrating within 72 hours.
- **Available Detention Volume:** The available detention volume is the equivalent water depth in the pavement system above the underdrain. It may include any usable void space up to and including the permeable surface. In order to qualify as detention volume, the flow rate leaving the underdrain must be controlled to 0.15 cfs/acres or less. The detention volume is not reduced for solids management as solids control is required independent of the detention volume.

- **Overflow:** Permeable pavement systems should be provided with an overflow in the event of storm systems larger than can be handled by the system. The overflow may include catch basins located in the pavement or adjacent to the pavement.

Example Calculation

Permeable pavement systems generally provide a highly distributed area for infiltration. The following example calculation illustrates the infiltration component for the volume credit.

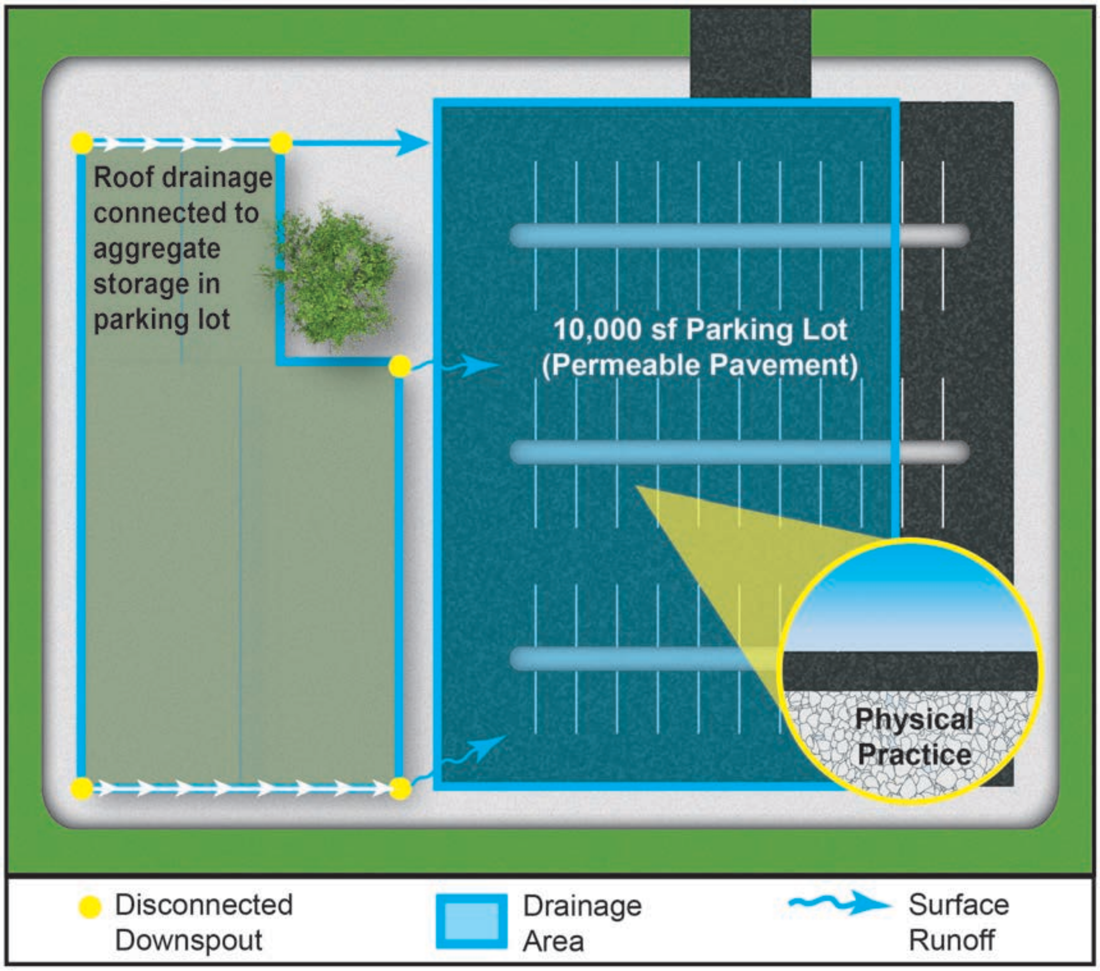

Figure 19: Schematic for Permeable Pavement Example

PERMEABLE PAVEMENT VOLUME CREDIT CALCULATION EXAMPLE

A commercial property is applying for a volume credit for permeable pavement. The site has the following characteristics:

- Drainage Area: 10,000 sf from parking lot plus 5,000 from roof runoff = 15,000 sf
- Total Impervious Area: 17,500 square feet
- Infiltration Rate: 0.1 in/hr
- Allowable Drain Time: 72 hr
- Permeable Pavement: > 25% of the parking lot (2,500 sf); Aggregate Storage Layer: 5,000 square feet of the parking lot. Therefore physical practice: 5,000 square feet.
- Aggregate (under the parking lot): 24 inches
- Usable Void Ratio in Aggregate: 35%
- Underdrain is located 12 inches off the bottom of the practice.

The calculation methodology selected is the *Equivalent Rainfall Method*.

PERMEABLE PAVEMENT VOLUME CREDIT CALCULATION EXAMPLE (continued)

STEP 1 Determine the Equivalent Water Depth (EWD) provided for retention (**below** the underdrain):

$$EWD\ Provided\ (in) = Aggregate\ Depth\ (in) * Void\ Ratio = 12 * 0.35 = 4.2\ in$$

STEP 2 Determine if the volume under the underdrain will drain in the allotted time:

$$Min.\ Required\ Infiltration\ Rate\left(\frac{in}{hr}\right) = \frac{EWD\ Provided\ (in)}{Allowable\ Drain\ Time\ (hrs)} = \frac{4.2\ in}{72\ hr} = 0.06\ in/hr$$

Make sure that the actual infiltration rate (0.10 in/hr) is greater than the minimum required infiltration rate (0.06 in/hr). Since yes, proceed to Step 3.

STEP 3 Determine the retention volume provided:

$$Retention\ Volume\ (cf) = Practice\ Area\ (sf) * \frac{EWD\ (in)}{12} = 5{,}000\ sf * \frac{4.2\ in}{12\ in} = 1{,}750\ cf$$

STEP 4 Determine the equivalent rainfall that corresponds to the volume in Step 3:

$$Equivalent\ Rainfall\ Depth\ (in) = \frac{Retention\ Volume\ (cf)}{Impervious\ Drainage\ Area\ (sf)} = \frac{1{,}750}{15{,}000} * 12 = 1.4\ in$$

STEP 5 Calculate the volume credit if 1.4 inches of rainfall retained on the site: Plug in regression equation:

Volume Credit = 1 – 2.5(-2.536 * Rainfall Depth (inches))
Volume Credit = 1 – 2.5(-2.536*1.4)
Volume Credit = 97%

STEP 6 Calculate the practice credit:

$$Practice\ Credit\ (\%) = Volume\ Credit\ (\%) * 0.4 = 97\% * 0.4 = 38.8\%$$

STEP 7 Calculate the site credit:

$$Site\ Credit\ (\%) = \frac{Managed\ Impervious}{Total\ Impervious} * Practice\ Credit\ (\%) = \frac{15{,}000\ sf}{17{,}500\ sf} * 38.8\% = 33.25\%$$

PERMEABLE PAVEMENT PEAK FLOW CREDIT CALCULATION

If permeable pavement meets the requirements for detention (i.e., controlled release rate of 0.15 cfs/acre), the practice is eligible to receive a peak flow credit. The example below is a continuation of the previous permeable pavement volume credit calculation and shows how to earn a peak flow credit. The assumptions and site characteristics are the same from the previous example.

STEP 1 Determine the EWD provided for detention (***above*** the underdrain):

$$EWD\ Provided\ (in) = Aggregate\ Depth\ (in) * Void\ Ratio = 12 * 0.35 = 4.2\ in$$

STEP 2 Determine the runoff volume for the 100-year event: As a simplified site, and using Equation 6.7, the 100-year event volume is calculated as:

$$V_{100} = \frac{11{,}750\ cf}{Impervious\ Acre} * acres = 11{,}750 * 0.34\ acres = 3{,}995\ cf$$

STEP 3 Determine the runoff volume for the 2-year event: From Equation 7, the 2-year event is calculated as:

$$V_{2} = \frac{3{,}541\ cf}{Impervious\ Acre} * acres = 3{,}541 * 0.34\ acres = 1{,}204\ cf$$

STEP 4 Determine the actual detention volume and confirm it is sufficient for a 2-year storm event:

$$V_{provided} = Physical\ Size\ of\ Practice\ (sf) * EWD\ (ft) = 5{,}000\ sf * \left(\frac{4.2}{12}\right) = 1{,}750\ cf$$

The actual volume is greater than the 2-year event volume. As a result, this practice is eligible for a peak flow credit.

STEP 5 Calculate the peak flow credit:

$$Peak\ Flow\ Credit\ (\%) = \frac{V_{provided}}{V_{100}} * 100 = \frac{1{,}750\ cf}{3{,}995\ cf} * 100 = 44\%$$

STEP 6 Determine the practice credit:

$$Practice\ Credit\ (\%) = Volume\ Credit * 0.4 + Peak\ Flow\ Credit * 0.4 = 97\% * 0.4 + 44\% * 0.4 = 56.4\%$$

PERMEABLE PAVEMENT PEAK FLOW CREDIT CALCULATION (continued)

STEP 7 Determine the site credit:

$$Site\ Credit\ (\%) = \frac{Managed\ Impervious}{Total\ Impervious} * Practice\ Credit\ (\%) = \frac{15{,}000\ sf}{17{,}500\ sf} * 56.4\% = 48.34\%$$

Detention Ponds and Detention Volumes Provided in Other Practices

Detention practices target large storms to limit the peak flow rate that discharges into the sewer system. Their primary function is to store a specified volume and release it slowly over a defined period of time.

The two most popular examples of detention practices are open surface detention basins and subsurface storage chambers.

Detention basins can either be dry or wet. Dry detention basins are large facilities designed without a permanent pool of water. The outlets are designed such that storm water runoff is detained for a period of time, typically 24 hours to 72 hours.

Underground retention/detention may be useful for developments where land availability and land costs limit the use of surface detention practices and in retrofit and redevelopment settings. Pretreatment is crucial for maintaining proper functionality of the storage practice and should be designed to remove sediment, floatables, and oils if prevalent in the drainage area.

Dry Detention Basin

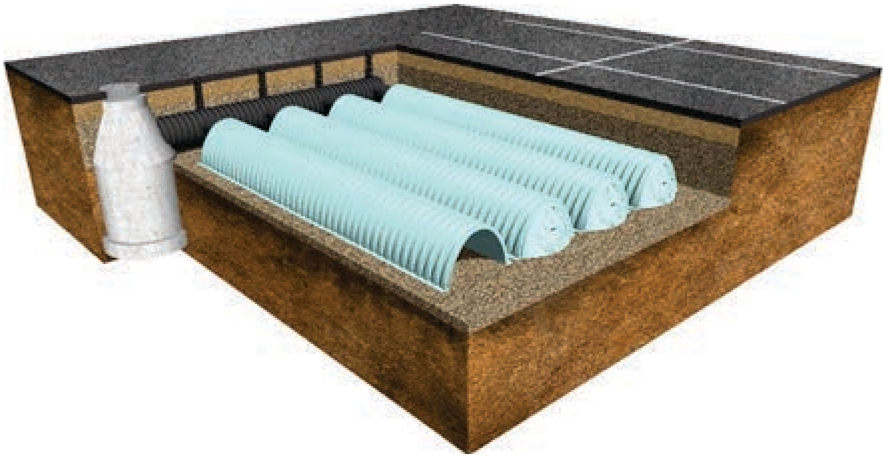

Figure 20: Subsurface Detention Chambers

The peak flow credit is based on the fraction of volume detained relative to the volume associated with a ***100-year storm event***. The detention system must also have a controlled release rate. The ***controlled release rate*** is intended to control flow rates into the combined sewer system, reducing the likelihood of a combined sewer overflow discharge and the risk of flooding. Unless the detention practice provides retention capabilities, detention practices are not eligible for volume credits.

The items that impact the peak flow credit for detention is volume detained and release rate.

- **Volume Detained:** The maximum peak flow credit is provided for detention practices that can store the 100-year storm event. This volume is generally determined using *standard detention calculations*.

The *volume* detained is considered the:

Constructed volume in practice *plus* additional volume in influent sewers minus volume designated for sediment storage

The **minimum** *volume detained* must be sufficient for the two year event to be eligible for a peak flow credit:

- **Volume Eligible for Credit:** The volume to be considered in the calculation may include sewers tributary to the detention practice. Only that volume that is below the emergency overflow will be considered for a peak flow credit. The volume must be provided in an intentional storm water practice or its tributary sewers to be considered as detention volume.
- **Sediment Storage:** Detention practices need planned locations to manage sediment so that they do not reduce the performance of the detention area. A sediment trap upstream of the practice can assist in this objective. The designer may either:
    - Install a manufactured treatment device upstream of the practice from which sediment is routinely removed; or
    - Install a sediment forebay and/or sediment storage area upstream of the detention practice.
- **Outlet:** A requirement associated with the drainage charge credit is that the outlet is controlled to reduce discharge rates to the sewer system during storm events.
    - **Release Rate:** 0.15 cfs/acre (release rate based on all tributary acres, not only impervious acres).
    - **Dewatering:** 24-72 hours.
- **Emergency Overflow or Bypass:** A planned emergency overflow or detention bypass must be provided in the event the system is full.

Detention Basin Calculations

The primary calculation for the required detention volume and associated peak flow credits is shown in the following detention pond calculation example.

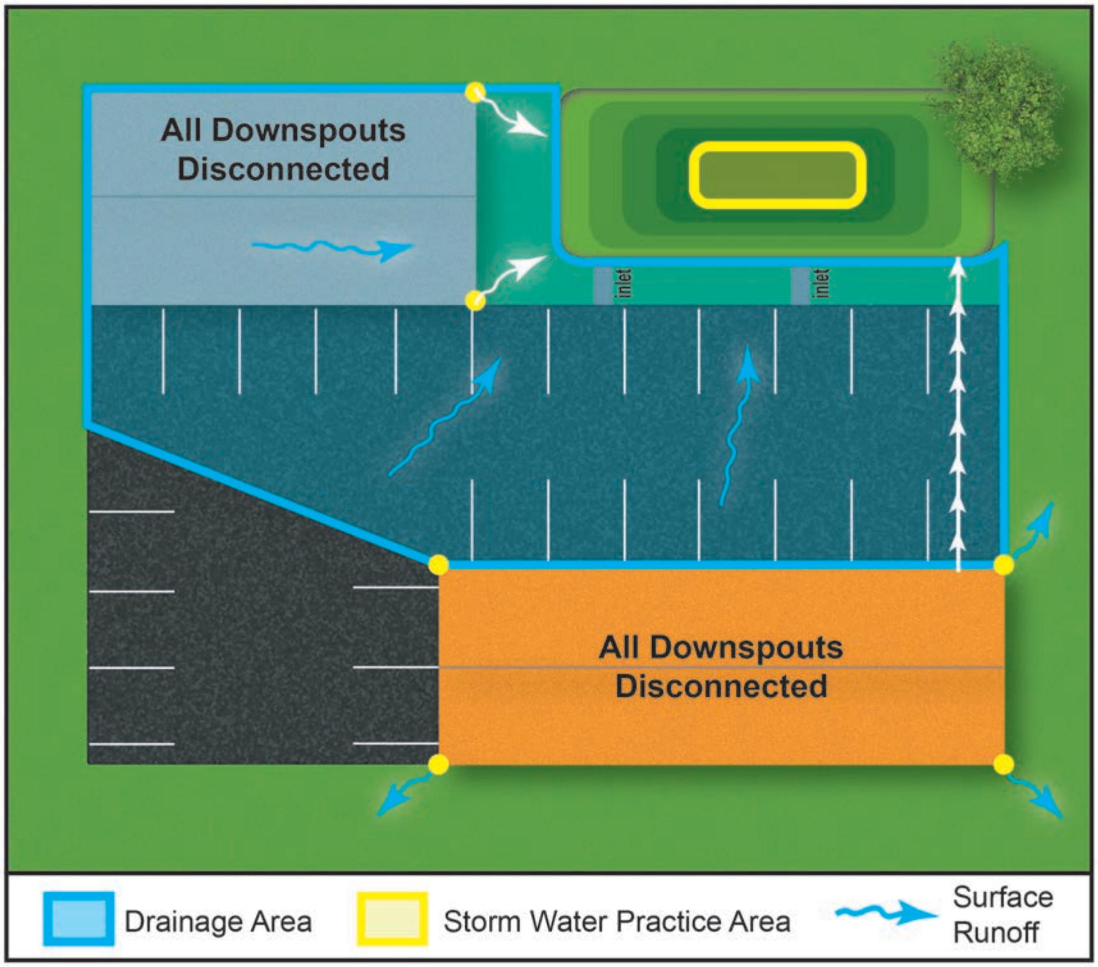

Figure 21: Schematic for Detention Pond Calculation Example

DETENTION POND CALCULATION EXAMPLE

The owner of a commercial shopping center is applying for a peak flow credit for a proposed detention pond on the corner of the property. The owner is able to direct runoff from 3.2 acres of impervious area to a detention practice that has a storage volume of 30,000 cubic feet. The outlet from the practice controls flow to no more than 0.15cfs/acre of tributary area.

- Tributary Area = 3.2 acres of impervious area
- The total site impervious area is 4.0 acres
- The Rational Coefficient is treated as 1 since pervious area is ignored
- The allowable discharge rate [Q_R] for the 100-year storm event (presumed to be 0.15 cfs/acre) is achieved
- The pond has an approved manufactured treatment device to remove solids

STEP 1 Determine the volume required. As the simplified impervious only site is used in this calculation, the volume required per acre for the 100-year and 2-year storms respectively is:

$$V_{100} = 11{,}750 \text{ cf} / (\text{impervious acre}) * \text{acres} = 11{,}750 * 3.2 \text{ acres} = 37{,}600 \text{ cf}$$

$$V_{2} = 3{,}541 \text{ cf} / (\text{impervious acre}) * \text{acres} = 3{,}541 * 3.2 \text{ acres} = 11{,}331 \text{ cf}$$

STEP 2 Confirm that the volume provided excludes solids management volume. As this site includes a manufactured treatment device on the site, $V_{provided}$ is equal to the volume of the detention practice.

STEP 3 Confirm that the volume provided is sufficient for a 2-year storm event.

$$V_{provided} = 30{,}000 \text{ cf which is greater than } 11{,}331 \text{ cf}$$

STEP 4 Calculate the peak flow credit based on the proposed size of the detention pond.

$$\text{Peak Flow Credit } (\%) = \frac{V_{provided}}{V_{100}} = \frac{30{,}000}{37{,}600} * 100 = 80\%$$

STEP 5 Calculate the practice credit for the detention pond.

$$\text{Practice Credit } (\%) = \text{Peak Flow Credit} * 0.4 = 80\% * 0.4 = 32\%$$

DETENTION POND CALCULATION EXAMPLE (continued)

STEP 6 Calculate the site credit by prorating for the overall impervious area.

$$Site\ Credit\ (\%) = Practice\ Credit\ (\%) * \frac{Managed\ Impervious}{Total\ Impervious} = 32\% * \frac{3.2\ acres}{4.0\ acres} = 25.6\%$$

Green Roof

Green roofs are built to a number of different standards that cannot be accommodated in standardized credit methodologies. DWSD recommends that volume reductions resulting from green roof construction be calculated using the EPA National Stormwater Calculator or results of monitoring efforts. Green roofs may offer significant annual volume reductions however they typically do not provide measureable benefits for peak flow control.

Water Harvesting

Water harvesting and water reuse operations can significantly reduce the average annual volume release from a site. The reduction is primarily a function of the storage volume provided and the amount of water reused on site. The storage volume provided may offer some peak flow control as well if sized and managed properly. The calculations for water harvesting operations are site specific and more advanced.

DWSD has developed a water balance calculator for systems that reuse stored storm water for irrigation or non-irrigation purposes.

Information that is needed to determine the practice volume credit:

- **Impervious Area Tributary to Pond:** The impervious area generating runoff to the storm water practice.
- **Pervious Area Tributary to Pond:** The pervious area generating runoff to the storm water practice.
- **Turf Area for Irrigation:** This is the turf area that is suitable for irrigation and for which a sprinkler system has been installed.
- **Pond Surface Area:** This is the open water area associated with the low pool of the storm water pond. It is used to calculate evaporation from the pond. If water storage is in a closed system, the pond surface area is zero.
- **Available Pond Volume:** This is the available storage volume of the pond above minimum pool elevation and below the outlet elevation.
- **Flow Capacity of Irrigation System:** This is the capacity of the irrigation system to dewater stored runoff in gallons per minute.
- **Designed Min Storm Water Reuse Flow Rate:** If water is reused for other operation, this is the System's average flow rate during normal operation.

For properties that are seeking a water reuse credit, monitoring of the system is required. Monitoring is intended to confirm continued operation of the reuse system and that the system is performing in reasonable agreement with the expectation at the time of the credit. The example shown in Table 5 and Figure 22 qualifies for a 90.9% annual volume credit.

TABLE 5 - Input Data Required for Water Reuse Calculator		
Input Data		
Uncontrolled Impervious Area to DWSD Sewer	0.00	acres
Impervious Area Tributary to Pond	17.43	acres
Pervious Area Tributary to Pond	21.03	acres
Turf Area for Irrigation	0	acres
Pond Surface Area	1.707	acres
Available Pond Volume	342,378	cu ft
Flow Capacity of Irrigation System	0	gpm
Design of Storm Water Process Reuse Flow Rate	100.0	gpm

OWNER:	XYZ Enterprises	BY:	DWSD
ADDRESS:	1225 Anywhere Street	DATE	October 1, 2016
DESCRIPTION OF SITE:	This property is a manufacturing facility that is installing a detention pond. Water from the detention pond will be reused for process in the manufacturing operation.		

User Instructions: Input the values noted in the "Input Data" section. The spreadsheet will calculate the fraction of annual rainfall that is an accepted reuse/ evaporation volume. This is a prototype tool for use in drainage charge calculations. The property owner may supply alternate calculations if desired.

Input Data			Description
Uncontrolled Impervious Area to DWSD Sewer	0.00	acres	This is the area generating uncontrolled runoff directly discharging to a DWSD combined sewer
Impervious Area Tributary to Pond	17.43	acres	This is the impervious area generating runoff to the stormwater practice
Pervious Area Tributary to Pond	21.03	acres	This is the pervious area generating runoff to the stormwater practice
Turf Area for Irrigation	0	acres	This is the turf area that is suitable for irrigation and for which a sprinkler system has been installed
Pond Surface Area	1.707	acres	This is the open water area associated with the low pool of the stormwater pond.
Available Pond Volume	342,378	cu ft	This is the available storage volume of the pond above minimum pool elevation and below the outlet elevation.
Flow Capacity of Irrigation System	0	gpm	This is the capacity of system to dewater stored runoff in gallons per minute. If unknown, leave blank.
Design Stormwater Process Reuse Flow Rate	100.00	gpm	This is the average process reuse flow rate during normal operation. Assumed to operate 24/7.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Initial Abstraction Impervious, Inches/Event	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	-
Monthly Excess Precipitation for Impervious Area, Inches	1.57	1.56	2.00	2.76	2.76	3.11	2.94	2.86	2.54	1.99	2.21	2.17	28.46
Conversion Ratio for Impervious Area to Runoff (0-1)	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	-
Initial Abstraction Pervious, Inches/Event	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	-
Monthly Excess Precipitation for Pervious, Inches	1.03	1.07	1.34	2.04	2.09	2.45	2.24	2.21	1.93	1.44	1.59	1.53	20.97
Conversion Ratio for Pervious Area to Runoff (0-1)	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	-
Monthly Runoff to Pond - Impervious Area, Inches	1.41	1.40	1.80	2.48	2.48	2.80	2.64	2.57	2.29	1.79	1.98	1.95	25.61
Monthly Runoff to Pond - Pervious Area, Inches	0.41	0.43	0.54	0.81	0.84	0.98	0.90	0.88	0.77	0.58	0.64	0.61	-
Monthly Runoff to Pond, Cubic Feet	132,614	132,742	169,269	228,457	240,022	272,871	255,622	249,892	221,143	171,135	188,614	185,683	2,459,064
Monthly Runoff Directly to DWSD, Cubic Feet	0	0	0	0	0	0	0	0	0	0	0	0	0
Manual Discharge All Volume to DWSD, Yes/No	Yes	Yes	No	No	No	No	No	No	No	No	No	Yes	-
Manual Discharge to DWSD, Cubic Feet	132,614	132,742	0	0	0	0	0	0	0	0	0	194,659	460,015
Average Volume in Pond Per Event, Cubic Feet	0	0	2,597	8,038	12,055	22,305	17,999	15,875	21,125	8,078	7,227	0	-
Monthly Runoff in Excess of Pond to DWSD, Cubic Feet	0	0	0	0	0	1,716	2,658	2,443	3,853	761	432	0	11,874
Potential Water Reuse, Gallon/Minute	100	100	100	100	100	100	100	100	100	100	100	100	-
Potential Water Reuse, Cubic Feet/Day	19,250	19,250	19,250	19,250	19,250	19,250	19,250	19,250	19,250	19,250	19,250	19,250	-
Water Reuse Cubic Feet/Month	0	0	164,677	230,665	228,890	264,695	252,508	242,853	224,731	170,110	185,572	0	1,964,702
Soil/Plant Irrigation Potential, Inches/Day	0.00	0.00	0.00	0.11	0.21	0.21	0.21	0.21	0.21	0.21	0.11	0.00	-
Soil/Plant Irrigation Potential, Inches/Month	0.0	0.0	0.0	3.2	6.6	6.4	6.6	6.6	6.4	6.6	3.2	0.0	45.86
Soil/Plant Irrigation Potential, Cubic Feet/Month	0	0	0	0	0	0	0	0	0	0	0	0	0
Irrigation System Capacity, Gallon/Minute	0	0	0	0	0	0	0	0	0	0	0	0	-
Irrigation System Potential, Cubic Feet/Month	0	0	0	0	0	0	0	0	0	0	0	0	-
Irrigation Usage, Cubic Feet/Month	0	0	0	0	0	0	0	0	0	0	0	0	0
Monthly Pan Evaporation Rate, Inches/Month	0.87	1.21	2.16	3.69	5.43	6.54	6.85	5.9	4.17	3.07	1.62	1.00	42.51
Pan Evaporation Conversion Factor	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	-
Monthly Evaporation Rate Potential, Inches/Month	0.61	0.85	1.51	2.58	3.80	4.58	4.80	4.13	2.92	2.15	1.13	0.70	29.76
Potential Evaporation from Pond, Cubic Feet	0	0	407	1,650	2,481	5,304	4,891	3,636	2,648	932	524	0	22,473
Total Monthly Runoff Generated, Cubic Feet	132,614	132,742	169,269	228,457	240,022	272,871	255,622	249,892	221,143	171,135	188,614	185,683	2,459,064
Total Monthly Runoff to DWSD Sewer, Cubic Feet	132,614	132,742	0	0	0	1,716	2,658	2,443	3,853	761	432	194,659	471,888

Annual Percent Reduction in Runoff from All Impervious Area:	90.9%	Annual Percent Reduction in Runoff from Controlled Impervious Area:	90.9%

Figure 22: Water Reuse Calculator Spreadsheet

Peak flow credits will be available based on the total volume in the storage, the frequency at which it may be exceeded based on a long term continuous simulation and the median available volume based on a long term continuous simulation.

Exploratory Technologies

Exploratory storm water practices can be used by the property owner. Exploratory technologies are generally patented or other proprietary practices for which performance is not well documented in the engineering community. The property owner will be responsible for performance verification monitoring for a period of time (minimum of one year) to quantify the performance of the practice.

Hydrologic Computational Methods

In addition to the various computational methods previously described, DWSD accepted standard engineering calculations for the determination of storm water practice performance. Table 6 lists the common methods, all of which are acceptable to use.

TABLE 6 - Hydrologic Computational Methods

Method	Description
Rational and Modified Rational Method	**The Rational Method dates back to 1889 and was originally used to only estimate the peak discharge from a storm event. More recently it has been applied as a linear relationship between rainfall and runoff. The Modified Rational Method is used for detention storage sizing.**
Curve Number Hydrology	**The Natural Resources Conservation Service (NRCS) curve number (CN) method may be used to estimate the direct runoff volume from a storm event. When coupled with a unit hydrograph approach, the curve number method may be used to estimate a complete runoff hydrograph.**
EPA National Stormwater Calculator (SWC)	**EPA's National Stormwater Calculator (SWC) is a desktop application that estimates the annual amount of rainwater and frequency of runoff from a specific site in the United States. The SWC does not model discrete design storms, flood control storage systems or pipe conveyance. More information and a download for the calculator can be found here:** https://www.epa.gov/water-research/national-stormwater-calculator
EPA Storm Water Management Model (SWMM)	**USEPA's SWMM is a public domain software. SWMM is a comprehensive hydrologic and hydraulic modeling software. Recent updates allow the user to integrate storm water practices into a management system. More information and downloads can be found at:** https://www.epa.gov/water-research/storm-water-management-model-swmm

Simple, Moderate and Complex Approaches

EPA SWMM is the preferred hydrologic/hydraulic model for modeling storm water drainage in an urban setting. Recognizing the inherent complexities of SWMM and the technical expertise required, the simpler approaches previously described have been developed using SWMM simulations which have been simplified into equations. The Rational, Modified Rational and Curve Number methods are typically applied in a spreadsheet calculation. By themselves the methods do not model storm water practices such as bioretention and porous pavement. Separate calculations are incorporated to simulate the effects of storage and infiltration.

Sites implementing several practices to manage storm water, specifically when the practices are arranged in series, may be required to use more sophisticated calculation approaches to demonstrate the net result.

Volume Credit

The volume credit is determined based on long term average rainfall data. DWSD's non-residential credits are based on approximately 50 years of continuous rainfall data. The necessary continuous rainfall data is built into the information presented in earlier sections of this guide.

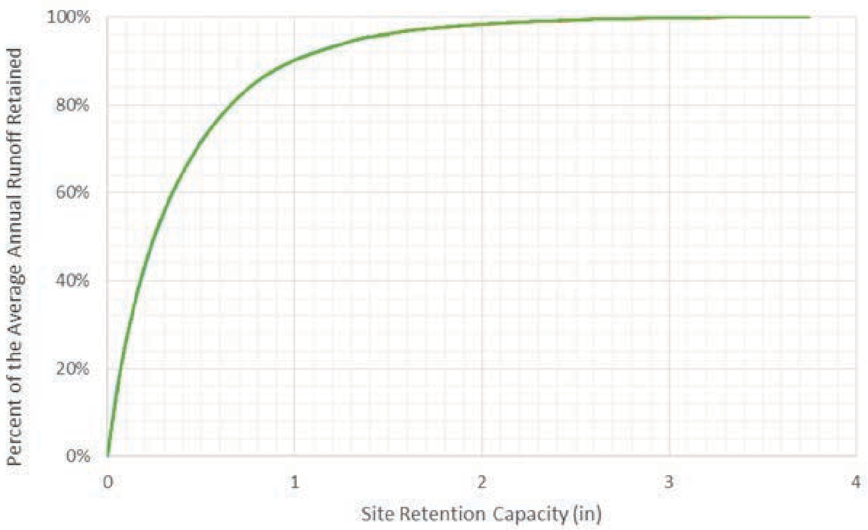

Figure 23: Annual Runoff Retained Relationship

Retention Capacity (in)	Percent Retained
0	0.0
0.1	26.9
0.2	43.5
0.3	55.6
0.4	64.7
0.5	71.8
0.6	77.3
0.7	81.7
0.8	85.3
0.9	88.1
1	90.2
1.1	91.8
1.2	93.2
1.3	94.4
1.4	95.3
1.5	96.1
2	98.3
3	99.8
3.75	100.0

For applicants using more sophisticated hydrologic tools, such as the National SWC or SWMM, a minimum of 10 years of continuous rainfall data must be used in calculating the volume credit. Necessary rainfall information can be obtained from the National SWC. When using EPA SWMM long term rainfall records will need to be downloaded from the National Weather Service.

An alternative to explicitly modeling the long term rainfall is to use the non-exceedance rainfall data in the chart for Figure 23. This chart presents the relationship between the Site Retention Capacity and the average annual runoff retained. For example, if the first 1-inch of every rainfall event was retained on site, that is equivalent to retaining 85% of the annual volume. This is the relationship used in the volume credit

Peak Flow Credit

Peak flow credits are based on providing the necessary detention storage volume for a minimum of a 2-year and a maximum of a 100-year storm event. A requirement for obtaining the peak flow credit is that the outlet from the storm water practice is controlled at 0.15 cfs/acre. The simplified relationships presented in Section 6.3.4 are based on a variation of the Modified Rational method.

Generally, double counting the retention volume used for volume reduction and the detention volume for the peak flow control is not allowed. However, flexibility is provided for complex systems that use extensive periods of continuous simulation, which is the use of historic rainfall data over an extended period of time. These typically involve some component of storm water reuse.