A Guide to Credits for Commonly Used Stormwater Management Practices

This guide discusses the most commonly used stormwater 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.

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Introduction

This guide discusses the most commonly used stormwater management 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 stormwater management 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 stormwater management practices to new, existing, and redevelopment sites and contains technical guidance and variations for the stormwater management practices eligible for credits. The LID Manual can be used to assist customers in designing their stormwater management 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 stormwater 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 stormwater management 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 (see Figure 5.2 in Chapter 5 and calculation examples in this section). As discussed in Chapter 5, 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.

Effective Porosity in Soil and Aggregate Layers

The effective porosity that is available in soil and aggregate layers is a determinant of the performance of the stormwater management practice. Many stormwater management practices rely on the temporary storage of stormwater in these layers. The effective porosity is dependent on the specific media.

In soil, the effective porosity 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 stormwater management practices rely on the temporary storage of stormwater 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 stormwater management 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:

Equivalent Water Depth (in)
*= surface storage (in)+(soil depth(in) * effective porosity)+(aggregate depth (in) * effective porosity)*

Figure 1 illustrates two stormwater management practice cross sections. The aggregate has an effective porosity of 0.30, the soil has an effective porosity 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 stormwater management 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.

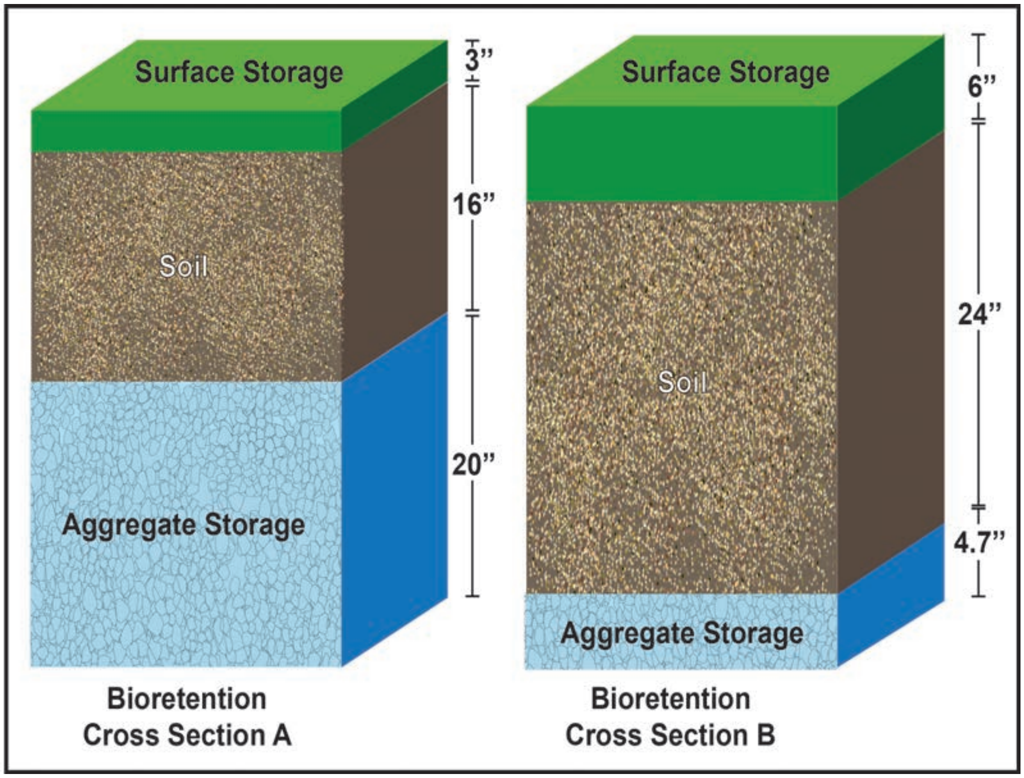


Figure 1: Equivalent Water Depth in Stormwater Practice Cross Section

TABLE 1 - Maximum Equivalent Water Depths in Retention Zone of a Stormwater Management 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

Stormwater management 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.

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

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

Detention: The ability to temporarily store stormwater 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 stormwater management practice.

For water storage provided above the side slopes, different methodologies for calculating the volumes detained and retained can be submitted for evaluation as long as the methodology is supported with calculations, justifications, and assumptions. No volume credit will be given for infiltration on the side slopes as typically the side slopes are compacted during construction activities.

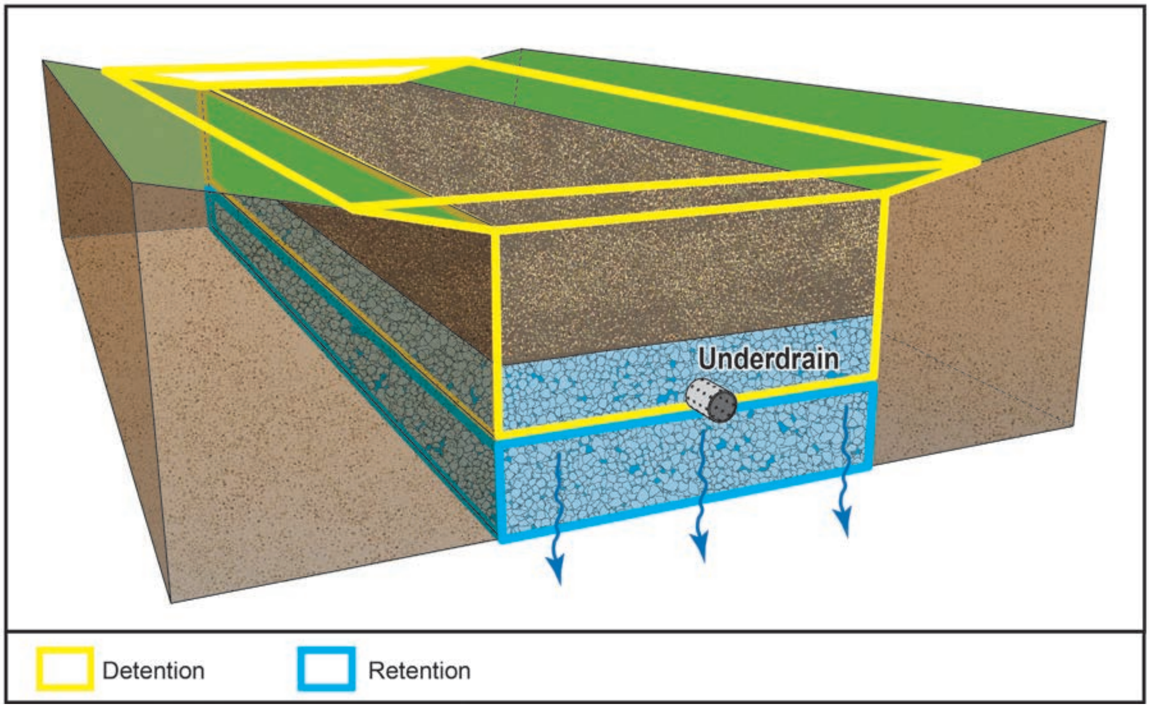


Figure 2: Retention Versus Detention Components of Bioretention Practices

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.

Retention and Detention Determined by Underdrain Outlet Elevation

Most stormwater management 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.

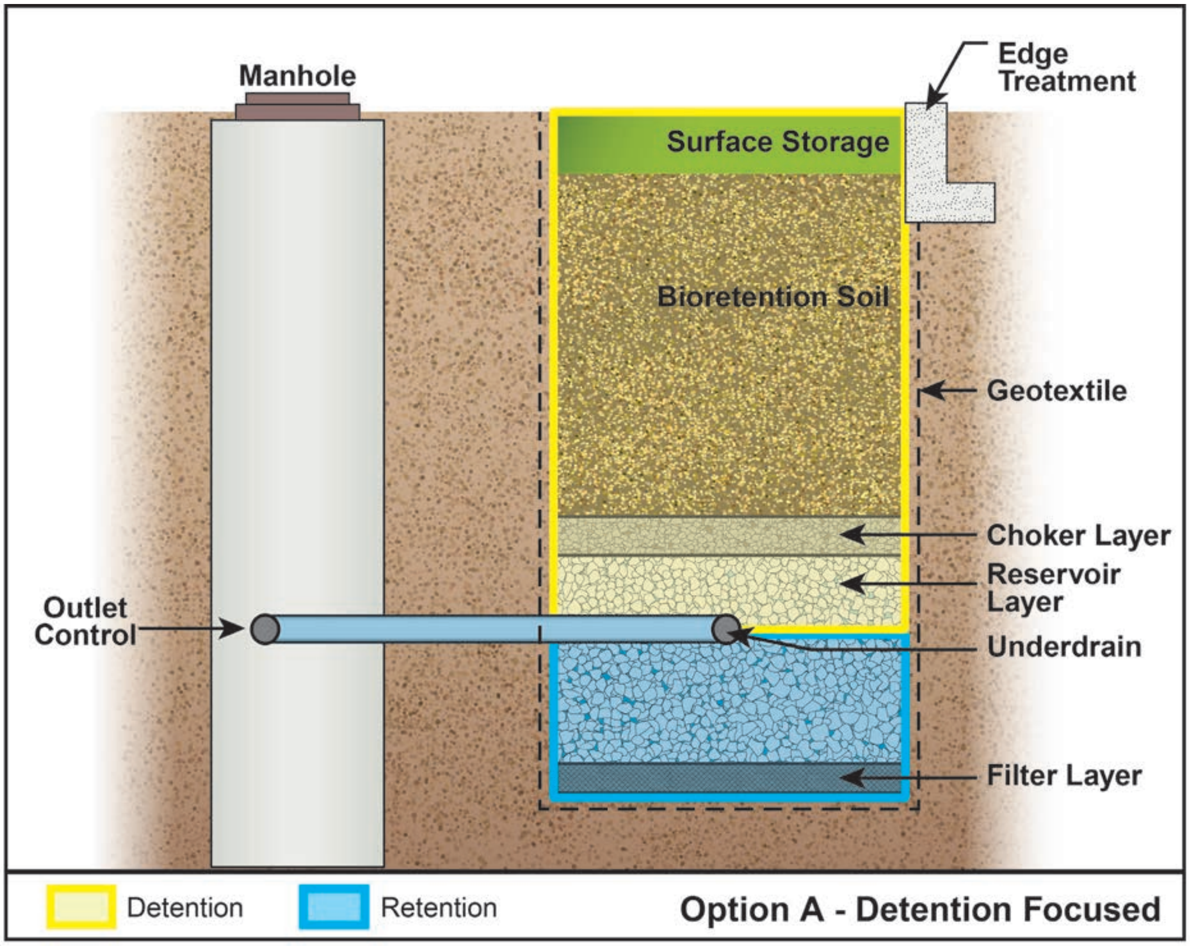


Figure 3: Standard Outlet Underdrain: Majority of Equivalent Water Depth Used for Detention

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.

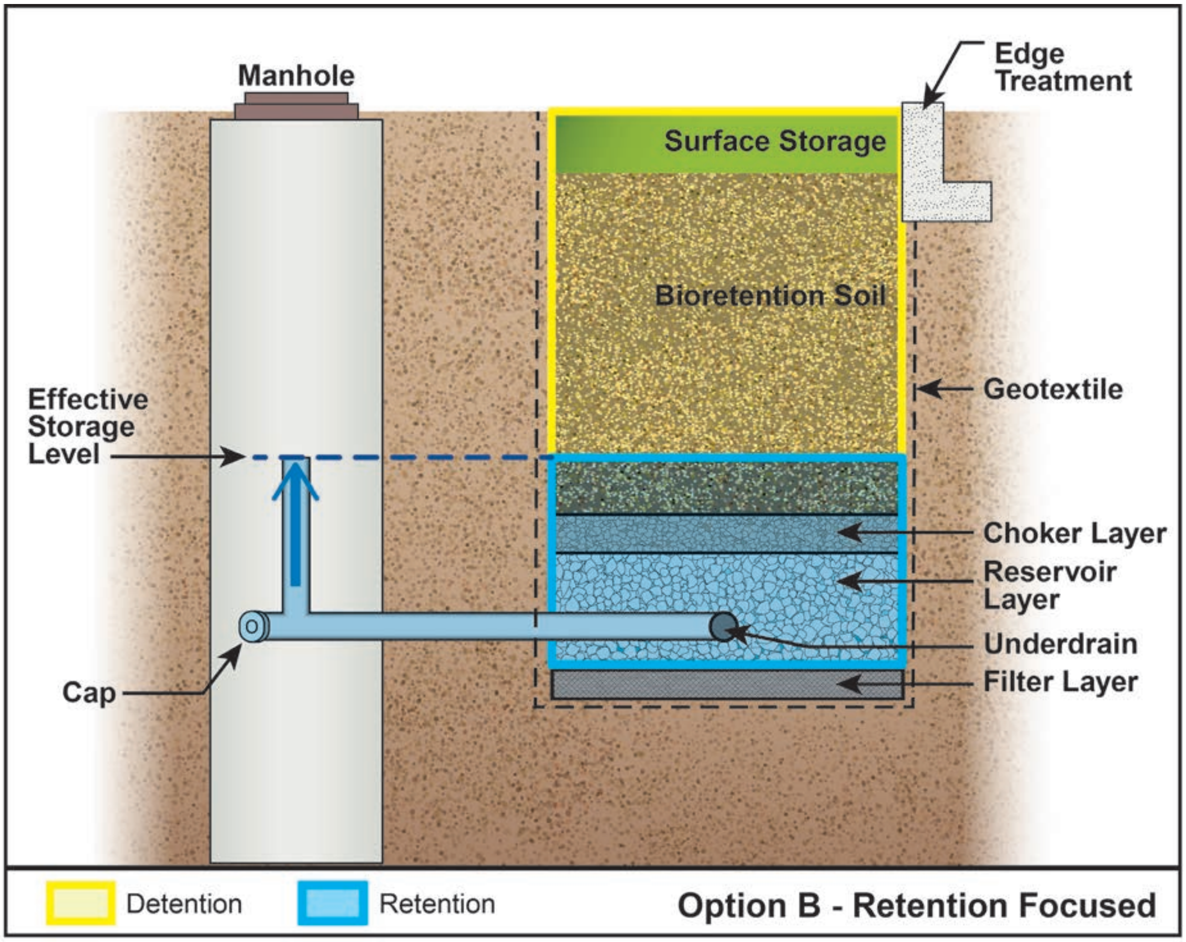


Figure 4: Upturned Elbow Outlet Underdrains: More Equivalent Water Depth Used for Retention

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 stormwater management 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 stormwater management 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 stormwater management 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 inches per hour infiltration rate is permitted.

Stormwater Management Practice Ratio

The practice ratio uses the concept of a stormwater practice area. The “practice ratio” is a comparison of the stormwater practice area to the drainage area. The definition of the stormwater practice area is specific to each practice type (see Table 2). The drainage area is the area draining to the stormwater management practice. This approach is used in the disconnected impervious method. The general formula for the practice ratio is:

Equation1

$$Practice\ Ratio = \frac{Stormwater\ Practice\ Area}{Drainage\ Area}$$

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

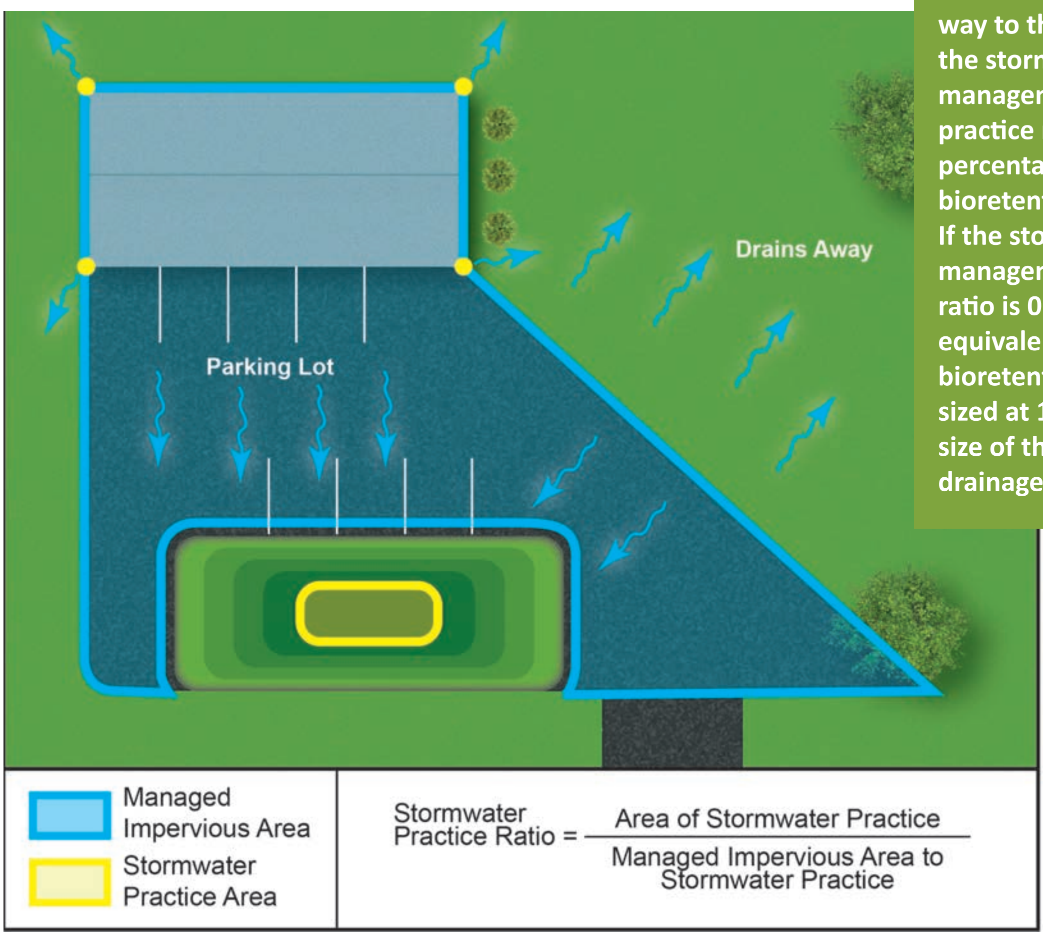


Figure 5: Stormwater Management Practice Ratio

Stormwater Practice Area

The stormwater 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 - Commonly Used Stormwater Practice Area Definitions

Practice Type	Stormwater Practice Area for Infiltration
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 for infiltration, 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.**

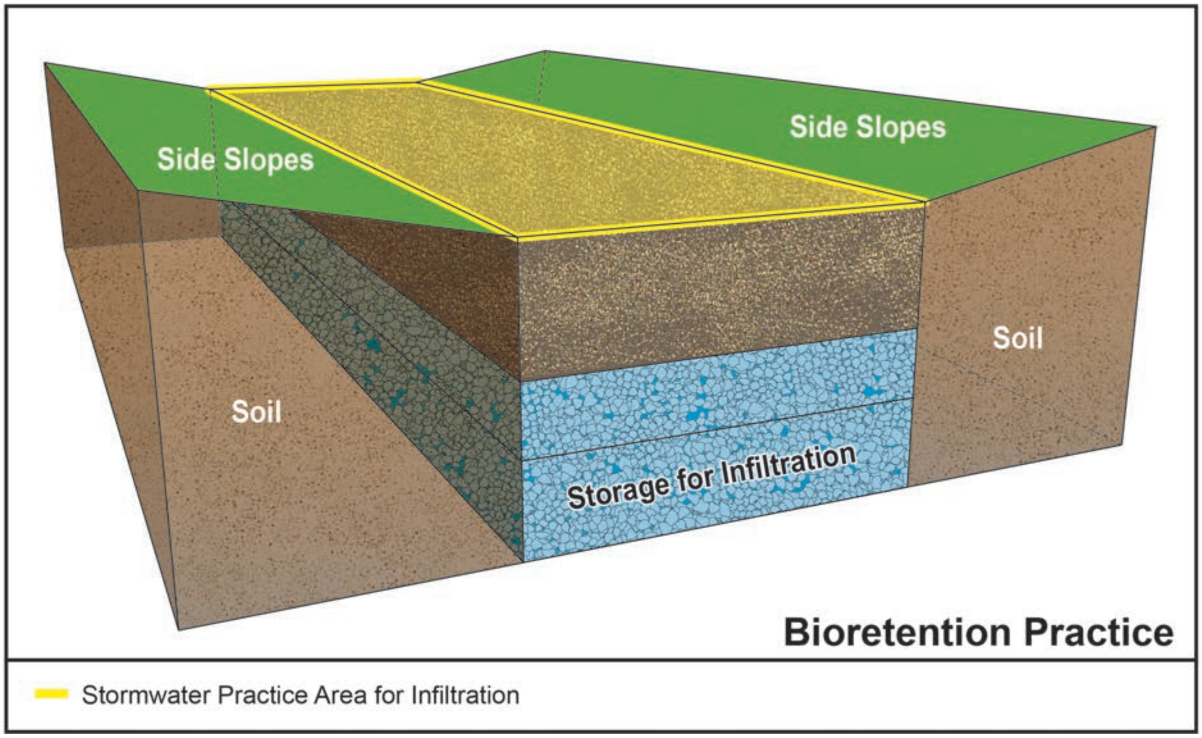


Figure 6: Bioretention Systems Practice Area for Infiltration

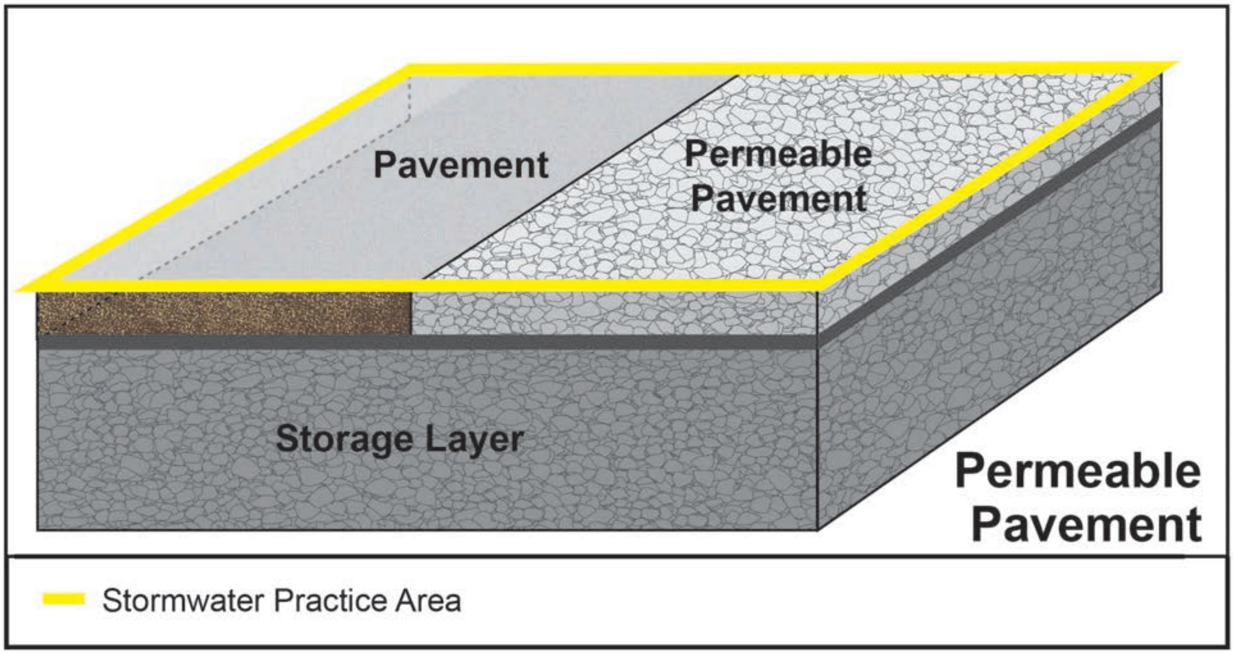


Figure 7: Permeable Pavement Practice Area

Drainage Area to the Stormwater Management Practice

The *Drainage Area*, in Equation1 is the area that is tributary to the stormwater management 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 stormwater management practice area for bioretention is the surface area of the bioretention not including the side slopes.

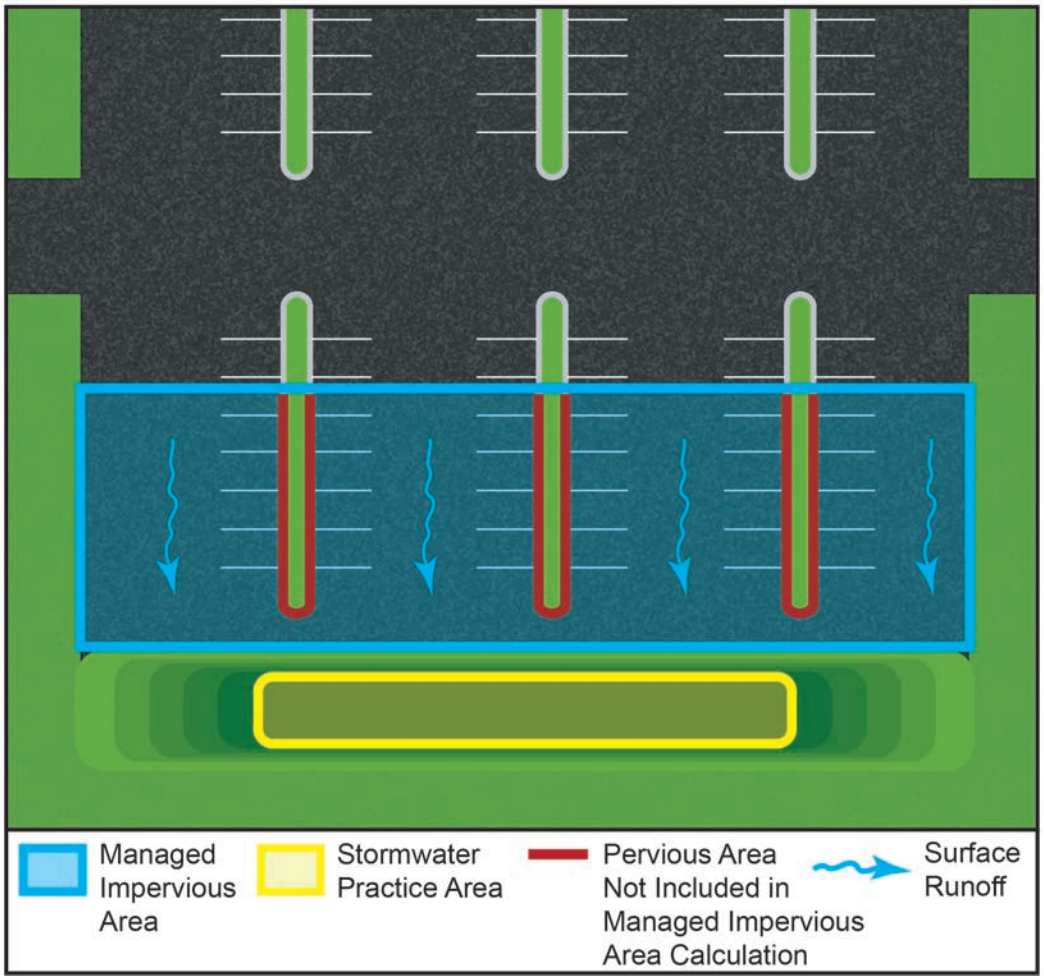


Figure 8: Managed Impervious Area to the Stormwater Management Practice

Credit Calculation Methods

A wide variety of options are available to quantify credits for the most commonly used stormwater management 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:

- **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 flexible to varying cross sections based on design. This method should be used 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 stormwater 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:

- **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 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 stormwater management 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 stormwater management practices in series or complex routing techniques. These may be used for sites where desired by the design professional.

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 Equation2. 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.

Equation2

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

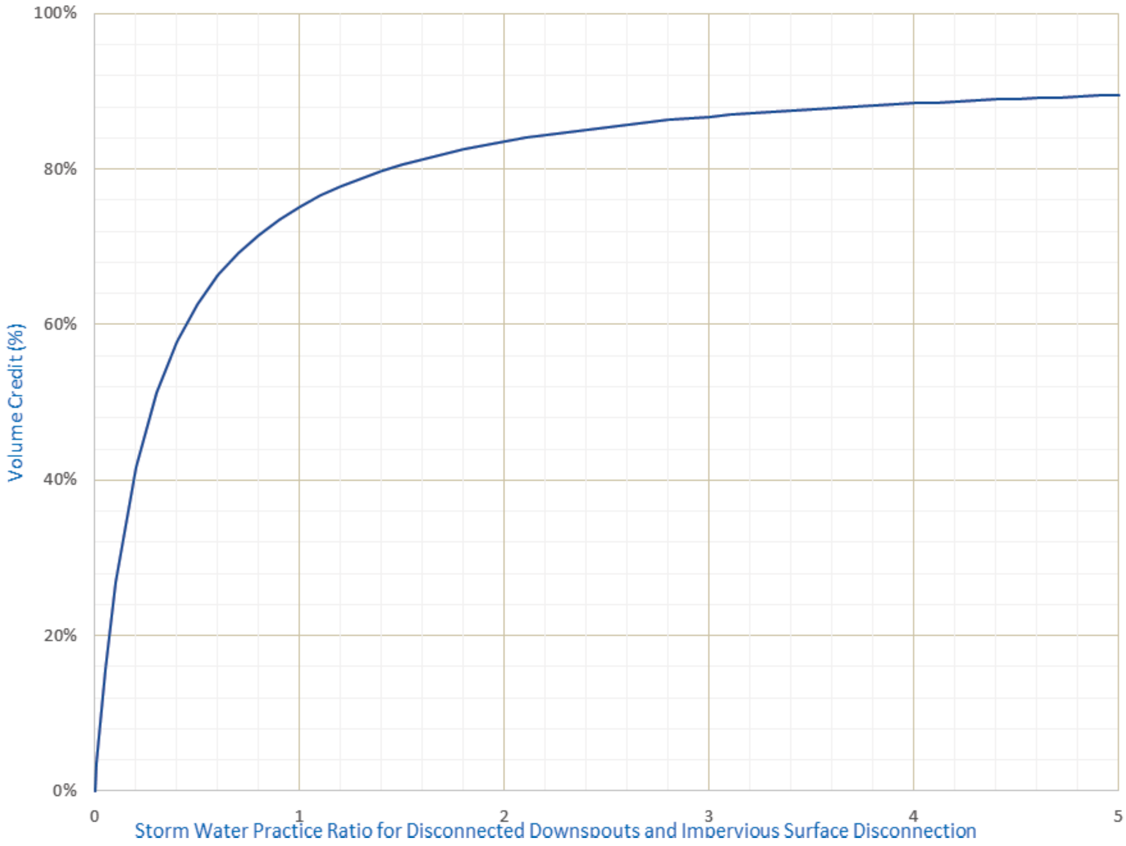


Figure 9: Disconnected Imperviousness Credit

For example, if the practice ratio is 2, then the corresponding volume credit is 84%. A stormwater management 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 calculated equivalent water depth will often be different than the values shown in Table 1.

The volumetric credit is then determined from the equation:

Equation3

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

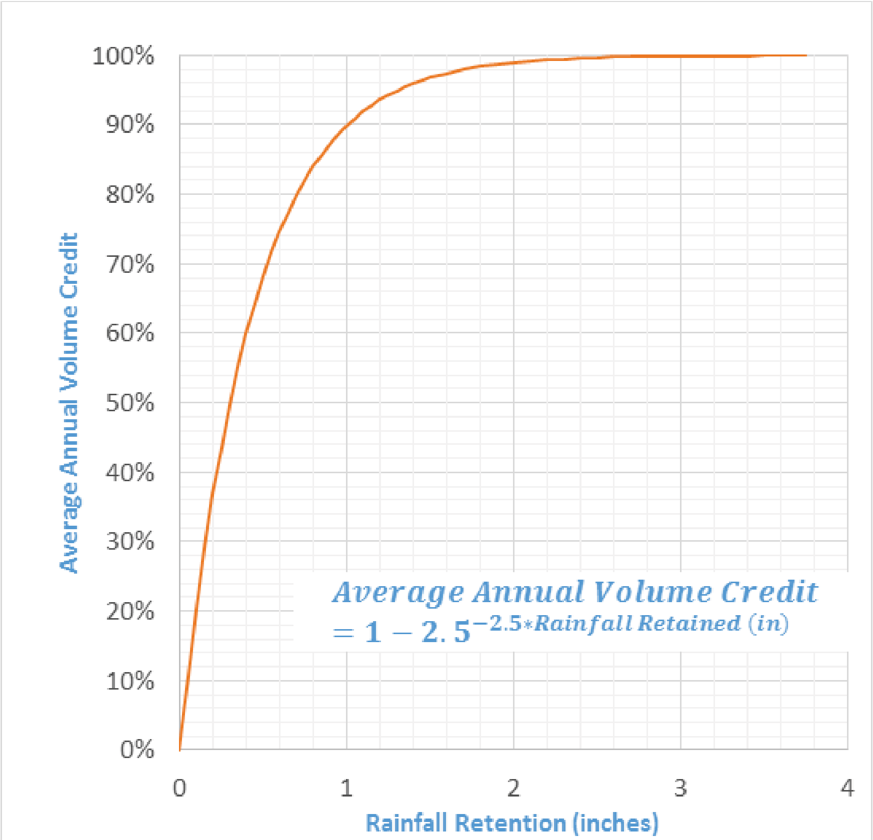


Figure 10: Equivalent Rainfall Depth Credit

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 commonly used practices);
- 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 should 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 stormwater management 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.

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

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

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

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

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

Note: The method shown simplifies runoff as equal to 100% of rainfall on impervious areas and 0% of rainfall on pervious areas.

STEP 5 Determine the volume credit from the regression equation.

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

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

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

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

This example assumes that the designer is working to size the stormwater management practice based on a desired credit. See the preceding example to determine a credit if the size of the stormwater management 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.

$$\text{Volume Credit (\%)} = (1 - 2.5^{-2.5r}) * 100$$
$$\text{where } r \text{ is the equivalent rainfall depth (in)}$$

STEP 4 Determine the necessary retention volume.

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

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 stormwater management practices. This methodology is based on the Modified Rational Method, which can be used for detention pond sizing. As a simplified 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:

- Drainage Area to the detention practice
- Rational Coefficient (can be ignored if >75% impervious)
- Allowable discharge rate for the 100-year, 24-hour 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, Managed Impervious Area (acres)
- C, Rational Coefficient (dimensionless)
- Q_R, peak allowable discharge rate for the 100-year, 24-hour storm event (cfs/acre)
- D, storm duration (minutes)
- I, rainfall intensity (inches per hour)
- t, recurrence interval (years)
- V_n, required detention volume for the n-year event (ft^3)

Equation4: Detention Volume (Modified Rational Method)

$$V_n = \text{Runoff Volume - Volume Released}$$
$$\text{where Runoff Volume} = D * C * I * A \text{ and Volume Released} = D * Q_r * A$$

Equation4 is rewritten with variables and shown in Equation 7. Basic calculations of variables are as follows:

The critical storm duration is based on Equation 6.5:

Equation 6: Critical Storm Duration for 2- and 100-Year 24-hour Storm Events

$$D_2 = 21.352 \left(\frac{Q_R}{C}\right)^{-0.998} \qquad D_{100} = 49.988 \left(\frac{Q_R}{C}\right)^{-0.984}$$

Simplified calculation (considering impervious areas only):
Q_R = 0.15 and C = 1, D_{100} = 323 minutes, D_2 = 142 minutes.

The rainfall intensity is calculated from Equation6:

Equation6: 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, 24-hour storm event, I = 0.75
2-year, 24-hour storm event, I = 0.64

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

Equation7: Volume Required for Selected Event

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

Plugging the provided values into Equation 6 and simplifying gives the following Equation for each storm:

Equations 7A and 7B: Volume required for 100-year, 24-hour and 2-year, 24-hour storm events

$$V_{100} = 11{,}750 \frac{cf}{Impervious\ Acre} * A\ (ac)$$

$$V_2 = 4{,}220 \frac{cf}{Impervious\ Acre} * A\ (ac)$$

The peak flow credit for the practice is then:

Equation 8: Detention Peak Flow Credit

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

APPLICATION OF THE 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, 24-hour 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, 24-hour event volume; or b) design for a lesser volume. The minimum volume that qualifies for a peak flow credit is the 2-year, 24-hour event volume (V_2 = 4,220 cf/ impervious acre). The peak flow credit is determined by Equation 8.

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

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.

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

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

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

Minimum Design Criteria for Credit Quantification

Minimum design criteria are identified for each commonly used stormwater management 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 stormwater 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 stormwater to infiltrate into the soil.

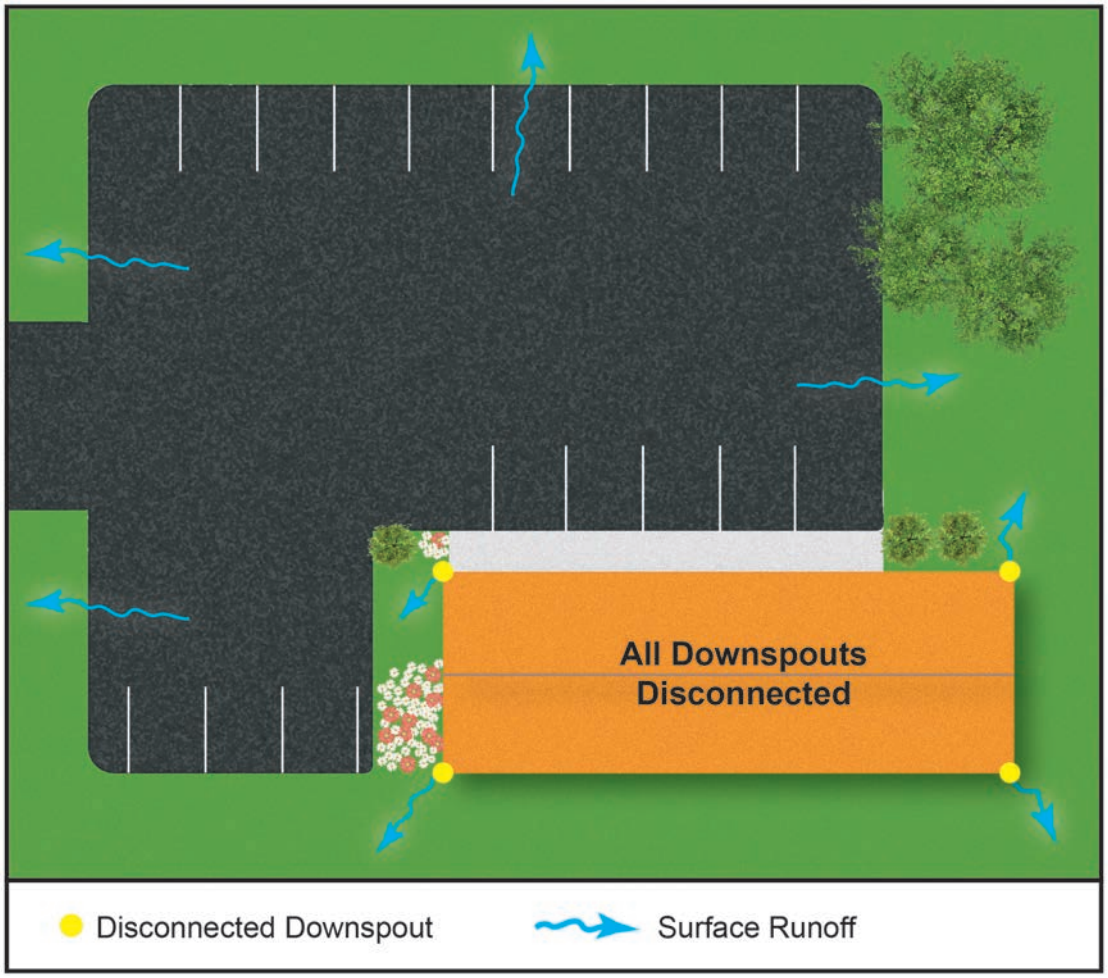


Figure 11: Disconnected Downspouts Draining to Pervious Area

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:

  - **Surface Area 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). 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.

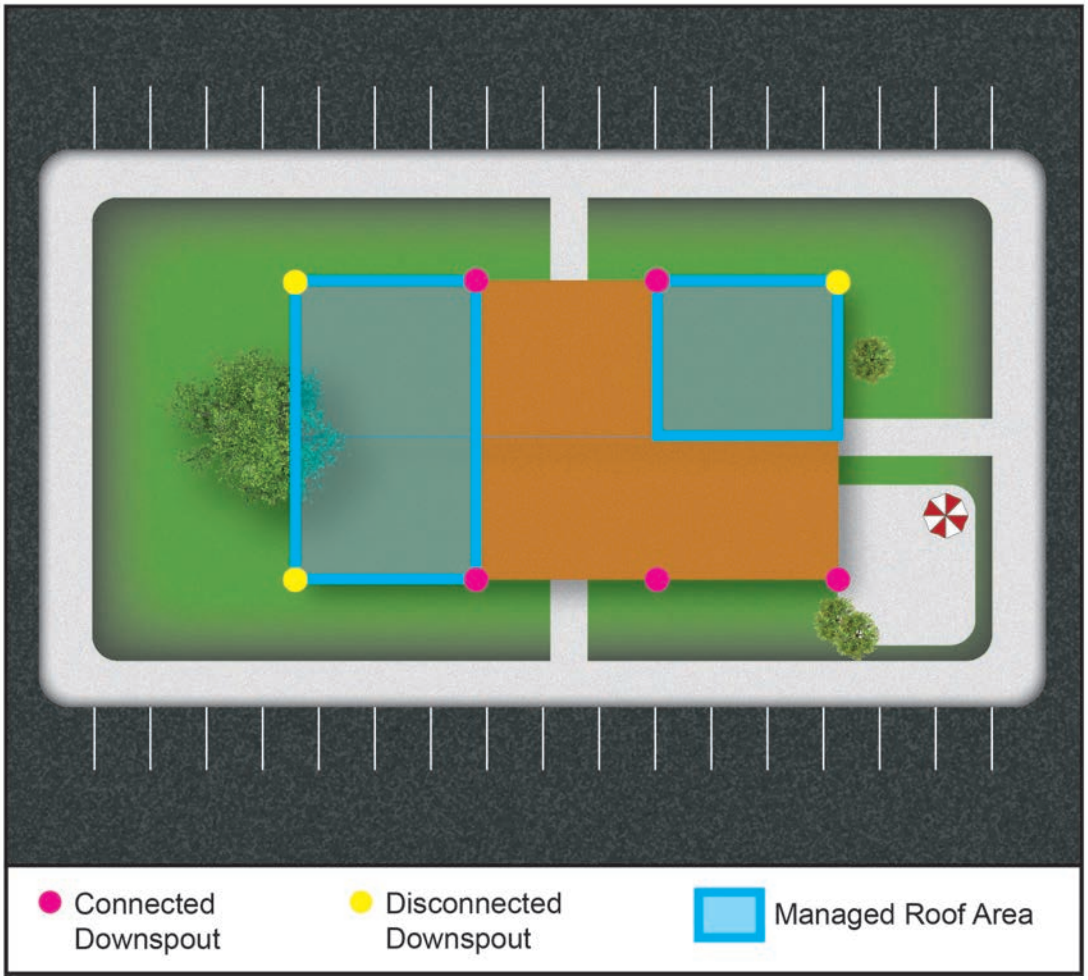


Figure12: Schematic for Downspout Disconnected Example

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 (sf) (roof and parking lot and sidewalk)
Roof Area: 2,800 sf, 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 Figure12 (varies from 20-25 feet).

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

STEP 2 Calculate the individual stormwater practice ratios:

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

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

STEP 3 Calculate the volume credit:

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

- Downspout 1: Volume Credit = 0.94 * (0.36/(0.25+0.36)) * 100 = 55%
- Downspout 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%

DOWNSPOUT DISCONNECTION EXAMPLE (continued)

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

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

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

STEP 5 Calculate the site credit:

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

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

$$Rounded\ Site\ Credit\ (\%) = 5.0\%$$

Impervious Surface Disconnection

Customers are eligible to receive an impervious disconnection credit by directing stormwater from impervious surfaces to pervious surface areas. Examples include driveways, impervious walkways and parking areas. Impervious surface disconnection allows stormwater 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 impervious drainage area 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:
  - **Surface Area 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). 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.

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 (A): 3,000 square feet (sf)
Total Site Impervious Area: 12,000 sf
Practice Area: 2,500 sf

STEP 1 Calculate the Practice Ratio:

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

STEP 2 Calculate the Volume Credit:

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

STEP 3 Calculate the practice credit:

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

STEP 4 Prorate the practice credit to the site:

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

$$\text{Rounded Site Credit (\%)} = 8.0\%$$

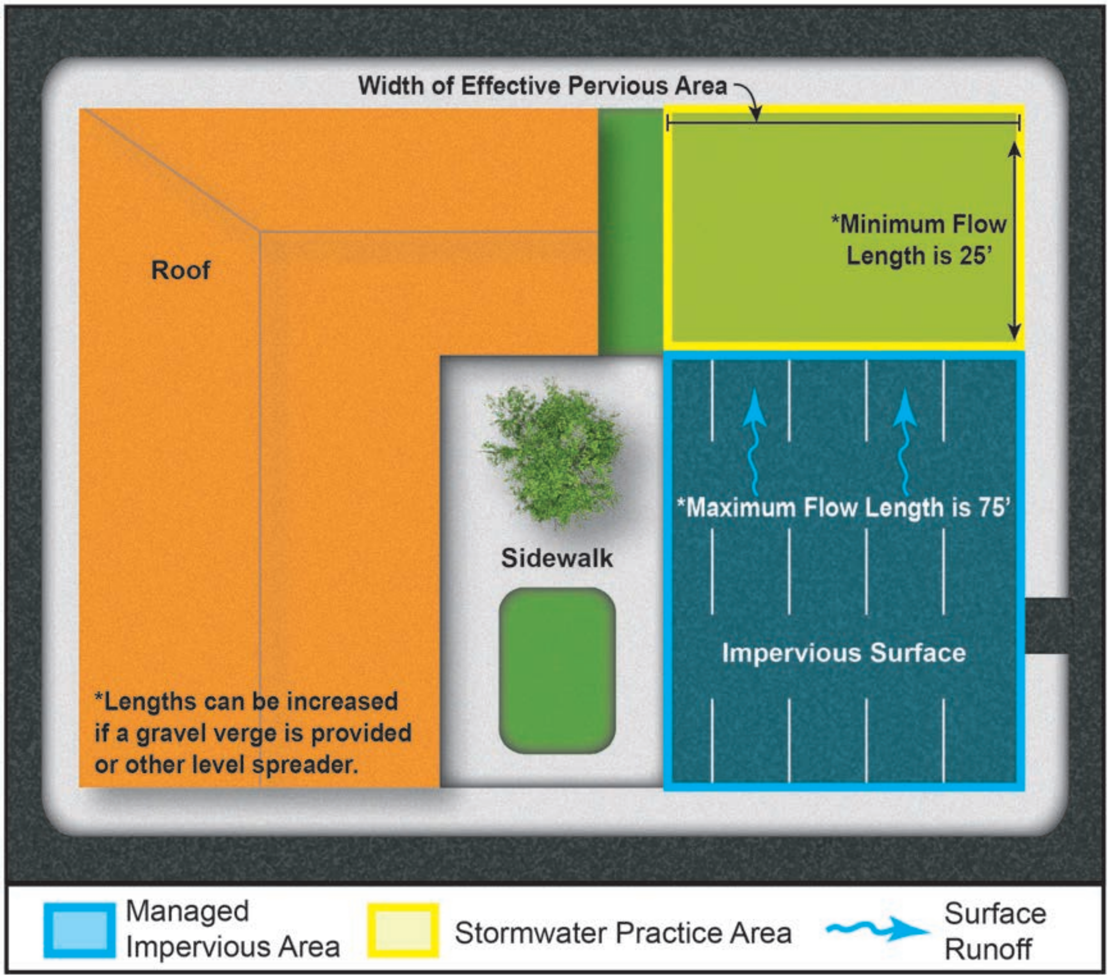


Figure 13: Schematic for Impervious Surface Disconnection Example

Bioretention

Bioretention stormwater management 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 3 - Common 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, typically less engineered
Bioretention	Nonresidential sites	Typically installed in vegetated areas to manage runoff from surrounding impervious areas
Bioswale	Along roadways	Integrates a bioretention system into a swale that also conveys stormwater
Curb extension	Road rights-of-way or along private driveways	Generally in rights-of-way and manages runoff from streets
Planter boxes	Highly urban areas, sites without lawn	Structural walls, highly compact; usually above ground level and captures runoff from roofs
Tree trenches	Highly urban areas, parking lots, sidewalks	Structural walls, suspended pavement systems; usually below-ground and captures runoff from adjacent surfaces

Other than rain gardens, bioretention systems are engineered stormwater management practices that include such elements as aggregate storage, filter layers, and special planting soils that are specifically designed to manage, treat and store stormwater 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.

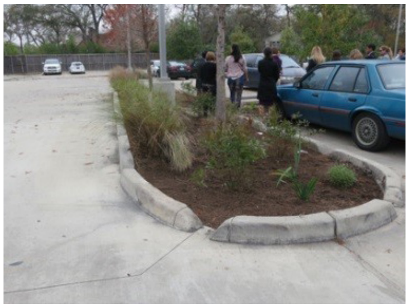
Credit related design criteria includes:

- **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.
- **No Infiltration Over DWSD Pipe:** Current DWSD policy states that stormwater must be managed and sufficiently isolated from the DWSD drainage system to prevent drainage the of the site, through infiltration, into DWSD sewers.

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 in Planter Boxes



Bioretention Islands in Parking Lots

Bioretention between Parking Lot Aisles

- **No Infiltration Over DWSD Pipe:** Current DWSD policy states that stormwater must be managed and sufficiently isolated from the DWSD drainage system to prevent drainage the of the site, through infiltration, into DWSD sewers.

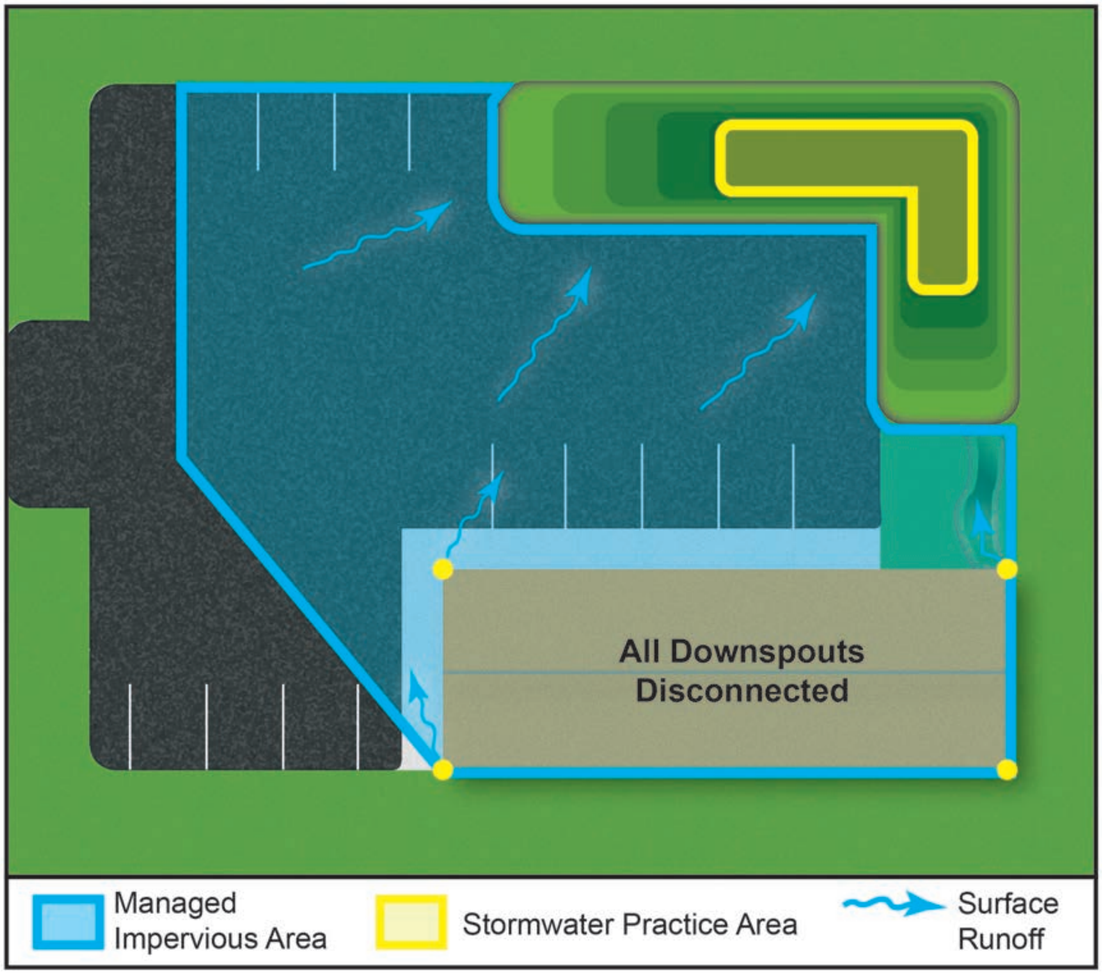


Figure 15: Bioretention Calculation Example

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 (A): 5,000 square feet (sf)
Total Site Impervious Area: 6,500 sf
Practice Area: 750 sf
Soil Infiltration Rate: 0.1 in/hr

The calculation methodology used is the Equivalent Rainfall Depth method.

STEP 1 Determine maximum Equivalent Water Depth (EWD) based on infiltration rate:

The soil has an infiltration rate of 0.1 inches/hour.

$$Max.\ EWD_{(Retention)}\ (in) = Infiltration\ Rate \left(\frac{in}{hr}\right) * Duration\ (hrs) = 0.1 * 72 = 7.2\ in$$

STEP 2 Determine cross section and placement of underdrain. Calculate the EWD (Retention). $EWD_{Retention}$ is the storage below the underdrain.

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

- 18 inches of aggregate with an effective porosity of 0.4 = 7.2 inches
- Underdrain (located 18 inches from bottom of practice)
- 4 inches of aggregate with an effective porosity of 0.4 = 1.6 inches
- 20 inches of soil with an effective porosity of 0.25 = 5 inches

$EWD_{Retention}$ = 7.2 inches

STEP 3 Determine the retention volume provided:

$$Retention\ Volume\ (cf) = Practice\ Area\ (sf) * \frac{EWD_{Ret}\ (in)}{12} = 750\ sf * \frac{7.2\ in}{12\ in} = 450\ cf$$

STEP 4 Determine Equivalent Rainfall that corresponds to volume in Step 3.

$$Equivalent\ Rainfall\ Depth\ (in) = \frac{Retention\ Volume\ (cf)}{Managed\ Impervious\ Area\ (sf)} = \frac{450\ cf}{5{,}000\ sf} * 12 = 1.08\ in$$

BIORETENTION CALCULATION EXAMPLE – RETENTION ONLY (continued)

STEP 5 Calculate the volume credit if 1.08 inches of rainfall remained on the site using Equation 6.3: $Volume\ Credit\ (\%) = (1 - 2.5^{-2.5\ *\ Equivalent\ Rainfall\ Depth\ (in)}) * 100$

$Volume\ Credit\ (\%) = (1 - 2.5^{-2.5\ *\ 1.08}) * 100$
$Volume\ Credit\ (\%) = 91.6\%$

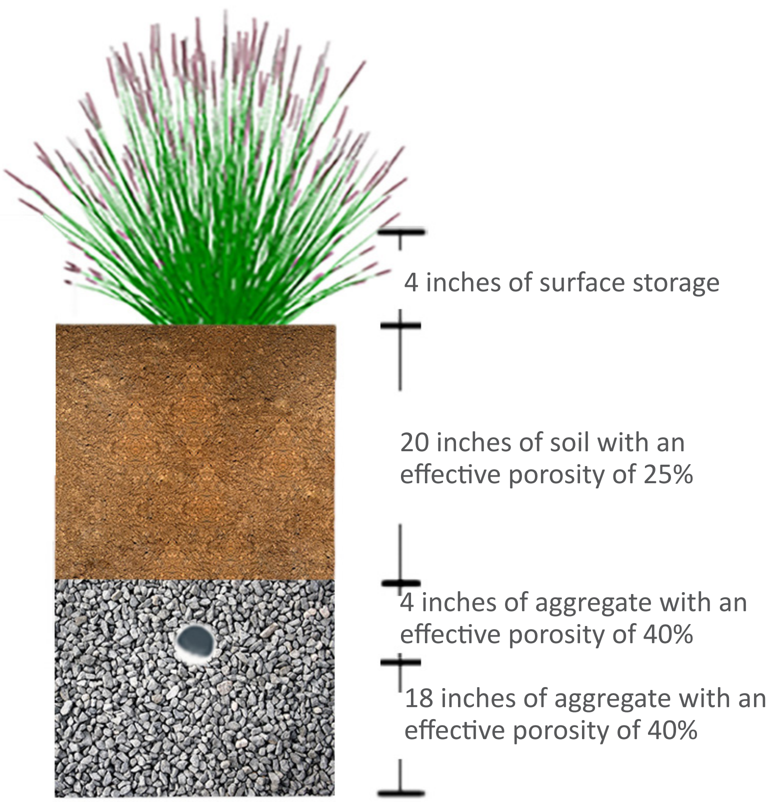
STEP 6 Calculate the practice credit:

$$Practice\ Credit\ (\%) = Volume\ Credit\ (\%) * 0.4 = 91.6\% * 0.4 = 36.6\%$$

STEP 7 Calculate the site credit:

$$Site\ Credit\ (\%) = Practice\ Credit\ (\%) * \frac{Managed\ Impervious\ Area}{Total\ Site\ Impervious\ Area} = 36.6\% * \frac{5{,}000\ sf}{6{,}500\ sf} = 28.1\%$$

$Rounded\ Site\ Credit\ (\%) = 29.0\%$



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 (A): 5,000 sf (0.11 acre)

Total Site Impervious Area: 6,500 sf

Practice Area: 750 sf

Soil Infiltration Rate: 0.1 in/hr

Cross Section:

- 18 inches of aggregate with an effective porosity of 0.4
- Underdrain (18 inches from bottom of practice)
- 4 inches of aggregate with an effective porosity of 0.4
- 20 inches of soil with an effective porosity of 0.25

STEP 1 Determine the minimum volume required to obtain a detention credit: The detention credit requires adequate volume to store the 2-year, 24-hour event. Refer to Equation 6.7B.

$$V_2 = 4{,}220 \frac{cf}{Impervious\ Acre} * A\ (ac)$$

$$V_2 = 4{,}220 \frac{cf}{Impervious\ Acre} * 0.11\ ac = 464.2\ cf$$

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

$$EWD_{detention} = \frac{464.2\ cf}{750\ sf} = 0.62\ ft = 7.4\ in$$

Note: There is no maximum EWD for the Detention Zone.

STEP 3 Consider the potential EWD based on chosen cross section: EWD (in) = surface storage (in) + soil depth (in) * effective porosity + aggregate depth (in) * effective porosity

As part of the practice design, the designer determines that the depth of water on the surface of the practice would be 4 inches. The EWD $_{Detention}$ is the storage space above the underdrain.

$$EWD_{Detention} = 4.0\ in + (4.0\ in * 0.4) + (20\ in * 0.25) = 10.6\ in$$

STEP 4 Determine the actual detention volume:

$$V_{provided} = \frac{10.6\ in}{12\ in/ft} * 750\ sf = 662.5\ cf$$

BIORETENTION CALCULATION EXAMPLE – RETENTION AND DETENTION (continued)

STEP 5 Determine the peak flow credit: Using Equation7A, calculate the percentage of the 100-year, 24-hour storm volume that is provided.

$$V_{100} = 11{,}750 \frac{cf}{Impervious\ Acre} * A\ (ac)$$

$$Peak\ Flow\ Credit = \frac{V_{provided}}{V_{100}} * 100 = \frac{662.5}{0.11 * 11{,}750} * 100 = 51.3\%$$

STEP 6 Calculate the practice credit (for both Retention and Detention credits).

$$Practice\ Credit = Volume\ Credit * 0.4 + Peak\ Flow\ Credit * 0.4 = 91.6\% * 0.4 + 51.3\% * 0.4 = 57.2\%$$

STEP 7 Calculate the site credit:

$$Site\ Credit\ (\%) = Practice\ Credit\ (\%) * \frac{A}{Total\ Site\ Impervious\ Area} = 57.2\% * \frac{5{,}000\ sf}{6{,}500\ sf} = 44.0\%$$

$$Rounded\ Site\ Credit\ (\%) = 44.0\%$$

Permeable Pavement

Several design options are available for using permeable pavements to intercept, contain, filter, and where appropriate infiltrate stormwater 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).

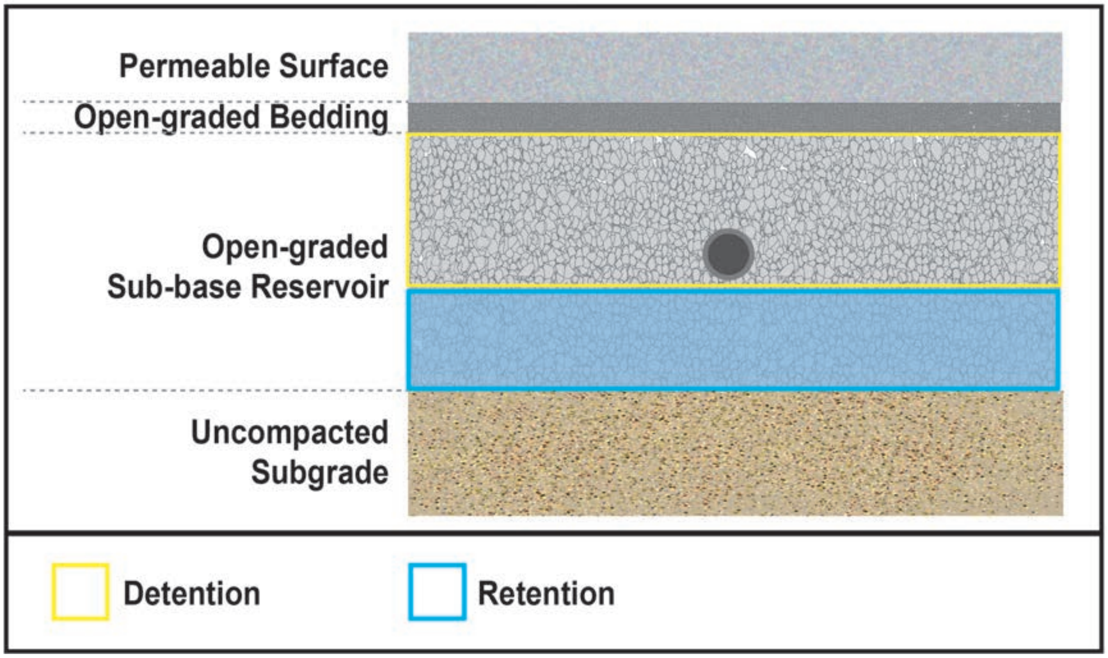


Figure 17: Retention and Detention in Permeable Pavements

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 2:1 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.
- **No Infiltration Over DWSD Pipe:** Current DWSD policy states that stormwater must be managed and sufficiently isolated from the DWSD drainage system to prevent drainage the of the site, through infiltration, into DWSD sewers.

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.

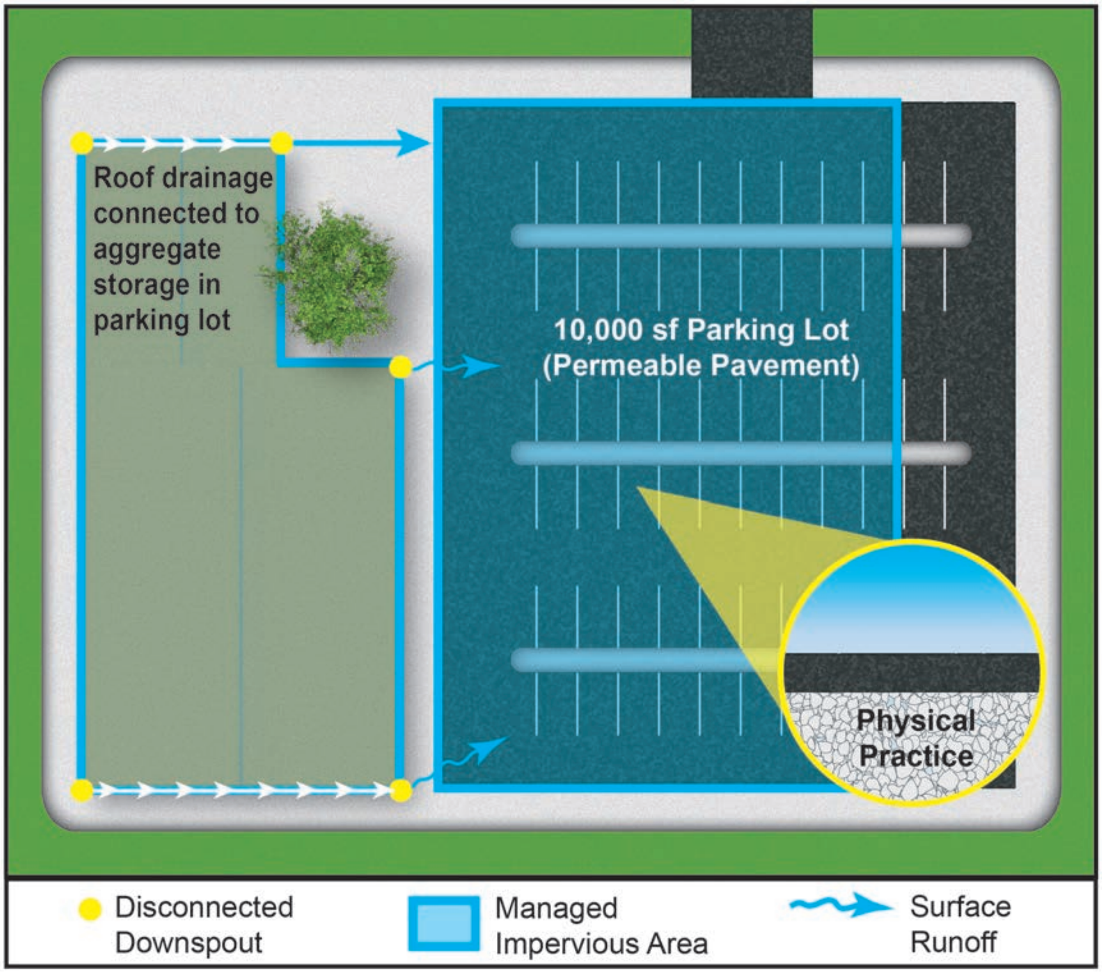


Figure 18: Schematic for Permeable Pavement Example

PERMEABLE PAVEMENT VOLUME CREDIT CALCULATION EXAMPLE

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

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

PERMEABLE PAVEMENT VOLUME CREDIT CALCULATION EXAMPLE (continued)

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

$$EWD\ Provided\ (in) = Aggregate\ Depth\ (in) * Effective\ Porosity = 12 * 0.35 = 4.2\ in$$

STEP 2 Determine if the volume under the underdrain will drain in the allotted time by comparing the EWD and infiltration rate to the maximum values in Table 1. The maximum value for a 0.1 in/hr rate is 7.2 inches.

$$EWD\ provided\ (in) = \frac{4.2\ in}{<7.2\ in}\ (max\ EWD\ for\ 0.1 \left(\frac{in}{hr}\right) rate)$$

STEP 3 Determine the retention volume provided:

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

STEP 4 Determine Equivalent Rainfall Depth that corresponds to volume in Step 3.

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

STEP 5 Calculate the volume credit if 1.4 inches of rainfall remained on the site using Equation 6.3: $Volume\ Credit\ (\%) = (1 - 2.5^{-2.5\ *\ Equivalent\ Rainfall\ Depth\ (in)}) * 100$

$$Volume\ Credit\ (\%) = (1 - 2.5^{-2.5\ *\ 1.4}) * 100$$
$$Volume\ Credit\ (\%) = 96\%$$

STEP 6 Calculate the practice credit:

$$Practice\ Credit\ (\%) = Volume\ Credit\ (\%) * 0.4 = 96\% * 0.4 = 38.4\%$$

STEP 7 Calculate the site credit:

$$Site\ Credit\ (\%) = \frac{Managed\ Impervious\ Area}{Total\ Site\ Impervious\ Area} * Practice\ Credit\ (\%) = \frac{15{,}000\ sf}{17{,}500\ sf} * 38.4\% = 32.9\%$$

$$Rounded\ Site\ Credit\ (\%) = 33.0\%$$

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):

$$EWD\ Provided\ (in) = Aggregate\ Depth\ (in) * Effective\ Porosity = 12 * 0.35 = 4.2\ in$$

Note: There is no maximum EWD for the Detention Zone.

STEP 2

Determine the runoff volume for the 100-year, 24-hour event: As a simplified site, and using Equation 7A, the 100-year, 24-hour event volume is calculated using:

$$V_{100} = 11{,}750\ \frac{cf}{Impervious\ Acre} * A\ (ac)$$

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

STEP 3

Determine the runoff volume for the 2-year, 24-hour event: From Equation 7B, the 2-year, 24-hour event is calculated using:

$$V_2 = 4{,}220\ \frac{cf}{Impervious\ Acre} * A\ (ac)$$

$$V_2 = 4{,}220\ \frac{cf}{Impervious\ Acre} * A\ (ac) = 4{,}220 * 0.34\ acres = 1{,}435\ cf$$

STEP 4

Determine the actual detention volume and confirm it is sufficient for a 2-year, 24-hour 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, 24-hour event volume. As a result, this practice is eligible for a peak flow credit.

STEP 5

Calculate the peak flow credit:

$$Peak\ Flow\ Credit\ (\%) = \frac{V_{provided}}{V_{100}} * 100 = \frac{1{,}750\ cf}{3{,}995\ cf} * 100 = 43.8\%$$

PERMEABLE PAVEMENT PEAK FLOW CREDIT CALCULATION (continued)

STEP 6 Determine the practice credit:

$$\text{Practice Credit (\%)} = \text{Volume Credit} * 0.4 + \text{Peak Flow Credit} * 0.4 = (96.0\% * 0.4) + (43.8\% * 0.4) = 54.2\%$$

STEP 7 Determine the site credit:

$$\text{Site Credit (\%)} = \frac{\text{Managed Impervious Area}}{\text{Total Site Impervious Area}} * \text{Practice Credit (\%)} = \frac{15{,}000\ sf}{17{,}500\ sf} * 54.2\% = 46.5\%$$

$$\text{Rounded Site Credit (\%)} = 47.0\%$$

Detention Ponds and Detention Volumes Provided in Other Practices

Dry Detention Basin

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.

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.

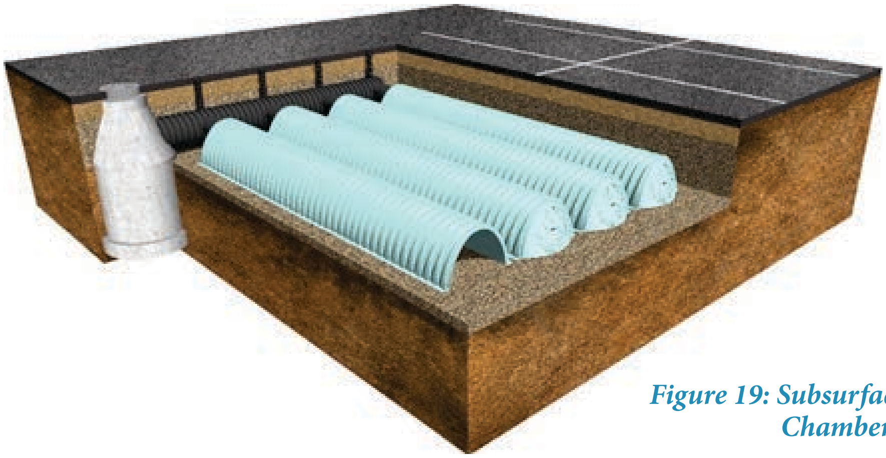


Figure 19: Subsurface Detention Chambers

The peak flow credit is based on the fraction of volume detained relative to the volume associated with a ***100-year, 24-hour 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, 24-hour 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 stormwater management 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 total acres draining to practice, 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.

- **No Infiltration Over DWSD Pipe:** Current DWSD policy states that stormwater must be managed and sufficiently isolated from the DWSD drainage system to prevent drainage the of the site, through infiltration, into DWSD sewers.

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.

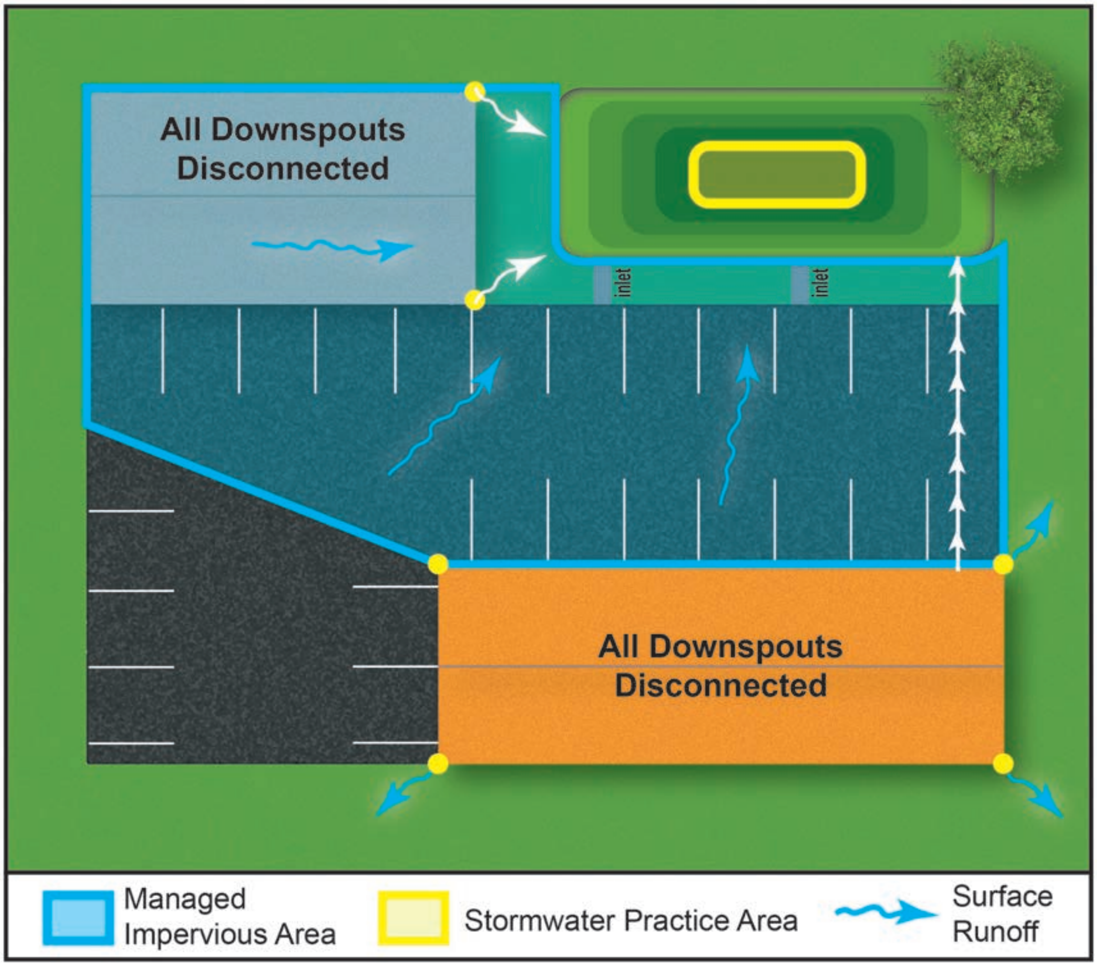


Figure 20: Schematic for Detention Pond Calculation Example

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.

- Managed Impervious Area (A) = 3.2 acres (ac) 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 [Qr] for the 100-year, 24-hour 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, 24-hour and 2-year, 24-hour storms respectively is:

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

$$V_{2} = 4{,}220 \text{ cf} / (\text{impervious acre}) * A \text{ (ac)} = 4{,}220 * 3.2 \text{ ac} = 13{,}504 \text{ cf}$$

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, 24-hour storm event.

$$V_{provided} = 30{,}000 \text{ cf which is greater than } 13{,}504 \text{ cf}$$

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.

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

$$Rounded\ Site\ Credit\ (\%) = 26.0\%$$

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 stormwater for irrigation or non-irrigation purposes. The calculator is available for use upon request.

Information that is needed to determine the practice volume credit:

- **Managed Impervious Area to Pond:** The impervious area generating runoff to the stormwater management practice.
- **Managed Pervious Area to Pond:** The pervious area generating runoff to the stormwater management 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 stormwater 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 Stormwater 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 4 and Figure 21 qualifies for a 90.9% annual volume credit.

TABLE 4 - 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 Stormwater 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	1.99	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	0.89	0.77	0.58	0.64	0.61	-
Monthly Runoff to Pond, Cubic Feet	132,614	132,742	169,269	238,457	240,022	272,871	255,622	249,892	221,143	171,135	189,614	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	2,587	8,038	12,055	22,305	17,999	15,675	21,135	8,079	7,227	0	-
Monthly Runoff in Excess of Pond to DWSD, Cubic Feet	0	0	0	0	0	1,716	2,668	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	242,852	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	3.3	6.6	6.4	6.6	6.6	6.4	6.6	3.3	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	238,457	240,022	272,871	255,622	249,892	221,143	171,135	189,614	185,683	2,459,064
Total Monthly Runoff to DWSD Sewer, Cubic Feet	132,614	132,742	0	0	0	1,716	2,668	2,443	3,853	761	432	194,659	471,889

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

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

Figure 21: 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 stormwater management practices may be used by the property owner if approved by DWSD. 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 to quantify the performance of the practice as required by DWSD Technical Review Committee.

Hydrologic Computational Methods

In addition to the various computational methods previously described, DWSD accepted standard engineering calculations for the determination of stormwater management practice performance. Table 5 lists the common methods, all of which are acceptable to use.

TABLE 5 - 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 Stormwater 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 stormwater management 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 stormwater 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 stormwater management 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 stormwater, 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.

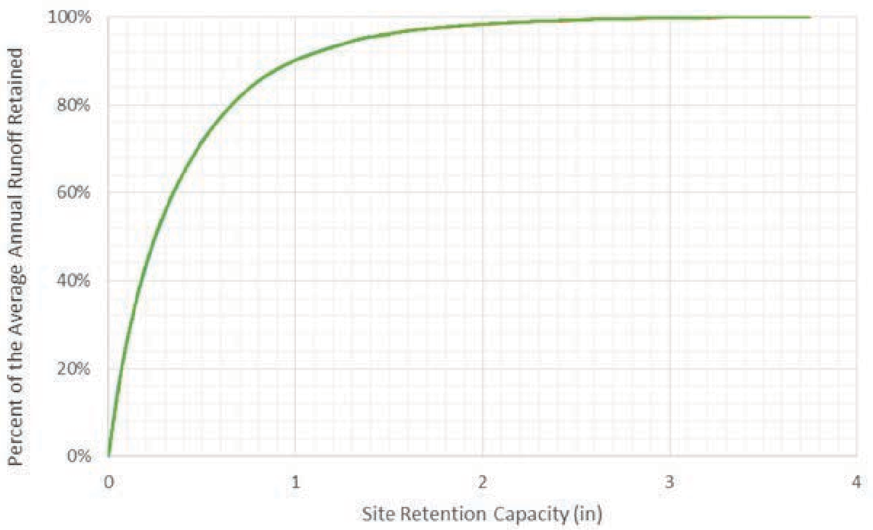


Figure 22: Annual Runoff Retained Relationship

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 22. 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, 24-hour and a maximum of a 100-year, 24-hour storm event. A requirement for obtaining the peak flow credit is that the outlet from the stormwater management 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 stormwater reuse.