

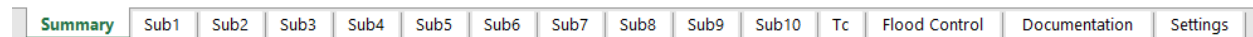
LGROW DESIGN SPREADSHEET TUTORIAL

General

The LGROW Design Spreadsheet is a tool used to demonstrate that a proposed site meets the requirements provided in the community/county stormwater standards manual (Manual). It is not intended to be used for detailed design of stormwater BMPs. The spreadsheet can be used to model a single discharge point from the site including structural BMPs in series or parallel.

Layout

The LGROW Design Spreadsheet consists of several worksheets identified by tabs at the bottom of the spreadsheet. The following tabs are included:



- **Summary:** This tab is used to provide a general site description including subcatchment connectivity. This tab also provides a summary of the site hydrology, channel protection volumes, and water quality volumes.
- **Sub1 through Sub10:** These tabs are used to specify the characteristics of each subcatchment. Each site can be divided into as many as 10 subcatchments. This is useful when Low Impact Development concepts are used, as channel protection and water quality BMPs are typically distributed throughout the site.
- **Tc (Time-of-Concentration):** This tab is used to specify the time-of-concentration for the entire site for both the existing and developed condition. The time-of-concentration is used to compute peak discharges required for specifying the detention flood control volume.
- **Flood Control:** This tab is used to determine the required detention or retention volume needed to meet the flood control requirements. The tab also provides site-wide discharge and volume summaries.
- **Documentation:** This tab describes the calculations made by the spreadsheet. Links to this page are located throughout the spreadsheet.
- **Settings:** This tab does not allow user entry. It displays some of the key community-specific settings (if not hidden).

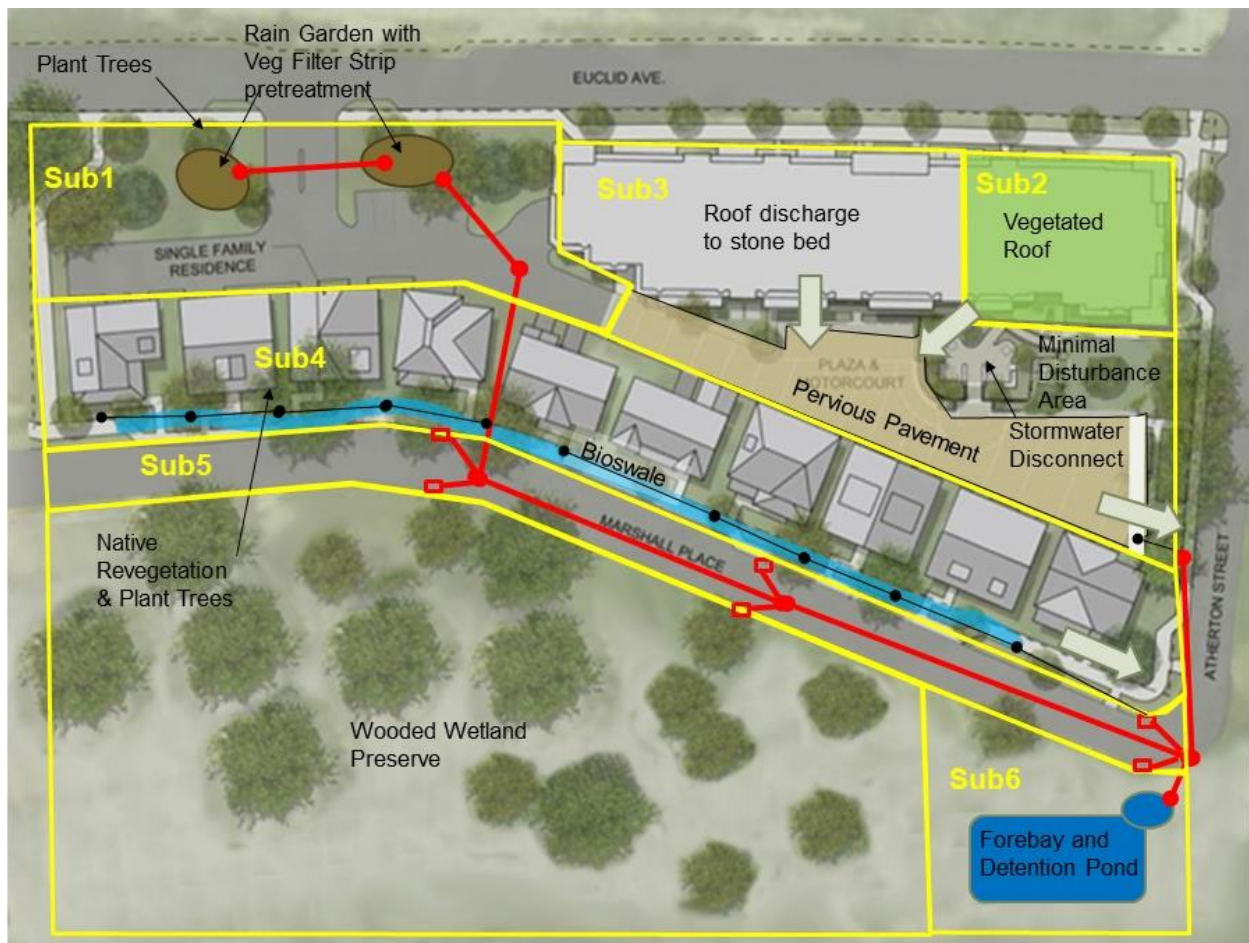
Notes on Use and Data Entry

- After opening the spreadsheet, you will need to enable the use of an embedded macro. Look for the security warning and click "Enable Content."
- Data is entered in yellow cells. Green cells allow selection of items from pulldown menus or buttons. All other cells are locked to avoid the user making changes to embedded equations.

- A red triangle in the upper right-hand corner of a cell indicates a comment is embedded with directions or further explanation for the user.
- The user can type in actual values or equations in any of the data (yellow) cells. The equations can be linked to other data cells or to calculated values in the white cells. It is highly recommended that the user input equations and link to other cells in the spreadsheet to allow for dependent values to be updated as changes are made (refer to *Linking Cells and Using Equations* on page 12).
- Do not use Cut, Copy, or Paste. Copying and pasting data from another copy of the spreadsheet can inadvertently create links between the spreadsheets.
- Warning and error messages will appear in red text. Notices will appear in blue text. Warnings do not affect computations, but errors must be corrected for results to be computed.

Case Study

A case study was used to generate screen shots for this tutorial and illustrate the use of the LGROW Design Spreadsheet. The site layout for the case study is shown below. The full case study is provided in a separate LGROW Design Spreadsheet.



Summary Tab

Information required in the first three sections of the Summary tab is identical to that in the Stormwater Worksheet. A separate worksheet need not be submitted if the LGROW Design Spreadsheet is used.

Project Description

Enter all required information. Click the check box to select all special conditions that apply to the site.

Project Description															
Development Name	Case Study No. 1														
Location	Urban Township														
Address															
Developer/Owner	John Doe														
Engineering Firm	Doe Engineering & Surveying, Inc.														
Engineer	RJH														
Date															
	<table border="1"> <thead> <tr> <th>Select if Yes</th> <th>Notes</th> </tr> </thead> <tbody> <tr> <td><input checked="" type="checkbox"/></td> <td>County Drain No. 1; detention basin discharges to drain located on east side of property.</td> </tr> <tr> <td><input type="checkbox"/></td> <td></td> </tr> <tr> <td><input type="checkbox"/></td> <td></td> </tr> <tr> <td><input checked="" type="checkbox"/></td> <td>Site located in MS4 urbanized area; disturbance > 1 acre; discharge to waters of the state.</td> </tr> <tr> <td><input type="checkbox"/></td> <td></td> </tr> <tr> <td><input type="checkbox"/></td> <td></td> </tr> </tbody> </table>	Select if Yes	Notes	<input checked="" type="checkbox"/>	County Drain No. 1; detention basin discharges to drain located on east side of property.	<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>	Site located in MS4 urbanized area; disturbance > 1 acre; discharge to waters of the state.	<input type="checkbox"/>		<input type="checkbox"/>	
Select if Yes	Notes														
<input checked="" type="checkbox"/>	County Drain No. 1; detention basin discharges to drain located on east side of property.														
<input type="checkbox"/>															
<input type="checkbox"/>															
<input checked="" type="checkbox"/>	Site located in MS4 urbanized area; disturbance > 1 acre; discharge to waters of the state.														
<input type="checkbox"/>															
<input type="checkbox"/>															
Drainage District	<input checked="" type="checkbox"/>														
Watershed Policy	<input type="checkbox"/>														
Redevelopment	<input type="checkbox"/>														
MS4	<input checked="" type="checkbox"/>														
Hotspot	<input type="checkbox"/>														
Coldwater Stream	<input type="checkbox"/>														

Sensitive Areas

Select all sensitive areas from the pulldown list that apply to the site.

Sensitive Areas	
Indicate on site plan and select all that apply.	
Description	Notes
Wetlands	Preserve wooded wetland area

Channel Protection Volume Basis

Specify the pre-development land use definition. Select either “Existing” or “Pre-Settlement” as applicable for the site per the Manual. Depending on the community, this may be “hard wired” to allow only one definition.

Indicate if channel protection volume is not required for the site, or will be provided offsite, or if a payment-in-lieu program will be utilized.

Channel Protection Volume Basis	
Pre-development Land Use Definition	Existing
	Not Required
	Provided Offsite
	Notes

Subcatchment Connectivity

The ability to divide the site into subcatchments allows the channel protection and water quality volumes to be routed through BMPs placed in series or in parallel, and helps to ensure proper sizing of individual BMPs to meet the required volumes. This section provides a way for the user to specify the number of subcatchments and how the subcatchments are connected to each other.

The available subcatchment names (Sub1, Sub2, ..., Sub10) can be given to any subcatchment. However, the process of specifying subcatchments must start at the upstream end and proceed downstream. The Downstream Subcatchment is the next subcatchment with a treatment BMP to which stormwater runoff is routed. Only the final downstream subcatchment (usually used for the detention or retention basin) should have “none” selected in the “Downstream Subcatchment” column. If a site drains to multiple flood control basins, a separate spreadsheet must be completed for each discharge point from the site. An error message will appear until the user completes the selection of all downstream subcatchments.

If mistakes are made in this process, or subcatchments are omitted, added or renumbered, the user can simply delete the contents of the green cells and start over. An error message will appear if a number greater than 10 is entered, or if all downstream subcatchments have not been selected.

Subcatchment Connectivity		
Number of Subcatchments	<input type="text" value="6"/>	
Subcatchment Name	Downstream Subcatchment	Subcatchment Description
Sub1	Sub6	Drives, Parking, and Rain Garden
Sub2	Sub3	Vegetative Roof
Sub3	Sub6	Standard Roof and Plaza
Sub4	Sub6	Single Family Units
Sub5	Sub6	Street
Sub6	none	Detention Pond

In the case study, Sub 1 is routed to Sub 6 and not Sub 5 (storm sewer in the street) because Sub 5 has no structural BMPs to further treat the runoff from Sub 1 either for channel protection or water quality.

Defining Subcatchments

Subcatchment delineation is based on the developed condition.

In general, a subcatchment should be defined as the area draining to a single structural BMP or BMP treatment train. Delineate subcatchments so each structural BMP to be analyzed is located at the receiving end of the subcatchment. This is important to ensure proper sizing of the BMP.

A separate subcatchment should be used for the detention or retention basin footprint and any pervious area surrounding it.

A separate subcatchment should be used for any offsite area routed to the detention or retention basin.

Catchbasins

A separate subcatchment can be delineated for each catchbasin located along the main line of a storm sewer (i.e. in series). This may be useful when the number of catchbasins is limited and the user wishes to get credit for the water quality treatment provided by the catchbasin.

If the user does not need to count the water quality provided by the onsite catchbasins, they can be ignored, and a single subcatchment may be defined for an entire run or network of storm sewer.

Finally, if a single subcatchment is used and no other pass-through water from upstream complicates matters, the water quality volume from the subcatchment can be prorated by the amount that enters each catch basin located in series. (Refer to example under Special Cases).

Pervious Pavement and Vegetated Roof

A separate subcatchment should be used for a pervious pavement or vegetated roof area. The subcatchment may simply be the area of the pervious pavement or vegetated roof if no other drainage areas are directed to it.

Upstream areas that discharge to the stone bed under a pervious pavement may be routed from an upstream subcatchment or included as part of the subcatchment containing the pervious pavement. (Refer to example under Special Cases).

Linear BMPs

Linear BMPs such as bioswales and grassed swales can be handled with a single subcatchment if the contributing drainage area is consistent along the length (i.e. roadway, uniform frontage). The subcatchment for a linear BMP should be divided at the point where any additional lateral flow contribution enters the BMP.

Subcatchment Hydrology Summary

This section provides a summary table of the information entered for each subcatchment in the Sub tabs. Information is provided for both existing and developed land use. This section allows for a quick comparison of subcatchment acres and change in percent impervious. These factors have an effect on the volume of stormwater runoff from each subcatchment.

Subcatchment Hydrology Summary						
Subcatchment Name	Existing			Developed		
	Area [ac]	% Impervious	Pervious CN	Area [ac]	% Impervious	Pervious CN
Sub1	1.20	0%	50	1.20	50%	37
Sub2	0.40	0%	61	0.40	100%	
Sub3	1.60	0%	61	1.60	72%	62
Sub4	1.60	0%	61	1.60	69%	60
Sub5	0.80	0%	61	0.80	100%	
Sub6	0.40	0%	80	0.40	0%	90
Site Totals and Averages:	6.00	0%	60	6.00	67%	60

Subcatchment Results Summary

The two tables in this section provide channel protection and water quality results for the entire site.

Channel Protection

The channel protection volume table summarizes the results from each subcatchment, then totals the values to provide results for the entire site. The table shows for each subcatchment the required channel protection volume (CPV) generated from the subcatchment, the unmet CPV from upstream subcatchments, the CPV credited to the BMPs in the subcatchment, and the unmet CPV sent to downstream subcatchments.

In the case study, only 63% of the site total CPV is met by onsite retention. To meet the channel protection requirement 11,397 cft of extended detention is needed for the unmet portion of the CPV. The 0.088 cfs release rate is calculated to allow drainage in 72 hours.

The 1-year existing peak discharge is shown here for quick comparison if MS4 permit requirements limit the extended detention maximum release rate to that value. The comment (red triangle) instructs the user on how to proceed if the calculated extended detention release rate is greater than the 1-year peak discharge.

Channel Protection Volume from Structural BMPs				
Subcatchment Name	Channel Protection Volume [cft]			
	Required	Upstream	Credited	Unmet
Sub1	4,610	0	4,610	0
Sub2	3,073	0	1,725	1,348
Sub3	8,905	1,348	10,254	0
Sub4	8,396	0	3,145	5,250
Sub5	6,146	0	0	6,146
Sub6	0	11,397	0	11,397
Total	31,130		19,734	

Percent of Channel Protection Volume met by Onsite Retention	63
Minimum Required Extended Detention Volume [cft]	11,397
Required Extended Detention Release Rate [cfs]	0.088
1-year Existing Peak Discharge [cfs]	0.19

Water Quality

A summary table is provided to account for water quality volume and TSS removal. This table shows whether the water quality volume is met for each subcatchment and for the entire site. Since unmet water quality volume can be passed down from one subcatchment to the next, the criterion is met for the site if it is met for the downstream-most subcatchment.

The TSS accounting shows for each subcatchment the amount generated, the amount passed down from upstream subcatchments, and amount removed.

In the case study, the TSS Removal Efficiency of 98% is computed by dividing the 13,702 units removed by the 14,000 generated.

Water Quality Volume and TSS Removal						
Subcatchment Name	Water Quality Volume [cft]	Volume Met	TSS			
			Generated	Upstream	Total	Removed
Sub1	2,197	Yes	2,197	0	2,197	2,076
Sub2	1,183	Yes	1,183	0	1,183	1,065
Sub3	3,775	Yes	3,775	118	3,894	3,465
Sub4	3,999	Yes	3,999	0	3,999	3,831
Sub5	2,846	No	2,846	0	2,846	581
Sub6	0	Yes	0	2,982	2,982	2,684
Total	14,000	Yes	14,000			13,702
					TSS Removal Efficiency [%]	98
					80% TSS removal met?	Yes

Sub Tabs

1. Description

Section 1 displays the subcatchment description entered in the Summary tab as an identifier.

1. Description	
Subcatchment Description:	<input type="text" value="Drives, Parking and Rain Garden"/>

2. Runoff

Land Use

Section 2 allows the user to enter information about the existing and developed land uses so runoff volumes can be computed. Areas can be given in acres or square feet.

Areas for existing and developed land use should typically match since subcatchment delineation is based on the developed condition. In cases where a drainage divide is altered by the development, the areas contributing to an outlet may not match. A warning will appear if areas do not match.

The Pre-settlement Curve Number in the Existing Land Use table is only relevant to the channel protection volume calculations if the channel protection standard for the site requires that predevelopment conditions reflect pre-settlement conditions. Pre-settlement hydrology numbers are included in the Results Summary table regardless.

2. Runoff				Click here for documentation	
Existing Land Use	HSG	Area	Units	Curve Number	
				Existing	Pre-settlement
Pasture or range land - good	A	0.60	acre	39	30
Pasture or range land - good	B	0.60	acre	61	58
			acre		
			acre		
			acre		
			acre		
			acre		
			acre		
		1.20	acre	50	44
Notes:					
Existing is pasture. Half is HSG A with remainder HSG B					
Developed Land Use	HSG	Area	Units	Curve Number	Notes
DIST: Impervious (paved parking lot, roof, driveway, etc.)	B	0.60	acre	98	
DIST: Open spaces (grass cover) - good	A	0.49	acre	39	
S-BMP: Meadow	A	3,300	sqft	30	Rain Garden
N-BMP: Native revegetation: Plant trees (200 sqft per tree): W	A	1,600	sqft	30	
			acre		
			acre		
			acre		
			acre		
		1.20	acre	37	
Notes:					

Developed land uses are classified as “Disturbed” (DIST), “Non-structural BMPs” (N-BMP), “Structural BMP Surface” (S-BMP), and “Other Existing Land Uses” (EXIST).

Disturbed

Select “Disturbed” land uses for any areas of the site with earth disturbance.

Non-structural BMPs

Select “Non-structural BMPs” where these will be used to reduce the volume of runoff and exempt the application area from water quality accounting. In the case study, note how tree planting provides credit as a non-structural BMP with 200 sqft per tree counted as “woods – good” instead of “open spaces (grass cover) –good.” The total square feet can be directly entered without converting it to acres.

Impervious Area with Stormwater Disconnect

Stormwater disconnect can be selected as a non-structural BMP when a supplemental paved area discharges over and onto a minimal disturbance area or other natural retention area (not a designed structural BMP) that meets minimum size and slope criteria. If supplemental paved areas sheet flow into a structural BMP (e.g. filter strip, bioswale, bioretention/rain garden) connected to the stormwater conveyance system, it is not disconnected, but should be counted as impervious area contributing to the BMP.

In the case study, the patio in Sub 3 is counted as a stormwater disconnect as it drains onto the relatively larger minimal disturbance area. The single family homes in Sub 4 are not considered disconnected. Although they do not connect to the storm sewer directly, they drain into the bioswale, which is connected to the storm sewer, so the bioswale must be sized to treat runoff generated from these impervious areas.

Developed Land Use	HSG	Ar
N-BMP: Impervious area with stormwater disconnect		
----- STRUCTURAL BMP SURFACE -----		
S-BMP: Water		
S-BMP: Meadow		
S-BMP: Open spaces (grass cover) - good		
----- OTHER EXISTING LAND USES -----		
EXIST: Impervious (paved parking lot, roof, driveway, etc.)		
EXIST: Cultivated land		

Structural BMP Surface

Select “Structural BMP Surface” to account for the surface runoff characteristics of structural BMPs located in pervious areas of the site and exempt from water quality accounting. Three options are provided:

1. Water: Select for detention/retention basins with a permanent pool or surface water temporarily ponded during the rain event.
2. Meadow: Select for vegetative BMPs, including those that temporarily pond surface water, to receive credit for channel protection.
3. Open spaces (grass cover) – good: Select for vegetative BMPs with mowed turf grass, including those that temporarily pond surface water, to receive credit for channel protection.

Note that pervious pavement and vegetative roof are not included here as a structural BMP surface because they are applied to impervious areas of the site. They are accounted for later in Sections 3 and 4 where they can be selected as structural BMPs to treat the runoff volume from the roof or pavement surface.

Other Existing Land Uses

Select “Other Existing Land Uses” for offsite areas, or undisturbed areas of the site if a non-structural BMP from the pulldown list does not properly reflect the onsite protected area. Existing land uses are all exempt from water quality accounting.

Subcatchment Runoff Volumes

Runoff volumes for developed land use are summarized for each subcatchment. Values are provided for the full range of rainfall frequencies.

Runoff volume information is useful when sizing retentive BMPs, and allows the user to easily check the BMP Volume Provided (in Section 3b) against the cumulative runoff volume from the subcatchment (including any upstream subcatchments with pass-through flow). Since retentive BMPs may be designed larger than the minimum required channel protection volume, this information allows the user to design the BMP for a particular design frequency, or conversely to determine the design frequency for which the BMP is sized.

It should be noted that the “Volume Retained by BMPs” row will not be populated until information is entered in Section 3b as applicable.

Subcatchment Runoff Volume for Developed Land Use					
Rainfall Frequency	1-year	2-year	10-year	25-year	100-year
Volume from this Subcatchment [cft]	4,340	5,076	7,746	9,878	14,114
Volume from Upstream Subcatchments [cft]	0	0	0	0	0
Cumulative Runoff Volume [cft]	4,340	5,076	7,746	9,878	14,114
Volume Retained by BMPs this Subcatchment [cft]	4,340	4,789	4,789	4,789	4,789
Volume Released [cft]	0	287	2,957	5,089	9,325

3. Channel Protection Volume

Section 3 provides calculations for channel protection volume and sizing retentive BMPs.

3. Channel Protection Volume		Click here for documentation			
3a. Required Channel Protection Volume					
Is Channel Protection Volume required? If no, provide reason.	Yes				
2-year, 24-hour Runoff Volume for Developed Condition [cft]	5,076				
2-year, 24-hour Runoff Volume for Pre-development Condition [cft]	466				
Minimum Required Channel Protection Volume this Subcatchment [cft]	4,610				
Unmet Channel Protection Volume from Upstream Subcatchments [cft]	0				
Required Channel Protection Volume [cft]	4,610				
3b. Structural BMPs used to meet Channel Protection Volume					
Structural BMP	A Infiltration Area [sqft]	V Storage Volume [cft]	i Design Infiltration Rate [in/hr]	Drain Time [hr]	Volume Provided [cft]
Bioretention / Rain Garden	2,800	1,750	2.74	2.74	4,789
				N.A.	
				N.A.	
				N.A.	
				N.A.	
Total Volume					4,789
Credited Channel Protection Volume					4,610
Percentage of Channel Protection Volume Met by Retention					100%
Notes:					
Volume is 0.5 ft surface ponding; media voids do not provide storage volume since subsoil is more pervious (i.e. treat like a retention basin)					

3a. Required Channel Protection Volume

Section 3a shows the increase in 2-year runoff volume. This is the channel protection volume. If any upstream subcatchments do not fully provide the required channel protection volume, the unmet portion is added here.

3b. Structural BMPs used to meet Channel Protection Volume

Section 3b allows the user to select structural BMPs from the pulldown list. All BMPs are retentive.

Enter information about the selected BMP in the three columns to the right. Note that the information required varies by the selected BMP. For example, if Vegetated Roof is selected, only the infiltration area and the storage volume are required to be entered for the computations. The spreadsheet automatically shades out the unused column(s). Values may be typed in the shaded cells, but they are not used in the computations. Note that the infiltration area is not the surface area of the BMP.

The value entered for design infiltration rate can be obtained from field permeability tests, the design infiltration rates by USDA soil texture class given in the Manual, or the infiltration rate calculator in Section 3c. In all cases the limiting value of the underlying soil or filter media must be entered.

The drain time of the storage volume is provided so it can be checked against maximum allowable drain times by BMP given in the Manual.

The volume provided by each BMP (V_{bmp}) is the storage volume of the BMP plus the volume of water that infiltrates during the period when the BMP is receiving runoff and capable of infiltrating at the design rate. The case study illustrates how the volume provided is more than the storage volume.

The credited channel protection volume shown is the sum of the volumes provided by each BMP, limited by the sum of the 2-year runoff volume from the subcatchment and any unmet channel protection volume from upstream subcatchments. In the case study, since the required channel protection volume is less than the volume provided by the BMP, the credited channel protection volume is set at the lower value.

3c. Infiltration Rate Calculator for BMP Media

The infiltration rate calculator is a handy tool to compute the equivalent infiltration rate of BMP filter media in inches per hour when the user is given hydraulic conductivities in feet per day and must apply these with Darcy’s Law. The conversion between hydraulic conductivity and infiltration rate is not a simple units conversion. The infiltration rate is a function of the depth of the filter media and the average head on the filter.

Filter media type is selected from the pulldown list with a yellow data cell provided for user entry. Selection of more than one filter media component assumes a homogeneous mixture of the filter media, and not placement in separate layers. If separate layers of filter media are proposed, only the limiting layer should be used.

As shown in the case study, a simple units conversion from a hydraulic conductivity of 4.69 ft/day results in 2.35 in/hr, which is less than the computed infiltration rate of 2.74 in/hr using Darcy’s Law. The difference becomes more pronounced when head increases and depth of filter media decreases.

3c. Infiltration Rate Calculator for BMP Media		
Filter Media Component	K [ft/day]	Weight
Compost (loose)	8.7	25
Coarse Sand	3.5	70
Topsoil (<10% clay)	1.3	5
Average Hydraulic Conductivity of Filter Media [ft/day]		4.69

	Value
Average Head on the Filter [ft]	0.50
Depth of Filter Media [ft]	3.00
Infiltration Rate [in/hr]	2.74

Notes:
Infiltration testing yielded an in-situ infiltration rate of 20 inches/hour for underlying soil. Design infiltration rate = 10 inches/hour.

Infiltration testing indicates that the underlying soil will allow for a design infiltration rate of 10 in/hr. The infiltration rate calculator gives a rain garden media infiltration rate of 2.74 in/hr. Therefore, the limiting infiltration rate used in Section 3b is 2.74 in/hr.

Linking Cells and Using Equations

In the case study, the storage volume uses the infiltration area in an equation input by the user, as illustrated below. Likewise, the design infiltration rate is linked to the infiltration rate in Section 3c.

E61		=3500*0.5			
A	B	C	D	E	F
		Structural BMP	A Infiltration Area [sqft]	V Storage Volume [cft]	i Design Infiltration Rate [in/hr]
60					
61		Bioretention / Rain Garden	2,800	1,750	2.74

4. Water Quality Volume

Section 4 computes the water quality volume. The calculations need to distinguish between four types of directly connected impervious area - flat roofs, pitched roofs, unpaved, and paved. The default is paved. An error message will appear if values entered for roofs/unpaved are greater than the sum of directly connected impervious area.

In the case study, all the impervious areas are paved so no values are provided in the yellow cells. The result is 2,197 cft of runoff from this subcatchment needing water quality treatment.

4. Water Quality Volume		Click here for documentation	
Sum of Directly Connected Impervious Area [ac]	0.60		
Flat Roofs/Unpaved [ac]			
Pitched Roofs [ac]			
Paved [ac]	0.60		
Sum of Directly Connected Disturbed Pervious Area [ac]	0.49		
Sandy Soils (HSG A) [ac]	0.49		
Silty Soils (HSG B) [ac]	0.00		
Clayey Soils (HSG C&D) [ac]	0.00		
Minimum Required Water Quality Volume this Subcatchment [cft]	2,197	Generated this Subcatchment	TSS 2,197
Water Volume from Upstream Subcatchments [cft]	0	From Upstream Subcatchments	0
Water Volume to be Treated [cft]	2,197	TSS to be Treated	2,197
Notes:			

Section 4 also computes the TSS generated from a subcatchment. For simplicity in accounting, one unit of TSS is defined as the TSS carried by one unit of untreated runoff.

BMPs selected by the user need to be able to treat the water quality volume generated by this subcatchment plus any untreated runoff from upstream subcatchments. The TSS to be treated is the amount generated in this subcatchment plus any TSS carried down from upstream subcatchments. In Sub1 of the case study, there are no upstream contributions, so the water volume to be treated is the same number as the TSS to be treated.

5. TSS Accounting

Section 5 shows how the BMPs meet the water quality volume requirement and calculates the TSS removed by the BMPs.

The list of BMPs available in the pulldown is longer here than in Section 3. Section 3 included only those BMPs that retain the water onsite. Section 5 adds BMPs that treat the water as it passes through. BMPs are listed as either “Retentive” (RET) or “Pass-through” (PASS) BMPs. Calculations are performed differently for each. It is important that the BMPs are listed in order from upstream to downstream in the treatment train.

The treated water volume entered in the second column varies depending on the type of BMP being used. For pass-through BMPs, enter the portion of the water quality volume that passes through the BMP. This is not the storage volume of the BMP. For retentive BMPs enter the volume provided by the BMP (V_{bmp}, defined on Page 11).

The TSS removal efficiency is populated from accepted values in the Manual, unless a removal efficiency must be supplied by a third-party. The cells under the “Third-party Supplied” column will be shaded unless a value is needed. The effective TSS removal efficiency is then computed as the removal efficiency multiplied by the ratio of the treated water volume to the water volume in the stream approaching the BMP. This allows for cases where only a portion of the water volume is treated by a BMP.

When a retentive BMP is used upstream in the treatment train, the volume approaching the next BMP is reduced by amount of retention provided. When a pass-through BMP is used upstream in the treatment train, the entire pass-through volume is used as the volume stream approaching the next BMP.

5. TSS Accounting		Click here for documentation			
BMPs Used in Treatment Train	Treated Water Volume [cft]	TSS Removal Efficiency			TSS Removed
		Tabulated	Third-Party Supplied	Effective	
PASS: Vegetated Filter Strip (sized for pretreatment)	2,197	50		50	1,098
RET: Bioretention/Rain Garden	4,789	89		89	978
					0
					0
					0
					0
					0
Released Water Volume [cft]	0	Total TSS Removed			2,076
Water Quality Volume met?	Yes	TSS Remaining			121
		TSS Removal Efficiency [%]			95
Notes:					

TSS Removed

The units of TSS removed by each BMP are computed and totaled. The total is then subtracted from the units of TSS to be treated in the stream (from Section 4) to obtain TSS remaining. Finally, the TSS removal efficiency is computed for the subcatchment. Since the calculations for TSS removed are not readily apparent from the spreadsheet, it is helpful to use the case study to illustrate.

In the case study, the Vegetative Filter Strip sized for pretreatment is a Pass-through BMP, which treats all 2,197 cft of water flowing through it. The TSS removal efficiency is 50% resulting in the removal of $2,197 * 0.5 = 1,098$ units of TSS.

The Rain Garden is a retentive BMP. It removes TSS at a higher rate but only from the volume retained. The treated water volume for the rain garden is linked to the “Volume Provided” column in Section 3b. This volume is much larger than the water quality volume entering the BMP. Since 1,098 units of TSS were removed in the filter strip, the rain garden will remove 89% of the remaining TSS. So, $0.89 * (2,197 - 1,098) = 978$ units of TSS removed. Even though there is no water (from the water quality event) leaving the BMP, the remaining 121 units of TSS are “passed down” to the next subcatchment for further TSS removal calculations. This occurs because the removal efficiency for retentive BMPs is always less than 100% to account for reduced performance over time and other unknowns. Results show the water quality volume is met and the TSS removal efficiency is 95%, computed by dividing the 2,076 units removed by the 2,197 units to be treated.

Tc Tab

The worksheet in the Tc tab uses TR-55 methodology. The time-of-concentration is needed to calculate peak discharges and determine the size of detention storage.

The time-of-concentration is computed separately for existing and developed conditions. The flow path is split into sheet flow; shallow concentrated flow; and open channels, swales and pipes. A warning will appear if sheet flow exceeds the maximum allowable flow distance. The time-of-concentration is calculated following the longest flow route (in terms of travel time).

Developed											Click here for documentation
Sheet Flow											
Type	US Elevation [ft]	DS Elevation [ft]	Flow Distance [ft]	Manning's n	Slope [ft/ft]						Travel Time [hr]
Short grass	818.00	817.00	95.00	0.150	0.0105						0.23
Subtotal											0.23
Shallow Concentrated Flow (after 300 feet of sheet flow)											
Type	US Elevation [ft]	DS Elevation [ft]	Flow Distance [ft]	Slope [ft/ft]	Velocity [ft/s]						Travel Time [hr]
Subtotal											0.00
Open Channels, Swales, and Pipes											
Type	US Elevation [ft]	DS Elevation [ft]	Flow Distance [ft]	Area [sqft]	Wetted Perimeter [ft]	User Specified, n	Manning's n	Slope [ft/ft]	Velocity [ft/s]	Travel Time [hr]	
Grass	817.00	816.00	250.00	5	10		0.025	0.0040	2.37	0.03	
Concrete	816.00	813.70	600.00	1.2	3.9		0.013	0.0038	3.23	0.05	
Subtotal											0.08
Developed Total without Storage Device [hr]											0.31
Storage Device											
Storage Volume [cft]	10-year Design Discharge [cfs]	Description									Travel Time [hr]
1750	1.22	Storage volume in raingarden									0.40
Subtotal											0.40
Developed Time-of-Concentration [hr]											0.71

Additional flow time associated with runoff passing through structural BMPs can be calculated using the Storage Device table in the Tc tab. The additional flow time is calculated as the BMP storage volume divided by the 10-year design discharge. Peak discharge entering the BMP is calculated using the Rational Method, or the CN Method via computer program (SSA, WIN-TR55) or a separate LGROW Design Spreadsheet. Storage devices should only be included if they are part of the longest flow route. The Storage Device table may be completed to calculate BMP travel time when selecting "User" input in the Flood Control tab, and does not require completing the entire Tc tab.

In the case study, the developed time-of-concentration is increased from 0.31 hour to 0.71 hour after accounting for the storage in all structural BMPs located along the longest flow route.

Flood Control Tab

The Flood Control tab is used to specify time-of-concentration for the site, compute the flood control volume, and provide site-wide volume and discharge results for a range of rainfall frequencies.

Time-of-Concentration

The existing and developed times-of-concentration can be specified in one of two ways. Values from the worksheet in the Tc tab can be selected, or user supplied values can be entered manually. In the case study, the method selected is "Worksheet." Regardless of the value supplied by the user or in the worksheet, the value used will never be less than 0.1 hour. An error message will appear if a time-of-concentration greater than 20 hours is entered.

Time-of-Concentration			Click here for documentation
	Worksheet	User	Value Used
Existing [hr]	0.66		0.66
Developed [hr]	0.71		0.71
Notes:			Method Selected
			Worksheet

Flood Control Volume

The spreadsheet can be used to compute the flood control volume using either detention or retention.

The user is required to check whether emergency overflow routes are available if the basin overtops. A notice will appear if additional flood protection is needed.

Flood Control Volume		Click here for documentation
Detention - Routing Method		Retention
Design Storm	25-year	Design Storm
Developed Peak Discharge [cfs]	7.17	Site Runoff Volume [cft]
		104,650
Allowable Discharge Worksheet	Select	Runoff Volume Retained by BMPs [cft]
Standard Discharge [cfs] - 0.13 [cfs/ac]	0.78	41,161
Alternate Discharge [cfs]	0.00	Unretained Runoff Volume [cft]
		63,489
Detention Required?	Yes	
Allowable Discharge [cfs]	0.78	
Required Storage Volume [cft]	19,942	
Time to Drain [hrs]	14.2	
Calculate Detention Storage Volume		Calculated
No Emergency Overflow Routes	<input type="checkbox"/>	
Notes:		

Detention

Select the design storm event from the pulldown. Use the option button to select the standard discharge or an alternate user-supplied value. If the developed peak discharge is less than or equal to the selected allowable discharge, no detention storage is required.

The detention storage is calculated using an embedded macro. To run this macro, simply press the “Calculate Detention Storage Volume” button. A notice to the right of the button will remind you if this needs to be done. An error message will appear if the allowable discharge is zero.

A notice will appear if the existing runoff volume is less than or equal to the developed runoff volume. The user is notified because an alternate release rate may be allowed under these conditions.

Underground detention storage is handled the same as an above-ground detention basin. Remember to count only the void spaces in any media used to provide the required storage volume.

In the case study 19,942 cft is the total storage volume required in the detention basin before discharging offsite. This volume includes the extended detention volume reported in in the Summary tab, but it does not include structural BMP volumes entered in the Sub tabs. The volume provided in all structural BMPs (Vbmp) is used to reduce the inflow volume to the detention basin.

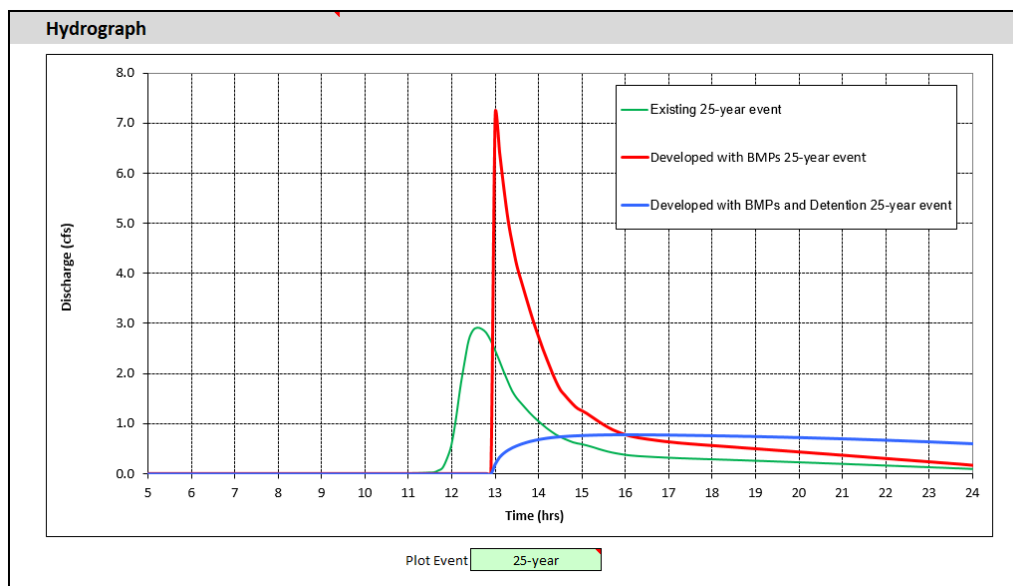
Note that any changes in subcatchment properties impacting time-of-concentration, runoff depth, retention volume, and any changes to allowable site discharge will impact the required detention storage volume. Be sure to check that the detention volume is calculated after making these changes.

Retention

When a retention basin or other infiltration practice is used for flood control, the area and storage volume are entered in the Sub tab(s) in Section 3 to receive credit for channel protection. The Retention summary shown on the Flood Control tab will credit the user with the volume provided in the Sub tabs. The “Unretained Runoff Volume” will be equal to zero when retentive BMPs are adequately sized to meet the flood control volume.

Hydrograph

The Flood Control tab also provides a plot showing outflow hydrographs for the “Existing,” “Developed with BMPs,” and “Developed with BMPs and Detention” cases. Hydrograph plots are selectable for different rainfall events.



Results Summary

Finally, a site-wide volume and discharge results summary table is provided. The user can select desired volume units (cubic feet or acre-feet).

Average runoff depth is provided for comparison with rainfall depth. Peak discharges are shaded differently from volumes for ease of comparison between development conditions.

The “Volume retained by BMPs” row of the table shows that the volume retained by BMPs, which was limited to the 2-year rainfall volume in Section 3b, increases with rainfall depth for larger storms until the available water storage volume of the BMPs is reached.

Results Summary					
Volume Units	cft				
Rainfall					
Source and Distribution	24-hour, NOAA Atlas 14 at Grand Rapids Intl AP, NRCS MSE4				
Rainfall Frequency	1-year	2-year	10-year	25-year	100-year
Rainfall Depth [in]	2.22	2.56	3.77	4.66	6.27
Pre-settlement Land Use					
Average Runoff [in]	0.10	0.18	0.58	0.98	1.87
Peak Discharge [cfs]	0.07	0.22	1.10	2.25	4.95
Runoff Volume [cft]	2,238	3,886	12,707	21,432	40,749
Existing Land Use					
Percent Impervious	0%	0%	0%	0%	0%
Average Runoff [in]	0.15	0.24	0.71	1.16	2.14
Peak Discharge [cfs]	0.19	0.34	1.54	2.91	5.92
Runoff Volume [cft]	3,211	5,234	15,425	25,300	46,708
Developed Land Use					
Percent Impervious	67%	67%	67%	67%	67%
Average Runoff [in]	1.46	1.72	2.69	3.42	4.80
Peak Discharge [cfs]	3.84	4.62	7.50	9.74	13.69
Runoff Volume [cft]	31,848	37,547	58,522	74,579	104,650
Volume Retained by BMPs [cft]	18,949	21,466	29,090	34,889	41,161
Volume Released [cft]	12,899	16,081	29,432	39,690	63,489
Peak Discharge Released [cfs]	1.45	1.95	4.55	7.17	11.75
Developed with BMPs and Detention					
Peak Discharge Released [cfs]	0.35	0.41	0.62	0.78	5.15
Maximum Volume Detained [cft]	3,949	5,382	12,764	19,942	19,923

Special Cases

Case Study: Catchbasins

When a storm sewer run or network is included in a single subcatchment, and no pass-through water is added from upstream subcatchments, the TSS removal achieved by the catchbasin sumps can be handled by pro-rating the treated water volume by the area entering each catch basin.

For example, in Sub5 of the case study each of the catch basin pairs treats one third of the water quality volume from the subcatchment.

5. TSS Accounting		Click here for documentation			
BMPs Used in Treatment Train	Treated Water Volume [cft]	TSS Removal Efficiency			TSS Removed
		Tabulated	Third-Party Supplied	Effective	
PASS: Catchbasin	949	22		7	209
PASS: Catchbasin	949	22		7	193
PASS: Catchbasin	949	22		7	179
					0
					0
					0
					0
Released Water Volume [cft]	2,846			Total TSS Removed	581
Water Quality Volume met?	No			TSS Remaining	2,265
				TSS Removal Efficiency [%]	20

Notes:

Case Study: Pervious Pavement with Elevated Underdrain and Roof Discharge

When a BMP is designed with an elevated underdrain to be both pass-through and retentive, the TSS removal can be handled by considering the BMP as a vertical treatment train. In other words, storm water runoff enters the lower (retentive) BMP component first, and as it fills to the elevation of the underdrain, the stormwater enters the upper (pass-through) BMP component. Only the lower portion is used to meet the channel protection volume.

In the case study, the underlying soils in Sub3 have a relatively low infiltration rate of 0.5 inches per hour. So, the stone bed (void fraction of 0.4) of the pervious pavement is designed with an underdrain set 2 feet above the bottom. The result is that only the lower 2 feet of stone bed storage can be used to meet channel protection volume requirement. The volume provided is computed as 31,502 cft.

For TSS accounting, the lower 2 feet of the pervious pavement stone bed is treated as a retentive BMP since it does not have an underdrain, while the upper 1 foot is treated as a pass-through BMP since it has an underdrain. Since the lower 2 feet fills up first, it is the first BMP in the treatment train. Since all the water quality volume can be retained in the lower part of the pervious pavement, the treated water volume in the upper part is zero.

5. TSS Accounting		Click here for documentation			
BMPs Used in Treatment Train	Treated Water Volume [cft]	TSS Removal Efficiency			TSS Removed
		Tabulated	Third-Party Supplied	Effective	
RET: Pervious Pavement	31,502	89		89	3,465
PASS: Pervious Pavement (underdrain)	0	84		0	0
PASS: Pervious Pavement, roof discharge to stone bed (underdrain)	0	50		0	0
					0
					0
					0
					0
Released Water Volume [cft]	0	Total TSS Removed			3,465
Water Quality Volume met?	Yes	TSS Remaining			428
		TSS Removal Efficiency [%]			89

Notes:

Roof Discharge

In Sub3 of the case study, the BMP “PASS: Pervious Pavement, roof discharge to stone bed (underdrain)” is shown as zero because the volume of roof runoff is fully contained in the lower retentive portion of the pervious pavement. However, if the underdrain were placed on the bottom of the pervious pavement section, the user would select this BMP for the water quality runoff volume from the roof (area of the roof * 0.815 * 1 inch of rain). The user would then select “PASS: pervious pavement (underdrain)” for the runoff from the pervious pavement (area of the pavement * 0.98 * 1 inch of rain), or the remaining water volume to be treated. The spreadsheet allows the user to account for these sources separately because the TSS removal efficiency differs for each.

Retention Storage Volumes

The storage volume below a positive surface outlet in a retentive BMP is counted as retention storage volume.

The storage volume above the surface outlet in a retentive BMP should be counted as detention storage volume. Although a certain amount of water occupying the storage volume above the surface outlet may still exfiltrate through the BMP, this fraction is ignored to size the detention portion of the BMP. If a more detailed analysis is required, the system should be modeled with both exfiltration and surface discharge.

Perforated pipe, alone or in an infiltration trench, does not count toward retention volume if the pipe has a slope and a surface outlet. Only the portion below the surface outlet counts toward retention.