

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 (i.e. workbook). 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 Sub8:** These tabs are used to specify the characteristics of each subcatchment. Each site can be divided into as many as 8 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.
- **Notes:** This tab provides an unlocked worksheet to be utilized as the user sees fit.
- **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.

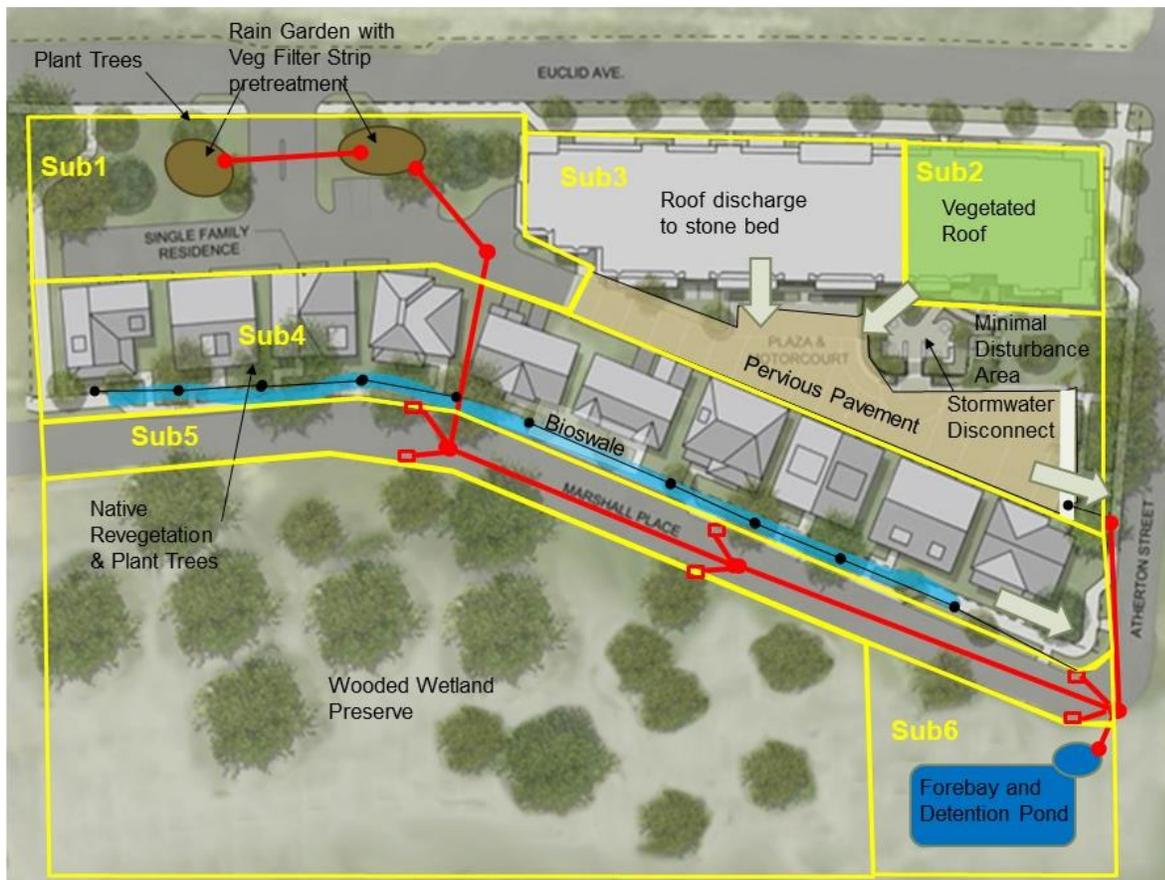
Notes on Use and Data Entry

- 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 “Clear Worksheet” button is provided at the top of each tab to allow the user to clear all input data entered in a worksheet by clicking the button and then hitting the delete key, without having to clear each cell individually.
- 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 10).
- 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 | Design Firm | Doe Engineering & Surveying Inc. |
| Address/Location | Urban Township | Engineer | RJH |
| Developer/Owner | Jane Doe | Date | 9/16/2021 |
| Run | | | |
| | Select if Yes | Notes | |
| Drainage District | <input checked="" type="checkbox"/> | County Drain No. 1; detention basin discharges to drain located on east side of property | |
| Watershed Policy | <input type="checkbox"/> | | |
| Redevelopment/Addition | <input type="checkbox"/> | | |
| MS4 | <input checked="" type="checkbox"/> | Site located in MS4 urbanized area; disturbance > 1 acre; discharge to waters of the state | |
| 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.

Indicate if channel protection volume is not required for the site, or will be provided offsite, or if the alternative approach will be used. A notice will appear if the alternative approach is selected.

| Channel Protection Volume Basis | | |
|-------------------------------------|--------------------------|-------|
| Pre-development Land Use Definition | Existing | Notes |
| Not Required | <input type="checkbox"/> | |
| Provided Offsite | <input type="checkbox"/> | |

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, ..., Sub8) 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 8 is entered, or if all downstream subcatchments have not been selected.

| Subcatchment Connectivity | | |
|---------------------------|-------------------------|----------------------------------|
| Number of Subcatchments | | 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 subsubcatchment 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 need not be delineated for each catchbasin inlet. A single subcatchment may be defined for an entire run or network of storm sewer. (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.

| Subcatchment Hydrology Summary | | | | | | |
|----------------------------------|-------------|--------------|------------|-------------|--------------|------------|
| Subcatchment Name | Existing | | | Developed | | |
| | Area [ac] | % Impervious | Average CN | Area [ac] | % Impervious | Average CN |
| Sub1 | 1.20 | 0% | 50 | 1.20 | 50% | 68 |
| Sub2 | 0.40 | 0% | 61 | 0.40 | 100% | 98 |
| Sub3 | 1.60 | 0% | 61 | 1.60 | 72% | 88 |
| Sub4 | 1.60 | 0% | 61 | 1.60 | 69% | 86 |
| Sub5 | 0.80 | 0% | 61 | 0.80 | 100% | 98 |
| Sub6 | 0.40 | 0% | 80 | 0.40 | 0% | 90 |
| | | | | | | |
| | | | | | | |
| Site Totals and Averages: | 6.00 | 0% | 60 | 6.00 | 67% | 86 |

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 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 |
| Required Extended Detention Volume [cft] | 11,397 |
| Required Extended Detention Release Rate [cfs] | 0.088 |
| 1-year Existing Peak Discharge [cfs] | 0.15 |

Water Quality

A summary table is provided to account for water quality volume and Total Suspended Solids (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 13,707 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 | Yes | 2,846 | 0 | 2,846 | 626 |
| Sub6 | 0 | Yes | 0 | 2,937 | 2,937 | 2,643 |
| Total | 14,000 | Yes | 14,000 | | | 13,707 |
| TSS Removal Efficiency [%] | | | | | | 98 |
| 80% TSS removal met? | | | | | | Yes |

Sub Tabs

Runoff

Land Use

This section 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 CPV 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.

A weighted Curve Number is provided for reference although it is not used in the spreadsheet calculations. Runoff volumes are computed for each landuse–soil combination and then summed.

| Sub1: Drives, Parking and Rain Garden | | | | | | |
|--|-----|------|-------|------------------------------|----------------|-------------|
| 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 | |
| | | | | | | |
| | | | | | | |
| | | 1.20 | acre | 50 | 44 | |
| 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): Woods | | A | 1,600 | sqft | 30 | |
| | | | | | | |
| Notes: | | | 1.20 | acre | 68 | |
| Existing is pasture. Half is HSG A with remainder HSG B | | | | | | |

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 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 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 in the CPV section where they can be selected as structural BMPs to capture (retain) 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 Retained against the cumulative runoff volume from the subcatchment. Since retentive BMPs may be designed larger than the minimum required CPV, 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.

| 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 |

Channel Protection Volume

This section provides calculations for CPV and sizing retentive BMPs.

| Channel Protection Volume | | Click here for documentation | | | |
|---|----------------------------------|------------------------------|---|-----------------|--------------------------|
| Required Channel Protection Volume | | 2-year Runoff Volumes [cft] | | | |
| Is Channel Protection Volume required? If no, provide reason. | Yes | Developed | Pre-developed | | |
| Required this Subcatchment [cft] | 4,610 | 5,076 | 466 | | |
| Unmet from Upstream Subcatchments [cft] | 0 | | | | |
| Required Channel Protection Volume [cft] | 4,610 | | | | |
| 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 Retained [cft] |
| Bioretention / Rain Garden | 3,300 | 1,650 | 2.35 | 2.56 | 4,628 |
| | | | | N.A. | |
| | | | | N.A. | |
| | | | | N.A. | |
| Totals | | 1,650 | | | 4,628 |
| 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) | | | | | |

Required Channel Protection Volume

This section shows the increase in 2-year runoff volume, which is also referred to as the channel protection volume (CPV). If any upstream subcatchments do not fully provide the required CPV, the unmet portion is added here.

Structural BMPs used to meet Channel Protection Volume

This table 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 for Filter Media. 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 retained by each 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. (Refer to Retention Storage Volumes under Special Cases for guidelines on what can be counted as retention).

The credited CPV shown is the sum of the volumes retained by each BMP, limited by the sum of the 2-year runoff volume from the subcatchment and any unmet CPV from upstream subcatchments.

In the case study, the volume retained by the BMP is greater than the storage volume. Also, since the required CPV is less than the volume retained, the credited CPV is set at the lower value.

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.

| E37 | | =D37*0.5 | | | |
|-----|---|----------------------------|----------------------------------|------------------------------|---|
| A | B | C | D | E | F |
| | | Structural BMP | A Infiltration Area [sqft] | V Storage Volume [cft] | i Design Infiltration Rate [in/hr] |
| 36 | | | | | |
| 37 | | Bioretention / Rain Garden | 3,300 | 1,650 | 2.35 |

Water Quality Volume

This section computes the water quality volume. The water quality volume is calculated for all impervious areas (including gravel) entered in the Developed Land Use table and for disturbed pervious areas entered in the table. 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.

| Water Quality Volume | | Click here for documentation | | |
|--|--------------|--|--------------------|-------------------------|
| | | Paved [ac] | Pitched Roofs [ac] | Flat Roofs/Unpaved [ac] |
| Sum of Directly Connected Impervious Area [ac] | 0.60 | 0.60 | | |
| Sum of Directly Connected Disturbed Pervious Area [ac] | 0.49 | | | |
| Required Volume this Subcatchment [cft] | 2,197 | TSS Generated this Subcatchment | | 2,197 |
| Volume from Upstream Subcatchments [cft] | 0 | TSS from Upstream Subcatchments | | 0 |
| Water Quality Volume to be Treated [cft] | 2,197 | TSS to be Treated | | 2,197 |

This section also computes the TSS generated from the 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.

TSS Accounting

This table 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 the CPV section. The CPV table included only those BMPs that retain the water onsite. The TSS Accounting table 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 retained by the BMP. A Constructed Filter is a pass-through BMP that must be designed similar to a retentive BMP to ensure it captures the desired water quality volume.

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.

| TSS Accounting | | | | | |
|---|----------------------------|------------------------|-------------|----------------------------|-------------|
| BMPs Used in Treatment Train | Treated Water Volume [cft] | TSS Removal Efficiency | | | TSS Removed |
| | | Tabulated | Third-Party | Effective | |
| PASS: Vegetated Filter Strip (sized for pretreatment) | 2,197 | 50 | | 50 | 1,098 |
| RET: Bioretention/Rain Garden | 4,628 | 89 | | 89 | 978 |
| | | | | | 0 |
| | | | | | 0 |
| | | | | | 0 |
| Released Water Volume [cft] | 0 | | | Total TSS Removed | 2,076 |
| Water Quality Volume met? | Yes | | | TSS Remaining | 121 |
| Notes: | | | | TSS Removal Efficiency [%] | 95 |

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 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 Retained” column in the CPV section. 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.

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. 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.

The calculator can also be used to determine an infiltration rate for top dressing placed in retentive BMPs (subject to any limiting values given in the Manual). In the case of retentive BMPs, the simple units conversion of the hydraulic conductivity of the media is used as it is most conservative.

As shown in the case study, a units conversion from a hydraulic conductivity of 4.69 ft/day results in 2.35 in/hr used for the retentive rain garden BMP.

| Infiltration Rate Calculator for Filter 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 |

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

| Retentive BMP | Value |
|---------------------------|-------|
| Infiltration Rate [in/hr] | 2.35 |

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

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 Time-of-Concentration | | | | | | | | | | 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] |
| 1650 | 1.22 | Storage Volume in raingarden | | | | | | | | 0.38 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| Subtotal | | | | | | | | | | 0.38 |
| Developed Time-of-Concentration [hr] | | | | | | | | | | 0.68 |

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 0.68 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] | 0.68 | | 0.68 |

Method Selected: **Worksheet**

Notes:

Flood Control Volume

The spreadsheet can be used to compute the flood control volume using either detention or retention. The flood control volume is the storage volume required for the design storm.

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 - Summary of Volumes | |
| Design Storm | 25-year | Design Storm | 100-year |
| Total Contributing Area [ac] | 6.00 | Site Runoff Volume [cft] | 104,650 |
| Developed Peak Discharge [cfs] | 6.49 | BMP Storage Volume [cft] | 24,341 |
| Allowable Discharge Worksheet | Select | BMP Infiltrating Volume [cft] | 16,659 |
| Standard Discharge [cfs] - 0.13 [cfs/ac] | 0.78 | Total Volume Provided [cft] | 41,001 |
| Alternate Discharge [cfs] | | Runoff Volume Retained by BMPs [cft] | 41,001 |
| Credited BMP Retention Volume | Volume Retained | Unretained Runoff Volume [cft] | 63,649 |
| Detention Required? | Yes | | |
| Allowable Discharge [cfs] | 0.78 | | |
| Required Storage Volume [cft] | 17,948 | Required Storage Volume [cft] | 88,952 |
| Time to Drain [hrs] | 12.8 | | 0.85 x "Site Runoff Volume" |
| 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.

Not all communities follow the same rules for crediting the retention provided by BMPs when determining the storage volume required for flood control. The spreadsheet allows the user to select from a drop-down list to credit all, only a portion, or none of the retention volume provided by onsite stormwater BMPs. The retention volume is subtracted off the front of the inflow hydrograph entering the detention basin.

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.

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.

In the case study 17,948 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 retained in all structural BMPs is used to reduce the inflow volume to the detention basin.

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) to receive credit for channel protection. The “Retention - Summary of Volumes” section on the Flood Control tab provides the cumulative storage and infiltrating volumes from the Sub tab(s) for use in determining the Required Storage Volume.

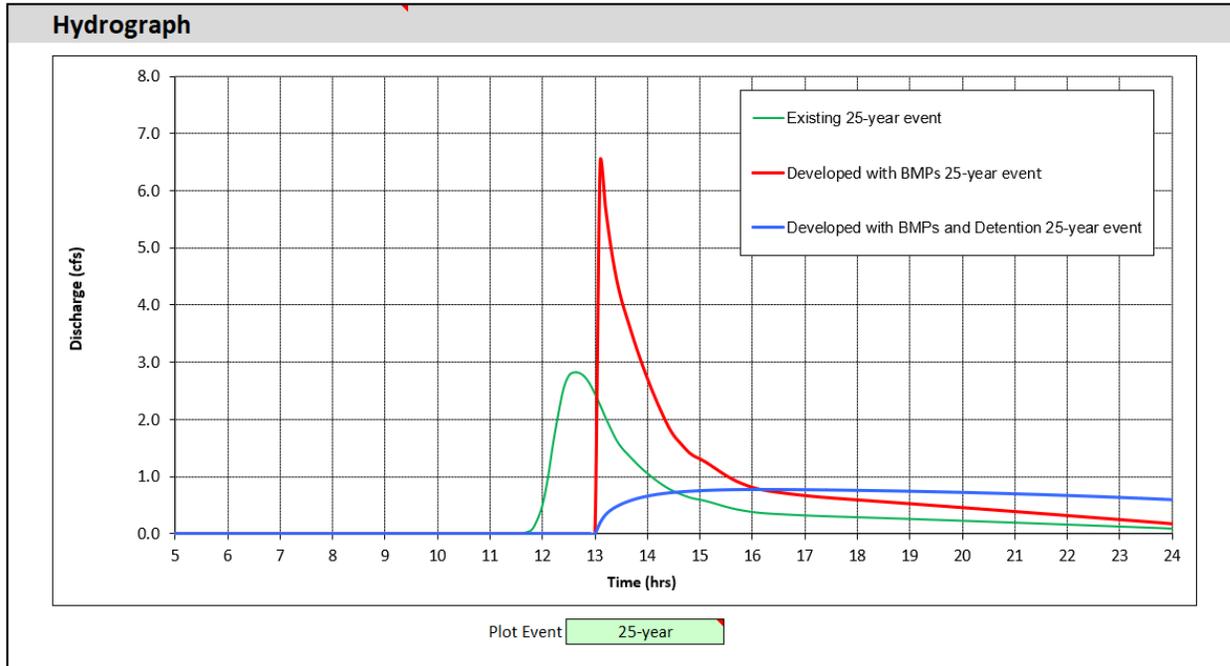
Not all communities follow the same rules for sizing retention BMPs used for flood control. Therefore, the Required Storage Volume must be entered by the user based on the directions programmed into the spreadsheet from the Settings tab. These directions will print below the “Required Storage Volume” cell.

In the case study, a storage volume of 88,952 cft is required if a retention basin were to be used for flood control. The storage volume provided by the retentive BMPs would be subtracted from the total required volume, so the retention basin would need to store the balance of 64,611 (88,952 – 24,341) cft.

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.

The plot below from the case study illustrates how the front of the inflow hydrograph to the detention basin is truncated by the retentive BMPs.



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. Time-of-concentrations are provided for reference. 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, 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 | | | | | |
| Time-of-Concentration [hr] | 0.66 | | | | |
| 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 | | | | | |
| Time-of-Concentration [hr] | 0.66 | | | | |
| Percent Impervious | 0% | 0% | 0% | 0% | 0% |
| Average Runoff [in] | 0.15 | 0.24 | 0.71 | 1.16 | 2.14 |
| Peak Discharge [cfs] | 0.15 | 0.32 | 1.45 | 2.83 | 5.82 |
| Runoff Volume [cft] | 3,211 | 5,234 | 15,425 | 25,300 | 46,708 |
| Developed Land Use | | | | | |
| Time-of-Concentration [hr] | 0.68 | | | | |
| Percent Impervious | 67% | 67% | 67% | 67% | 67% |
| Average Runoff [in] | 1.46 | 1.72 | 2.69 | 3.42 | 4.80 |
| Peak Discharge [cfs] | 3.66 | 4.53 | 7.51 | 9.79 | 14.01 |
| Runoff Volume [cft] | 31,848 | 37,547 | 58,522 | 74,579 | 104,650 |
| Volume Retained by BMPs [cft] | 18,949 | 21,305 | 28,929 | 34,728 | 41,001 |
| BMP Volume Credited to Detention [cft] | 18,949 | 21,305 | 28,929 | 34,728 | 41,001 |
| Volume Released [cft] | 12,899 | 16,242 | 29,593 | 39,850 | 63,649 |
| Peak Discharge Released [cfs] | 1.15 | 1.80 | 4.61 | 6.49 | 12.05 |
| Developed with BMPs and Detention | | | | | |
| Peak Discharge Released [cfs] | 0.34 | 0.42 | 0.66 | 0.78 | 6.15 |
| Maximum Volume Detained [cft] | 3,462 | 5,157 | 12,828 | 17,948 | 17,930 |

Special Cases

Case Study: Catchbasins

The user may take credit for the water quality treatment provided by the initial catchbasin that receives water from the contributing area.

When a storm sewer run or network is included in a subcatchment, the Treated Water Volume is equal to the total water quality volume for the subcatchment because all water is entering the storm sewer by a catchbasin. The Treated Water Volume can also be pro-rated if only a portion of the subcatchment is entering the storm sewer through a catchbasin.

If a storm sewer run or network is included in a subcatchment with pass-through water from upstream subcatchments, the pass-through water will be counted as being treated by the catchbasin in the downstream subcatchment. In this case, it is better to route the upstream subcatchment to the next downstream treatment BMP.

For example, in Sub5 of the case study the water quality volume is treated by at least one catch basin.

| Water Quality Volume | | Click here for documentation | | | |
|--|----------------------------|--|--------------------|-------------------------|--------------|
| | | Paved [ac] | Pitched Roofs [ac] | Flat Roofs/Unpaved [ac] | |
| Sum of Directly Connected Impervious Area [ac] | 0.80 | 0.80 | | | |
| Sum of Directly Connected Disturbed Pervious Area [ac] | 0.00 | | | | |
| Required Volume this Subcatchment [cft] | 2,846 | TSS Generated this Subcatchment | | 2,846 | |
| Volume from Upstream Subcatchments [cft] | 0 | TSS from Upstream Subcatchments | | 0 | |
| Water Quality Volume to be Treated [cft] | 2,846 | TSS to be Treated | | 2,846 | |
| TSS Accounting | | | | | |
| BMPs Used in Treatment Train | Treated Water Volume [cft] | TSS Removal Efficiency | | | TSS Removed |
| | | Tabulated | Third-Party | Effective | |
| PASS: Catchbasin | 2,846 | 22 | | 22 | 626 |
| | | | | | 0 |
| | | | | | 0 |
| | | | | | 0 |
| | | | | | 0 |
| Released Water Volume [cft] | 2,846 | Total TSS Removed | | | 626 |
| Water Quality Volume met? | Yes | TSS Remaining | | | 2,220 |
| Notes: | | TSS Removal Efficiency [%] | | | 22 |

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 CPV.

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 CPV requirement. The volume retained 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.

| Water Quality Volume | | Click here for documentation | | | |
|---|----------------------------|--|--------------------|-------------------------|--------------|
| | | Paved [ac] | Pitched Roofs [ac] | Flat Roofs/Unpaved [ac] | |
| Sum of Directly Connected Impervious Area [ac] | 1.15 | 0.55 | | 0.60 | |
| Sum of Directly Connected Disturbed Pervious Area [ac] | 0.10 | | | | |
| Required Volume this Subcatchment [cft] | 3,775 | TSS Generated this Subcatchment | | 3,775 | |
| Volume from Upstream Subcatchments [cft] | 0 | TSS from Upstream Subcatchments | | 118 | |
| Water Quality Volume to be Treated [cft] | 3,775 | TSS to be Treated | | 3,894 | |
| TSS Accounting | | | | | |
| BMPs Used in Treatment Train | Treated Water Volume [cft] | TSS Removal Efficiency | | | TSS Removed |
| | | Tabulated | Third-Party | 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 |
| Released Water Volume [cft] | 0 | Total TSS Removed | | | 3,465 |
| Water Quality Volume met? | Yes | TSS Remaining | | | 428 |
| Notes: | | TSS Removal Efficiency [%] | | | 89 |

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.

Regional Detention Storage Volume

When a site contributes to a previously constructed regional detention basin with differing design criteria, the LGROW Design Spreadsheet can be used to determine the additional flood control volume needed for any combination of proposed site impervious and drainage area greater than those used in the original design assumptions. One of the following three methods can be employed:

Method 1 – Expansion of the Regional Basin

1. Run the spreadsheet for the existing site, including the proposed improvements up to the allowable percent impervious (Runoff C) with the previous allowable release rate, and the design storm per the current standards. Record the resulting “Required Storage Volume” from the Flood Control tab.
2. Run the spreadsheet for the proposed site with all proposed improvements with the previous allowable release rate, and the design storm per the current standards. Record the resulting “Required Storage Volume” from the Flood Control Tab.
3. Subtract the results of Step 1 from the results of Step 2. The difference is the additional storage volume needed for the increased impervious.

This method allows the existing site (and proposed site up to the allowable percent impervious) to be “grandfathered” into the previously approved stormwater standards for the development.

Method 2 – Onsite Detention

If detention must be provided onsite instead of expanding the regional basin the required storage volume must be computed for the parcel using current standards. Follow the steps outlined above with the standard release rate. If lands are added, or the impervious increase is large enough, computer modeling may be needed as onsite detention may not fully mitigate the runoff volume increase to the regional basin.

Method 3 – Onsite Retention of the Flood Control Event Volume Increase

1. Run the spreadsheet for the existing site, including the proposed improvements up to the allowable percent impervious (Runoff C). Record the resulting flood control event Runoff Volume for Developed Land Use from the Flood Control tab Results Summary section.
2. Run the spreadsheet for the proposed site with all proposed improvements. Record the resulting flood control event Runoff Volume for the Developed Land Use from the Flood Control tab Results Summary section.
3. Subtract the results of Step 1 from the results of Step 2. The difference is the retention volume needed to mitigate the increased impervious area. Depending on the community, the retention volume could be either the “Volume Retained” or the “BMP Storage Volume.”