San Diego BMP Sizing Calculator Methodology

Prepared for
San Diego County Copermittees
Original Submittal: May 2011
Final Submittal: January 2012

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Prepared by Eric Mosolgo, PE
and Tony Dubin, PE

Brown and Caldwell
9665 Chesapeake Drive, Suite 201
San Diego, California 92123

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Section 1

LID Sizing Factor Methodology

This chapter describes the modeling approach used to size low-impact development best management practices (LID BMPs) for the San Diego Hydromodification Management Plan (HMP), including the range of scenarios performed and key assumptions for describing pre-project and post-project conditions, and BMP hydraulics. This chapter also describes the type, configurations and dimensions of the LID BMPs modeled in support of the BMP Sizing Calculator software. The memo is organized into the following sections:

- Section 1.1 provides a brief overview of the HSPF model setup and BMP sizing process.
- Section 1.2 describes in greater detail how the HSPF models are setup for the San Diego HMP, including key input data.
- Section 1.3 summarizes the general process for computing LID BMP sizing factors.
- Section 1.4 describes the physical configurations of the BMPs.
- Section 1.5 summarizes HSPF model parameters used in the analysis.
- Section 1.6 summarizes unit runoff ratios developed as part of the analysis.
- Section 1.7 summarizes the LID BMP sizing factor results

1.1 Sizing Factor Approach

The purpose of the runoff simulation for existing and post-development site conditions is to evaluate the effectiveness of BMPs which mitigate the increase in stormwater runoff resulting from the conversion of pervious land surfaces to impervious surfaces. The pre-project runoff regime must be characterized for a variety of baseline soil groups, land cover, slope and rainfall scenarios. Increases in runoff peaks and durations from each of these baseline scenarios establish the impacts to be fully mitigated by a BMP in a particular site development project. This section summarizes the overall steps used in this study to size BMPs.

1.1.1 Develop Pre-Project and Post-Project Runoff Time Series

San Diego County and its Copermittees' approach to compliance with the stormwater runoff control provision of its NDPES permit is to ensure that post-project runoff at any given development does not exceed pre-project runoff peaks or durations for the range of flows that could potentially have significant impacts on receiving streams. This approach aims to address the potential impacts of an individual development and the cumulative effects of many developments in the same watershed.

Brown and Caldwell has developed sets of HSPF model parameters to represent a range of pre-project site conditions that may be encountered in San Diego County. The parameter selection process and parameter values are summarized in Section 1.5. The various possible combinations of these parameters determined the number of "scenarios" that might be required to adequately characterize the pre-project condition for any given development project in the County. Runoff from each scenario was simulated using locally collected rainfall time series data.

Once a continuous runoff time series was generated for the rainfall period of record for each scenario, partial duration frequency and duration analyses were performed on each time series to identify recurrence frequencies and durations for different size runoff events. (This step is needed to characterize the peak flows for various recurrence intervals). Unit runoff ratios developed as part of this analysis are located in Section 1.6

Consistent with the general design guidance in the *Countywide Model SUSMP*, designers are expected to minimize the amount of pervious surface that drains to BMPs. Post-project site runoff was therefore evaluated by simulating runoff from a unit area converted to 100 percent impervious surface. Comparing the pervious surface model output with the impervious surface model output shows the effects of development prior to adding a BMP.

1.1.2 Model the Hydraulic Response of BMPs

The project team constructed representations of each BMP in HSPF. For example, a bioretention basin is represented with separate surface ponding, growing medium, storage layers, an overflow relief outlet, a restricted underdrain outlet (as appropriate), and transmissivity of underlying soils. The configuration of these BMP elements and associated hydraulic characteristics can be varied to determine the configuration that provides the best performance in the least amount of space. The HSPF method for representing BMP facilities is called an F-TABLE, and is described further in Section 1.3.

1.1.3 Establish BMP Sizing Factors

To compute sizing factors for each BMP, the impervious runoff time series was routed through the BMP to develop a post-project “mitigated” runoff time series. Each BMP mitigates post-project runoff by providing infiltration and/or reduction of discharge rates to the drainage system. The post-project mitigated time series is then compared to the pre-project runoff time series to assess BMP performance. The BMP size (typically surface area) was varied over the course of multiple model iterations until a size was identified that adequately matched post-project to pre-project runoff. The runoff comparison was performed both for peak rates and durations. The following standard was applied to assess BMP performance:

Flow duration control - For flow rates ranging from 10, 30 or 50 percent of the pre-project 2-year runoff event ($0.1Q_2$, $0.3Q_2$, or $0.5Q_2$) to the pre-project 10-year runoff event (Q_{10}), the post-project discharge rates and durations shall not deviate above the pre-project rates and durations by more than 10 percent over and more than 10 percent of the length of the flow duration curve. The specific lower flow threshold will depend on results from the SCCWRP channel screening study and the critical flow calculator, as detailed in Chapter 4. A flow threshold of $0.1Q_2$ corresponds to a channel with a HIGH susceptibility to erosion, a flow threshold of $0.3Q_2$ corresponds to a channel with a MEDIUM susceptibility to erosion, and a flow threshold of $0.5Q_2$ corresponds to a channel with a LOW susceptibility to erosion.

Peak flow control - For flow rates ranging from the lower flow threshold to Q_5, the post-project peak flows shall not exceed pre-project peak flows. For flow rates from Q_5 to Q_{10}, post-project peak flows may exceed pre-project flows by up to 10 percent for a 1-year frequency interval. For example, post-project flows could exceed pre-project flows by up to 10 percent for the interval from Q_9 to Q_{10} or from $Q_{5.5}$ to $Q_{6.5}$, but not from Q_8 to Q_{10}.

1.1.4 Incorporate Sizing Factors into BMP Sizing Calculator

The sizing factors computed using the above process were incorporated into the BMP Sizing Calculator that development engineers and municipal plan review staff will use to describe site hydrology, compute pre- and post-project runoff rates, and size BMPs.

During the site design process, the project applicant's engineer will divide a project site into separate drainage management areas that will drain to individual BMPs. Based on the type of BMP selected, the amount of impervious and pervious tributary land, and local soil type and site slope, the BMP Sizing Calculator will look up the appropriate value derived from the HSPF modeling analysis. To account for rainfall variability across the County, BMP sizing factors have been developed for three distinct rainfall basins.

The BMP Sizing Calculator will also provide options for using self-retaining landscaping, soil amendments, and other techniques to limit site runoff, and contains a conservative approach to scale BMPs based on tributary pervious areas (i.e., in addition to the tributary impervious areas).

It should be noted that the appropriate lower flow threshold can be determined using the BMP Sizing Calculator. If no channel assessment is performed, then the lower flow threshold defaults to $0.1Q_2$. If a channel assessment is conducted, then the lower flow threshold is determined by the more conservative result between two tools – the SCCWRP channel assessment tool and the low flow calculator.

The SCCWRP channel assessment tool is discussed in depth in Appendix B of the approved San Diego Hydromodification Management Plan. Two tools are included – a lateral channel susceptibility screening tool and a vertical channel susceptibility tool. Both tools return results of HIGH, MEDIUM, or LOW susceptibility to erosion. The most conservative result between the two SCCWRP screening tools, in other words the most restrictive result, is the final result for the SCCWRP portion of the analysis. If the lateral tool returns MEDIUM susceptibility and the vertical tool returns LOW susceptibility, then the SCCWRP result would be MEDIUM.

Next, the user must enter basic channel information into the low flow calculator. The required channel information includes the channel bottom width, channel top width, bank height, the channel material (alluvial silt, cobbles, etc.), and the channel slope. Given this input data, the low flow calculator calculates the resultant flow associated with critical shear stress. This flow is compared to the 2-year draining to the location of the cross section location. The 2-year flow for the critical flow calculator is based upon the Wanaanen and Crippen regression equation for this South Coast Region of California.

$$Q_2 = 0.14 * A^{0.72} * P^{1.62}$$

Where Q_2 = 2-year recurrence peak flow (cfs)

A = total watershed area draining to the channel assessment (or geomorphic assessment) point of compliance (square mi)

P = mean annual precipitation (inches)

It should be noted that the Project Basin Area, which is entered in the Basin Manager's "Basin" tab, denotes the total area for the cumulative project site Drainage Management Areas (DMAs) draining to the project-specific point of compliance. The "Point of Compliance" (POC) discussed generically throughout this document is for BMP assessment. The POC for BMP assessment is a point downstream of the BMP, normally where runoff leaves the site at the project boundary. The Project-Specific BMP POC should not be confused with the POC for channel assessment. The POC for channel assessment is the point in the main channel where project runoff confluences with flow in the main channel. The subsequent analysis of channel susceptibility to erosion is based upon the total watershed area draining to the main channel (project runoff and offsite upstream runoff draining to the main channel at that location).

1.2 HSPF Model Development

1.2.1 HSPF Model Overview

An HSPF modeling study of a single watershed typically begins with gathering hydrologic information about the area, such as precipitation data, soil groups, growing medium layer depths, vegetation types, vegetation canopy thickness, etc. This information is used to develop appropriate input parameters to the HSPF model. HSPF parameters fall into three general categories:

1. **Prescriptive parameters** that set flags and specify algorithms to use.
2. **Measured or estimated parameters**, such as basin area, that are set by GIS analysis or physical measurement.
3. **Calibration parameters** that may be estimated by measurement, but must be adjusted during the model calibration process. Examples of calibration parameters are infiltration rates, upper soil depth, and groundwater conductivity.

Together these parameters describe the vertical movement (e.g., interception, depression storage, infiltration, evapotranspiration) and lateral movement (e.g., surface runoff, interflow, groundwater flow) of water in HSPF.

The purpose of hydrologic modeling within the HMP is to produce a County-wide assessment tool for sizing BMPs. This requires several modifications to the approach used in evaluating a single watershed. Sets of regional, representative parameters were applied to a theoretical unit area (1 acre model watershed), instead of developing and calibrating a specific watershed model. The representative model parameters were initially selected based on other HSPF studies in the area, such as the Santa Monica Bay HSPF watershed-scale model developed by staff at the Southern California Coastal Water Research Project (SCCWRP). In addition, the range of parameter variations across different soil types and slope values were estimated using other references, including EPA Technical Note 6 and various Brown and Caldwell studies (*Summary of HSPF Modeling Reports in Southern California – May 2009, HMP Modeling Approach and BMP Configurations – March 2010, Selection of PERLND Parameter for HSPF Modeling – April 2010).* The HSPF model parameters that are used to characterize the hydrologic response of pervious land surfaces to rainfall area (e.g., PERLND parameters) are described in detail in Section 1.5.

Adapting the compiled HSPF parameters for use in San Diego County required an assessment of the local characteristics that affect surface runoff, such as precipitation data, basic soil groups and vegetation cover. The following sections briefly summarize the range and variability in rainfall volumes and soil types within the County.

1.2.2 Rainfall Data Evaluation

Evaluating the distribution of rainfall across the County helped determine:

1. Precipitation gauges to use as input to HSPF for modeling simulations and
2. Extent of rainfall variation throughout the County.

The San Diego Alert Network operates a series of precipitation stations across the County, and the National Oceanographic and Atmospheric Administration (NOAA) operates a station at Lindbergh Field in San Diego. A total of 18 rainfall data sets are available for use with hydromodification management modeling. Rainfall station data sets, containing at least 30 years of hourly data, were evaluated in detail by Brown and Caldwell, which prepared and submitted summary technical memoranda that assessed the data records, identified data gaps, and provided recommendations for filling the data gaps. The Lindbergh Field gauge, which is meticulously maintained by the National Weather Service, contains no data gaps and was not edited by Brown and Caldwell.

Table 1-1 lists reference information about the gauges and Figure 1-1 shows the variation in mean annual rainfall depth. Mean annual precipitation values vary from 8.7 inches at Bonita to 30.4 inches at Lake Cuyamaca, with the majority of stations recording annual rainfall amounts between 10 and 15 inches. Scaling from the base rainfall stations was originally proposed, but the Land Development work group decided at the December 15, 2010 meeting to defer potential rainfall scaling efforts until a future date.

Based upon a review of the available rainfall information and to provide adequate geographic coverage of San Diego County, LID BMP sizing factors were developed for three rainfall stations (Lindbergh Field, Oceanside, and Lake Wohlford) and incorporated into the BMP Sizing Calculator.

Table 1-1. San Diego County Rain Gauge Station Reference Information

Station Name	Watershed	Start Date	End Date	Length of Record	Latitude	Longitude	Elevation (ft)	Max Hour Rain (in)	Mean Annual Rain (in)
Bonita	Sweetwater River	11/25/1970	5/25/2008	37 years	32.3922	-117.0203	120	1.10	8.7
Encinitas	North County Coastal	9/4/1963	6/30/2008	45 years	33.0237	-117.1639	242	0.88	10.2
Escondido	Escondido Creek	9/24/1964	5/23/2008	44 years	33.0711	-117.0542	645	0.88	13.7
Fallbrook	San Luis Rey River	7/25/1951	6/30/2008	57 years	33.213	-117.1513	675	1.40	15.1
Fashion Valley	San Diego River	1/2/1968	6/30/2008	40 years	32.4555	-117.1033	20	0.96	10.3
Flinn Springs	San Diego River	8/8/1963	6/30/2008	45 years	325055	-1165129	880	1.05	13.1
Kearny Mesa	San Diego River	9/8/1964	6/30/2008	44 years	32.5003	-117.0744	425	1.40	11.0
Lake Cuyamaca	Upper San Diego River	9/1/1967	6/30/2008	41 years	32.5921	-116.3513	4590	2.30	30.4
Lake Henshaw	Upper San Luis Rey River	1/2/1950	6/30/2008	58 years	331419	-1164542	2990	1.79	22.3
Lake Wohlford	Upper Escondido Creek	10/8/1949	7/7/2008	59 years	33.0959	-117.0016	1490	1.60	16.8
Lindbergh Field	Coastal – San Diego Bay	10/17/1948	6/30/2008	60 years	32.7333	-117.1833	15	1.36	9.8
Lower Otay	Otay River	8/28/1951	6/30/2008	57 years	32.3632	-116.554	491	0.84	10.3
Oceanside	San Luis Rey River	7/1/1951	6/30/2008	57 years	33.1238	-117.2112	30	1.20	11.7
Poway	Los Penasquitos River	10/4/1962	6/30/2008	46 years	32.5658	-117.0346	440	0.80	12.0
Ramona	Upper San Dieguito River	8/8/1963	6/30/2008	45 years	33.0253	-116.5139	1450	1.16	14.2
San Onofre	North County Coastal	11/25/1970	6/30/2008	38 years	33.2105	-117.3155	162	1.60	11.3
San Vicente	San Diego River	1/1/1973	6/10/2008	35 years	32.55	-116.5558	663	1.00	12.7
Santee	San Diego River	1/1/1973	9/26/2008	36 years	32.502	-117.013	300	1.00	13.2

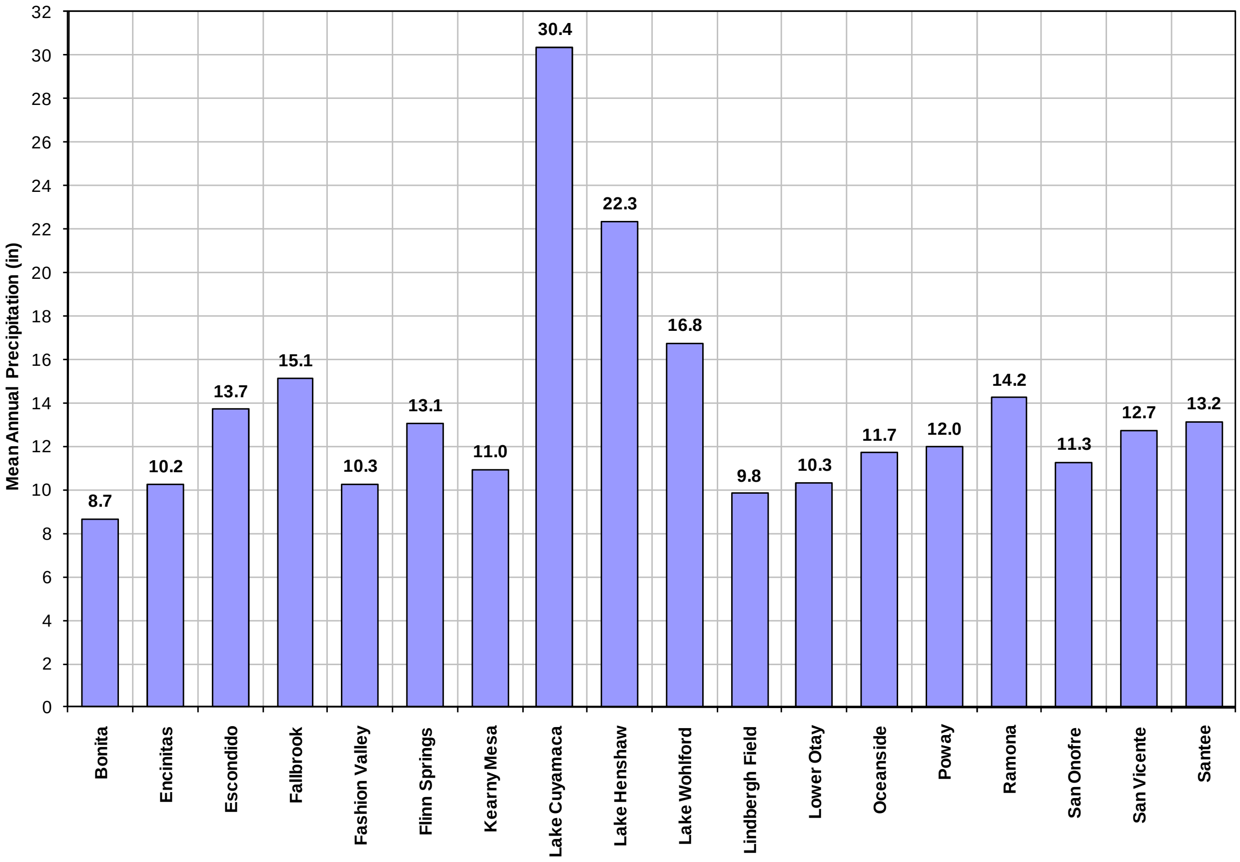


Figure 1-1. Rainfall Variation in San Diego County

1.2.3 San Diego Soils Map Evaluation

The HSPF model development was based on the commonly occurring and easy-to-identify soil hydrologic groupings used by the National Soils Conservation Service (NRCS). The NRCS uses four groupings called (in decreasing order of hydraulic conductivity) Group A, B, C and D. Group A soils are sandy and exceedingly well drained, while Group D soils are typically poorly drained clays. Group B and Group C soils exhibit hydraulic characteristics between those of Group A and Group D soils.

Figure 1-2 shows NRCS soil mapping for San Diego County. According NRCS data, about 43 percent of San Diego County is classified as NRCS Group D soils. Approximately one-quarter of the County consists of Group C soils and one-quarter Group B soils. The remaining 7 percent is classified as Group A soils. The well drained Group A and Group B soils occur more commonly in the eastern portions of the County that are not covered under this HMP. The central and western portions of the county consist mainly of the less hydraulically conductive Group C and Group D soils.

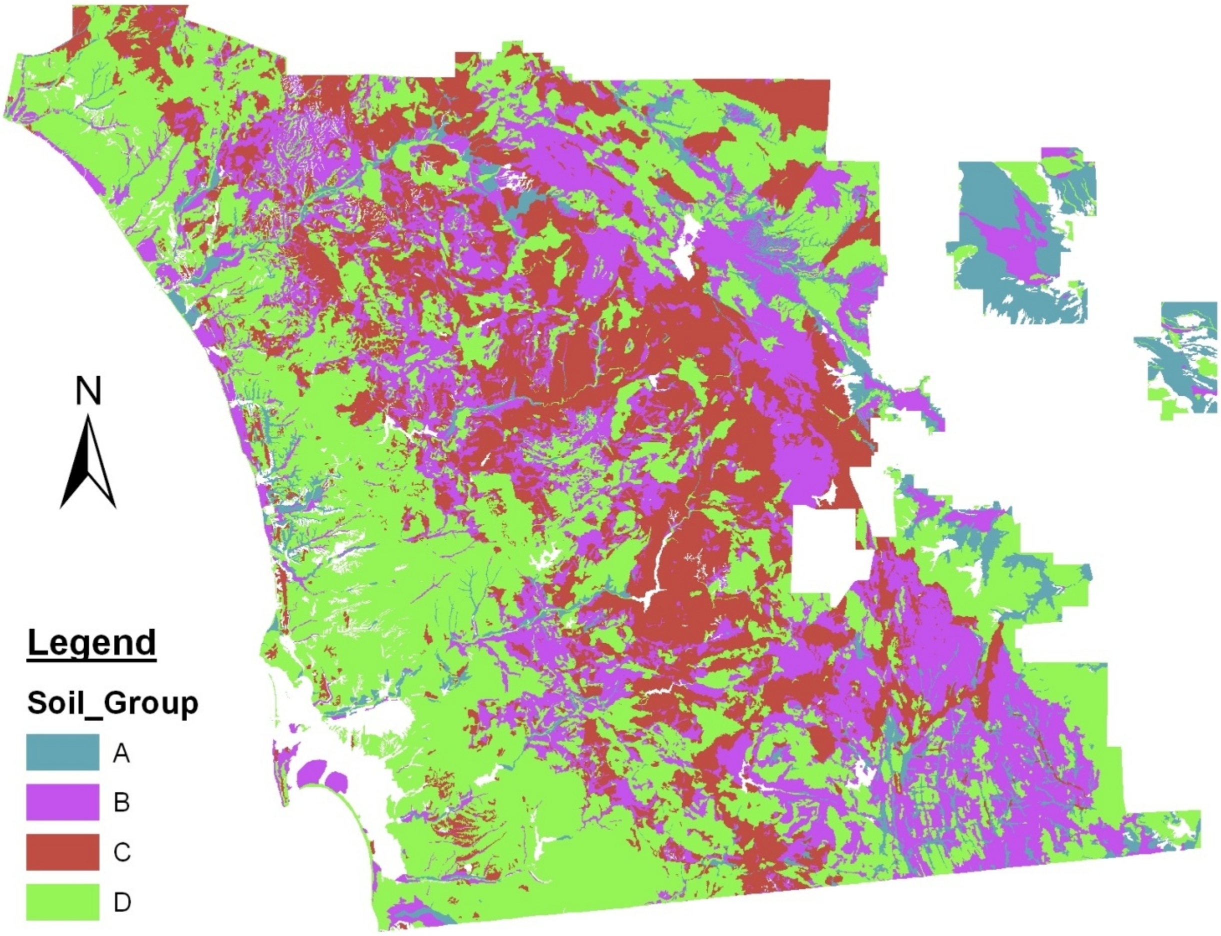


Figure 1-2. NRCS Soils Mapping of San Diego County

1.2.4 Scenarios Modeled

HSPF was used to characterize 12 different pre-project runoff scenarios corresponding to 4 soil types and 3 ranges of slopes. The range of land cover and vegetation types is not sufficiently variable among developable lands to require separate scenarios for different pre-project pervious land cover types. Table 1-2 below summarizes the scenario components. The specific HSPF pervious land surface parameters for these scenarios are described separately in Section 1.5.

Table 1-2. HSPF Scenarios for Characterizing Pre-Project Conditions

Scenario No.	NRCS Soil Group	Land Cover	Slope
1	A	Scrub, Shrub	Low (<5%)
2	A	Scrub, Shrub	Moderate (>5% and <15%)
3	A	Scrub, Shrub	Steep (>15%)
4	B	Scrub, Shrub	Low (<5%)
5	B	Scrub, Shrub	Moderate (>5% and <15%)
6	B	Scrub, Shrub	Steep (>15%)

Table 1-2. HSPF Scenarios for Characterizing Pre-Project Conditions

Scenario No.	NRCS Soil Group	Land Cover	Slope
7	C	Scrub, Shrub	Low (<5%)
8	C	Scrub, Shrub	Moderate (>5% and <15%)
9	C	Scrub, Shrub	Steep (>15%)
10	D	Scrub, Shrub	Low (<5%)
11	D	Scrub, Shrub	Moderate (>5% and <15%)
12	D	Scrub, Shrub	Steep (>15%)

1.3 Hydrologic Modeling Approach to Sizing BMPs

This section describes the technical approach used to represent BMPs in the HSPF modeling. The discussion focuses on the key physical aspects of BMP performance (i.e., how a BMP routes water through its different layers) and how these physical processes are represented in HSPF. This section also describes key hydraulic and modeling assumptions and how these assumptions impact both the modeling process and the accuracy of the results across the full range of flow conditions.

1.3.1 General BMP Characteristics

The flow control BMP designs selected by the San Diego County Copermittees include some combination of detention storage and water quality treatment media. For example, the bioretention BMP includes (in order of vertical routing) a surface ponding layer, a growing medium layer, and a storage layer. Each layer has a configuration, porosity, volume, and hydraulic conditions that influence the rate of flow to the next layer.

HSPF uses stage-storage-discharge tables to represent the hydraulic behavior of devices that detain and discharge water (e.g., LID BMPs included in the HMP). The *stage* represents depth of water in the facility, the *storage* represents the volume of water stored in the facility for that stage, and the *discharge* is the calculated outflow for that stage. Outflow may be via an orifice, infiltration, evaporation, or any other mechanism for which a relationship to stage or storage can be defined.

The following general hydraulic assumptions were applied to all of the modeled BMPs:

- Inflow is uniformly distributed over the area of the BMP (i.e., level-pool ponding).
- Infiltration and soil water movement is a 1-dimensional flux in the vertical direction (neglecting lateral flows is a conservative assumption).
- Soil moisture within a homogeneous growing medium layer is assumed to be evenly distributed throughout the growing medium layer both vertically and horizontally. This assumes an engineered BMP would be free of macropores.
- Percolation from the growing medium layer to the storage layer is computed based on unsaturated or saturated hydraulic equations, depending on the amount of moisture contained in the growing medium during each model time step.
- Water flows out the bottom of the BMP into the surrounding soil at the rate of saturated hydraulic conductivity.

  - The sandy loam soil used for the growing medium has an effective porosity of 0.412, based on Table 5.3.2 in the Handbook of Hydrology (Maidment, 1993). A sensitivity analyses conducted to determine the effect of porosity on BMP performance determined that porosity has little influence on the required sizing factor.
  - Evaporation data is consistent with data provided in the HSPF/BASINS software package for the San Diego region.

The percolation rate from the growing medium is based on the unsaturated and saturated hydraulic conductivity. During the BMP sizing simulations, the rate is capped to match the combined capacity of the orifice and the saturated hydraulic conductivity of the underlying soils.

1.3.2 Bioretention BMP HSPF Representation

The bioretention BMP is modeled using two FTABLEs. The first FTABLE represents the surface ponding layer, growing medium layer, and overflow outlet. The second FTABLE represents the storage layer, exfiltration to surrounding soils, and underdrain outflow, if applicable. Percolation from the growing medium to the storage layer is modeled as an outflow from the first FTABLE and inflow to the second FTABLE.

FTABLE 1:

Stormwater routed from impervious surfaces first enters the upper layer of an In-Ground Planter, represented by the example FTABLE 1 shown in Figure 1-3. The HSPF model assumes that all inflow will infiltrate if the layer is not saturated. This is a reasonable assumption based on the anticipated range of inflows (see Appendix A for a complete discussion of soils physics). The growing medium layer is represented by depths from 0 to 1.5 feet. The volume of storage at 1.5 feet is equal to the storage within the growing medium layer at saturation. Above this depth, water is stored in the ponding reservoir.

Water contained in the upper growing medium layer is stored as soil moisture. Although there are depths indicated in the first column of the FTABLE, the soil water is considered to be evenly distributed throughout the growing medium layer (e.g. a soil depth of 0.5 feet in FTABLE 1 corresponds to one-third saturated, not water filling the bottom 0.5 feet of the upper growing medium layer). Above 1.5 feet, water ponds on the planter surface, and the FTABLE 1 depth column corresponds to the actual water surface.

The fourth column in FTABLE 1 lists the rate of soil water percolation out the bottom of the upper growing medium layer and into the lower gravel layer. This column is calculated using Darcy's Law and the van Genuchten relations (see Appendix A). Percolation does not occur unless the soil water content exceeds the holding capacity of the soil (i.e., the gravitational head is greater than the suction or *matric head* within the soil pores). The percolation rate calculations assume a free surface at the interface with the lower layer. However, the percolation rate is limited if the lower layer reaches capacity and becomes saturated. In this case the percolation rate through the upper layer is limited to the percolation rate though the lower layer, which in itself is limited by the total outflow from the lower layer through the underdrain orifice and percolation to the surrounding soil. Thus, the percolation rate through the upper layer is limited to underdrain outflow rate plus a small amount of percolation to the surrounding soil when the planter reaches capacity.

The fifth column in the FTABLE is the outflow through the overflow, which is calculated using a weir equation (see Appendix A). Outflow through the overflow does not occur until the depth of storage in the ponding reservoir is above the overflow elevation.

```
  FTABLE      1
 rows  cols                                            ***
   31     5
     Depth       Area    Volume     Q Perc     Q Over   ***
      (ft)    (acres) (acre-ft)      (cfs)      (cfs)   ***
      0.00       0.03    0.0000     0.0000      0.000
      0.10       0.03    0.0012     0.0000      0.000
      0.20       0.03    0.0024     0.0000      0.000

                                                              Soil
      1.40       0.03    0.0168     0.0132      0.000
      1.50       0.03    0.0180     0.0707      0.000
   ------------------------------------------------------------
      1.60       0.03    0.0210     0.0760      0.000
                                                              Ponding

      2.40       0.03    0.0495     0.1957      0.100
      2.50       0.03    0.0525     0.1957      0.312
  END FTABLE1
```

Figure 1-3. Example FTABLE Describing Upper Layer of In-Ground Planter

FTABLE 2:

The second FTABLE represents the lower gravel layer and the underdrain. Percolation outflow from the first FTABLE is routed as inflow to the second example FTABLE as shown in Figure 1-4. This FTABLE represents the lower gravel layer, which has a depth of 1.5 feet above the underdrain orifice invert plus an additional 1 foot sump below the underdrain (total depth of gravel layer is 2.5 feet). The percolation rate out the bottom of the lower layer is limited by the hydraulic conductivity of the surrounding soil, which is a conservative assumption (percolation will actually be faster when native soils are unsaturated). All such assumptions will be validated and/or refined subsequent to collection of data from the post-construction HMP monitoring program.

When an underdrain is included in the configuration, the 'Q Outlet' column is included in the FTABLE for the outflow rate. This rate is calculated using the orifice equation (see Appendix A) so that the underdrain flow will match lower flow threshold when the lower gravel layer is fully saturated.

```
 FTABLE      2
rows cols                                                ***
  16    5
    Depth      Area    Volume    Q Perc  Q Outlet        ***
     (ft)   (acres) (acre-ft)     (cfs)     (cfs)        ***
     0.00      0.03    0.0000    0.0000     0.000
     0.10      0.03    0.0012    0.0001     0.000
     0.20      0.03    0.0025    0.0007     0.001
     0.30      0.03    0.0037    0.0007     0.005
     0.40      0.03    0.0050    0.0007     0.018
     0.50      0.03    0.0062    0.0007     0.047
     0.60      0.03    0.0075    0.0007     0.104
     0.70      0.03    0.0087    0.0007     0.133
     0.80      0.03    0.0100    0.0007     0.142
     0.90      0.03    0.0112    0.0007     0.151
     1.00      0.03    0.0125    0.0007     0.159
     1.10      0.03    0.0137    0.0007     0.167
     1.20      0.03    0.0149    0.0007     0.174
     1.30      0.03    0.0162    0.0007     0.181
     1.40      0.03    0.0174    0.0007     0.190
     1.50      0.03    0.0187    0.0007     0.195
 END FTABLE2
```

Figure 1-4. Example FTABLE Describing Lower Gravel Layer of In-Ground Planter

1.3.3 Iterative BMP Sizing Steps

Once the geometric characteristics of the BMP were represented in FTABLEs, as described above, the sizing factors were computed using an iterative process involving multiple HSPF simulations and statistical analyses. The process involved varying the surface area until peak flow and flow duration control were achieved.

The ability of the BMP to achieve peak flow and flow duration control was evaluated by generating and comparing partial duration series statistics and flow duration statistics for:

(a) Pre-project runoff from a pervious land surface and

(b) Post-project outflow from the BMP serving an equivalent area that has been converted to an impervious surface.

A 24-hour inter-event period (as defined by 24 hours with BMP outflow less than 0.003 cfs/ac) was used to separate storm events in the partial duration series. The footprint of the BMP was included in the calculations to preserve equivalence between the pre-project and post-project analysis (i.e., Pre-project Area = Impervious Area + BMP Area). The HSPF model allowed rainfall directly on the BMP.

BMP surface area was increased incrementally (for each computational iteration) until flow and duration control were achieved. Flow and duration control were considered to be achieved when the mitigated post-project peak flows and flow durations were less than or equal to the pre-project flows, as defined by the performance criteria in the Final HMP.

1.4 Low Impact Development (LID) BMP Descriptions

This section describes the LID BMPs that are included in the Countywide Model SUSMP, focusing on the elements that are explicitly represented within HSPF. The following LID BMPs will be evaluated for flow control and/or water quality treatment:

1. Bioretention
2. Cistern with bioretention
3. Bioretention with flow control vault
4. Flow-through planter
5. Infiltration facility

Non-structural strategies for stormwater management, such as pervious pavement, self-retaining areas, and self-treating areas are described in Chapter 3.

1.4.1 Bioretention

The bioretention facility consists of a surface ponding layer, a growing medium layer, and a below ground storage layer (see Figure 1-5). The bioretention BMP captures water in the ponding layer, filters it through a growing medium that consists of soil and plant roots, percolates water from the growing medium into a storage layer, and then slowly discharges treated stormwater via exfiltration to surrounding native soils and regulated discharge through an underdrain pipe to the local stormwater drainage system. For applications with well-draining native soils (e.g., NRCS hydrologic group A or B soils), an underdrain pipe would not be included.

For the HMP, the bioretention BMP was simulated using separate a) ponding layer, b) growing medium, and c) storage layer components. The following depths were assumed for each layer:

- **Ponding layer:** 10-inches active storage, 2-inches of freeboard above overflow relief
- **Growing medium:** 18-inches of soil at an assumed porosity of 41.2 percent
- **Storage layer:** 30-inches of gravel at 40 percent porosity

As described above in Section 1.3.3, the plan area of the BMP was iteratively sized until the BMP controls limited outflows to levels that less than or equal to pre-project conditions across flow rates ranging from the lower flow control limit ($0.1Q_2$, $0.3Q_2$ or $0.5Q_2$) to the upper flow control limit (Q_{10}). The sizes of the ponding layer and storage layer were converted into volumes, so that the project designer can flexibly configure the ponding layer and storage layer to meet site constraints. For example, the design engineer could configure the ponding layer with half the depth but twice the plan area called for by the sizing factor if this fits the project site. Additionally, the designer could use commercially-available storage vessels to meet the volume requirements instead of using gravel.

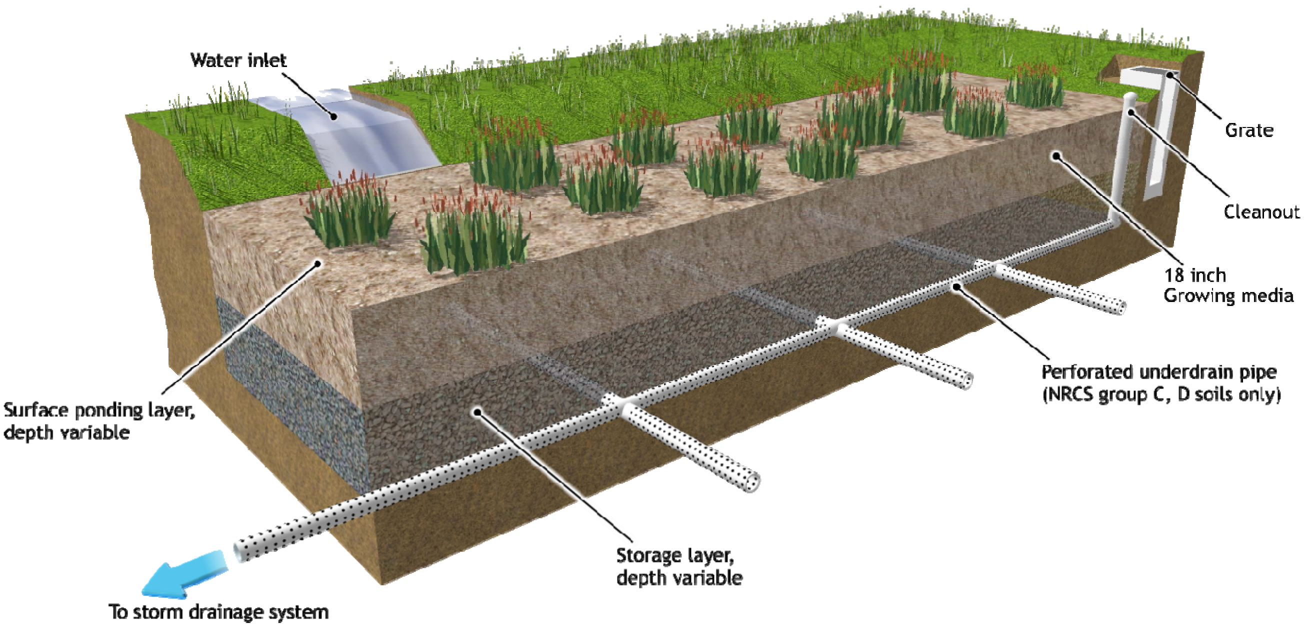


Figure 1-5. Bioretention BMP Example Illustration

1.4.2 Cistern with Bioretention

The cistern with bioretention BMP is a flow-control and treatment control BMP. The cistern component captures and detains site runoff, and then slowly releases the water to a nearby bioretention device that provides water quality treatment by filtering the stormwater through its soil matrix. The bioretention facility sizing is based on a surface area sizing factor of 0.04 and ponding depths as detailed in the Countywide Model SUSMP for water quality BMPs.

The cistern will contain two outlets. A lower orifice will be located at the bottom of the cistern and will be designed to release water at the lower flow control limit ($0.1Q_2$, $0.3Q_2$ or $0.5Q_2$) where it will be routed through the bioretention device. Because the cistern accomplishes the flow control requirement, the bioretention only provides water quality treatment and an underdrain is permissible for all soil groups. However, due to the high infiltration capacity of NRCS hydrologic group A soils, the underdrain should only be used in Group B, C, and D soils. For Group A soils, the bioretention element is not necessary and cistern discharges should be routed into native soils for infiltration and treatment. A small depression should be included in the landscaping to provide sufficient time for infiltration to occur. Typically, flows to a cistern facility are from rooftops, which do not generate heavy concentrations of the standard pollutants of concern. Thus, infiltration of flows from rooftops is generally considered to be OK provided that the soils have capacity to infiltrate.

For the HMP, the performance of the cistern with bioretention BMP was simulated using the following key assumptions:

- **Cistern configuration:** The cistern is modeled as a 4-foot tall vessel. However, designers could use other configurations (different cistern heights), as long as the lower outlet orifice is sized to properly restrict outflows and the minimum required volume is provided.
- **Cistern upper outlet:** The upper outlet from the cistern would consist of a weir or other flow control structure with the overflow invert set at an elevation of 7/8 of the water height associated with required volume of the cistern – V1 (see Figure 1-6). For the assumed 4-foot water depth in the cistern associated with the sizing factor analysis, the overflow invert is assumed to be located at

an elevation of 3.5 feet above the bottom of the cistern. The overflow weir would be sized to pass the peak design flow based on the tributary drainage area.

- **Bioretention configuration:** The bioretention needs only a small depression/ponding area to settle inflows prior to infiltration (for Type A soils). For water quality treatment (Type B, C, and D soils), the bioretention area should be 1.5 feet deep and contain the soil mixture specified in the *Countywide Model SUSMP* that allows a continuous infiltration rate of 5 inches per hour. The bioretention basin should be sized to pass the cistern outlet flows.

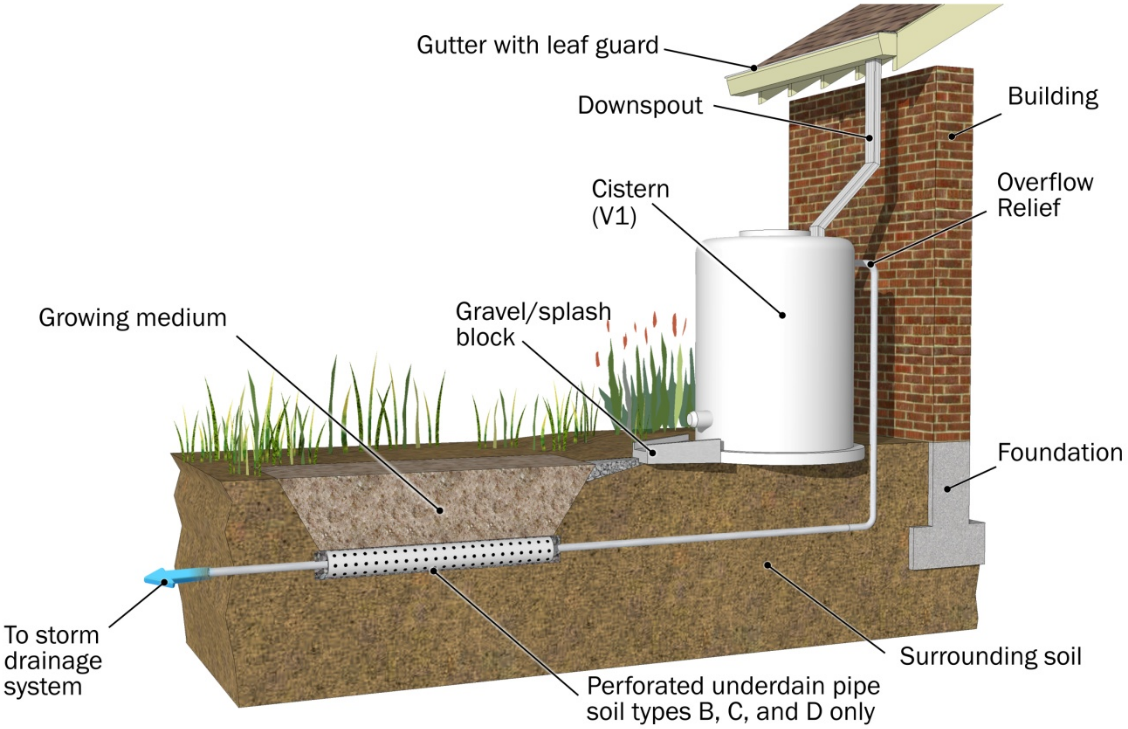


Figure 1-6. Cistern with Bioretention BMP Example Illustration

1.4.3 Bioretention with Vault

This BMP configuration routes stormwater through a bioretention basin for water quality treatment, and then discharges water to a nearby vault for detention and release (see Figure 1-7). The bioretention facility sizing is based on a surface area sizing factor of 0.04 and ponding depths as detailed in the Countywide Model SUSMP for water quality BMPs.

The vault contains a lower orifice to restrict outflows to meet the HMP's flow control requirements. The vault portion of the BMP could be located below, adjacent or farther away from the bioretention portion of the BMP. This BMP is particularly effective in commercial applications where distributed water quality treatment outflows could be collected into a single vault for flow control underneath a parking lot. There is no water quality treatment-only option.

For the HMP, the performance of the bioretention with vault BMP was simulated using the following key assumptions:

- **Bioretention configuration:** The bioretention portion of this BMP is designed similarly to the bioretention BMP, except that the storage layer would be only deep enough to contain a perforated underdrain pipe to convey treated runoff to the vault portion of the BMP.
- **Vault configuration:** The vault contains concrete side walls and top, as well as an access hatch for inspection and maintenance. The bottom of the vault is open to allow infiltration to the surrounding soils. The vault was simulated as a 4-foot deep chamber, but the designer could select other configurations that were similar or lesser depths.
- **Vault outlets:** The vault contains two outlets. The lower outlet is a flow control orifice that releases water at a maximum rate equal to the lower flow control limit ($0.1Q_2$, $0.3Q_2$, $0.5Q_2$). The upper outlet from the vault is an overflow pipe or weir with an invert located at 80 percent of the water height associated with required volume of the cistern – V1 (see Figure 1-7). For the assumed 4-foot water depth in the vault associated with the sizing factor analysis, the overflow invert is assumed to be located at an elevation of 3.2 feet above the bottom of the vault and the overflow outlet should be designed for a capacity equal to the design flow rate (as calculated from a single-event model based upon criteria set forth in the County of San Diego Hydrology Manual). The overflow relief should be located no lower than the elevation of the vault's inlet pipe.

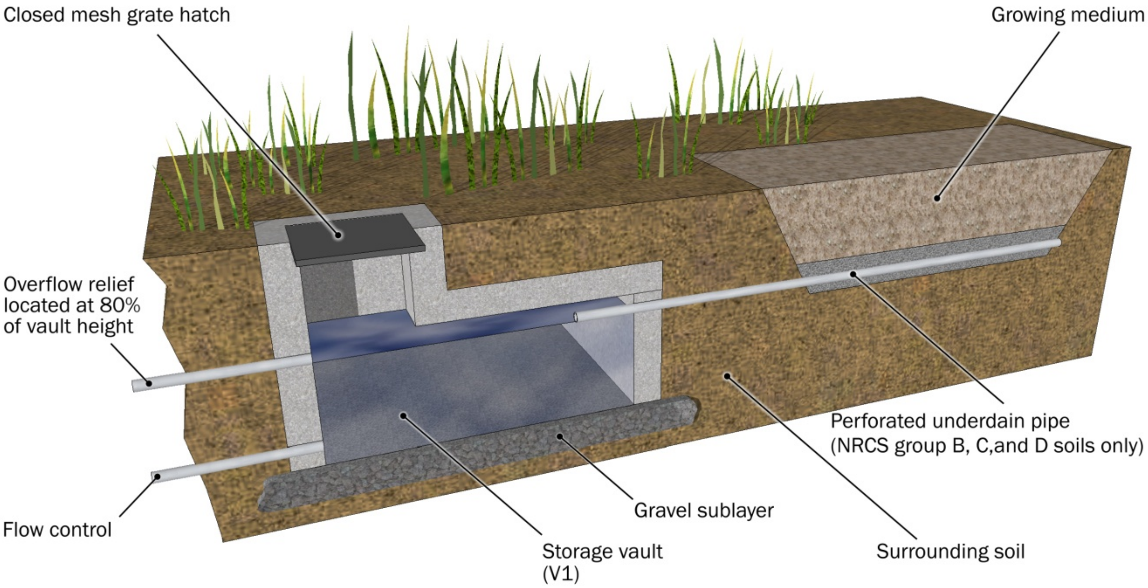


Figure 1-7. Bioretention with Vault BMP Example Illustration

1.4.4 Flow-Through Planter

Flow-through planters treat and detain runoff without allowing seepage into the underlying soil. Typical applications would be next to buildings or on steep slopes, where the infiltration associated with bioretention facilities could cause problems. Flow-through planters typically receive runoff via downspouts leading from the roofs of adjacent buildings. However, they can also be set in-ground and receive sheet flow from adjacent paved areas.

Pollutants are removed as runoff passes through the growing medium layer and is collected in an underlying storage layer (see Figure 1-8). A perforated-pipe underdrain is typically connected to a storm drain or other discharge point. An overflow inlet conveys flows which exceed the capacity of the planter. The flow through planter BMP should only be used in Group C or D soil applications. Flow through planters are fully lined BMPs designed for installation in scenarios in which infiltration is not feasible. These situations typically correspond to C and D soils which do not promote infiltration of storm water. For highly infiltrative A and B soils, the concept of adding a full liner is not common.

For the HMP, we simulated the flow through planter BMP using separate a) ponding layers, b) growing medium, and c) storage layer components. We assumed the following depths for each layer:

- **Ponding layer:** 10-inches active storage, 2-inches of freeboard above overflow relief
- **Growing medium:** 18-inches of soil at an assumed porosity of 41.2 percent
- **Storage layer:** 30-inches of gravel at 40 percent porosity

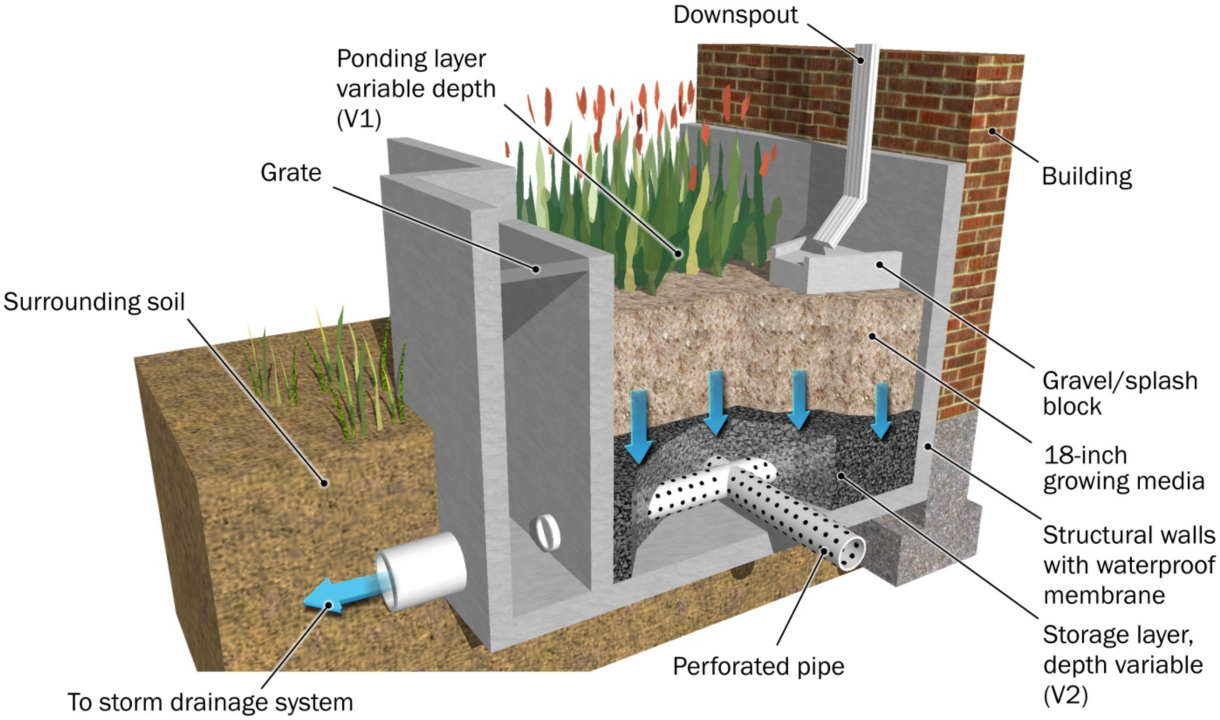


Figure 1-8. Flow-Through Planter BMP Example Illustration

1.4.5 Infiltration Facilities

The infiltration facility BMP is a below ground structure that can be used in areas with well-drained soils, such as NRCS Group A or B soils. The facility consists of an initial soil layer to trap pollutants underlain with gravel, drain rock or some other free draining material (see Figure 1-9). The infiltration facility BMP should have an access hatch to limit access.

For the HMP, the infiltration facility BMP was simulated using the following key assumptions:

- **Ponding layer:** a nominal 6-inch ponding layer should be included below the access hatch to allow for water spreading and infiltration during intense storms.
- **Soil layer:** 12 inches of soil should be included to remove pollutants
- **Free draining layer:** The drywell is sized assuming a 6-foot deep free draining layer. However, designers could use shallower facility depths.

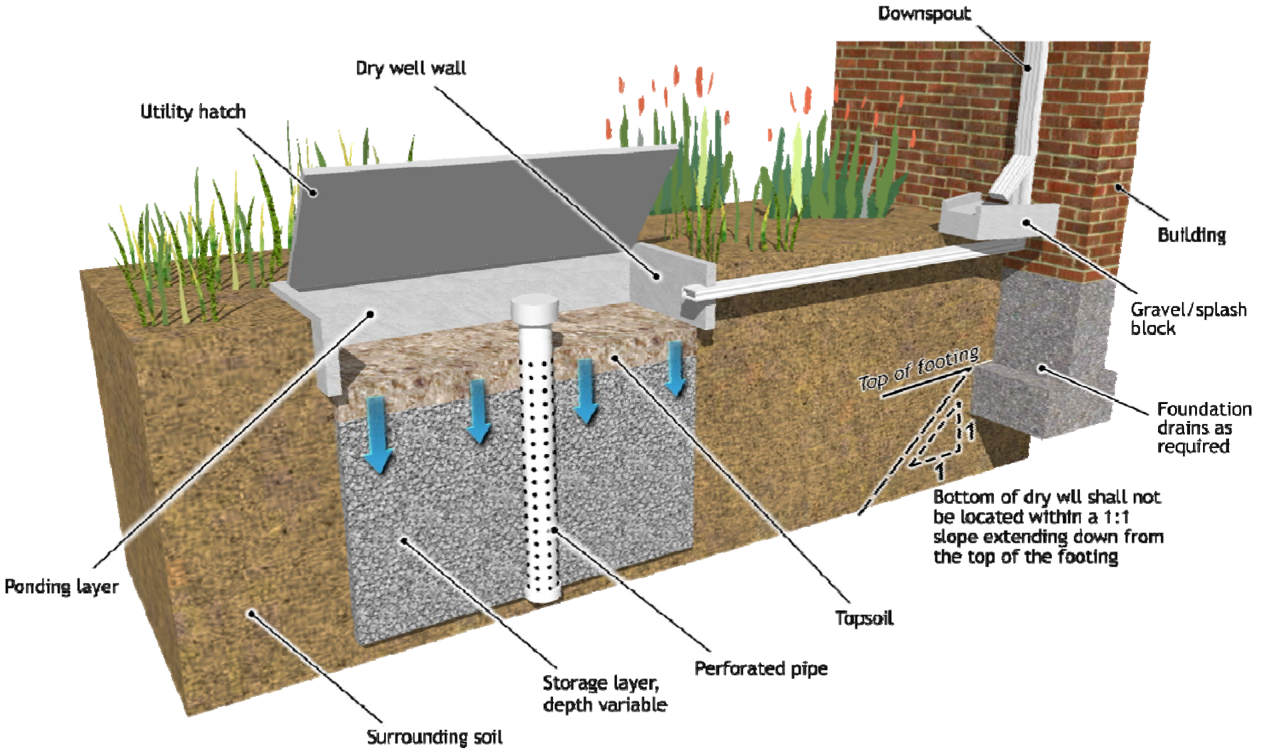


Figure 1-9. Infiltration Facility BMP Example Illustration

1.5 HSPF Model Parameters

This section presents the HSPF PERLND (pervious land cover) parameters recommended for the San Diego HMP's LID BMP sizing analysis. These parameter values were used in HSPF to simulate runoff rates and other hydrologic processes across a range of pervious surface conditions. The resulting long-term runoff time series (and key statistical series computed from these time series) form the pre-project condition baseline that new and redevelopment projects must match by mitigating site runoff rates and durations through the use of BMPs.

- Section 1.5.1 defines a PERLND and describes how HSPF simulates water movement on and through pervious surfaces.
- Section 1.5.2 describes the published studies using HSPF that were reviewed for this project.
- Section 1.5.3 summarizes the available PERLND parameter sets that were reviewed.
- Section 1.5.4 describes how Brown and Caldwell (BC) tested various parameter values to identify sensitive parameters and examined how the selection of specific parameter values would affect the runoff time series.
- Section 1.5.5 presents conclusions and recommendations.

1.5.1 PERLND Description and Schematic

The PERLND block within the HSPF input file contains parameters that affect the vertical and lateral movement of water moisture through a pervious land segment. Figure 1-10 is a schematic view of the PERLND water budget terms and key HSPF parameters. The schematic illustrates the movement of water among interception storage, upper zone storage, lower zone storage, groundwater storage, and deep/inactive groundwater storage. The schematic also illustrates flux terms, such as overland flow and interflow.

The algorithms that control the movement among these storage layers are described thoroughly in the HSPF User's Manual, which is available from the US EPA as part of the BASINS documentation (http://water.epa.gov/scitech/datait/models/basins/bsnsdocs.cfm). The parameters listed in Figure 1-10 are described in greater detail in Section 1.5.2.

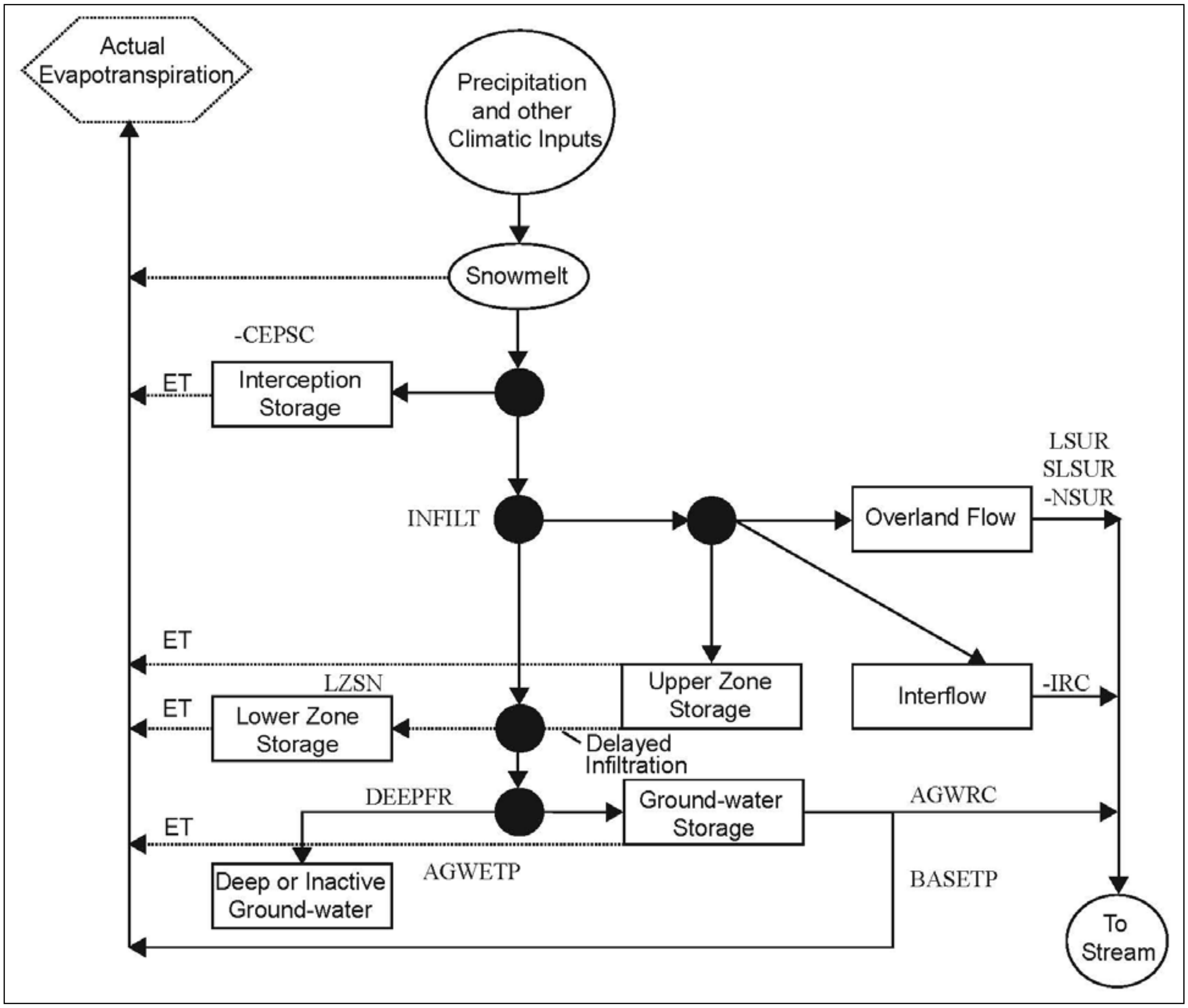


Figure 1-10. HSPF PERLND Water Moisture Schematic (Adapted from HSPF User's Manual)

For definition of terms, see Table 1-3.

1.5.2 PERLND Characteristics

The PERLND parameters shown in Figure 1-10 are located in the PWATER section of the PERLND block. PWATER, in turn, is divided into four sections, titled PWAT-PARM1, PWAT-PARM2, PWAT-PARM3, and PWAT-PARM4.

PWAT-PARM1 is a series of flags that specify how various algorithms are to be used to compute hydrologic functions.

PWAT-PARM2, PWAT-PARM3 and PWAT-PARM4 contain a series of climate, geology, topography, and vegetation parameters and initial conditions.

Table 1-3 contains brief descriptions of the HSPF parameters used to characterize pervious land surfaces, along with commonly used ranges of values for these parameters. The parameters that often affect stormwater runoff most (INFILT, LZSN, LZETP) are highlighted in the table below. These highlighted parameters were the focus of the investigation of the range and variation among local HSPF studies and the testing of prospective parameters. The descriptions and parameter ranges in the table were adapted from *EPA BASINS Technical Note 6 – Estimating Hydrologic and Hydraulic Parameters for HSPF*, which is available from the EPA web site, http://www.epa.gov/waterscience/basins/bsnsdocs.html

Table 1-3. List of PERLND PWATER Parameters, Definitions and Common Range of Values $^{(a)}$

PWAT-PARM1 – Flags

Parameter	Units	Description	Range of Values
CSNOFG	None	Flag to use snow simulation data; must be set to 0 if the SNOW simulation algorithms are to be used.	0 or 1
RTOPFG	None	Flag to select overland flow routing method. Set TOPFG=1; This method has been subjected to more widespread application.	1
UZFG	None	Flag to select upper zone inflow computation method Set UZFG=1; This method has been subjected to more widespread application.	1
VCSFG	None	Flag to select constant or monthly-variable interception storage capacity, CEPSC. Monthly value can be varied to represent seasonal changes in foliage cover	0 or 1
VUZFG	None	Flag to select constant or monthly-variable upper zone nominal soil moisture storage, UZSN.	0 or 1
VMNFG	None	Flag to select constant or monthly-variable Manning=s n for overland flow plane, NSUR. .	0 or 1
VIFWFG	None	Flag to select constant or monthly-variable interflow inflow parameter, INTFW. Monthly values are not often used.	0 or 1
VIRCFG	None	Flag to select constant or monthly varied interflow recession parameter, IRC. Monthly values are not often used.	0 or 1
VLEFG	None	Flag to select constant or monthly varied lower zone evapotranspiration (ET) parameter, LZETP.	0 or 1

PWAT-PARM2

Parameter	Units	Description	Range of Values
FOREST	None	Fraction of land covered by forest that will continue to transpire in winter (i.e. coniferous). This is only relevant if snow is being considered (i.e., CSNOFG=1 in PWATER-PARM1).	0 to 0.95
LZSN	Inches	Lower zone nominal soil moisture storage. This parameter affects the proportion of water going to surface runoff, interflow and active groundwater	2 to 15
INFILT	in/hr	INFILT is the parameter that controls the overall division of the available moisture from precipitation (after interception) into surface runoff. This is NOT equivalent to a field-measured infiltration rate.	0.001 to 0.50

Table 1-3. List of PERLND PWATER Parameters, Definitions and Common Range of Values (a)

LSUR	Feet	Length of assumed overland flow plane. LSUR approximates the average length of travel for water to reach any drainage path such as streams, swales, ditches, etc.	Estimate from mapping or GIS
SLSUR	ft/ft	Average slope of assumed overland flow path. Average SLSUR values for each land use being simulated can often be estimated directly with GIS capabilities.	Estimate from mapping or GIS
KVARY	1/inches	Groundwater recession flow parameter used to describe non-linear groundwater recession rate.	0.0 to 5.0
AGWRC	None	Groundwater recession rate or ratio of current groundwater discharge to that from 24 hours earlier.	0.85 to 0.999
PWAT-PARM3			
Parameter	**Units**	**Description**	**Range of Values**
PETMAX	Deg F	Temperature below which ET will be reduced to 50% of that in the input time series.	32 to 48
PETMIN	Deg F	Temperature at and below which ET will be zero. PETMIN represents the temperature threshold where plant transpiration is effectively suspended.	30 to 40
INFEXP	None	Exponent that determines how much a deviation from nominal lower zone storage affects the infiltration rate. This parameter is commonly set to a value of 2.	1 to 3
INFILD	None	Ratio of maximum and mean soil infiltration capacities. This parameter is commonly set to a value of 2.	1 to 3
DEEPFR	None	The fraction of infiltrating water that is lost to deep/inactive aquifers with the remaining fraction assigned to active groundwater storage that contributes base flow to the stream.	0.0 to 0.5
BASETP	None	ET by riparian vegetation as active groundwater enters streambed; specified as a fraction of potential ET, which is fulfilled only as outflow exists.	0.0 to 0.2
AGEWTP	None	Fraction of PERLND that is subject to direct evaporation from groundwater storage, e.g. wetlands or marsh areas.	0.0 to 0.2
PWAT-PARM4			
Parameter	**Units**	**Description**	**Range of Values**
CEPSC	inches	Amount of rainfall, in inches, which is retained by vegetation, never reaches the land surface, and is eventually evaporated.	0.01 to 0.40
UZSN	inches	Nominal upper zone soil moisture storage. UZSN is related to land surface characteristics, topography, and LZSN.	0.05 to 2.0
NSUR	None	Manning's friction coefficient, n, for overland flow plane.	0.02 to 0.50
INTFW	None	Coefficient that determines the amount of water that enters the ground from surface detention storage and becomes interflow	1.0 to 10.0
IRC	None	Interflow recession coefficient IRC is the ratio of the current daily interflow discharge to the interflow discharge on the previous day.	0.3 to 0.85
LZETP	None	Index to lower zone evapotranspiration LZETP affects ET from the lower zone, which represents the primary soil moisture storage and root zone of the soil profile.	0.1 to 0.9

(a) A. The parameter descriptions and ranges were obtained from the EPA BASINS Technical Note 6.

The INFILT parameter in HSPF does not correspond directly to field measured infiltration (see HSPF documentation for more detail) and as such should not be directly compared to parameter values from single-event models such as TR-55.

1.5.3 Available Studies and HSPF Parameter Sources

Brown and Caldwell collected and examined published Southern California studies that used HSPF to perform hydrologic modeling. This effort was previously summarized in the technical memorandum entitled *Summary of HSPF Modeling Reports in Southern California*, dated May 2009. Whenever possible, HSPF input files that were used in these studies were also collected. BC examined studies of the following models and study areas:

- **Santa Monica Bay Watershed** – The Southern California Coastal Water Research Project (SCCWRP) and Tetra Tech created HSPF models to simulate hydrologic processes and pollutant loadings to Santa Monica Bay. The specific parameter values were selected by calibrating an HSPF model to flow monitoring data in the Santa Monica Bay watershed, specifically on Malibu Creek. The values represent a composite of the various upstream soils and land uses.
- **Calleguas Creek** – This project was a pilot study to evaluate the use of HSPF as a management tool for comprehensive watershed assessment within the climatic, physiographic, and topographic conditions of Ventura County. The Calleguas Creek model, developed by Aqua Terra Consultants, simulates watershed hydrology using a combination of six different land use categories, topographic data and soils data and includes some level of calibration.
- **San Diego Hydrology Model (SDHM)** – The San Diego Hydrology Model (SDHM) uses a graphical user interface and pre-selected HSPF parameters to simulate stormwater runoff from development sites and size stormwater control facilities to mitigate the impacts of land use changes. SDHM includes HSPF parameters for soil and land use combinations. The SDHM user's manual is available in the download section of Clear Creek Solutions' web site.

Other HSPF input sources were also examined for relevant information:

- **EPA BASINS Technical Note 6** – The EPA publication (July 2000) is a useful guide that describes key HSPF parameters and suggests initial values. This technical note provides BASINS users with guidance in how to estimate the input parameters in the ATEMP, SNOW, PWATER, IWATER, HYDR, and ADCALC portions of the HSPF model.
- **Western Washington Hydrology Model (WWHM)** – Developed by Clear Creek Solutions for the Washington Department of Ecology to size stormwater control facilities in western Washington. The model runs HSPF to generate hourly runoff data. The interface and range of input types are generally similar to the SDHM.
- **Calabazas Creek** – In 1997, Aqua Terra Consultants used HSPF to study multipurpose design of detention facilities in Calabazas Creek watershed for the Santa Clara Valley Water District.

1.5.4 Range of Southern California HSPF Parameters

Brown and Caldwell has compiled and assessed the similarities and variations among the PERLND parameters used for the Santa Monica Bay, Calleguas Creek and SDHM work efforts. For reference, BC also compiled the parameters contained in EPA BASINS Technical Note 6, WWHM version 3, and the Contra Costa HMP. Table 1-4 lists the minimum, maximum and average values of the PERLND PWATER parameters for each study.

It is difficult to make a direct comparison among the parameters used in previous studies, because these modeling efforts examined entire watersheds with varying levels of development, reservoirs and regulation, and water demands and usages. However, focusing on the general range of specific parameter can be informative. For example, the Santa Monica Bay and Calleguas Creek model files use generally similar values for the key parameters, such as INFILT and LZSN (lower zone storage nominal), while the Santa Monica study used a substantially higher value of LZETP (lower zone evapotranspiration potential). The SDHM, which specifies parameters for ranges of soils, land uses and slopes, has INFILT, LZSN and LZETP parameters that are in the same range as the Santa Monica Bay and Calleguas Creek models.

Table 1-4. Compilation of PERLND Parameters

		Southern California HSPF Research							General HSPF Research										Contra Costa HSPF Research						
		Santa Monica Bay	Calleguas			SDHM			Tech Note 6				WWHM v.3 (moderate slopes)						Calabazas Creek				Contra Costa HMP		
		Value	Min	Max	Avg	Min	Max	Avg	Typical		Full Range		NRCS Group C			NRCS Group A/B			Developed		Open Space		Min	Max	Avg
									Min	Max	Min	Max	Forest	Grass	Pasture	Forest	Grass	Pasture	Min	Max	Min	Max			
PWAT_PARM2	Units																								
FOREST	none	0	0	0	0	N/A	N/A	N/A	0	0.5	0	0.95	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0	0
LZSN	inches	9.8	3	12.5	8.7	3.5	5.2	4.5	3	8	2	15	5	5	5	4.5	4.5	4.5	7	7	7	7	7	7	7
INFILT	in/hr	0.04	0.02	0.2	0.11	0.02	0.10	0.05	0.01	0.25	0.001	0.5	2	1.5	0.8	0.08	0.06	0.03	0.03	0.03	0.03	0.03	0.3	0.03	0.1595
LSUR	feet	201	150	400	319	200.0	400.0	312.5	200	500	100	700	400	400	400	400	400	400	200	250	150	200	660	660	660
SLSUR	ft/ft	0.03	0.00	0.30	0.11	0.1	0.3	0.1	0.01	0.15	0.001	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.0065	0.0533	0.068	0.28	0.1	0.1	0.1
KVARY	1/inches	3.0	0.5	1	0.61	0.8	3.0	1.5	0	3	0	5	0.3	0.3	0.3	0.5	0.5	0.5	0	0	0	0	0	0	0
AGWRC	none	0.92	0.80	1.00	0.91	1.0	1.0	1.0	0.92	0.99	0.85	0.999	0.996	0.996	0.996	0.996	0.996	0.996	0.8	0.95	0.8	0.95	0.95	0.95	0.95
PWAT_PARM3																									
PETMAX (F)	F	35	40	40	40	NA	NA	NA	35	45	32	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	40	40	40
PETMIN (F)	F	30	35	35	35.0	NA	NA	NA	30	35	30	40	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	35	35	35
INFEXP	none	2	2	2	2	2.0	3.0	2.3	2	2	1	3	2	2	2	2	2	2	2	2	2	2	2	2	2
INFILD	none	2	2	2	2	2.0	2.0	2.0	2	2	1	3	2	2	2	2	2	2	2	2	2	2	2	2	2
DEEPFR	none	0.4	0	0.8	0.67	0.0	0.0	0.0	0	0.2	0	0.5	0	0	0	0	0	0	0.1	0.45	0.1	0.45	0.45	0.1	0.275
BASETP	none	0.05	0	0.26	0.05	0.0	0.0	0.0	0	0.05	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0
AGWETP	none	0.05	0	0	0	0.0	0.0	0.0	0	0.05	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0
PWAT_PARM4																									
CEPSC	inches	0.10	0.06	0.12	0.08	0.10	0.19	0.13	0.03	0.20	0.01	0.40	0.2	0.15	0.1	0.2	0.15	0.1	0.0	0.0	0.0	0.0	0.1	0.02	0.07
UZSN	inches	1.18	0.50	0.80	0.59	0.20	0.50	0.31	0.1	1	0.05	2	0.5	0.5	0.5	0.43	0.35	0.22	0.4	0.4	0.6	0.6	0.5	0.5	0.5
NSUR	none	0.20	0.15	0.25	0.18	0.20	0.35	0.27	0.15	0.35	0.02	0.5	0.35	0.3	0.25	0.35	0.3	0.25	0.1	0.2	0.4	0.4	0.3	0.3	0.3
INTFW	none	1.50	1.00	1.80	1.35	0.35	1.00	0.81	1	3	1	10	0	0	0	6	6	6	0.4	0.4	0.5	0.5	0.4	0.4	0.4
IRC	none	0.70	0.20	0.60	0.35	0.30	0.80	0.46	0.50	0.70	0.30	0.85	0.70	0.70	0.70	0.43	0.43	0.43	0.30	0.30	0.40	0.40	0.30	0.30	0.30
LZETP	none	0.70	0.40	0.50	0.43	0.20	0.69	0.51	0.20	0.70	0.10	0.90	0.70	0.40	0.25	0.70	0.40	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1.5.5 Evaluating HSPF Parameter Values

To determine the mix of pre-project conditions to include in the BMP Sizing Calculator, Brown and Caldwell examined the extent of variation in the PERLND parameters among the Santa Monica Bay, Calleguas Creek, and SDHM models.

Figures 1-11, 1-12 and 1-13 show the variation in the INFILT parameter used in the SDHM as function of slope and land cover. The INFILT parameter values clearly vary with slope. However, the INFILT parameter value is the same for the most common pre-project land cover types for new developments in San Diego County – shrub, grass, and dirt. The INFILT parameter value is higher for forest and lower for urban (i.e., compacted soils and irrigated landscapes), but these do not represent pre-project conditions that will be commonly managed by the BMP Sizing Calculator.

- Since the INFILT parameters are identical across the three most common pre-project land cover types, the modeling effort will focus on a single composite land cover type.
- The INFILT values vary significantly for different slopes. As such, parameter sets were prepared for low, moderate, and steep slope classifications (5, 10 and 15 percent, respectively). In many cases, LID BMPs will not be feasible in areas with slopes that are steeper than this range. Further, because the pre-sizing analysis would potentially under-estimate pre-project runoff rates from very steep sites, any LID facilities designed in such areas using the BMP Sizing Calculator would be conservatively sized.
- An urban parameter set is not needed for the BMP Sizing Calculator. The Countywide Model SUSMP encourages developers to manage runoff from landscaped surfaces using grading and soil amendments that emphasize infiltration to reduce site runoff from landscaped areas without implementing LID BMPs. An urban parameter set can be developed for the automated pond sizing tool, because ponds are expected to capture flows from a combination of impervious and urban landscaped surfaces.
- For Figures 1-11 through 1-16, the plot for “Dirt” mirrors the plot for “Shrub” and “Grassland.”

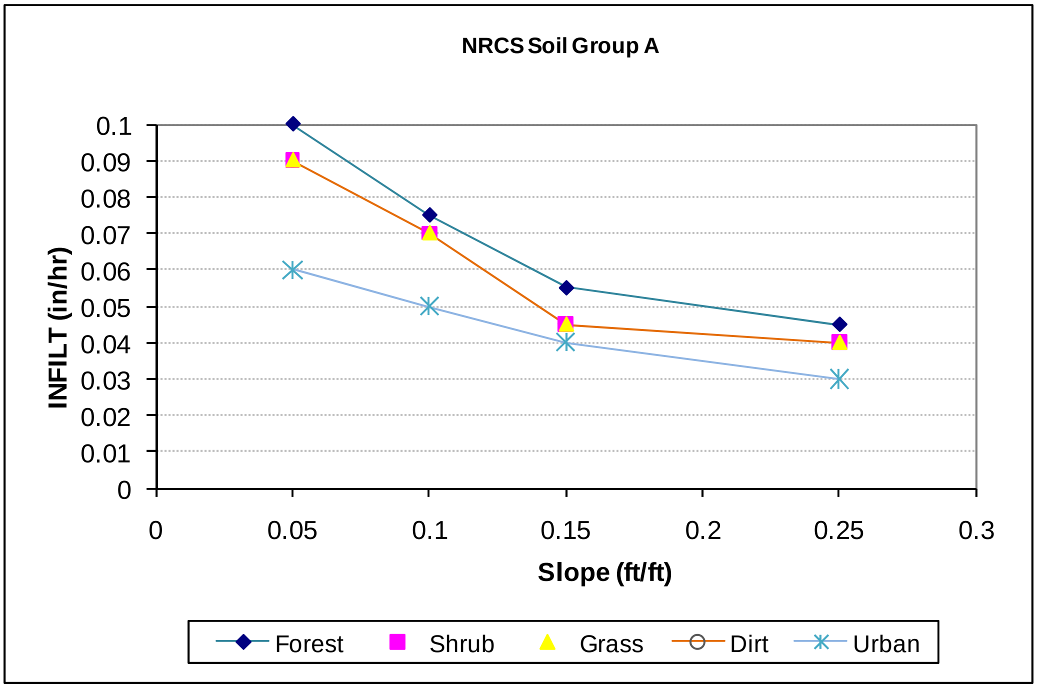


Figure 1-11. SDHM Variation in INFILT Parameter, NRCS Group A Soils

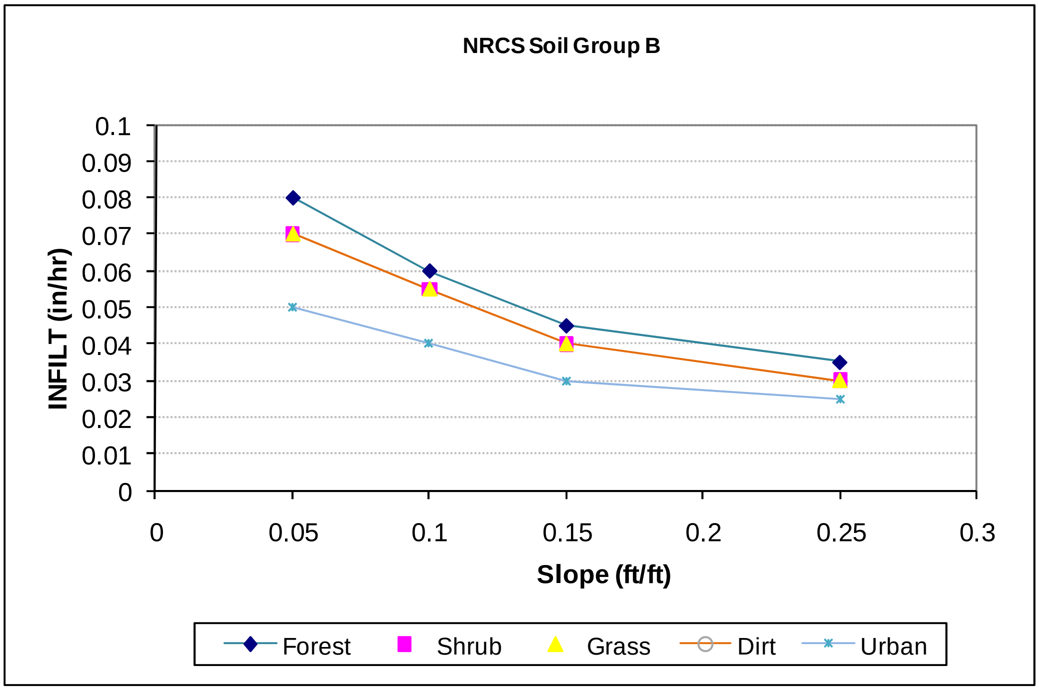


Figure 1-12. SDHM Variation in INFILT Parameter, NRCS Group B Soils

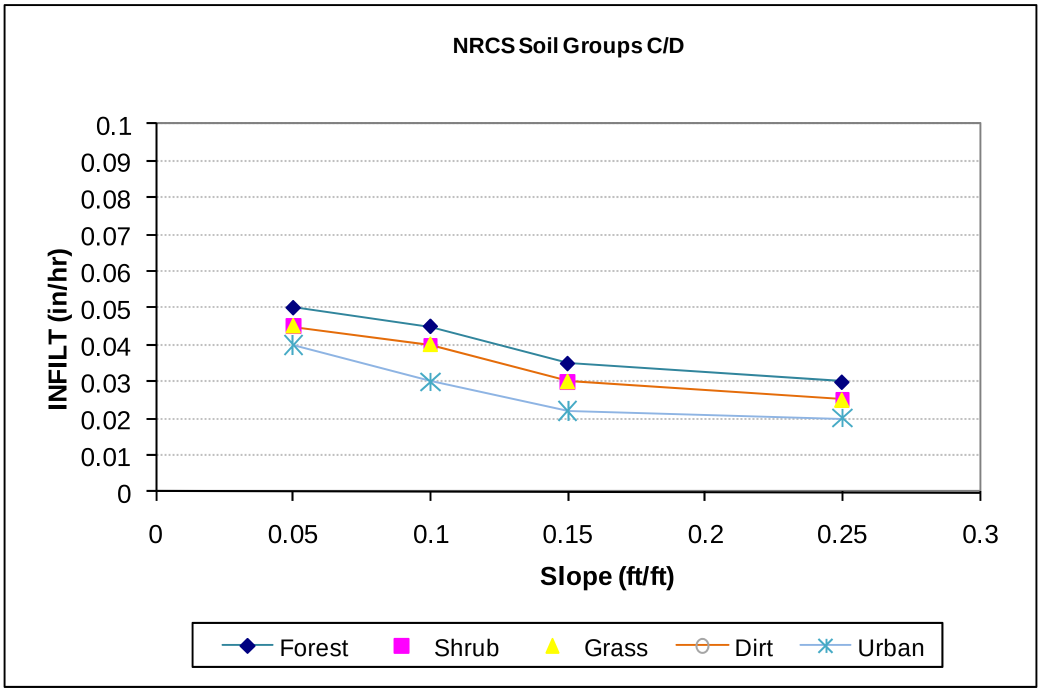


Figure 1-13. SDHM Variation in INFILT Parameter, NRCS Group C/D Soils

Figure 1-14, 1-15 and 1-16 show the SDHM model's assumed variations in the LZSN parameter as a function of slope and land cover type. Similar to the INFILT evaluation above, LZSN values are identical for the most common land cover types that will be incorporated in the BMP Sizing Calculator. These figures further reinforce the intention to focus on a single composite land cover type, while focusing on the differences in runoff generation potential associated with different soils and slopes.

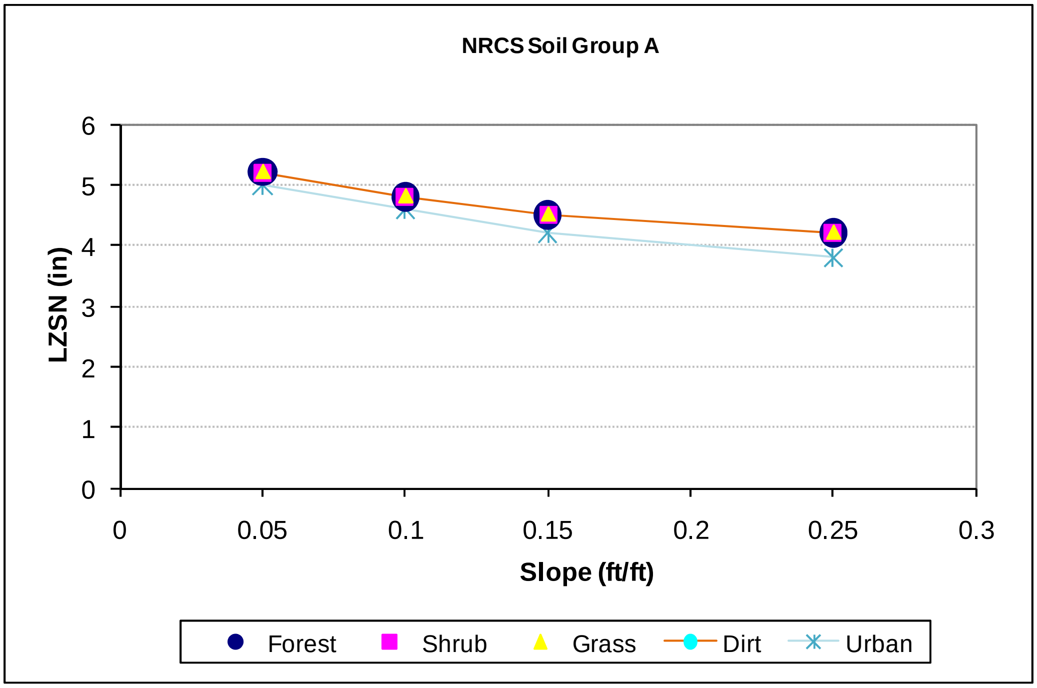


Figure 1-14. SDHM Variation in LZSN Parameter, NRCS Group A Soils

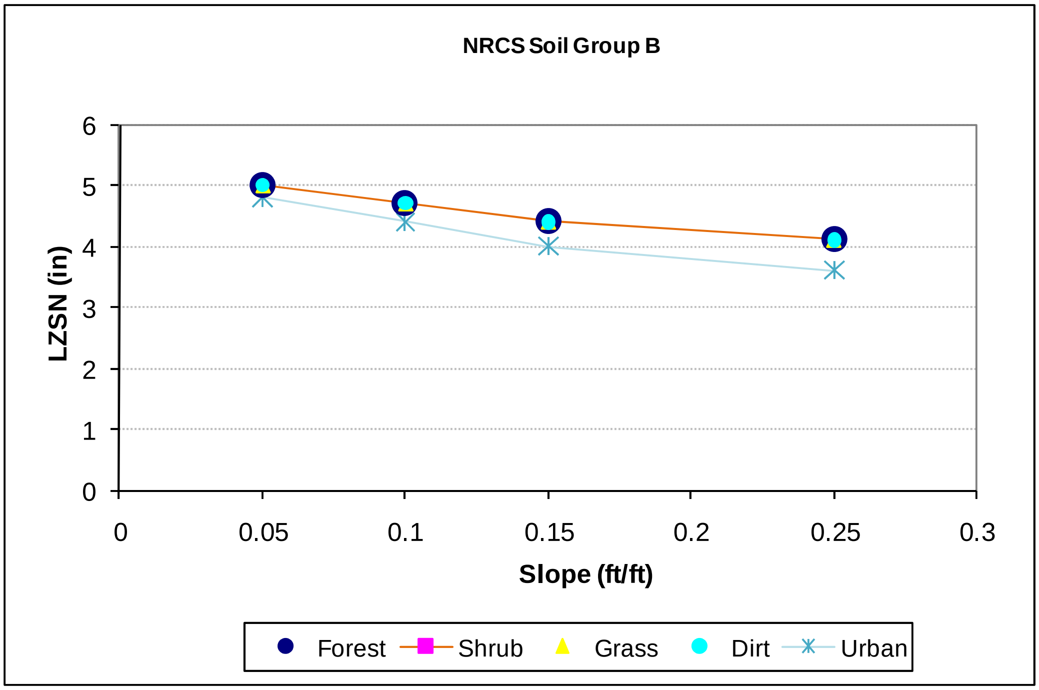


Figure 1-15. SDHM Variation in LZSN Parameter, NRCS Group B Soils

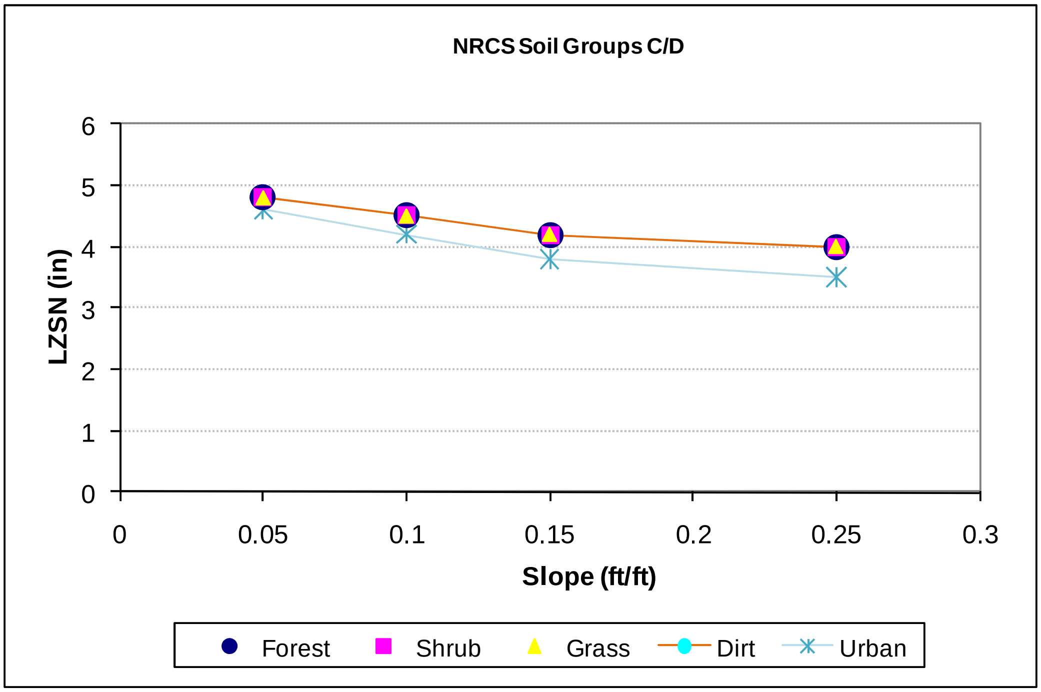


Figure 1-16. SDHM Variation in LZSN Parameter, NRCS Group C/D Soils

Information provided in Figures 1-11 through 1-16 documents parameter ranges from the SDHM software. Final parameter recommendations used for the analysis associated with the BMP Sizing Calculator are located in Table 1-5.

1.5.6 Recommended HSPF PERLND Parameters

The following recommended HSPF PERLND parameter values have been developed to use for the LID pre-sizing factor analysis that will be included in the BMP Sizing Calculator. The 12 parameter sets cover the four NRCS soil groups and three separate slopes. The precise values were obtained by combining the Santa Monica Bay, Calleguas Creek, and SDHM parameter sets.

Table 1-5. Recommended HSPF PERLND Parameters for BMP Modeling

		Group A			Group B			Group C			Group D		
		5%	10%	15%	5%	10%	15%	5%	10%	15%	5%	10%	15%
PWAT_PARM2	**Units**												
FOREST	None	0	0	0	0	0	0	0	0	0	0	0	0
LZSN	inches	5.2	4.8	4.5	5.0	4.7	4.4	4.8	4.5	4.2	4.8	4.5	4.2
INFILT	in/hr	0.090	0.070	0.045	0.070	0.055	0.040	0.050	0.040	0.032	0.040	0.030	0.02
LSUR	Feet	200	200	200	200	200	200	200	200	200	200	200	200
SLSUR	ft/ft	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15
KVARY	1/inches	3	3	3	3	3	3	3	3	3	3	3	3
AGWRC	None	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
PWAT_PARM3													
PETMAX (F)	F	35	35	35	35	35	35	35	35	35	35	35	35
PETMIN (F)	F	30	30	30	30	30	30	30	30	30	30	30	30
INFEXP	None	2	2	2	2	2	2	2	2	2	2	2	2
INFILD	None	2	2	2	2	2	2	2	2	2	2	2	2
DEEPFR	None	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASETP	None	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
AGEWTP	None	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
PWAT_PARM4													
CEPSC	inches	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
UZSN	inches	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
NSUR	None	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
INTFW	None	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
IRC	None	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
LZETP	None	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

The pervious land surface (PERLND) parameters used in the model are consistent with HSPF model of Santa Monica Bay and other studies. Parameter selection was documented in the Technical Memorandum entitled "Selection of PERLND Parameters for HSPF Modeling" in April 2010. The PERLND parameters values used for this project are also consistent with the values used in the SDHM model and the range of suggested values in EPA BASINS Technical Note 6.

1.6 Unit Runoff Ratios

Table 1-6 below summarizes unit runoff ratios determined by partial duration analysis for the various combinations of rain gauge, soil type, and slopes studied for the San Diego HMP. HSPF does not explicitly incorporate a time of concentration (Tc) parameter. Instead, HSPF calculated surface runoff travel time across a catchment using the parameters LSUR (length), NSUR (Manning's roughness coefficient), and SLSUR (slope in direction of travel). Varying these time-related parameters does not translate into large variances in the resultant unit peak flow rates since the input rainfall time step of one hour (based on accessible rainfall data) exceeds the travel time (or Tc) for the majority of development projects.

Using the total available rainfall record, peak hourly discharges were calculated and ranked. The recurrence interval was determined using the Cunnane plotting position method.

$$Tr = \frac{n + A}{m - B}$$

Where Tr = recurrence interval

n = number of years of record

m = rank of event

A = 0.2 (constant)

B = 0.4 (constant)

Table 1-6. Unit Runoff Ratios

Rain Gauge	Soil	Cover	Slope	Q_2 (cfs/acre)	Q_{10} (cfs/ac)
Lake Wohlford	A	Scrub	Low	0.136	0.369
Lake Wohlford	A	Scrub	Moderate	0.207	0.416
Lake Wohlford	A	Scrub	Steep	0.244	0.47
Lake Wohlford	B	Scrub	Low	0.208	0.414
Lake Wohlford	B	Scrub	Moderate	0.227	0.448
Lake Wohlford	B	Scrub	Steep	0.253	0.482
Lake Wohlford	C	Scrub	Low	0.245	0.458
Lake Wohlford	C	Scrub	Moderate	0.253	0.481
Lake Wohlford	C	Scrub	Steep	0.302	0.517
Lake Wohlford	D	Scrub	Low	0.253	0.48
Lake Wohlford	D	Scrub	Moderate	0.292	0.516
Lake Wohlford	D	Scrub	Steep	0.351	0.538
Lake Wohlford	A	Urban	Moderate	0.236	0.46

Table 1-6. Unit Runoff Ratios

Rain Gauge	Soil	Cover	Slope	Q_2 (cfs/acre)	Q_{10} (cfs/ac)
Lake Wohlford	B	Urban	Moderate	0.254	0.483
Lake Wohlford	C	Urban	Moderate	0.302	0.517
Lake Wohlford	D	Urban	Moderate	0.353	0.539
Lake Wohlford	Impervious		Moderate	0.555	0.773
Oceanside	A	Scrub	Low	0.035	0.32
Oceanside	A	Scrub	Moderate	0.093	0.367
Oceanside	A	Scrub	Steep	0.163	0.42
Oceanside	B	Scrub	Low	0.08	0.365
Oceanside	B	Scrub	Moderate	0.134	0.4
Oceanside	B	Scrub	Steep	0.181	0.433
Oceanside	C	Scrub	Low	0.146	0.411
Oceanside	C	Scrub	Moderate	0.185	0.433
Oceanside	C	Scrub	Steep	0.217	0.458
Oceanside	D	Scrub	Low	0.175	0.434
Oceanside	D	Scrub	Moderate	0.212	0.455
Oceanside	D	Scrub	Steep	0.244	0.571
Oceanside	A	Urban	Moderate	0.152	0.411
Oceanside	B	Urban	Moderate	0.188	0.434
Oceanside	C	Urban	Moderate	0.216	0.458
Oceanside	D	Urban	Moderate	0.247	0.571
Oceanside	Impervious		Moderate	0.557	0.949
Lindbergh	A	Scrub	Low	0.003	0.081
Lindbergh	A	Scrub	Moderate	0.018	0.137
Lindbergh	A	Scrub	Steep	0.061	0.211
Lindbergh	B	Scrub	Low	0.011	0.134
Lindbergh	B	Scrub	Moderate	0.033	0.174
Lindbergh	B	Scrub	Steep	0.077	0.23
Lindbergh	C	Scrub	Low	0.028	0.19

Table 1-6. Unit Runoff Ratios

Rain Gauge	Soil	Cover	Slope	Q_2 (cfs/acre)	Q_{10} (cfs/ac)
Lindbergh	C	Scrub	Moderate	0.075	0.232
Lindbergh	C	Scrub	Steep	0.108	0.274
Lindbergh	D	Scrub	Low	0.05	0.228
Lindbergh	D	Scrub	Moderate	0.104	0.266
Lindbergh	D	Scrub	Steep	0.143	0.319
Lindbergh	A	Urban	Moderate	0.046	0.194
Lindbergh	B	Urban	Moderate	0.078	0.235
Lindbergh	C	Urban	Moderate	0.107	0.271
Lindbergh	D	Urban	Moderate	0.145	0.32
Lindbergh	Impervious		Moderate	0.512	0.749

1.7 Sensitivity Analysis

Brown and Caldwell conducted a sensitivity analysis in January 2011 to compare sizing factors calculated with hourly rainfall data to sizing factors calculated with limited 15-minute rainfall data. The analysis suggests that the ‘flat’ slope category can be eliminated for Group C and D soils and that the ‘flat’ sizing factor can be reduced in Group B soils. The following is a summary of the sensitivity analysis method and results:

- The $0.5Q_2$ bioretention sizing factors were computed using the Oceanside 15-minute gauge (1976-1992) across the three slope and four soil groups. These factors were generally a little smaller than the factors computed using the longer hourly records for the same gauge (1960-2004).
- To make the 15-minute and hourly results more comparable, the bioretention hourly sizing factors were recomputed – using just the period from 1976-1992.
- The ‘flat’ sizing factors computed using 15-minute records are very similar to the ‘moderate’ sizing factors computed using the hourly time series for C, D soils. For Group B soils, the ‘flat’ sizing factor computed with the 15-minute data is half way between the ‘flat’ and ‘moderate’ value computed with the hourly data. The main reason is that the simulated Q_2 values are higher using the 15-minute record.
- For most soil/slope/cover combinations, the Q2 values computed from the 15-minute Oceanside gauge time steps is 2.5 to 3.0 times higher than Q2 values computed from the hourly input data.

Based on the results of the sensitivity analysis, Brown and Caldwell recommend setting ‘flat’ sizing factors equal to the ‘moderate’ sizing factor values for the Group C, D soil conditions and revising the Group B ‘flat’ sizing factors to equal the current average of the ‘flat’ and ‘moderate’ values.

The sensitivity analysis focused on whether 15-minute time step simulations would produce higher Q2 values and thus larger flow control orifice diameters in Group C and D soils (plus Group B soils for the bioretention with vault BMP). The analysis also focused on whether the higher Q2 values would affect the computed BMP sizing factor. Because the Group A soil BMPs do not contain an underdrain (with flow restrictor), BMPs constructed in Group A soils are not likely to be sensitive to the simulation time step (and associated small differences in Q2). As an example, results in Table 1-7 show that the Group A soil BMP sizing factors are not sensitive to the lower control threshold (whether 0.1Q2, 0.3Q2 or 0.5Q2).

1.8 LID BMP Sizing Factor Results

Surface area sizing coefficients represent ratio of the required BMP surface area to the contributing drainage area, assuming the contributing drainage area is 100 percent impervious. For cases where the contributing drainage area is less than 100 percent impervious, the composite sizing factor can be adjusted per guidelines set forth in the Model SUSMP. The surface ponding volumetric sizing factor is calculated by multiplying the surface area sizing factor by 10 inches (surface ponding depth) to convert into the minimum required surface ponding volume. The subsurface volumetric sizing factor is calculated by multiplying the surface area sizing factor by 1.5 feet (subsurface ponding depth above underdrain) and then multiplying by the void space factor of 0.4 to convert into the minimum required subsurface ponding volume in the gravel storage layer.

Required input to the LID section of the BMP Sizing Calculator includes LID types as well as the Drainage Area to each individual BMP (the total drainage area to a BMP can include multiple Drainage Management Areas). The output includes the minimum surface area and volume requirements for the BMPs. The proposed area and volume sizes must exceed the minimum sizes detailed in the output.

1.8.1 Bioretention

Table 1-7. Sizing Factors for Bioretention Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.5Q_2$	A	Flat	Lindbergh	0.060	0.0500	N/A
$0.5Q_2$	A	Moderate	Lindbergh	0.055	0.0458	N/A
$0.5Q_2$	A	Steep	Lindbergh	0.045	0.0375	N/A
$0.5Q_2$	B	Flat	Lindbergh	0.093	0.0771	N/A
$0.5Q_2$	B	Moderate	Lindbergh	0.085	0.0708	N/A
$0.5Q_2$	B	Steep	Lindbergh	0.065	0.0542	N/A
$0.5Q_2$	C	Flat	Lindbergh	0.100	0.0833	0.0600
$0.5Q_2$	C	Moderate	Lindbergh	0.100	0.0833	0.0600
$0.5Q_2$	C	Steep	Lindbergh	0.075	0.0625	0.0450
$0.5Q_2$	D	Flat	Lindbergh	0.080	0.0667	0.0480
$0.5Q_2$	D	Moderate	Lindbergh	0.080	0.0667	0.0480
$0.5Q_2$	D	Steep	Lindbergh	0.060	0.0500	0.0360
$0.5Q_2$	A	Flat	Oceanside	0.070	0.0583	N/A
$0.5Q_2$	A	Moderate	Oceanside	0.065	0.0542	N/A
$0.5Q_2$	A	Steep	Oceanside	0.060	0.0500	N/A
$0.5Q_2$	B	Flat	Oceanside	0.098	0.0813	N/A
$0.5Q_2$	B	Moderate	Oceanside	0.090	0.0750	N/A

Table 1-7. Sizing Factors for Bioretention Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.5Q_2$	B	Steep	Oceanside	0.075	0.0625	N/A
$0.5Q_2$	C	Flat	Oceanside	0.075	0.0625	0.0450
$0.5Q_2$	C	Moderate	Oceanside	0.075	0.0625	0.0450
$0.5Q_2$	C	Steep	Oceanside	0.060	0.0500	0.0360
$0.5Q_2$	D	Flat	Oceanside	0.065	0.0542	0.0390
$0.5Q_2$	D	Moderate	Oceanside	0.065	0.0542	0.0390
$0.5Q_2$	D	Steep	Oceanside	0.050	0.0417	0.0300
$0.5Q_2$	A	Flat	L Wohlford	0.050	0.0417	N/A
$0.5Q_2$	A	Moderate	L Wohlford	0.045	0.0375	N/A
$0.5Q_2$	A	Steep	L Wohlford	0.040	0.0333	N/A
$0.5Q_2$	B	Flat	L Wohlford	0.048	0.0396	N/A
$0.5Q_2$	B	Moderate	L Wohlford	0.045	0.0375	N/A
$0.5Q_2$	B	Steep	L Wohlford	0.040	0.0333	N/A
$0.5Q_2$	C	Flat	L Wohlford	0.065	0.0542	0.0390
$0.5Q_2$	C	Moderate	L Wohlford	0.065	0.0542	0.0390
$0.5Q_2$	C	Steep	L Wohlford	0.050	0.0417	0.0300
$0.5Q_2$	D	Flat	L Wohlford	0.055	0.0458	0.0330
$0.5Q_2$	D	Moderate	L Wohlford	0.055	0.0458	0.0330
$0.5Q_2$	D	Steep	L Wohlford	0.045	0.0375	0.0270
$0.3Q_2$	A	Flat	Lindbergh	0.060	0.0500	N/A
$0.3Q_2$	A	Moderate	Lindbergh	0.055	0.0458	N/A
$0.3Q_2$	A	Steep	Lindbergh	0.045	0.0375	N/A
$0.3Q_2$	B	Flat	Lindbergh	0.098	0.0813	N/A
$0.3Q_2$	B	Moderate	Lindbergh	0.090	0.0750	N/A
$0.3Q_2$	B	Steep	Lindbergh	0.070	0.0583	N/A
$0.3Q_2$	C	Flat	Lindbergh	0.110	0.0917	0.0660
$0.3Q_2$	C	Moderate	Lindbergh	0.110	0.0917	0.0660
$0.3Q_2$	C	Steep	Lindbergh	0.085	0.0708	0.0510
$0.3Q_2$	D	Flat	Lindbergh	0.100	0.0833	0.0600
$0.3Q_2$	D	Moderate	Lindbergh	0.100	0.0833	0.0600
$0.3Q_2$	D	Steep	Lindbergh	0.070	0.0583	0.0420
$0.3Q_2$	A	Flat	Oceanside	0.070	0.0583	N/A
$0.3Q_2$	A	Moderate	Oceanside	0.065	0.0542	N/A
$0.3Q_2$	A	Steep	Oceanside	0.060	0.0500	N/A
$0.3Q_2$	B	Flat	Oceanside	0.098	0.0813	N/A
$0.3Q_2$	B	Moderate	Oceanside	0.090	0.0750	N/A

Table 1-7. Sizing Factors for Bioretention Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.3Q_2$	B	Steep	Oceanside	0.075	0.0625	N/A
$0.3Q_2$	C	Flat	Oceanside	0.100	0.0833	0.0600
$0.3Q_2$	C	Moderate	Oceanside	0.100	0.0833	0.0600
$0.3Q_2$	C	Steep	Oceanside	0.080	0.0667	0.0480
$0.3Q_2$	D	Flat	Oceanside	0.085	0.0708	0.0510
$0.3Q_2$	D	Moderate	Oceanside	0.085	0.0708	0.0510
$0.3Q_2$	D	Steep	Oceanside	0.065	0.0542	0.0390
$0.3Q_2$	A	Flat	L Wohlford	0.050	0.0417	N/A
$0.3Q_2$	A	Moderate	L Wohlford	0.045	0.0375	N/A
$0.3Q_2$	A	Steep	L Wohlford	0.040	0.0333	N/A
$0.3Q_2$	B	Flat	L Wohlford	0.060	0.0500	N/A
$0.3Q_2$	B	Moderate	L Wohlford	0.055	0.0458	N/A
$0.3Q_2$	B	Steep	L Wohlford	0.045	0.0375	N/A
$0.3Q_2$	C	Flat	L Wohlford	0.075	0.0625	0.0450
$0.3Q_2$	C	Moderate	L Wohlford	0.075	0.0625	0.0450
$0.3Q_2$	C	Steep	L Wohlford	0.060	0.0500	0.0360
$0.3Q_2$	D	Flat	L Wohlford	0.065	0.0542	0.0390
$0.3Q_2$	D	Moderate	L Wohlford	0.065	0.0542	0.0390
$0.3Q_2$	D	Steep	L Wohlford	0.050	0.0417	0.0300
$0.1Q_2$	A	Flat	Lindbergh	0.060	0.0500	N/A
$0.1Q_2$	A	Moderate	Lindbergh	0.055	0.0458	N/A
$0.1Q_2$	A	Steep	Lindbergh	0.045	0.0375	N/A
$0.1Q_2$	B	Flat	Lindbergh	0.100	0.0833	N/A
$0.1Q_2$	B	Moderate	Lindbergh	0.095	0.0792	N/A
$0.1Q_2$	B	Steep	Lindbergh	0.080	0.0667	N/A
$0.1Q_2$	C	Flat	Lindbergh	0.145	0.1208	0.0870
$0.1Q_2$	C	Moderate	Lindbergh	0.145	0.1208	0.0870
$0.1Q_2$	C	Steep	Lindbergh	0.120	0.1000	0.0720
$0.1Q_2$	D	Flat	Lindbergh	0.160	0.1333	0.0960
$0.1Q_2$	D	Moderate	Lindbergh	0.160	0.1333	0.0960
$0.1Q_2$	D	Steep	Lindbergh	0.115	0.0958	0.0690
$0.1Q_2$	A	Flat	Oceanside	0.070	0.0583	N/A
$0.1Q_2$	A	Moderate	Oceanside	0.065	0.0542	N/A
$0.1Q_2$	A	Steep	Oceanside	0.060	0.0500	N/A
$0.1Q_2$	B	Flat	Oceanside	0.103	0.0854	N/A
$0.1Q_2$	B	Moderate	Oceanside	0.090	0.0750	N/A

Table 1-7. Sizing Factors for Bioretention Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.1Q_2$	B	Steep	Oceanside	0.075	0.0625	N/A
$0.1Q_2$	C	Flat	Oceanside	0.130	0.1083	0.0780
$0.1Q_2$	C	Moderate	Oceanside	0.130	0.1083	0.0780
$0.1Q_2$	C	Steep	Oceanside	0.110	0.0917	0.0660
$0.1Q_2$	D	Flat	Oceanside	0.130	0.1083	0.0780
$0.1Q_2$	D	Moderate	Oceanside	0.130	0.1083	0.0780
$0.1Q_2$	D	Steep	Oceanside	0.065	0.0542	0.0390
$0.1Q_2$	A	Flat	L Wohlford	0.050	0.0417	N/A
$0.1Q_2$	A	Moderate	L Wohlford	0.045	0.0375	N/A
$0.1Q_2$	A	Steep	L Wohlford	0.040	0.0333	N/A
$0.1Q_2$	B	Flat	L Wohlford	0.090	0.0750	N/A
$0.1Q_2$	B	Moderate	L Wohlford	0.085	0.0708	N/A
$0.1Q_2$	B	Steep	L Wohlford	0.065	0.0542	N/A
$0.1Q_2$	C	Flat	L Wohlford	0.110	0.0917	0.0660
$0.1Q_2$	C	Moderate	L Wohlford	0.110	0.0917	0.0660
$0.1Q_2$	C	Steep	L Wohlford	0.090	0.0750	0.0540
$0.1Q_2$	D	Flat	L Wohlford	0.100	0.0833	0.0600
$0.1Q_2$	D	Moderate	L Wohlford	0.100	0.0833	0.0600
$0.1Q_2$	D	Steep	L Wohlford	0.075	0.0625	0.0450

Q_2 = 2-year pre-project flow rate based upon partial duration analysis of long-term hourly rainfall records
Q_{10} = 10-year pre-project flow rate based upon partial duration analysis of long-term hourly rainfall records
A = Surface area sizing factor
V_1 = Surface volume sizing factor
V_2 = Subsurface volume sizing factor

1.8.2 Cistern with Bioretention

Table 1-8. Sizing Factors for Bioretention Plus Cistern Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.5Q_2$	A	Flat	Lindbergh	0.020	0.1200	N/A
$0.5Q_2$	A	Moderate	Lindbergh	0.020	0.1000	N/A
$0.5Q_2$	A	Steep	Lindbergh	0.020	0.1000	N/A
$0.5Q_2$	B	Flat	Lindbergh	0.020	0.3900	N/A
$0.5Q_2$	B	Moderate	Lindbergh	0.020	0.2000	N/A
$0.5Q_2$	B	Steep	Lindbergh	0.020	0.1200	N/A

Table 1-8. Sizing Factors for Bioretention Plus Cistern Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.5Q_2$	C	Flat	Lindbergh	0.020	0.1200	N/A
$0.5Q_2$	C	Moderate	Lindbergh	0.020	0.1200	N/A
$0.5Q_2$	C	Steep	Lindbergh	0.020	0.1000	N/A
$0.5Q_2$	D	Flat	Lindbergh	0.020	0.1000	N/A
$0.5Q_2$	D	Moderate	Lindbergh	0.020	0.1000	N/A
$0.5Q_2$	D	Steep	Lindbergh	0.030	0.0800	N/A
$0.5Q_2$	A	Flat	Oceanside	0.020	0.1600	N/A
$0.5Q_2$	A	Moderate	Oceanside	0.020	0.1400	N/A
$0.5Q_2$	A	Steep	Oceanside	0.030	0.1200	N/A
$0.5Q_2$	B	Flat	Oceanside	0.020	0.1900	N/A
$0.5Q_2$	B	Moderate	Oceanside	0.025	0.1600	N/A
$0.5Q_2$	B	Steep	Oceanside	0.035	0.1400	N/A
$0.5Q_2$	C	Flat	Oceanside	0.030	0.1400	N/A
$0.5Q_2$	C	Moderate	Oceanside	0.035	0.1400	N/A
$0.5Q_2$	C	Steep	Oceanside	0.040	0.1200	N/A
$0.5Q_2$	D	Flat	Oceanside	0.035	0.1200	N/A
$0.5Q_2$	D	Moderate	Oceanside	0.040	0.1200	N/A
$0.5Q_2$	D	Steep	Oceanside	0.040	0.1000	N/A
$0.5Q_2$	A	Flat	L Wohlford	0.025	0.1800	N/A
$0.5Q_2$	A	Moderate	L Wohlford	0.040	0.1400	N/A
$0.5Q_2$	A	Steep	L Wohlford	0.040	0.0800	N/A
$0.5Q_2$	B	Flat	L Wohlford	0.040	0.2100	N/A
$0.5Q_2$	B	Moderate	L Wohlford	0.040	0.2000	N/A
$0.5Q_2$	B	Steep	L Wohlford	0.040	0.1400	N/A
$0.5Q_2$	C	Flat	L Wohlford	0.040	0.1400	N/A
$0.5Q_2$	C	Moderate	L Wohlford	0.040	0.1400	N/A
$0.5Q_2$	C	Steep	L Wohlford	0.040	0.1000	N/A
$0.5Q_2$	D	Flat	L Wohlford	0.040	0.1000	N/A
$0.5Q_2$	D	Moderate	L Wohlford	0.040	0.1000	N/A
$0.5Q_2$	D	Steep	L Wohlford	0.040	0.0800	N/A
$0.3Q_2$	A	Flat	Lindbergh	0.020	0.1200	N/A
$0.3Q_2$	A	Moderate	Lindbergh	0.020	0.1000	N/A
$0.3Q_2$	A	Steep	Lindbergh	0.020	0.1000	N/A
$0.3Q_2$	B	Flat	Lindbergh	0.020	0.5900	N/A
$0.3Q_2$	B	Moderate	Lindbergh	0.020	0.3600	N/A
$0.3Q_2$	B	Steep	Lindbergh	0.020	0.1800	N/A

Table 1-8. Sizing Factors for Bioretention Plus Cistern Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.3Q_2$	C	Flat	Lindbergh	0.020	0.1800	N/A
$0.3Q_2$	C	Moderate	Lindbergh	0.020	0.1800	N/A
$0.3Q_2$	C	Steep	Lindbergh	0.020	0.1400	N/A
$0.3Q_2$	D	Flat	Lindbergh	0.020	0.1400	N/A
$0.3Q_2$	D	Moderate	Lindbergh	0.020	0.1400	N/A
$0.3Q_2$	D	Steep	Lindbergh	0.020	0.0800	N/A
$0.3Q_2$	A	Flat	Oceanside	0.020	0.1600	N/A
$0.3Q_2$	A	Moderate	Oceanside	0.020	0.1400	N/A
$0.3Q_2$	A	Steep	Oceanside	0.020	0.1200	N/A
$0.3Q_2$	B	Flat	Oceanside	0.020	0.2200	N/A
$0.3Q_2$	B	Moderate	Oceanside	0.020	0.1800	N/A
$0.3Q_2$	B	Steep	Oceanside	0.020	0.1600	N/A
$0.3Q_2$	C	Flat	Oceanside	0.020	0.1600	N/A
$0.3Q_2$	C	Moderate	Oceanside	0.020	0.1600	N/A
$0.3Q_2$	C	Steep	Oceanside	0.025	0.1400	N/A
$0.3Q_2$	D	Flat	Oceanside	0.020	0.1400	N/A
$0.3Q_2$	D	Moderate	Oceanside	0.025	0.1400	N/A
$0.3Q_2$	D	Steep	Oceanside	0.030	0.1200	N/A
$0.3Q_2$	A	Flat	L Wohlford	0.020	0.1800	N/A
$0.3Q_2$	A	Moderate	L Wohlford	0.025	0.1400	N/A
$0.3Q_2$	A	Steep	L Wohlford	0.030	0.0800	N/A
$0.3Q_2$	B	Flat	L Wohlford	0.025	0.2600	N/A
$0.3Q_2$	B	Moderate	L Wohlford	0.025	0.2400	N/A
$0.3Q_2$	B	Steep	L Wohlford	0.030	0.1800	N/A
$0.3Q_2$	C	Flat	L Wohlford	0.030	0.1800	N/A
$0.3Q_2$	C	Moderate	L Wohlford	0.030	0.1800	N/A
$0.3Q_2$	C	Steep	L Wohlford	0.035	0.1400	N/A
$0.3Q_2$	D	Flat	L Wohlford	0.030	0.1400	N/A
$0.3Q_2$	D	Moderate	L Wohlford	0.035	0.1400	N/A
$0.3Q_2$	D	Steep	L Wohlford	0.040	0.1000	N/A
$0.1Q_2$	A	Flat	Lindbergh	0.020	0.1200	N/A
$0.1Q_2$	A	Moderate	Lindbergh	0.020	0.1000	N/A
$0.1Q_2$	A	Steep	Lindbergh	0.020	0.1000	N/A
$0.1Q_2$	B	Flat	Lindbergh	0.020	0.5400	N/A
$0.1Q_2$	B	Moderate	Lindbergh	0.020	0.7800	N/A
$0.1Q_2$	B	Steep	Lindbergh	0.020	0.3400	N/A

Table 1-8. Sizing Factors for Bioretention Plus Cistern Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.1Q_2$	C	Flat	Lindbergh	0.020	0.3600	N/A
$0.1Q_2$	C	Moderate	Lindbergh	0.020	0.3600	N/A
$0.1Q_2$	C	Steep	Lindbergh	0.020	0.2400	N/A
$0.1Q_2$	D	Flat	Lindbergh	0.020	0.2600	N/A
$0.1Q_2$	D	Moderate	Lindbergh	0.020	0.2600	N/A
$0.1Q_2$	D	Steep	Lindbergh	0.020	0.1600	N/A
$0.1Q_2$	A	Flat	Oceanside	0.020	0.1600	N/A
$0.1Q_2$	A	Moderate	Oceanside	0.020	0.1400	N/A
$0.1Q_2$	A	Steep	Oceanside	0.020	0.1200	N/A
$0.1Q_2$	B	Flat	Oceanside	0.020	0.5100	N/A
$0.1Q_2$	B	Moderate	Oceanside	0.020	0.3400	N/A
$0.1Q_2$	B	Steep	Oceanside	0.020	0.2400	N/A
$0.1Q_2$	C	Flat	Oceanside	0.020	0.2600	N/A
$0.1Q_2$	C	Moderate	Oceanside	0.020	0.2600	N/A
$0.1Q_2$	C	Steep	Oceanside	0.020	0.2000	N/A
$0.1Q_2$	D	Flat	Oceanside	0.020	0.2000	N/A
$0.1Q_2$	D	Moderate	Oceanside	0.020	0.2000	N/A
$0.1Q_2$	D	Steep	Oceanside	0.020	0.1800	N/A
$0.1Q_2$	A	Flat	L Wohlford	0.020	0.1800	N/A
$0.1Q_2$	A	Moderate	L Wohlford	0.020	0.1400	N/A
$0.1Q_2$	A	Steep	L Wohlford	0.020	0.0800	N/A
$0.1Q_2$	B	Flat	L Wohlford	0.020	0.4400	N/A
$0.1Q_2$	B	Moderate	L Wohlford	0.020	0.4000	N/A
$0.1Q_2$	B	Steep	L Wohlford	0.020	0.3200	N/A
$0.1Q_2$	C	Flat	L Wohlford	0.020	0.3200	N/A
$0.1Q_2$	C	Moderate	L Wohlford	0.020	0.3200	N/A
$0.1Q_2$	C	Steep	L Wohlford	0.020	0.2200	N/A
$0.1Q_2$	D	Flat	L Wohlford	0.020	0.2400	N/A
$0.1Q_2$	D	Moderate	L Wohlford	0.020	0.2400	N/A
$0.1Q_2$	D	Steep	L Wohlford	0.020	0.1800	N/A

Q_2 = 2-year pre-project flow rate based upon partial duration analysis of long-term hourly rainfall records

Q_{10} = 10-year pre-project flow rate based upon partial duration analysis of long-term hourly rainfall records

A = Bioretention surface area sizing factor

V_1 = Cistern volume sizing factor

1.8.3 Bioretention with Vault

Table 1-9. Sizing Factors for Bioretention Plus Vault Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.5Q_2$	A	Flat	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	A	Moderate	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	A	Steep	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	B	Flat	Lindbergh	0.040	0.3600	N/A
$0.5Q_2$	B	Moderate	Lindbergh	0.040	0.2400	N/A
$0.5Q_2$	B	Steep	Lindbergh	0.040	0.1400	N/A
$0.5Q_2$	C	Flat	Lindbergh	0.040	0.1600	N/A
$0.5Q_2$	C	Moderate	Lindbergh	0.040	0.1600	N/A
$0.5Q_2$	C	Steep	Lindbergh	0.040	0.1200	N/A
$0.5Q_2$	D	Flat	Lindbergh	0.040	0.1400	N/A
$0.5Q_2$	D	Moderate	Lindbergh	0.040	0.1400	N/A
$0.5Q_2$	D	Steep	Lindbergh	0.040	0.1000	N/A
$0.5Q_2$	A	Flat	Oceanside	N/A	N/A	N/A
$0.5Q_2$	A	Moderate	Oceanside	N/A	N/A	N/A
$0.5Q_2$	A	Steep	Oceanside	N/A	N/A	N/A
$0.5Q_2$	B	Flat	Oceanside	0.040	0.2100	N/A
$0.5Q_2$	B	Moderate	Oceanside	0.040	0.1800	N/A
$0.5Q_2$	B	Steep	Oceanside	0.040	0.1400	N/A
$0.5Q_2$	C	Flat	Oceanside	0.040	0.1400	N/A
$0.5Q_2$	C	Moderate	Oceanside	0.040	0.1400	N/A
$0.5Q_2$	C	Steep	Oceanside	0.040	0.1200	N/A
$0.5Q_2$	D	Flat	Oceanside	0.040	0.1400	N/A
$0.5Q_2$	D	Moderate	Oceanside	0.040	0.1400	N/A
$0.5Q_2$	D	Steep	Oceanside	0.040	0.1200	N/A
$0.5Q_2$	A	Flat	L Wohlford	N/A	N/A	N/A
$0.5Q_2$	A	Moderate	L Wohlford	N/A	N/A	N/A
$0.5Q_2$	A	Steep	L Wohlford	N/A	N/A	N/A
$0.5Q_2$	B	Flat	L Wohlford	0.040	0.2600	N/A
$0.5Q_2$	B	Moderate	L Wohlford	0.040	0.2200	N/A
$0.5Q_2$	B	Steep	L Wohlford	0.040	0.1200	N/A
$0.5Q_2$	C	Flat	L Wohlford	0.040	0.1400	N/A
$0.5Q_2$	C	Moderate	L Wohlford	0.040	0.1400	N/A
$0.5Q_2$	C	Steep	L Wohlford	0.040	0.1000	N/A
$0.5Q_2$	D	Flat	L Wohlford	0.040	0.1200	N/A

Table 1-9. Sizing Factors for Bioretention Plus Vault Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.5Q_2$	D	Moderate	L Wohlford	0.040	0.1200	N/A
$0.5Q_2$	D	Steep	L Wohlford	0.040	0.0800	N/A
$0.3Q_2$	A	Flat	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	A	Moderate	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	A	Steep	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	B	Flat	Lindbergh	0.040	0.4500	N/A
$0.3Q_2$	B	Moderate	Lindbergh	0.040	0.3200	N/A
$0.3Q_2$	B	Steep	Lindbergh	0.040	0.1800	N/A
$0.3Q_2$	C	Flat	Lindbergh	0.040	0.1800	N/A
$0.3Q_2$	C	Moderate	Lindbergh	0.040	0.1800	N/A
$0.3Q_2$	C	Steep	Lindbergh	0.040	0.1400	N/A
$0.3Q_2$	D	Flat	Lindbergh	0.040	0.1600	N/A
$0.3Q_2$	D	Moderate	Lindbergh	0.040	0.1600	N/A
$0.3Q_2$	D	Steep	Lindbergh	0.040	0.1200	N/A
$0.3Q_2$	A	Flat	Oceanside	N/A	N/A	N/A
$0.3Q_2$	A	Moderate	Oceanside	N/A	N/A	N/A
$0.3Q_2$	A	Steep	Oceanside	N/A	N/A	N/A
$0.3Q_2$	B	Flat	Oceanside	0.040	0.2500	N/A
$0.3Q_2$	B	Moderate	Oceanside	0.040	0.2000	N/A
$0.3Q_2$	B	Steep	Oceanside	0.040	0.1600	N/A
$0.3Q_2$	C	Flat	Oceanside	0.040	0.1600	N/A
$0.3Q_2$	C	Moderate	Oceanside	0.040	0.1600	N/A
$0.3Q_2$	C	Steep	Oceanside	0.040	0.1400	N/A
$0.3Q_2$	D	Flat	Oceanside	0.040	0.1400	N/A
$0.3Q_2$	D	Moderate	Oceanside	0.040	0.1400	N/A
$0.3Q_2$	D	Steep	Oceanside	0.040	0.1200	N/A
$0.3Q_2$	A	Flat	L Wohlford	N/A	N/A	N/A
$0.3Q_2$	A	Moderate	L Wohlford	N/A	N/A	N/A
$0.3Q_2$	A	Steep	L Wohlford	N/A	N/A	N/A
$0.3Q_2$	B	Flat	L Wohlford	0.040	0.2900	N/A
$0.3Q_2$	B	Moderate	L Wohlford	0.040	0.2600	N/A
$0.3Q_2$	B	Steep	L Wohlford	0.040	0.1600	N/A
$0.3Q_2$	C	Flat	L Wohlford	0.040	0.1600	N/A
$0.3Q_2$	C	Moderate	L Wohlford	0.040	0.1600	N/A
$0.3Q_2$	C	Steep	L Wohlford	0.040	0.1200	N/A
$0.3Q_2$	D	Flat	L Wohlford	0.040	0.1200	N/A

Table 1-9. Sizing Factors for Bioretention Plus Vault Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.3Q_2$	D	Moderate	L Wohlford	0.040	0.1200	N/A
$0.3Q_2$	D	Steep	L Wohlford	0.040	0.0800	N/A
$0.1Q_2$	A	Flat	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	A	Moderate	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	A	Steep	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	B	Flat	Lindbergh	0.040	0.5900	N/A
$0.1Q_2$	B	Moderate	Lindbergh	0.040	0.5000	N/A
$0.1Q_2$	B	Steep	Lindbergh	0.040	0.3200	N/A
$0.1Q_2$	C	Flat	Lindbergh	0.040	0.3400	N/A
$0.1Q_2$	C	Moderate	Lindbergh	0.040	0.3400	N/A
$0.1Q_2$	C	Steep	Lindbergh	0.040	0.2400	N/A
$0.1Q_2$	D	Flat	Lindbergh	0.040	0.2600	N/A
$0.1Q_2$	D	Moderate	Lindbergh	0.040	0.2600	N/A
$0.1Q_2$	D	Steep	Lindbergh	0.040	0.1800	N/A
$0.1Q_2$	A	Flat	Oceanside	N/A	N/A	N/A
$0.1Q_2$	A	Moderate	Oceanside	N/A	N/A	N/A
$0.1Q_2$	A	Steep	Oceanside	N/A	N/A	N/A
$0.1Q_2$	B	Flat	Oceanside	0.040	0.4300	N/A
$0.1Q_2$	B	Moderate	Oceanside	0.040	0.3400	N/A
$0.1Q_2$	B	Steep	Oceanside	0.040	0.2400	N/A
$0.1Q_2$	C	Flat	Oceanside	0.040	0.2600	N/A
$0.1Q_2$	C	Moderate	Oceanside	0.040	0.2600	N/A
$0.1Q_2$	C	Steep	Oceanside	0.040	0.2000	N/A
$0.1Q_2$	D	Flat	Oceanside	0.040	0.2200	N/A
$0.1Q_2$	D	Moderate	Oceanside	0.040	0.2200	N/A
$0.1Q_2$	D	Steep	Oceanside	0.040	0.1600	N/A
$0.1Q_2$	A	Flat	L Wohlford	N/A	N/A	N/A
$0.1Q_2$	A	Moderate	L Wohlford	N/A	N/A	N/A
$0.1Q_2$	A	Steep	L Wohlford	N/A	N/A	N/A
$0.1Q_2$	B	Flat	L Wohlford	0.040	0.4300	N/A
$0.1Q_2$	B	Moderate	L Wohlford	0.040	0.3800	N/A
$0.1Q_2$	B	Steep	L Wohlford	0.040	0.2800	N/A
$0.1Q_2$	C	Flat	L Wohlford	0.040	0.2800	N/A
$0.1Q_2$	C	Moderate	L Wohlford	0.040	0.2800	N/A
$0.1Q_2$	C	Steep	L Wohlford	0.040	0.2000	N/A
$0.1Q_2$	D	Flat	L Wohlford	0.040	0.2200	N/A

Table 1-9. Sizing Factors for Bioretention Plus Vault Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.1Q_2$	D	Moderate	L Wohlford	0.040	0.2200	N/A
$0.1Q_2$	D	Steep	L Wohlford	0.040	0.1400	N/A

Q_2 = 2-year pre-project flow rate based upon partial duration analysis of long-term hourly rainfall records

Q_{10} = 10-year pre-project flow rate based upon partial duration analysis of long-term hourly rainfall records

A = Bioretention surface area sizing factor

V_1 = Vault volume sizing factor

1.8.4 Flow-Through Planters

Table 1-10. Sizing Factors for Flow-Through Planters

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.5Q_2$	A	Flat	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	A	Moderate	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	A	Steep	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	B	Flat	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	B	Moderate	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	B	Steep	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	C	Flat	Lindbergh	0.115	0.0958	0.0690
$0.5Q_2$	C	Moderate	Lindbergh	0.115	0.0958	0.0690
$0.5Q_2$	C	Steep	Lindbergh	0.080	0.0667	0.0480
$0.5Q_2$	D	Flat	Lindbergh	0.085	0.0708	0.0510
$0.5Q_2$	D	Moderate	Lindbergh	0.085	0.0708	0.0510
$0.5Q_2$	D	Steep	Lindbergh	0.065	0.0542	0.0390
$0.5Q_2$	A	Flat	Oceanside	N/A	N/A	N/A
$0.5Q_2$	A	Moderate	Oceanside	N/A	N/A	N/A
$0.5Q_2$	A	Steep	Oceanside	N/A	N/A	N/A
$0.5Q_2$	B	Flat	Oceanside	N/A	N/A	N/A
$0.5Q_2$	B	Moderate	Oceanside	N/A	N/A	N/A
$0.5Q_2$	B	Steep	Oceanside	N/A	N/A	N/A
$0.5Q_2$	C	Flat	Oceanside	0.075	0.0625	0.0450
$0.5Q_2$	C	Moderate	Oceanside	0.075	0.0625	0.0450
$0.5Q_2$	C	Steep	Oceanside	0.065	0.0542	0.0390
$0.5Q_2$	D	Flat	Oceanside	0.070	0.0583	0.0420
$0.5Q_2$	D	Moderate	Oceanside	0.070	0.0583	0.0420
$0.5Q_2$	D	Steep	Oceanside	0.050	0.0417	0.0300
$0.5Q_2$	A	Flat	L Wohlford	N/A	N/A	N/A

Table 1-10. Sizing Factors for Flow-Through Planters

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.5Q_2$	A	Moderate	L Wohlford	N/A	N/A	N/A
$0.5Q_2$	A	Steep	L Wohlford	N/A	N/A	N/A
$0.5Q_2$	B	Flat	L Wohlford	N/A	N/A	N/A
$0.5Q_2$	B	Moderate	L Wohlford	N/A	N/A	N/A
$0.5Q_2$	B	Steep	L Wohlford	N/A	N/A	N/A
$0.5Q_2$	C	Flat	L Wohlford	0.070	0.0583	0.0420
$0.5Q_2$	C	Moderate	L Wohlford	0.070	0.0583	0.0420
$0.5Q_2$	C	Steep	L Wohlford	0.050	0.0417	0.0300
$0.5Q_2$	D	Flat	L Wohlford	0.055	0.0458	0.0330
$0.5Q_2$	D	Moderate	L Wohlford	0.055	0.0458	0.0330
$0.5Q_2$	D	Steep	L Wohlford	0.045	0.0375	0.0270
$0.3Q_2$	A	Flat	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	A	Moderate	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	A	Steep	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	B	Flat	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	B	Moderate	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	B	Steep	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	C	Flat	Lindbergh	0.130	0.1083	0.0780
$0.3Q_2$	C	Moderate	Lindbergh	0.130	0.1083	0.0780
$0.3Q_2$	C	Steep	Lindbergh	0.100	0.0833	0.0600
$0.3Q_2$	D	Flat	Lindbergh	0.105	0.0875	0.0630
$0.3Q_2$	D	Moderate	Lindbergh	0.105	0.0875	0.0630
$0.3Q_2$	D	Steep	Lindbergh	0.075	0.0625	0.0450
$0.3Q_2$	A	Flat	Oceanside	N/A	N/A	N/A
$0.3Q_2$	A	Moderate	Oceanside	N/A	N/A	N/A
$0.3Q_2$	A	Steep	Oceanside	N/A	N/A	N/A
$0.3Q_2$	B	Flat	Oceanside	N/A	N/A	N/A
$0.3Q_2$	B	Moderate	Oceanside	N/A	N/A	N/A
$0.3Q_2$	B	Steep	Oceanside	N/A	N/A	N/A
$0.3Q_2$	C	Flat	Oceanside	0.105	0.0875	0.0630
$0.3Q_2$	C	Moderate	Oceanside	0.105	0.0875	0.0630
$0.3Q_2$	C	Steep	Oceanside	0.085	0.0708	0.0510
$0.3Q_2$	D	Flat	Oceanside	0.090	0.0750	0.0540
$0.3Q_2$	D	Moderate	Oceanside	0.090	0.0750	0.0540
$0.3Q_2$	D	Steep	Oceanside	0.070	0.0583	0.0420
$0.3Q_2$	A	Flat	L Wohlford	N/A	N/A	N/A

Table 1-10. Sizing Factors for Flow-Through Planters

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.3Q_2$	A	Moderate	L Wohlford	N/A	N/A	N/A
$0.3Q_2$	A	Steep	L Wohlford	N/A	N/A	N/A
$0.3Q_2$	B	Flat	L Wohlford	N/A	N/A	N/A
$0.3Q_2$	B	Moderate	L Wohlford	N/A	N/A	N/A
$0.3Q_2$	B	Steep	L Wohlford	N/A	N/A	N/A
$0.3Q_2$	C	Flat	L Wohlford	0.085	0.0708	0.0510
$0.3Q_2$	C	Moderate	L Wohlford	0.085	0.0708	0.0510
$0.3Q_2$	C	Steep	L Wohlford	0.060	0.0500	0.0360
$0.3Q_2$	D	Flat	L Wohlford	0.065	0.0542	0.0390
$0.3Q_2$	D	Moderate	L Wohlford	0.065	0.0542	0.0390
$0.3Q_2$	D	Steep	L Wohlford	0.050	0.0417	0.0300
$0.1Q_2$	A	Flat	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	A	Moderate	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	A	Steep	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	B	Flat	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	B	Moderate	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	B	Steep	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	C	Flat	Lindbergh	0.250	0.2083	0.1500
$0.1Q_2$	C	Moderate	Lindbergh	0.250	0.2083	0.1500
$0.1Q_2$	C	Steep	Lindbergh	0.185	0.1542	0.1110
$0.1Q_2$	D	Flat	Lindbergh	0.200	0.1667	0.1200
$0.1Q_2$	D	Moderate	Lindbergh	0.200	0.1667	0.1200
$0.1Q_2$	D	Steep	Lindbergh	0.130	0.1083	0.0780
$0.1Q_2$	A	Flat	Oceanside	N/A	N/A	N/A
$0.1Q_2$	A	Moderate	Oceanside	N/A	N/A	N/A
$0.1Q_2$	A	Steep	Oceanside	N/A	N/A	N/A
$0.1Q_2$	B	Flat	Oceanside	N/A	N/A	N/A
$0.1Q_2$	B	Moderate	Oceanside	N/A	N/A	N/A
$0.1Q_2$	B	Steep	Oceanside	N/A	N/A	N/A
$0.1Q_2$	C	Flat	Oceanside	0.190	0.1583	0.1140
$0.1Q_2$	C	Moderate	Oceanside	0.190	0.1583	0.1140
$0.1Q_2$	C	Steep	Oceanside	0.140	0.1167	0.0840
$0.1Q_2$	D	Flat	Oceanside	0.160	0.1333	0.0960
$0.1Q_2$	D	Moderate	Oceanside	0.160	0.1333	0.0960
$0.1Q_2$	D	Steep	Oceanside	0.105	0.0875	0.0630
$0.1Q_2$	A	Flat	L Wohlford	N/A	N/A	N/A

Table 1-10. Sizing Factors for Flow-Through Planters

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.1Q_2$	A	Moderate	L Wohlford	N/A	N/A	N/A
$0.1Q_2$	A	Steep	L Wohlford	N/A	N/A	N/A
$0.1Q_2$	B	Flat	L Wohlford	N/A	N/A	N/A
$0.1Q_2$	B	Moderate	L Wohlford	N/A	N/A	N/A
$0.1Q_2$	B	Steep	L Wohlford	N/A	N/A	N/A
$0.1Q_2$	C	Flat	L Wohlford	0.135	0.1125	0.0810
$0.1Q_2$	C	Moderate	L Wohlford	0.135	0.1125	0.0810
$0.1Q_2$	C	Steep	L Wohlford	0.105	0.0875	0.0630
$0.1Q_2$	D	Flat	L Wohlford	0.110	0.0917	0.0660
$0.1Q_2$	D	Moderate	L Wohlford	0.110	0.0917	0.0660
$0.1Q_2$	D	Steep	L Wohlford	0.080	0.0667	0.0480

Q_2 = 2-year pre-project flow rate based upon partial duration analysis of long-term hourly rainfall records

Q_{10} = 10-year pre-project flow rate based upon partial duration analysis of long-term hourly rainfall records

A = Surface area sizing factor

V_1 = Surface volume sizing factor

V_2 = Subsurface volume sizing factor

1.8.5 Infiltration Facilities

Table 1-11. Sizing Factors for Infiltration Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.5Q_2$	A	Flat	Lindbergh	0.040	0.1040	N/A
$0.5Q_2$	A	Moderate	Lindbergh	0.040	0.1040	N/A
$0.5Q_2$	A	Steep	Lindbergh	0.035	0.0910	N/A
$0.5Q_2$	B	Flat	Lindbergh	0.058	0.1495	N/A
$0.5Q_2$	B	Moderate	Lindbergh	0.055	0.1430	N/A
$0.5Q_2$	B	Steep	Lindbergh	0.050	0.1300	N/A
$0.5Q_2$	C	Flat	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	C	Moderate	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	C	Steep	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	D	Flat	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	D	Moderate	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	D	Steep	Lindbergh	N/A	N/A	N/A
$0.5Q_2$	A	Flat	Oceanside	0.045	0.1170	N/A
$0.5Q_2$	A	Moderate	Oceanside	0.045	0.1170	N/A
$0.5Q_2$	A	Steep	Oceanside	0.040	0.1040	N/A

Table 1-11. Sizing Factors for Infiltration Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.5Q_2$	B	Flat	Oceanside	0.065	0.1690	N/A
$0.5Q_2$	B	Moderate	Oceanside	0.065	0.1690	N/A
$0.5Q_2$	B	Steep	Oceanside	0.060	0.1560	N/A
$0.5Q_2$	C	Flat	Oceanside	N/A	N/A	N/A
$0.5Q_2$	C	Moderate	Oceanside	N/A	N/A	N/A
$0.5Q_2$	C	Steep	Oceanside	N/A	N/A	N/A
$0.5Q_2$	D	Flat	Oceanside	N/A	N/A	N/A
$0.5Q_2$	D	Moderate	Oceanside	N/A	N/A	N/A
$0.5Q_2$	D	Steep	Oceanside	N/A	N/A	N/A
$0.5Q_2$	A	Flat	L Wohlford	0.050	0.1300	N/A
$0.5Q_2$	A	Moderate	L Wohlford	0.050	0.1300	N/A
$0.5Q_2$	A	Steep	L Wohlford	0.040	0.1040	N/A
$0.5Q_2$	B	Flat	L Wohlford	0.078	0.2015	N/A
$0.5Q_2$	B	Moderate	L Wohlford	0.075	0.1950	N/A
$0.5Q_2$	B	Steep	L Wohlford	0.065	0.1690	N/A
$0.5Q_2$	C	Flat	L Wohlford	N/A	N/A	N/A
$0.5Q_2$	C	Moderate	L Wohlford	N/A	N/A	N/A
$0.5Q_2$	C	Steep	L Wohlford	N/A	N/A	N/A
$0.5Q_2$	D	Flat	L Wohlford	N/A	N/A	N/A
$0.5Q_2$	D	Moderate	L Wohlford	N/A	N/A	N/A
$0.5Q_2$	D	Steep	L Wohlford	N/A	N/A	N/A
$0.3Q_2$	A	Flat	Lindbergh	0.040	0.1040	N/A
$0.3Q_2$	A	Moderate	Lindbergh	0.040	0.1040	N/A
$0.3Q_2$	A	Steep	Lindbergh	0.035	0.0910	N/A
$0.3Q_2$	B	Flat	Lindbergh	0.058	0.1495	N/A
$0.3Q_2$	B	Moderate	Lindbergh	0.055	0.1430	N/A
$0.3Q_2$	B	Steep	Lindbergh	0.050	0.1300	N/A
$0.3Q_2$	C	Flat	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	C	Moderate	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	C	Steep	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	D	Flat	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	D	Moderate	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	D	Steep	Lindbergh	N/A	N/A	N/A
$0.3Q_2$	A	Flat	Oceanside	0.045	0.1170	N/A
$0.3Q_2$	A	Moderate	Oceanside	0.045	0.1170	N/A
$0.3Q_2$	A	Steep	Oceanside	0.040	0.1040	N/A

Table 1-11. Sizing Factors for Infiltration Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.3Q_2$	B	Flat	Oceanside	0.065	0.1690	N/A
$0.3Q_2$	B	Moderate	Oceanside	0.065	0.1690	N/A
$0.3Q_2$	B	Steep	Oceanside	0.060	0.1560	N/A
$0.3Q_2$	C	Flat	Oceanside	N/A	N/A	N/A
$0.3Q_2$	C	Moderate	Oceanside	N/A	N/A	N/A
$0.3Q_2$	C	Steep	Oceanside	N/A	N/A	N/A
$0.3Q_2$	D	Flat	Oceanside	N/A	N/A	N/A
$0.3Q_2$	D	Moderate	Oceanside	N/A	N/A	N/A
$0.3Q_2$	D	Steep	Oceanside	N/A	N/A	N/A
$0.3Q_2$	A	Flat	L Wohlford	0.050	0.1300	N/A
$0.3Q_2$	A	Moderate	L Wohlford	0.050	0.1300	N/A
$0.3Q_2$	A	Steep	L Wohlford	0.040	0.1040	N/A
$0.3Q_2$	B	Flat	L Wohlford	0.078	0.2015	N/A
$0.3Q_2$	B	Moderate	L Wohlford	0.075	0.1950	N/A
$0.3Q_2$	B	Steep	L Wohlford	0.065	0.1690	N/A
$0.3Q_2$	C	Flat	L Wohlford	N/A	N/A	N/A
$0.3Q_2$	C	Moderate	L Wohlford	N/A	N/A	N/A
$0.3Q_2$	C	Steep	L Wohlford	N/A	N/A	N/A
$0.3Q_2$	D	Flat	L Wohlford	N/A	N/A	N/A
$0.3Q_2$	D	Moderate	L Wohlford	N/A	N/A	N/A
$0.3Q_2$	D	Steep	L Wohlford	N/A	N/A	N/A
$0.1Q_2$	A	Flat	Lindbergh	0.040	0.1040	N/A
$0.1Q_2$	A	Moderate	Lindbergh	0.040	0.1040	N/A
$0.1Q_2$	A	Steep	Lindbergh	0.035	0.0910	N/A
$0.1Q_2$	B	Flat	Lindbergh	0.058	0.1495	N/A
$0.1Q_2$	B	Moderate	Lindbergh	0.055	0.1430	N/A
$0.1Q_2$	B	Steep	Lindbergh	0.050	0.1300	N/A
$0.1Q_2$	C	Flat	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	C	Moderate	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	C	Steep	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	D	Flat	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	D	Moderate	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	D	Steep	Lindbergh	N/A	N/A	N/A
$0.1Q_2$	A	Flat	Oceanside	0.045	0.1170	N/A
$0.1Q_2$	A	Moderate	Oceanside	0.045	0.1170	N/A
$0.1Q_2$	A	Steep	Oceanside	0.040	0.1040	N/A

Table 1-11. Sizing Factors for Infiltration Facilities

Lower Flow Threshold	Soil Group	Slope	Rain Gauge	A	V_1	V_2
$0.1Q_2$	B	Flat	Oceanside	0.065	0.1690	N/A
$0.1Q_2$	B	Moderate	Oceanside	0.065	0.1690	N/A
$0.1Q_2$	B	Steep	Oceanside	0.060	0.1560	N/A
$0.1Q_2$	C	Flat	Oceanside	N/A	N/A	N/A
$0.1Q_2$	C	Moderate	Oceanside	N/A	N/A	N/A
$0.1Q_2$	C	Steep	Oceanside	N/A	N/A	N/A
$0.1Q_2$	D	Flat	Oceanside	N/A	N/A	N/A
$0.1Q_2$	D	Moderate	Oceanside	N/A	N/A	N/A
$0.1Q_2$	D	Steep	Oceanside	N/A	N/A	N/A
$0.1Q_2$	A	Flat	L Wohlford	0.050	0.1300	N/A
$0.1Q_2$	A	Moderate	L Wohlford	0.050	0.1300	N/A
$0.1Q_2$	A	Steep	L Wohlford	0.040	0.1040	N/A
$0.1Q_2$	B	Flat	L Wohlford	0.078	0.2015	N/A
$0.1Q_2$	B	Moderate	L Wohlford	0.075	0.1950	N/A
$0.1Q_2$	B	Steep	L Wohlford	0.065	0.1690	N/A
$0.1Q_2$	C	Flat	L Wohlford	N/A	N/A	N/A
$0.1Q_2$	C	Moderate	L Wohlford	N/A	N/A	N/A
$0.1Q_2$	C	Steep	L Wohlford	N/A	N/A	N/A
$0.1Q_2$	D	Flat	L Wohlford	N/A	N/A	N/A
$0.1Q_2$	D	Moderate	L Wohlford	N/A	N/A	N/A
$0.1Q_2$	D	Steep	L Wohlford	N/A	N/A	N/A

Q_2 = 2-year pre-project flow rate based upon partial duration analysis of long-term hourly rainfall records

Q_{10} = 10-year pre-project flow rate based upon partial duration analysis of long-term hourly rainfall records

A = Surface area sizing factor

V_1 = Infiltration volume sizing factor

1.9 Modeling Observations and Lessons Learned

This section summarizes some of the key patterns among the BMP sizing factors.

1.9.1 Relationship between Annual Rainfall Volume and BMP Sizing Factors

In dryer areas of the County, the sizing factors computed for Group C and D soils are larger than in wetter parts of the County. This relationship does not apply in Group A and B soils. This result is somewhat counterintuitive, and several members of the Technical Advisory Committee (TAC) and Copermittee group noted that this result was not expected. The explanation comes from observations about how the BMPs work. Specifically:

- The BMP sizing factor is affected by a) how much the "impervious runoff" hydrograph must be lowered to match the "pre-project runoff" hydrograph and b) how quickly water can be released from the BMP; and b) how quickly water is allowed to be released.

- For Group C and D soils, the "impervious runoff" hydrograph does not need to be lowered as much as in Group A and B soils. This is because Group C and D soils produce more runoff during pre-project conditions.
- BMPs release water via infiltration to surrounding soils and outflow via an underdrain pipe, although the underdrain is generally applicable in Group C and D soils only. The underdrain pipe includes a flow restrictor that is sized so that its capacity matches the lower control threshold flow ($0.1Q_2$, $0.3Q_2$ or $0.5Q^2$).
- In wetter parts of the County, the underdrain can release water at a faster rate than in dryer parts of the County, because the pre-project Q2 rates are higher in the wetter areas. Of course, the "impervious runoff" hydrographs and "pre-project runoff" hydrographs are also higher in the wetter parts of the County, but the high underdrain release rates have a greater effect on the BMP sizing (see Figure 1-17).

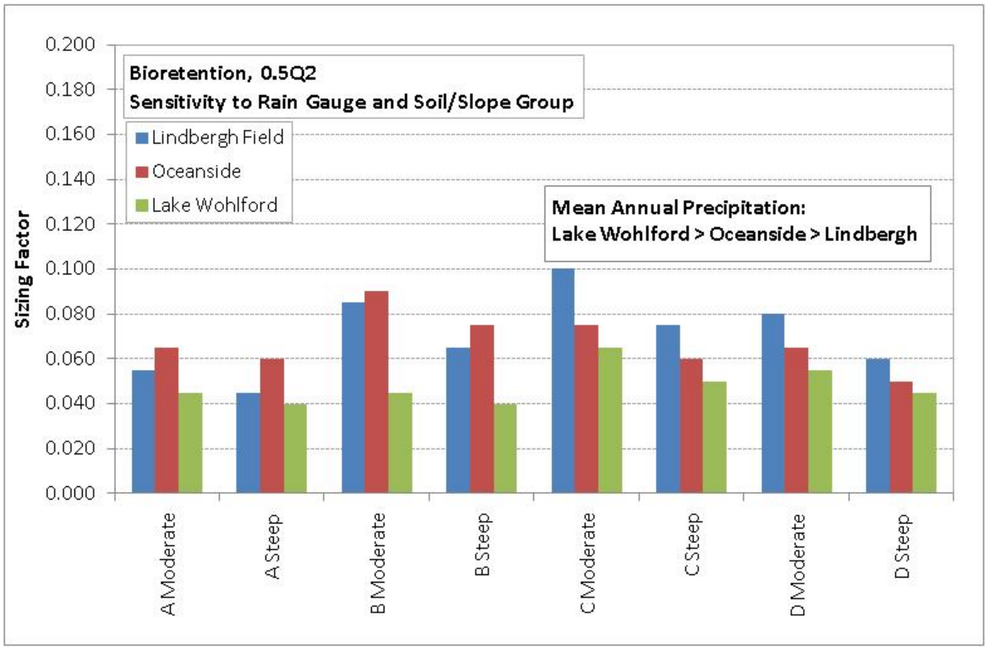


Figure 1-17. BMP sizing factors for Group C, D soils are smaller in wetter areas of the County

1.9.2 Relationship between Lower Control Threshold and BMP Sizing Factors

As noted above, the capacity of the underdrain flow restrictor plays a significant role in the size of a BMP. Three lower control standards are applied in the HMP ($0.1Q_2$, $0.3Q_2$, $0.5Q_2$) with the more restrictive control standard applying near water bodies that are highly susceptible to stream bank and channel erosion. Figures 1-18 through 1-20 illustrate this effect for the Lindbergh, Oceanside, and Lake Wolhford gauges. In Group C and D soils, the sizing factor is sensitive to the lower control threshold. The effect is non-linear; the difference between sizing factors computed using the $0.1Q_2$ and $0.5Q_2$ lower control thresholds is greatest in the dryer areas.

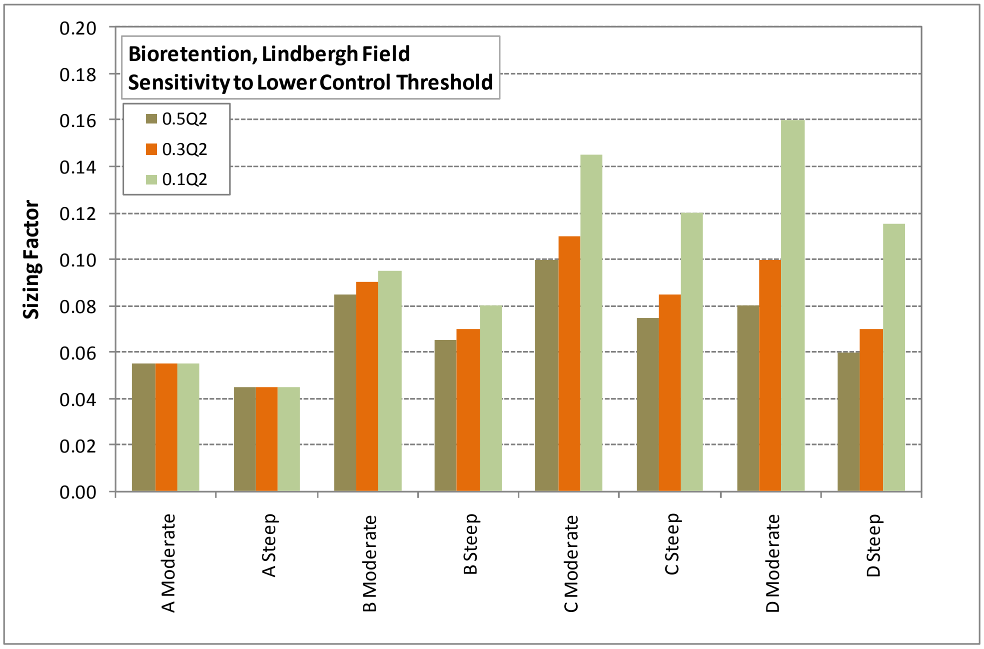


Figure 1-18. BMP sizing factors for Group C, D soils are larger for the more restrictive 0.1Q2 lower control threshold (Lindbergh)

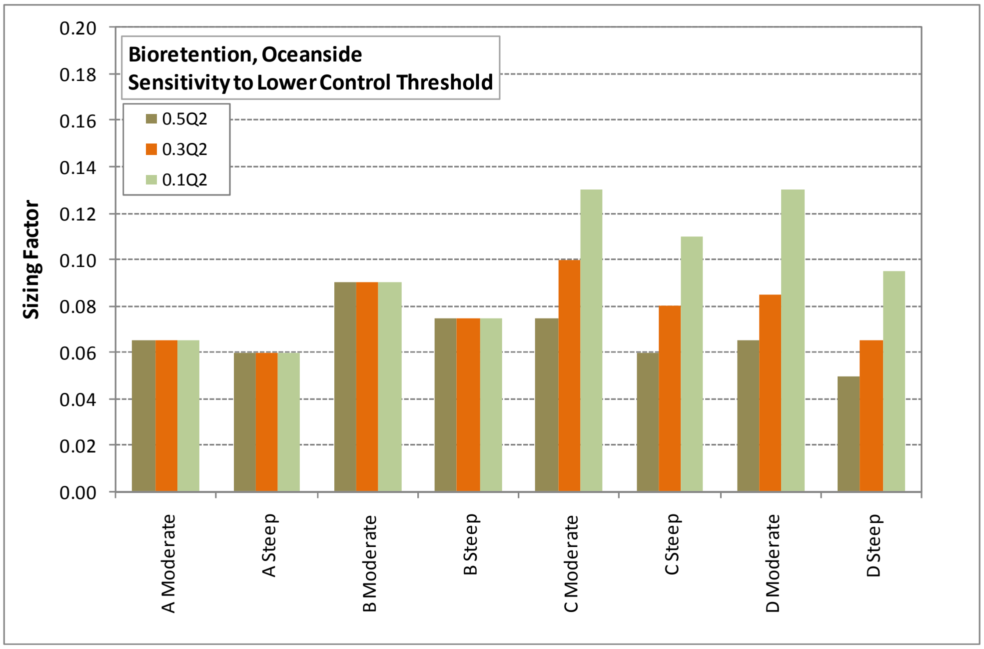


Figure 1-19. BMP sizing factors for Group C, D soils for 0.1Q2, 0.3Q2, 0.5Q2 lower control threshold (Oceanside)

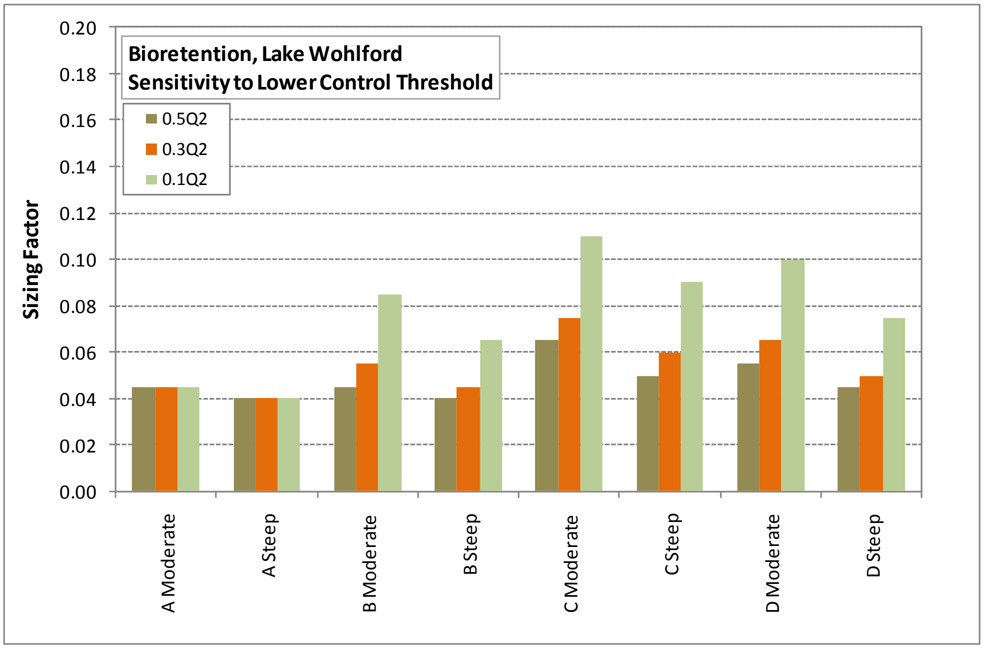


Figure 1-20. BMP sizing factors for Group C, D soils for 0.1Q2, 0.3Q2, 0.5Q2 lower control threshold (Lake Wohlford)

1.9.3 Influence of Infiltration Capacity in Low Permeability Group C and D Soils

The influence of infiltration on the BMP sizing factors for low permeability soils can be observed in the difference between Bioretention and Flow-Through Planter sizing factors. The only physical difference between these devices is that the Flow-Through Planter includes an impermeable bottom cap that prevents infiltration from occurring. In general, a Flow-Through Planter will need to be slightly larger than a Bioretention installed in the same conditions. Figure 1-21 shows the computed sizing factors for Bioretention and Flow-Through Planters for the Lake Wohlford gauge across a range of soil/slope conditions and lower control thresholds. This effect is a little more significant in Group C soils, which have a higher infiltration capacity than Group D soils.

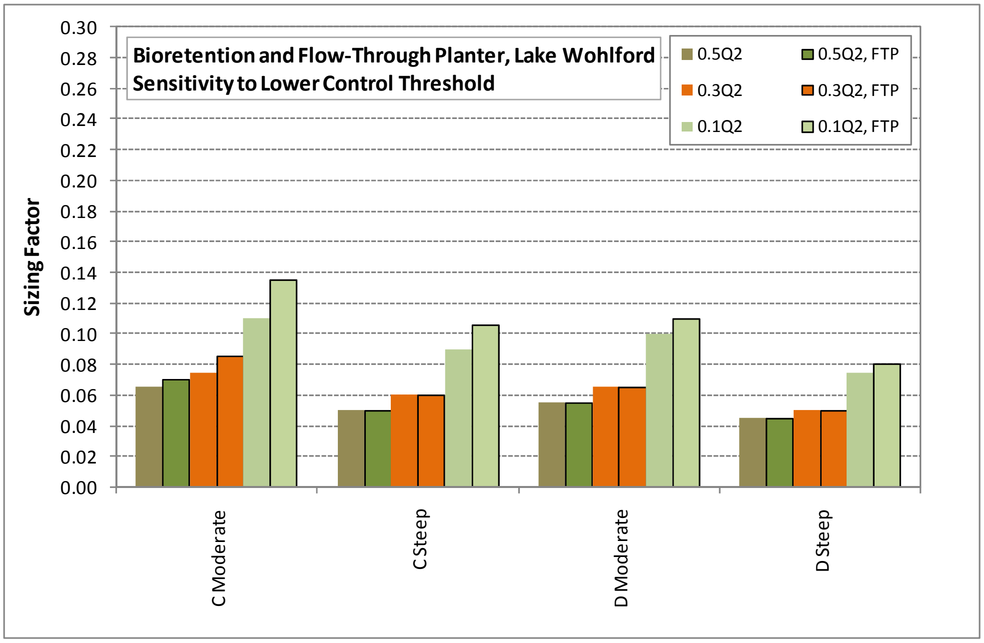


Figure 1-21. Flow through Planter sizing factors are larger than Bioretention due to lack of infiltration to surrounding soils

1.9.4 The Practical Lower Limit for Sizing LID Devices to Meet Flow Control

Outlet orifices from LID facilities should be sized based on criteria set forth by the governing municipality and best engineering practices. Outlet orifice sizing should consider both the allowable release rate, based on the applicable lower flow threshold, and facility detention times in comparison to vector control guidelines. Assuming 1.5 feet of free-draining gravel above the underdrain pipe, these orifice diameters would have the following hydraulic capacity:

D = 0.25 inches → Q = 0.0020 cfs

D = 0.50 inches → Q = 0.0080 cfs

For Group C and D soils, the underdrain flow restrictor capacity should be set to approximate the lower control threshold flow, which equals the pre-project $0.1Q_2$, $0.3Q_2$ or $0.5Q_2$ flow rate (depending on the susceptibility of the receiving water).

1.9.5 Site Conditions Not Suitable for Infiltration-Based LID Options

The purpose of the BMP Sizing Calculator is to assist in the sizing of BMPs to comply with NPDES permit requirements and to help municipal plan review staff simplify the review of project applications. The BMP Sizing Calculator is designed to be useful for the majority of development and redevelopment projects. However, users of the Sizing Calculator should make sure to use the software in coordination with sound engineering judgment – and sound hydrologic and hydraulic principals.

Users of the Sizing Calculator must consider the software to be a design and calculation aid, but not a replacement for a sound engineering approach.

Examples in which site conditions would not be suitable for infiltration-based BMPs include areas with high groundwater conditions, areas with contaminated groundwater, and situations in which infiltration of runoff would cause instability to existing or proposed structures or infrastructure, etc.

1.9.6 Sizing Calculator is an Area Accounting Tool, Not a Basin Model

The Sizing Calculator user should attempt to account for all elements of a project site through the definition of Drainage Management Areas (DMAs) and BMPs. The total area of the DMAs and BMPs should approximate the total site area. Including all areas – even those portions of the project site that will not be developed – will help the plan reviewer assess the completeness of the BMP sizing effort in the project application.

During the Sizing Calculator demonstration workshops, several members of the audience asked about how to define DMAs. DMAs should have the following properties:

- Each DMA should contain a single soil/cover/slope category
- Each DMA should drain to a single location
- Multiple DMAs can drain to the same BMP
- DMAs can be noncontiguous (this point is potentially confusing to new users). For example, multiple rooftops could be combined in the same DMA, so long as they all drain to the same location. It may make sense to manage roof and parking areas in separate DMAs, if the project could include “lower impervious” paving technologies such as porous pavement.
- Redevelopment projects can represent a challenge when defining DMAs, because the DMA boundaries are typically defined based on post-project topography and surface type. It is possible that the pre-project land cover type for a particular DMA may have consisted of partly paved and partly unpaved areas. In this case, the user should consider subdividing the DMAs so that each DMA has a unique pre-project land cover type. For redevelopment projects, it will be important for the project proponent to document assumptions and calculations to demonstrate that stormwater flows from all new impervious areas are properly managed.
- For redevelopment projects, existing impervious areas should be specified in the DMA setup for total project area accounting purposes. However, It is assumed that only runoff from new impervious surfaces will be routed to the proposed BMPs.
- For cases in which the 50 percent rule is applicable for redevelopment projects (and water quality treatment is required for the entire project site), it is recommended that the pre-project DMA land cover be defined as pervious and that all flows from the site flow to a treatment control BMP.

Section 2

Extended Detention Pond Sizing Methodology

2.1 Pond Sizing Overview

LID-based facilities have specific design configurations (depths of planting mediums, depths of gravel layers, overflow heights, etc.), which allows for facility sizing to be tied directly to the contributing watershed impervious area. Detention facilities, however, have multiple variable design variables including pond depth, pond side slopes, and outlet orifice sizes and locations above the basin floor. Therefore, an automated detention sizing routine is required to perform sizing given the user’s basic input design parameters.

The intended purpose of the automated detention sizing tool is to provide project applicants with a simplified approach to design detention facilities to meet hydromodification peak flow and flow duration control requirements. The general process will work as follows:

1. Enter information summarizing project site drainage conditions. Specifically, a proposed project site is divided into individual drainage areas, or drainage management areas (DMAs).
2. Enter hydrologic characteristics for each DMA, including the contributing drainage area, soil type (Group A, B, C or D), rainfall station, pre- and post-project land cover information (impervious cover), and DMA slope (average longitudinal slope across the DMA).
3. Based on the inputs for DMAs draining to a detention facility, the automated detention sizing tool constructs pre-project and post-project (unmitigated, without detention routing) long-term runoff time series. This is accomplished using a hydrograph database containing per-unit-area runoff rates for a full range of site conditions. This hydrograph database is created by running a series of long-term runoff simulations in HSPF.
4. Enter an initial configuration for the detention facility, including surface area, depth to riser overflow, and side slopes. For design of the outlet control structure, the automated sizing algorithm will use a pre-defined configuration that includes two flow control orifices and an overflow weir. Generally, a low flow orifice is placed at an elevation coincident with the bottom of the basin, a mid-level orifice is placed roughly halfway up the riser, and an overflow weir is located at the riser overflow elevation.
5. Post-project, unmitigated, long-term runoff time series will be routed through detention pond scenarios using a level-pool (Modified Puls) computational routing technique. The reservoir routing routine computes hourly values for detention basin inflow, basin ponding depth, basin exfiltration, and outflow through the outlet control structure. Basin outflows form the “mitigated post-project” time series that are compared to the pre-project conditions.
6. The software (automatic pond sizer) compares the mitigated post-project peak flows and flow durations with pre-project results within the geomorphically-significant flow range (between the lower flow threshold and the 10-year flow rate). If the mitigated post-project results are less than or equal to the pre-project flow (allowing for a 10-percent variance, per HMP BMP performance criteria), then the pond sizing is deemed complete and HMP performance criteria is satisfied.

7. If the current configuration does not meet the HMP performance requirements, the automated detention sizing procedure continues to iterate and perform the reservoir routing and statistical post-processing calculations until the pond is properly sized.

Input data for the automated pond sizer is generated as follows:

1. Lower and upper thresholds are pre-calculated based upon susceptibility analysis results entered by the user. Specific associated flow values are calculated based upon the pre-project site area, slope, soils and rainfall gauge. Post-project information related to site area, slope, soils and cover are also entered to define the post-development hydrologic condition.
2. The depth of the pond.
3. Side slopes for the detention pond are specified.
4. Outlet structure dimensions are automatically calculated based on the pond depth and lower flow threshold. The current assumptions are as follows:
    a. A low-level orifice is located at the bottom of the pond, and the diameter of the orifice is calculated based on matching the maximum discharge (when the pond is full) with the lower flow threshold ($0.1Q_2$ to $0.5Q_2$).
    b. A mid-level orifice is located at the middle depth of the pond, and the diameter of the orifice is calculated based on matching the maximum discharge (when the pond is full) with the upper flow threshold (i.e., Q_{10}).
    c. The upper-level overflow weir should be located at least 1 foot below the top of the pond, to provide for adequate freeboard.

Note that when the depth of the pond changes, the orifice sizes are recalculated due to the variation in the head over the orifice.

Flow durations are calculated by analyzing an input times series and calculating the total number of time steps for which the listed values fall within a specified set of ranges, or bins. For the purposes of this analysis, the full flow range of interest is between the lower flow threshold and the upper flow threshold (Q_{10}). The pond sizer subroutine is executed using both the pre-project time series and the post-project-mitigated time series hydrographs.

Results for pre-project and post-project-mitigated time series are compared based on the durations (total time) calculated for each of the flow bins. A “pass” or “fail” result is generated for each bin based on whether the post-project duration is less than or equal to the pre-project duration. The comparison takes into account the criteria variances detailed in the Final HMP.

If the flow duration criteria are met, the pond sizer then runs subsequent checks for the peak flow frequency criteria and drawdown time criteria. If all three criteria checks “pass,” then the proposed pond scenario “passes.”

If the results indicate that the pond is not adequately sized, then the size is automatically adjusted until HMP criteria is met.

2.2 Pond Sizing Example

The purpose of this section is to illustrate detention pond sizing using the San Diego BMP sizing calculator’s pond sizing module and verify if the sizing results provided by the tool meet the flow duration criteria as presented in the San Diego Hydromodification Management Plan (HMP).

According to HMP, BMP facilities are required to meet the following hydromodification flow duration control criteria:

- For flow rates ranging from 10, 30 or 50 percent of the pre-project 2-year runoff event (0.1Q2, 0.3Q2, or 0.5Q2) to the pre-project 10-year runoff event (Q10), the post-project discharge rates and durations shall not deviate above the pre-project rates and durations by more than 10 percent over and more than 10 percent of the length of the flow duration curve. The specific lower flow threshold will depend on results from the SCCWRP channel screening study and the critical flow calculator.

The following summary discusses the pond sizing computational method, example detention pond sizing, and verification of results produced by the BMP sizing calculator.

2.2.1 Pond Sizing Computational Methods

The pond sizing process involving construction of pre- and post-project runoff time series, hydrograph routing, and iterative sizing of the pond to meet the HMP criteria are discussed in this section.

2.2.2 Pre- and Post-Project Hydrographs

For the user provided site conditions, the BMP sizing calculator constructs the pre- and post-project (unmitigated) long-term runoff time series. The original time series were created through a pre-modeling exercise that involved HSPF software with historical rainfall data and the development of long-term, unit area hydrographs for each combination of soils, slopes and land covers. The drainage management area (DMA) specific time series were developed by adding together the component time series data that describe the different characteristics of the DMA (i.e. rainfall, area, soil, slope etc.).

After hydrograph construction, the BMP sizing calculator performs the routing of the post-project unmitigated, long-term runoff time series through the detention pond using a storage-indication (Modified Puls) computational routing technique. The reservoir routing routine then computes the following quantities for each hourly time step:

1. stormwater inflow
2. water depth
3. pond exfiltration
4. pond outflow through the outlet control structure.

The pond outflows will form the “post-project mitigated” time series that will be compared to the pre-project conditions. The computational methodology and data handling processes of the pond sizing routine is shown in Figure 2-5.

Outlet Structure Design

Outlet structure dimensions were automatically created by the sizing calculator based on the pond depth and lower flow threshold. The assumptions are as follows:

- A low-level orifice will be located at the bottom of the pond, and the diameter of the orifice will be calculated based on matching the maximum discharge (when the pond is full) with the lower flow threshold (e.g. 0.1Q2 for this example).
- A mid-level orifice will be located at the user specified depth of the pond, and the diameter of the orifice will be calculated based on matching the maximum discharge (when the pond is full) with the upper flow threshold (i.e., Q10).
- The upper-level overflow weir will be located 1 foot below the top of the pond, allowing 1 foot of freeboard. The weir length will also be provided by the user.

The BMP sizing calculator then performs the pond sizing computations to generate an internal array with the surface area, storage volume, and discharge rates versus stage/depth. This table is stored in memory for subsequent routing procedures. The total discharge from the pond is the sum of the lower orifice, middle orifice, overflow weir, and the exfiltration losses. This provides a proper mass balance for the pond. However, the outflow from the pond used to test for mitigated runoff conditions is just the sum of the lower orifice, middle orifice, and overflow weir discharges.

Hydrograph Routing

The BMP sizing calculator performs hydrograph routing using the storage-indication (also known as “Modified Puls”) method. Assuming the change in inflow and outflow is approximately linear over the time interval, the change in storage can be written as follows:

$$S_{j+1} - S_j = \frac{I_j + I_{j+1}}{2}\Delta t - \frac{Q_j + Q_{j+1}}{2}\Delta t$$

Equation 1

Where, S = storage, I = inflow, Q = outflow, and Dt = time increment. For use in the storage-indication method, Equation 1 on can be rewritten as:

$$\left(I_j + I_{j+1}\right) + \left(\frac{2S_j}{\Delta t} - Q_j\right) = \left(\frac{2S_{j+1}}{\Delta t} + Q_{j+1}\right)$$

Equation 2

The term on the right-hand side of Equation 2 is the storage-indication term used to look-up outflow discharge from the stage-storage-discharge relationship.

Flow Duration Comparison

The flow duration comparison method in the sizing calculator takes an input time series and calculates the total number of time steps for which the listed values fall within a specified set of ranges or bins. For the purposes of this analysis, the full flow range of interest is between the lower flow threshold (e.g. 0.1Q2) and the upper flow threshold (i.e., Q10).

This method is executed for both the pre-project time series hydrograph and the post-project-mitigated time series hydrograph. Next, the flow comparison method uses the flow duration analysis results for pre-project and post-project-mitigated time series to perform a direct comparison between the durations (total time) calculated for each of the flow bins. A “pass” or “fail” check is performed for each bin based on whether the post-project duration is less than or equal to the pre-project duration. The comparison takes into account the following allowable variance:

For flow rates ranging from lower threshold flow (0.1Q2) to the pre-project upper threshold flow (10-year runoff event, Q10), the post-project discharge rates and durations shall not deviate above the pre-project rates and durations by more than 10 percent over and more than 10 percent of the length of the flow duration curve per HMP criteria.

Pond Sizing Iterative Process

If the results from the flow comparison method indicate that the pond is not adequately sized, then the size is automatically adjusted upward one increment. If the user is sizing by adjusting the area of the pond then the sizing will be increased by a factor for each iterative step. The iterative re-sizing is terminated when the flow duration comparison results indicate that the pond is adequately sized.

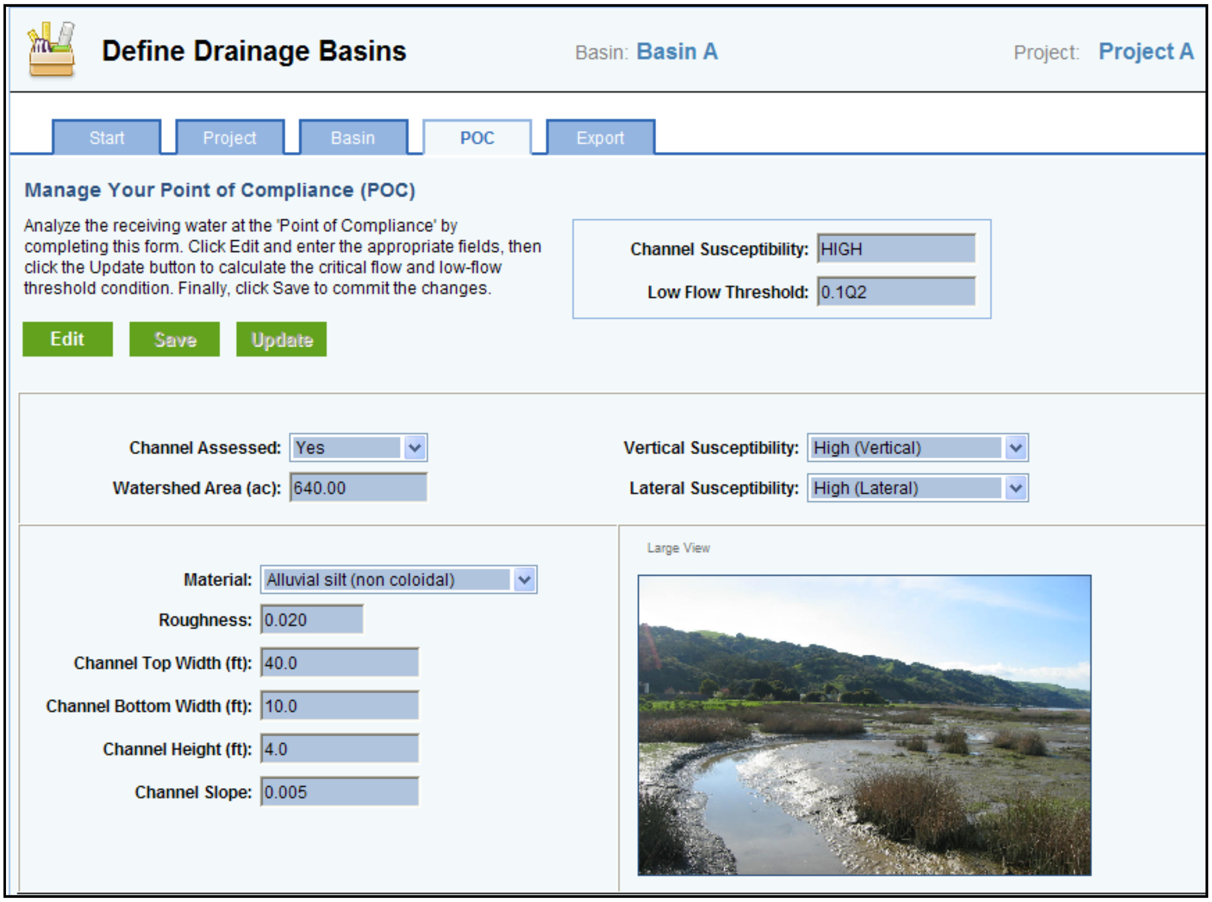
2.2.3 Example Detention Pond Sizing

For the example scenario, a project area of 20 acres encompassing a high density residential development was considered. Storm water runoff from the entire 20 acres project is assumed to drain to the detention pond (Project-Specific BMP POC) for hydromodification flow duration control before it drains to the receiving water. The example project area properties are provided in Table 2-1.

Table 2-1. Example Project Properties

Project Area	20 acres
Pre-Project Land cover	**Scrub**
Pre-Project Soil	**C**
Pre-Project Slope	**Moderate**
Rainfall Basin	**Lindbergh**

The Lindbergh rain gauge, with a mean annual precipitation of 10.2 inches, was the site-specific gauge used in the analysis (note that the mean annual precipitation value of 10.2 inches was derived from a County of San Diego study that analyzed rainfall patters between 1970-2000 – the mean annual precipitation value of 9.8 inches detailed in Table 1-1 was analyzed for a time period ranging from 1948 to 2008). Additionally, channel properties were entered in the user interface of the tool to determine the applicable lower flow threshold. Conservatively, the receiving channel was assumed to be of high susceptibility with alluvial silt as the bed material. The user also inputs the channel dimensions and slope of the channel (Figure 2-1).



Define Drainage Basins

Basin: **Basin A**

Project: **Project A**

Manage Your Point of Compliance (POC)

Analyze the receiving water at the 'Point of Compliance' by completing this form. Click Edit and enter the appropriate fields, then click the Update button to calculate the critical flow and low-flow threshold condition. Finally, click Save to commit the changes.

Channel Susceptibility: HIGH
Low Flow Threshold: 0.1Q2

Channel Assessed: Yes
Watershed Area (ac): 640.00
Vertical Susceptibility: High (Vertical)
Lateral Susceptibility: High (Lateral)

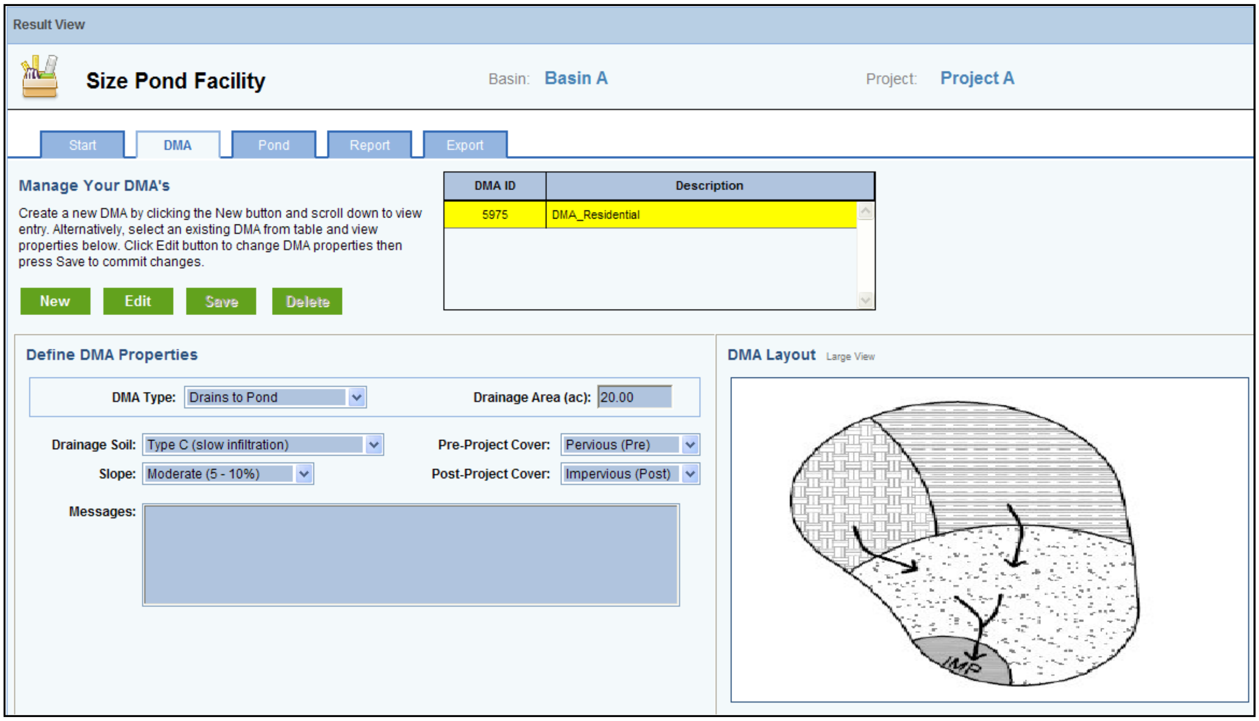
Material: Alluvial silt (non coloidal)
Roughness: 0.020
Channel Top Width (ft): 40.0
Channel Bottom Width (ft): 10.0
Channel Height (ft): 4.0
Channel Slope: 0.005

Figure 2-1. Example Channel Properties

2.2.4 Pond Sizing Results Verification

For the given pre- and post-project conditions, the pond sizing exercise was performed using the sizing calculator and results were verified for flow duration criteria specified by the HMP requirements.

As discussed in the previous section, the area draining to the pond is input as 20 acres. The user also inputs drainage area properties including existing and post-project surface types, soil, and slope (Figure 2-2). The next step is to size the pond.



Size Pond Facility

Basin: Basin A

Project: Project A

Manage Your DMA's

Create a new DMA by clicking the New button and scroll down to view entry. Alternatively, select an existing DMA from table and view properties below. Click Edit button to change DMA properties then press Save to commit changes.

DMA ID	Description
5975	DMA_Residential

Define DMA Properties

DMA Type: Drains to Pond

Drainage Area (ac): 20.00

Drainage Soil: Type C (slow infiltration)

Slope: Moderate (5 - 10%)

Pre-Project Cover: Pervious (Pre)

Post-Project Cover: Impervious (Post)

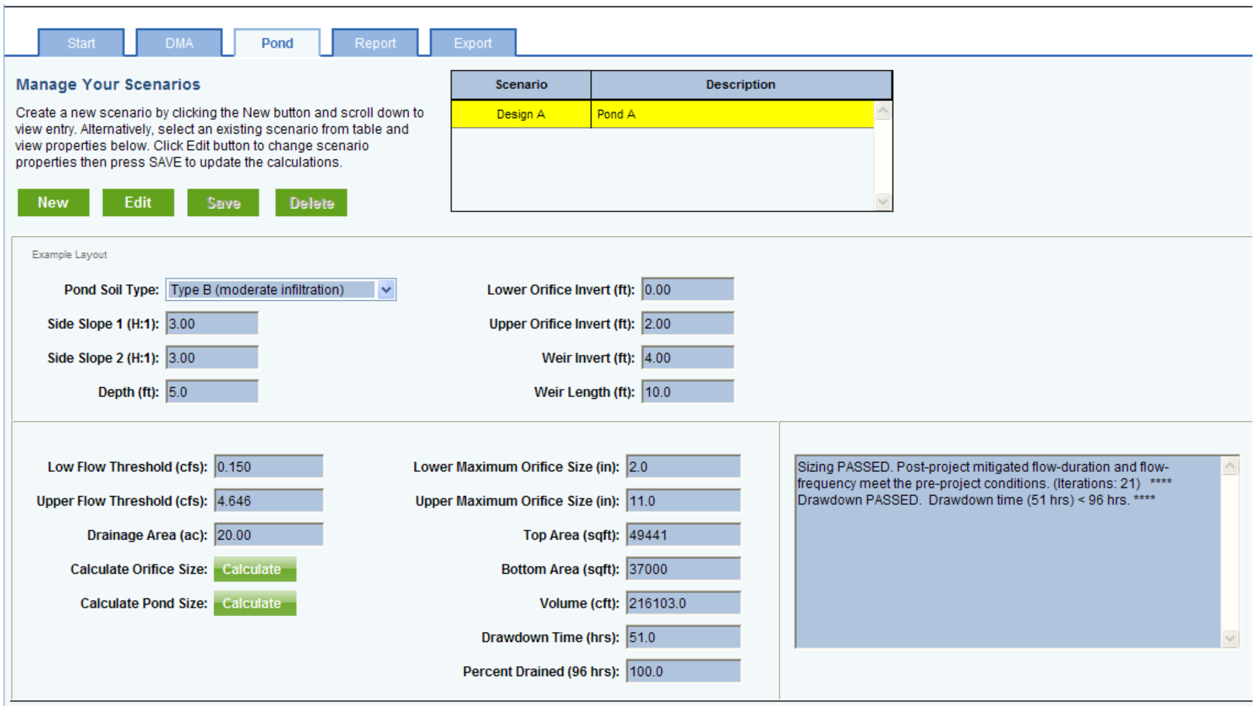
Messages:

Figure 2-2. Properties of DMA Draining to the Pond

While running the pond sizer, the user may try multiple design options (Design A, B, C etc.) to evaluate and select a suitable pond size that will meet the requirements. For each of these design options, the user may opt for facility soil types A, B, C, or D. These options provide an engineer or developer the flexibility to locate the facility depending upon favorable site conditions of the drainage area.

In the pond sizer, the user inputs pond side slopes, depth, orifice inverts, weir invert and length. Based on these input values, the sizing calculator first calculates orifice size. The pond area and volume are then computed iteratively until the size meets the HMP requirements as described in the previous sections. The sizing calculator also checks for maximum drawdown time to make sure it does not exceed 96 hours, which has been identified as the maximum allowable drawdown time by the County of San Diego's Department of Environmental Health.

Figure 2-3 illustrates the sizing results provided by the sizing calculator. These results indicate that a 5-foot pond with a top surface area of 49441 sq-ft and 3:1 side slopes is required to meet the HMP criteria. The top area is about 5.7 percent of the DMA draining to the pond. However, if the pond were located in a site with poorly drained soil, the area required may be considerably larger. The user should make proper engineering judgment in the location the pond and/or implement suitable LID measures upstream to reduce the pond size.



Manage Your Scenarios

Create a new scenario by clicking the New button and scroll down to view entry. Alternatively, select an existing scenario from table and view properties below. Click Edit button to change scenario properties then press SAVE to update the calculations.

Scenario	Description
Design A	Pond A

Example Layout

Pond Soil Type: Type B (moderate infiltration)
Side Slope 1 (H:1): 3.00
Side Slope 2 (H:1): 3.00
Depth (ft): 5.0
Lower Orifice Invert (ft): 0.00
Upper Orifice Invert (ft): 2.00
Weir Invert (ft): 4.00
Weir Length (ft): 10.0

Low Flow Threshold (cfs): 0.150
Upper Flow Threshold (cfs): 4.646
Drainage Area (ac): 20.00
Calculate Orifice Size:
Calculate Pond Size:
Lower Maximum Orifice Size (in): 2.0
Upper Maximum Orifice Size (in): 11.0
Top Area (sqft): 49441
Bottom Area (sqft): 37000
Volume (cft): 216103.0
Drawdown Time (hrs): 51.0
Percent Drained (96 hrs): 100.0

Sizing PASSED. Post-project mitigated flow-duration and flow-frequency meet the pre-project conditions. (Iterations: 21) **** Drawdown PASSED. Drawdown time (51 hrs) < 96 hrs. ****

Figure 2-3. Sizing Results Provided by the Pond Sizer

The results summary box show that the pond configuration meets flow duration criteria. Note that the drawdown time is estimated to be 51 hours, which satisfies the 96-hour maximum drawdown criteria. If the pond meets the flow duration criteria but does not meet the drawdown criteria, then the sizing calculator provides a warning and a recommendation to implement LID practices upstream of the pond.

To verify the sizing results, a comparison of pre-project and post-project mitigated flows was performed (note that the flows displayed in this analysis are based on hourly rainfall time steps). The sizing calculator provides flow versus duration values in the export option within the pond sizer. Figure 2-4 shows the flow duration comparison for the pond. It is apparent from the chart that the tool has iteratively resized the pond until the duration of all post-project mitigated flows are less than or equal to the pre-project flow durations within the lower and upper threshold flow values. Thus, HMP flow duration control criteria has been met for this example.

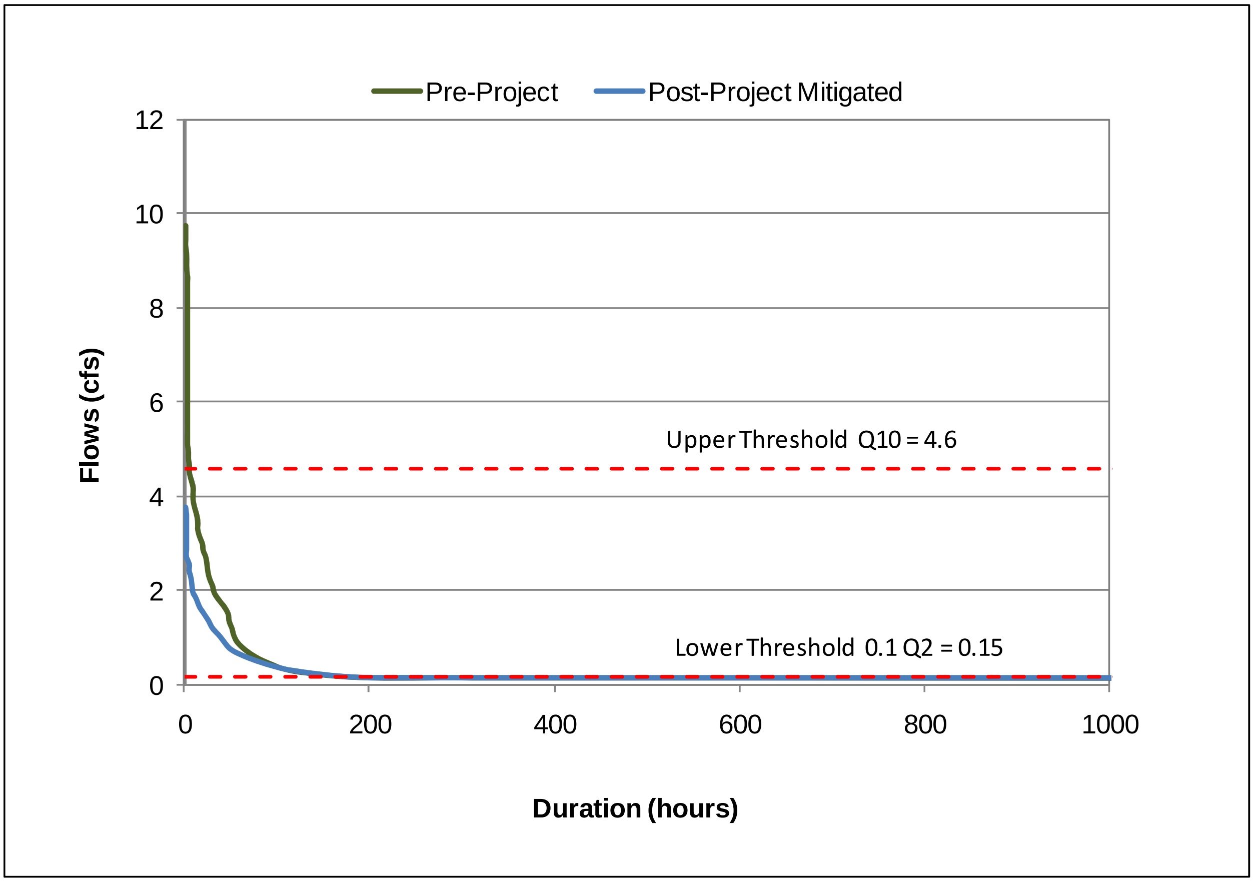


Figure 2-4. Flow Duration Comparison within the Lower and Upper Threshold Flows

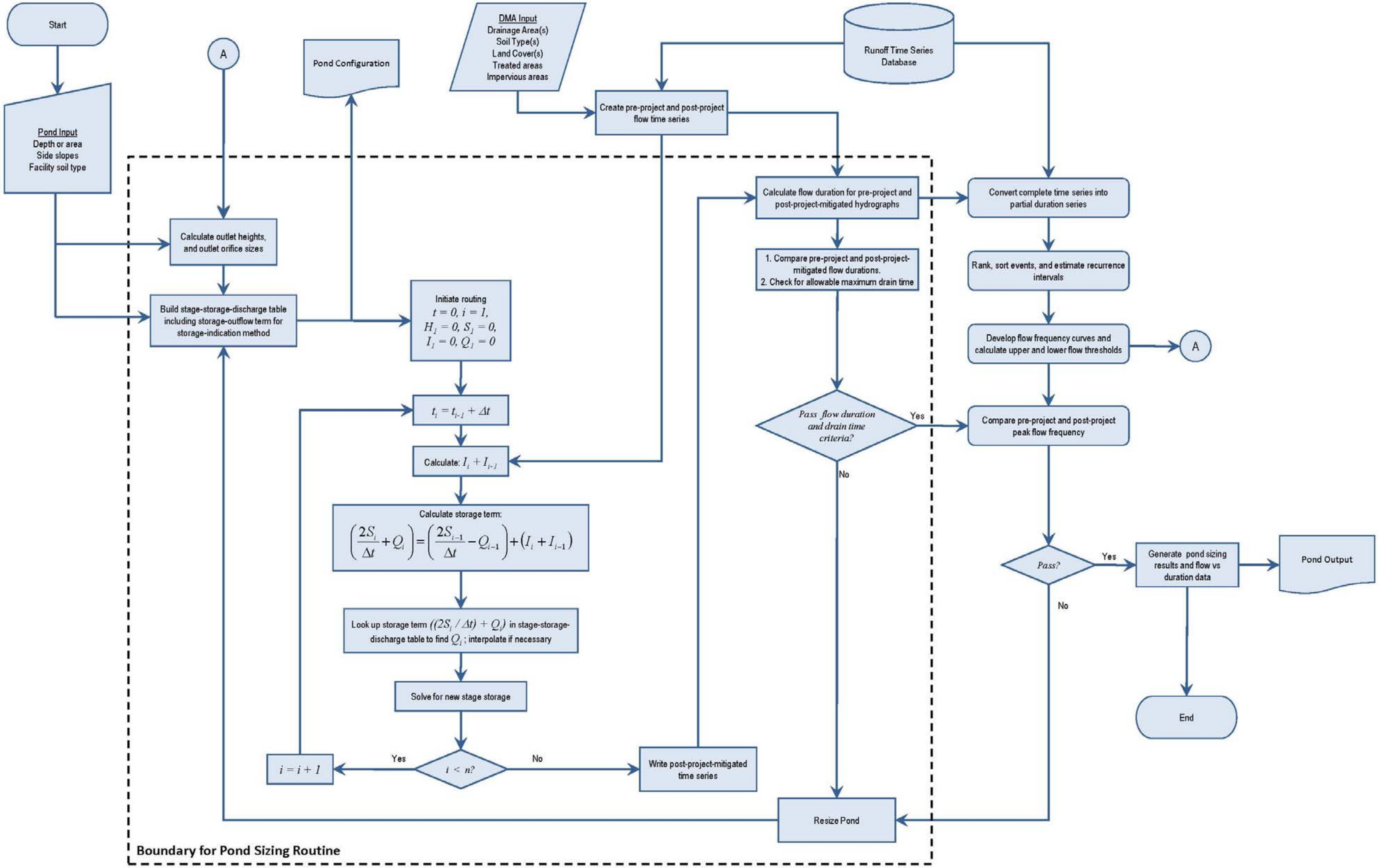


Figure 2-5 – Pond Sizing Flow Chart

Section 3

Non-Structural BMP Sizing Methodology

The San Diego Countywide SUSMP describes a method incorporating self-retaining landscaping into a development site's stormwater control strategy. This chapter summarizes the technical analysis used to develop the sizing requirements for self-retaining areas and pervious pavement.

Methodology prepared in this chapter corresponds to the analysis conducted for the Contra Costa HMP. The methodology developed for the Contra Costa HMP was replicated in the San Diego Countywide Model SUSMP.

To develop sizing criteria for self-retaining areas, Brown and Caldwell developed hydrologic models to represent their performance. BC ran model numerous simulations, iteratively adjusting the upstream tributary area until the self-retaining area met the HMP performance standard (e.g., post-project peak flows and durations no higher than pre-project levels for flow rates ranging from two-tenths of the 2-year flow to the 10-year flow ($0.2Q_2$ to Q_{10}).

3.1 Self-Retaining Area Sizing Criteria and Modeling Results

Self-retaining areas are specially contoured and landscaped to capture and infiltrate runoff from upstream, tributary areas. Self-retaining areas include small berms or concave landscape grading to limit site runoff and highly permeable soils to encourage infiltration. To estimate the amount of upstream impervious area that could be controlled by a self-retaining area, we worked collaboratively with the HMP project team to develop general design criteria. All modeling simulations assumed the following characteristics for self-retaining areas:

- Self-retaining areas would receive inflow from upstream impervious areas and direct precipitation. Outflows would include evapotranspiration, infiltration to deeper soils and surface overflows.
- Self-retaining areas would be graded to allow 3 inches of water ponding on the ground surface. If precipitation were to occur while the 3 inches of ponding storage were full, excess water would flow off the self-retaining area into the local stormwater conveyance system.
- Self-retaining areas would use amended soils to enhance infiltration capacity. We assumed the amended soils would have the following characteristics:
  - Amended oil depth = 18 inches
  - Soil porosity = 45 percent
- Soil infiltration was calculated using the Horton Infiltration method. The Horton Infiltration model assumes that infiltration rates are initially high, and then decay to a continuous, steady-state level. We surveyed published values for the initial and steady-state infiltration parameters and selected values that fit within the conservative portion of the parameter value range (see Table 3-1).
- Downward movement of water within the amended soils was computed based on in a simplified version of the hydraulic conductivity equations developed by van Genuchten (see Appendix A).
- Percolation from the amended soils to the surrounding soils will be limited by the saturated hydraulic conductivity of the surrounding soils (see Table 3-2).

Table 3-1. Horton Infiltration Model Equation and Parameters

Horton Infiltration Model: $f = f_c + \left(f_o - f_c\right)^{-kt}$

f = infiltration rate (in/hr)
fo = initial infiltration rate when soils are dry (in/hr)
fc = continuous infiltration rate (in/hr)
k = decay constant; k = 0.069 / min
t = time in hours

	f_o	f_c
Amended Soil (in Group A soil area) (a)	6 in/hr	0.30 in/hr
Amended Soil (all other soil types) (a)	3 in/hr	0.15 in/hr

(a) *The infiltration parameters for amended soils were averaged from published values for loamy soils and turf. We assumed that installations in Group A soils could include soil amendments to encourage plant growth but these soils would still provide higher infiltration rates than amended soils in areas with Group B, C, and D soils.*

Table 3-2. Saturated Hydraulic Conductivity Values for the NRCS Hydrologic Soil Groups

Soil Group	Saturated Hydraulic Conductivity
A	9.3 in/hr
B	0.52 in/hr
C	0.08 in/hr
D	0.024 in/hr

The performance of self-retaining areas was simulated using a combination of HSPF modeling and Matlab scripts. Rainfall data from the NOAA Martinez gauge was used in all the simulations. The HSPF model was used to compute long-term runoff from upstream impervious areas, rainfall onto the self-retaining area, evapotranspiration from the amended soils, as well as pre-project flows for NRCS Hydrologic Group A, B, C and D soils. The impervious runoff, rainfall and evapotranspiration time series were input to a Matlab script that simulated the ponding of water on the self-retaining area and the movement of water through the amended soils. The Matlab software contains a high-level programming language that allows for more flexibility in the representation of self-retaining areas and pervious pavement areas. The modeling results are shown in the following figures.

Figure 3-1 shows the peak surface outflow rates from self-retaining areas and pre-project conditions. The self-retaining area simulations assume the ratio of “upland directly connected impervious area” to “self-retaining area” is 1 to 1. Figure 3-2 shows flow durations curves for the same self-retaining area and pre-project simulations. Both Figure 3-1 and Figure 3-2 show pre-project runoff from Group D soils. Figure 3-3 and Figure 3-4 show pre-project and self-retaining areas peak flow frequency and flow durations, respectively, for Group C soils, Figure 3-5 and 3-6 summarize self-retaining area performance for Group B soils, and Figure 3-7 and 3-8 summarize self-retaining area performance for Group A soils.

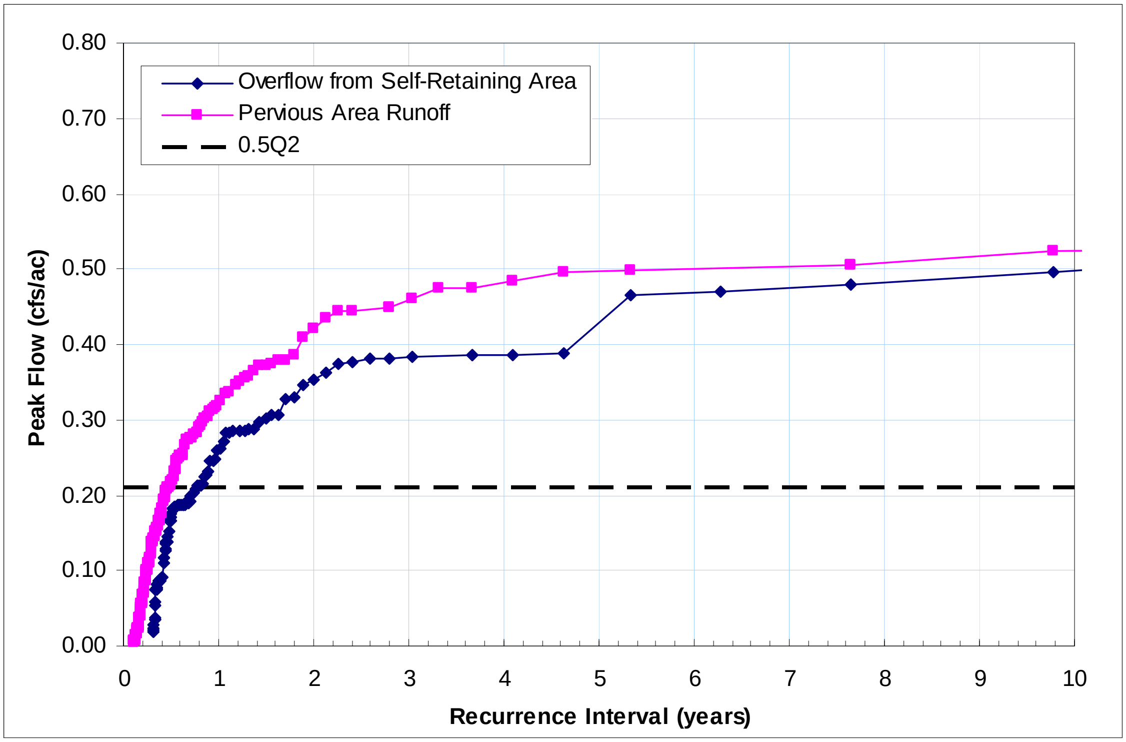


Figure 3-1. GROUP D SOILS: Peak Flows Frequency Statistics for Pre-Project and Self-Retaining Area Simulations with 1:1 Ratio of Upstream Connected Impervious Area

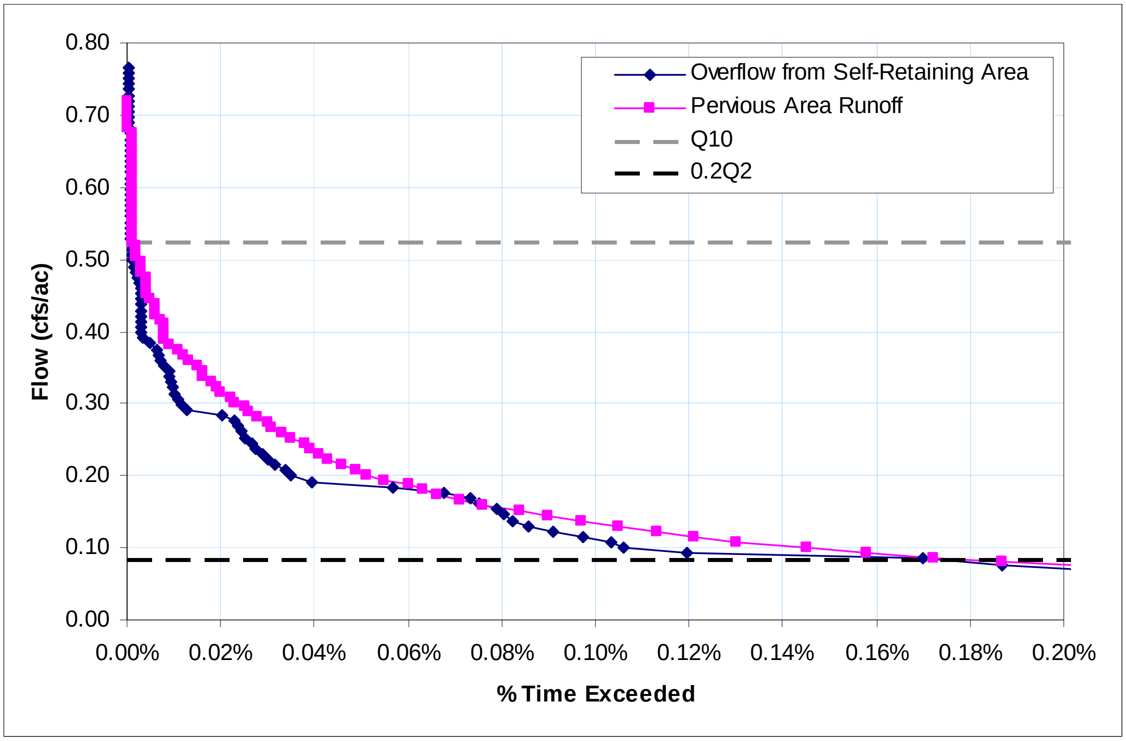


Figure 3-2. GROUP D SOILS: Comparison of Flow Duration Statistics for Pre-Project and Self-Retaining Area Simulations with 1:1 Ratio of Upstream Connected Impervious Area

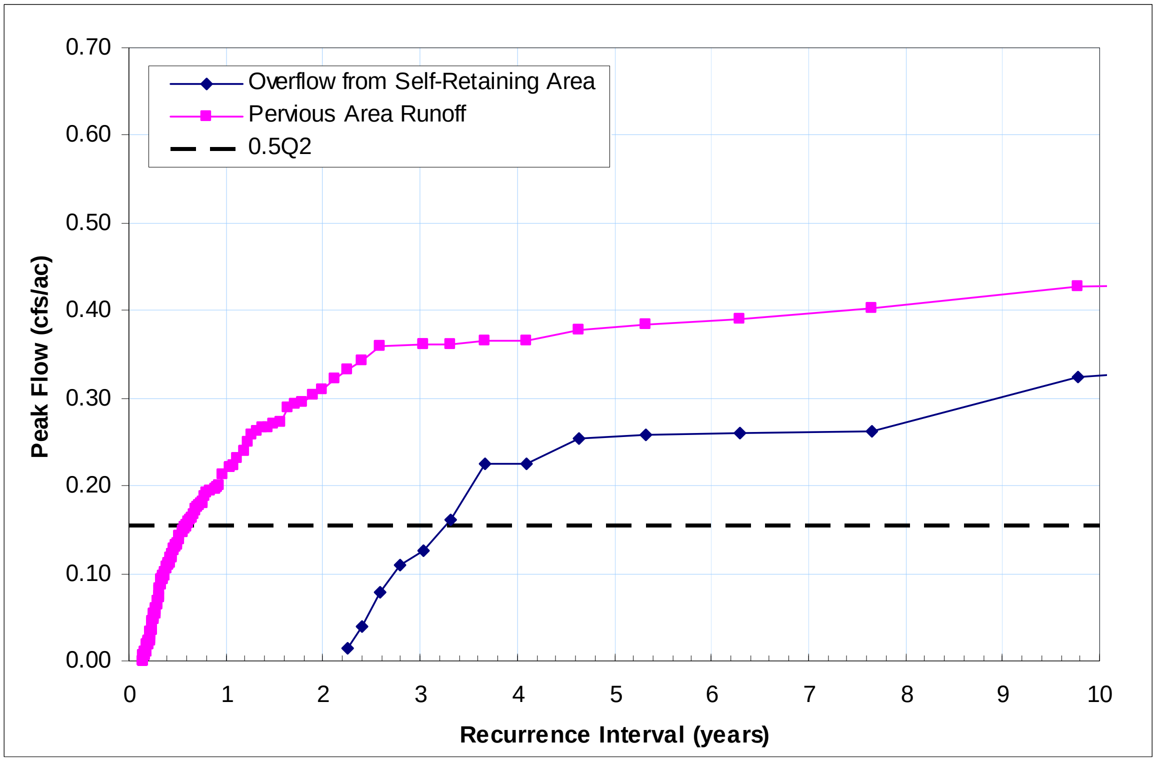


Figure 3-3. GROUP C SOILS: Peak Flows Frequency Statistics for Pre-Project and Self-Retaining Area Simulations with 1:1 Ratio of Upstream Connected Impervious Area

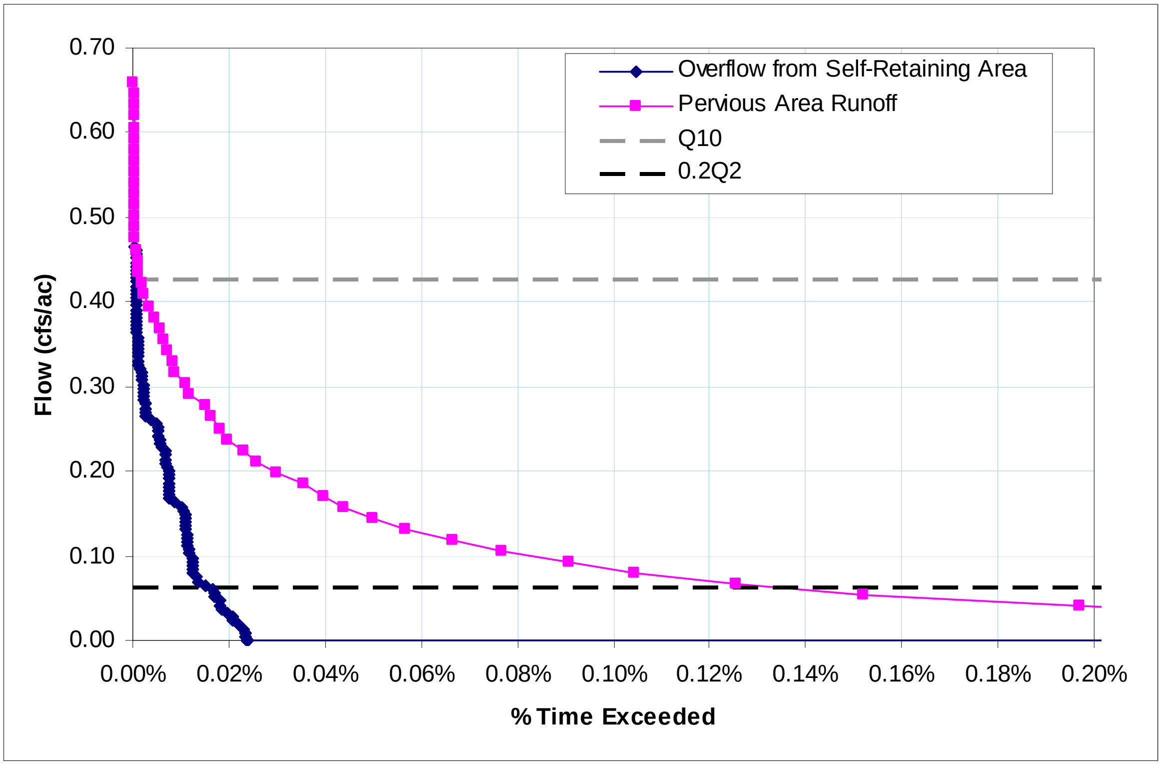


Figure 3-4. GROUP C SOILS: Comparison of Flow Duration Statistics for Pre-Project and Self-Retaining Area Simulations with 1:1 Ratio of Upstream Connected Impervious Area

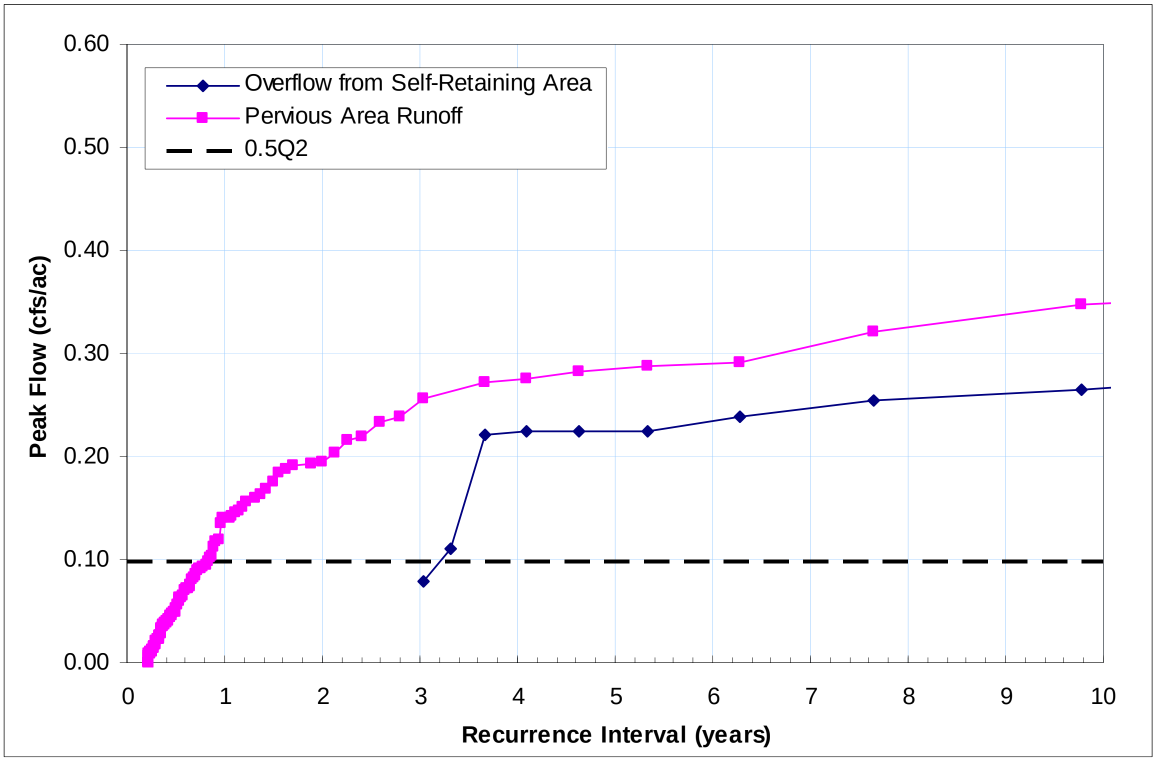


Figure 3-5. GROUP B SOILS: Peak Flows Frequency Statistics for Pre-Project and Self-Retaining Area Simulations with 1:1 Ratio of Upstream Connected Impervious Area

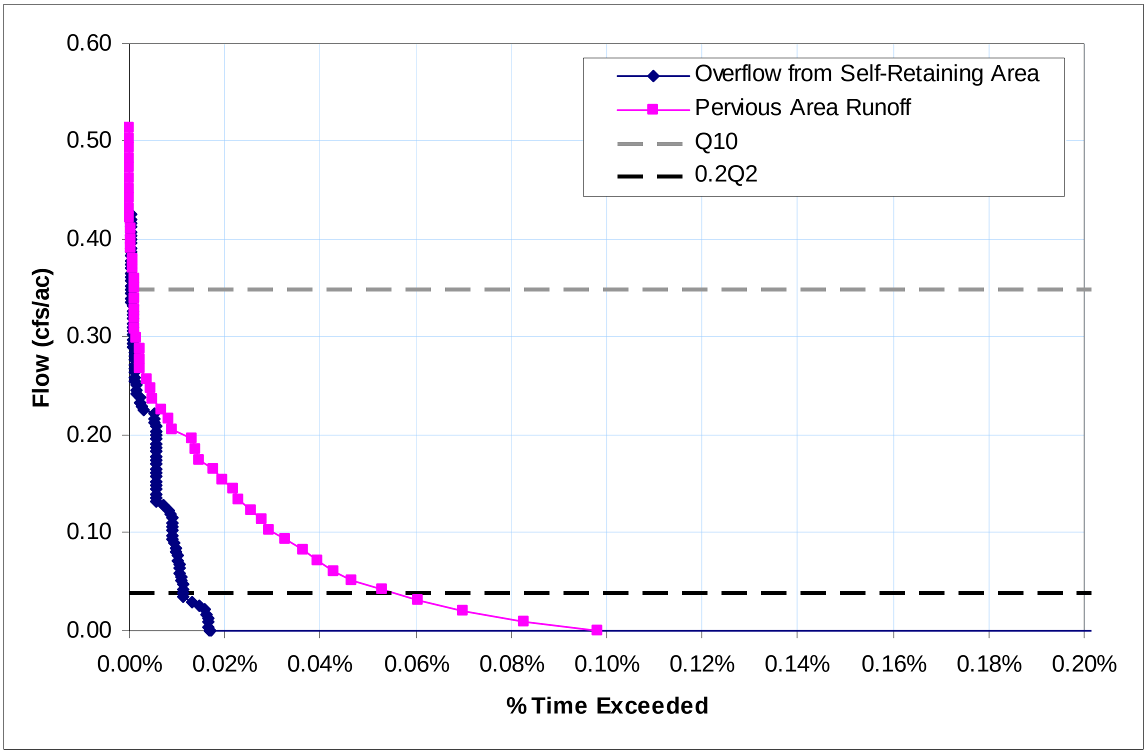


Figure 3-6. GROUP B SOILS: Comparison of Flow Duration Statistics for Pre-Project and Self-Retaining Area Simulations with 1:1 Ratio of Upstream Connected Impervious Area

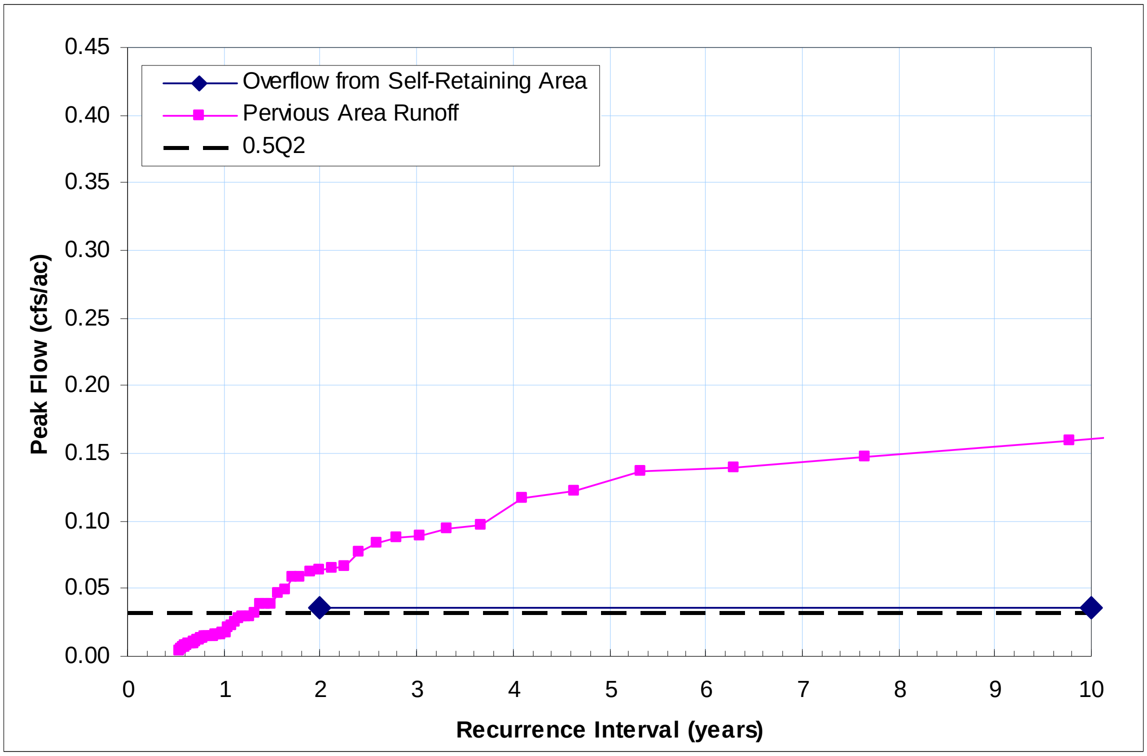


Figure 3-7. GROUP A SOILS: Peak Flows Frequency Statistics for Pre-Project and Self-Retaining Area Simulations with 1:1 Ratio of Upstream Connected Impervious Area

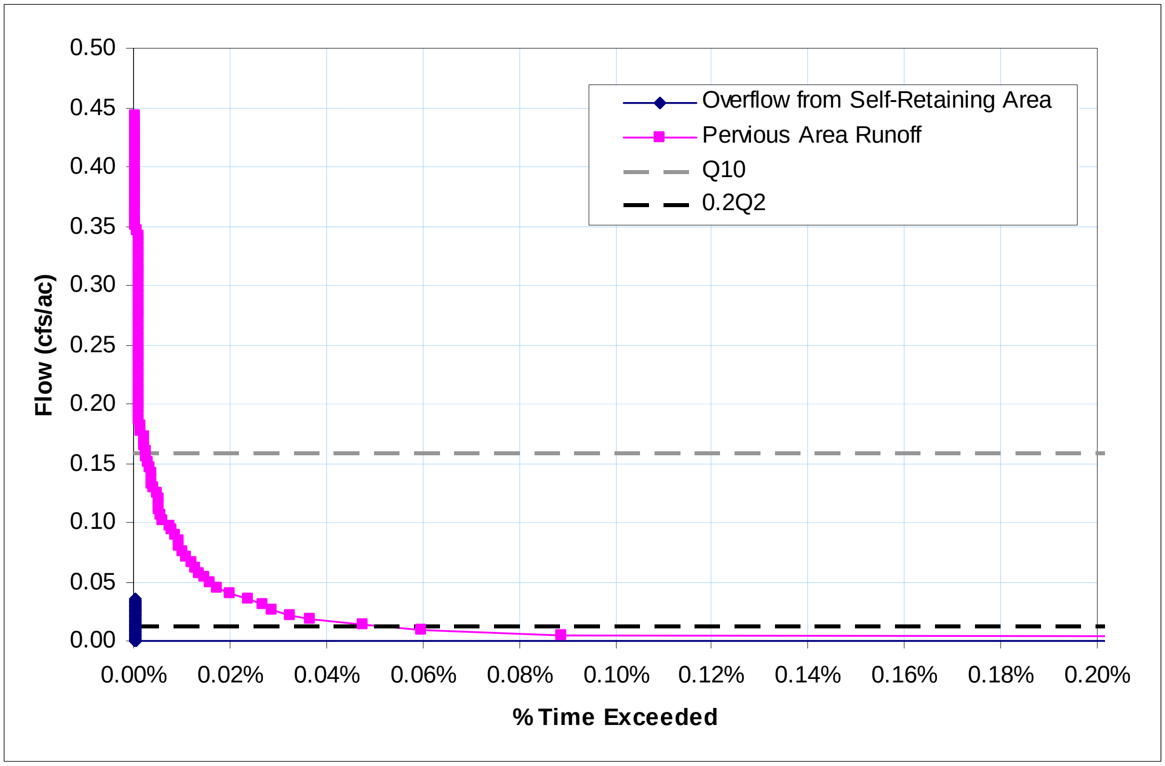


Figure 3-8. GROUP A SOILS: Comparison of Flow Duration Statistics for Pre-Project and Self-Retaining Area Simulations with 1:1 Ratio of Upstream Connected Impervious Area

Prior to implementing its HMP, Contra Costa based its self-retaining area sizing using the “Start at the Source” document for WQ treatment, requiring 1 part self-retaining area for every 2 parts impervious area. The modeling analysis detailed in this section confirmed adequacy of the “Start at the Source” ratio for WQ sizing and recommended doubling the ratio for (i.e., 1:1 impervious area to self-retaining area) to provide flow control + treatment. In many instances the Contra Costa hydromodification flow control BMPs (bioretention, etc.) were about twice as big as the WQ treatment versions of these same devices. Similarly in San Diego, the flow control BMPs are generally about twice as big as the *WQ treatment* BMPs. The previous work in Contra Costa County and the similarities in the San Diego HMP modeling results are sufficient to justify the 2:1 water quality and 1:1 hydromodification flow control sizing standards.

Section 4

Limitations

This document was prepared solely for the County of San Diego in accordance with professional standards at the time the services were performed and in accordance with the contract between County of San Diego and Brown and Caldwell dated September 2010. This document is governed by the specific scope of work authorized by the County of San Diego; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work.

References

Bicknell, B.R., Imhoff, J.C., et al. 1997. *Hydrological Simulation Program--Fortran, User's Manual for Version 11:* U.S. Environmental Protection Agency, National Exposure Research Laboratory, Athens, Ga., EPA/600/R-97/080, 755 p.

Brown and Caldwell. 2009. *Summary of HSPF Modeling Reports in Southern California.* May

Brown and Caldwell. 2010*. HMP Modeling Approach and BMP Configurations. March 2*.

Brown and Caldwell. 2010. *Selection of PERLND Parameter for HSPF Modeling.* April 23.

Chow, V.T.; D.R. Maidment; L.W. Mays. 1988. Applied Hydrology. McGraw-Hill Series in Water Resources and Environmental Engineering. McGraw-Hill, Inc. San Francisco. pp 103.

Eagleson, P.S. 1970. Dynamic Hydrology. McGraw-Hill, Inc. pp 291-305.

Environmental Protection Agency (EPA). 2000. BASINS Technical Note 6 – Estimating Hydrologic and Hydraulic Parameters for HSPF. July

Fayer, M.J.; M.L. Rockhold; and M.D. Campbell. 1992. "Hydrologic modeling of protective barriers: Comparison of field data and simulation results," Soil Science Society of America Journal, Vol 56 pp 690-700.

Idaho National Engineering and Environmental Laboratory (INEEL). March 2002. "Engineering Design File: Central Facilities Area Sewage Treatment Drainfield (CFA-08) Protective Cover Infiltration Study." Project File number 021048, Prepared for the U.S. Department of Energy, Idaho Operations Office, Idaho Falls, Idaho. Document Number EDF-2696.

Maidment, D.R. 1993. Handbook of Hydrology. McGraw-Hill, Inc. San Francisco. pp 5.6, 5.14, 5.34.

National Soil Conservation Service (NRCS). 2001. *National Engineering Handbook, Part 630 Hydrology, Appendix A: Hydrologic Soil Groups*. United States Department of Agriculture.

San Diego Copermittees. 2011. *Countywide Model SUSMP.* March.

San Diego Copermittees. 2011. *Hydromodification Management Plan.* March.

United States Bureau of Reclamation (USBR). 1987. Design of Small Dams, Third Edition. United States Department of the Interior, Water Resources Technical Publication. U.S. Government Printing Office, Washington D.C.

United States Environmental Protection Agency. 2000. BASINS Technical Note 6 – Estimating Hydrology and Hydraulic Parameters for HSPF. July.

van Genuchten, M. Th. 1980. "A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils." Soil Science Society of America Journal. Vol. 44, pp 892-898.

Appendix A

Assumed Hydraulics for the Modeling of BMPs