BROWN AND CALDWELL
9665 Chesapeake Drive, Suite 201
San Diego, CA 92123
Tel: 858-514-8822
Fax: 858-514-8833

Draft Technical Memorandum

Project Title: San Diego County Hydromodification Management Plan

Project No: 133904

San Diego County Hydromodification Management Plan

Subject: HMP Modeling Approach and BMP Configurations

Date: March 2, 2010

To: Sara Agahi, San Diego County

From: Tony Dubin, Brown and Caldwell
Eric Mosolgo, Brown and Caldwell

This memorandum describes the modeling approach that is being used to size low-impact development dbest 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. The memo also describes the type, configurations and dimensions of the LID BMPs that will be modeled in support of the BMP Sizing Tool software. The memo is organized into the following sections:

- **Section 1** provides a brief overview of the HSPF model setup and BMP sizing process.
- **Section 2** describes in greater detail how the HSPF models are setup for the San Diego HMP, including key input data.
- **Section 3** summarizes the general process for computing LID BMP sizing factors.
- **Section 4** describes the physical configurations of the BMPs.

1. Overview of HSPF Modeling and BMP Sizing 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 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 described in a separate technical memorandum entitled, *San Diego HMP HSPF Model Parameter Selections*, dated March 2010. 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).

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% impervious surface. Comparing the pervious surface model output with the impervious surface model output shows the effects of development prior to adding a BMP.

1.2 Model the Hydraulic Response of BMPs

The project team has 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 storage facilities is called an F-TABLE, and is described further in Section 3.1.1.

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 applied to assess BMP performance:

- Flow duration control -_For flow rates ranging from 10%, 30% or 50% 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% over and more than 10% 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.
- 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% for a 1-year frequency interval. For example, post-project flows could exceed pre-project flows by up to 10% 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}.

1.4 Incorporate Sizing Factors into BMP Sizing Calculator

The sizing factors computed using the above process will be incorporated into a 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, local soil type and site slope, the BMP Sizing Calculator will look up the appropriate value derived from the HSPF modeling analysis. An adjustment will be applied to the BMP sizing factor based on the location of the project in the County to account for the different rainfall characteristics.

The BMP Sizing Calculator will also provide prescriptive guidance on 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). The approaches to be used for scaling the sizing factors according to local rainfall variations will be described in a separate technical memorandum.

2. HSPF Model Development

This section describes in detail how HSPF models are developed to simulate pre-project and post-project runoff for San Diego County.

2.1 HSPF Modeling 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. For studies of individual watersheds, the values of calibration parameters are adjusted, or tuned, until the model simulations reproduce an observed stream flow record.

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, 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. 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 a separate memo entitled, *San Diego HMP HSPF Model Parameter Selections*, dated March, 2010.

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 subsections briefly summarize the range and variability in rainfall volumes and soil types within the County.

2.1.1 Rainfall Data Evaluation

Evaluating the distribution of rainfall across the County helped determine (1) which precipitation gauges to use as input to HSPF for modeling simulations and (2) the 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 Lindberg Field in San Diego. Eighteen stations with datasets containing at least 30 years of hourly data were evaluated in detail by Brown and Caldwell. Brown and Caldwell prepared and submitted summary technical memoranda that assessed the data records, identified data gaps, and provided recommendations for filling the data gaps.

Table 1 lists reference information about the gauges and Figure 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.

Table 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

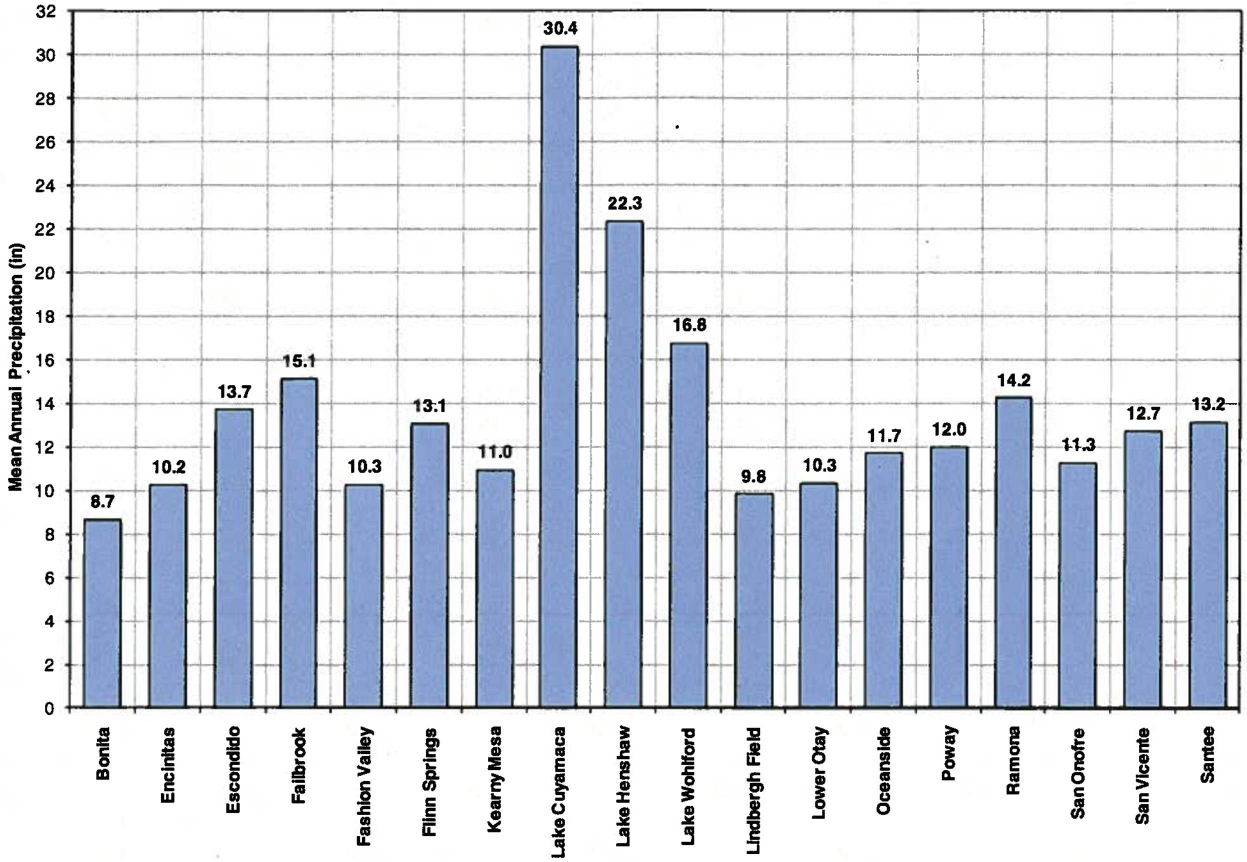


Figure 1. Rainfall Variation in San Diego County

2.1.2 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 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.

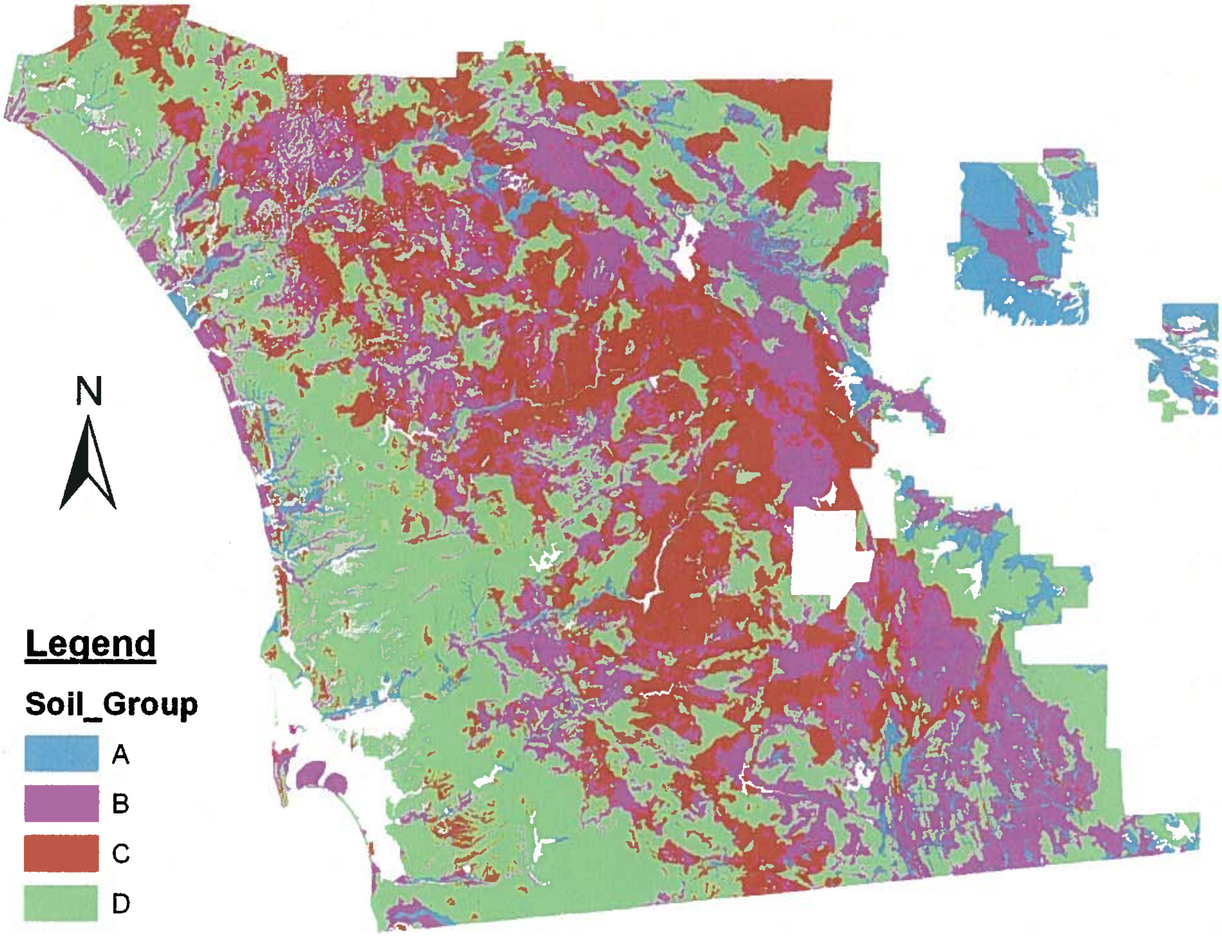


Figure 2. NRCS Soils Mapping of San Diego County

2.2 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 2 below summarizes the scenario components. The specific HSPF pervious land surface parameters for these scenarios are described separately in the *San Diego HMP HSPF Model Parameter Selections* technical memo.

Table 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 (10%)
3	A	Scrub, Shrub	Steep (>15%)
4	B	Scrub, Shrub	Low (<5%)
5	B	Scrub, Shrub	Moderate (10%)
6	B	Scrub, Shrub	Steep (>15%)

Table 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 (10%)
9	C	Scrub, Shrub	Steep (>15%)
10	D	Scrub, Shrub	Low (<5%)
11	D	Scrub, Shrub	Moderate (10%)
12	D	Scrub, Shrub	Steep (>15%)

3. Hydrologic Modeling Approach to Sizing BMPs

This section describes the technical approach used to represent BMPs in the HSPF model. 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.

3.1 General BMP Characteristics

The flow control BMP designs selected by San Diego County and its Copermittees all 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 its configuration, porosity, volume, and hydraulic conditions that influence the rate of flow to the next layer (see Figure 3).

HSPF uses stage-storage-discharge tables to represent the hydraulic behavior of devices that detain and discharge water (e.g., all of the 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 BMPs modeled:

- 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, based 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, 1994). A sensitivity analyses conducted to determine the

effect of porosity on BMP performance determined that porosity has little influence on the required sizing factor.

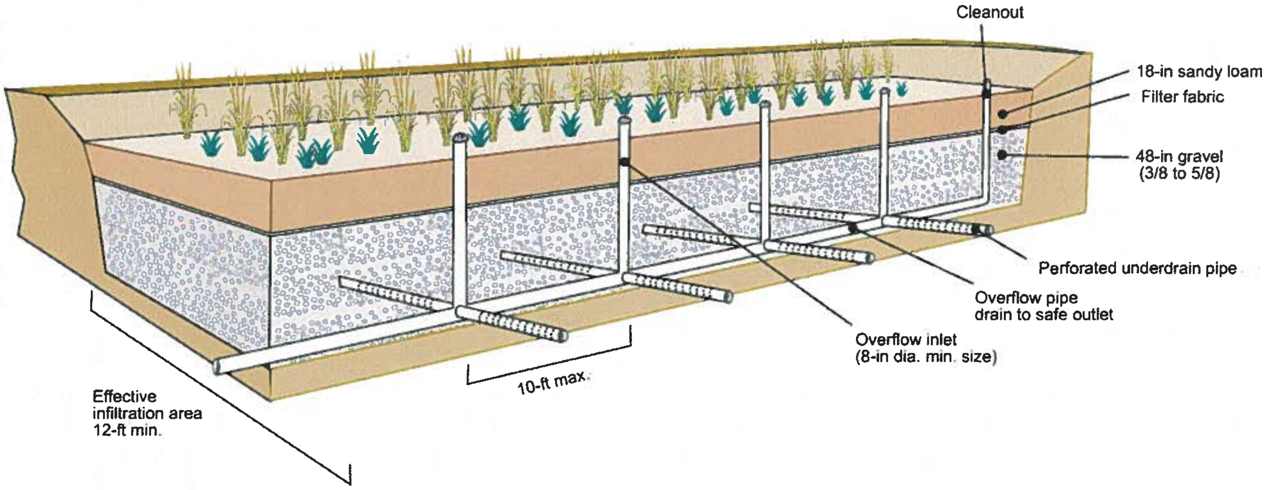


Figure 3. Cross-Section View of Bioretention BMP, Group C/D Soil Configuration

3.1.1 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.

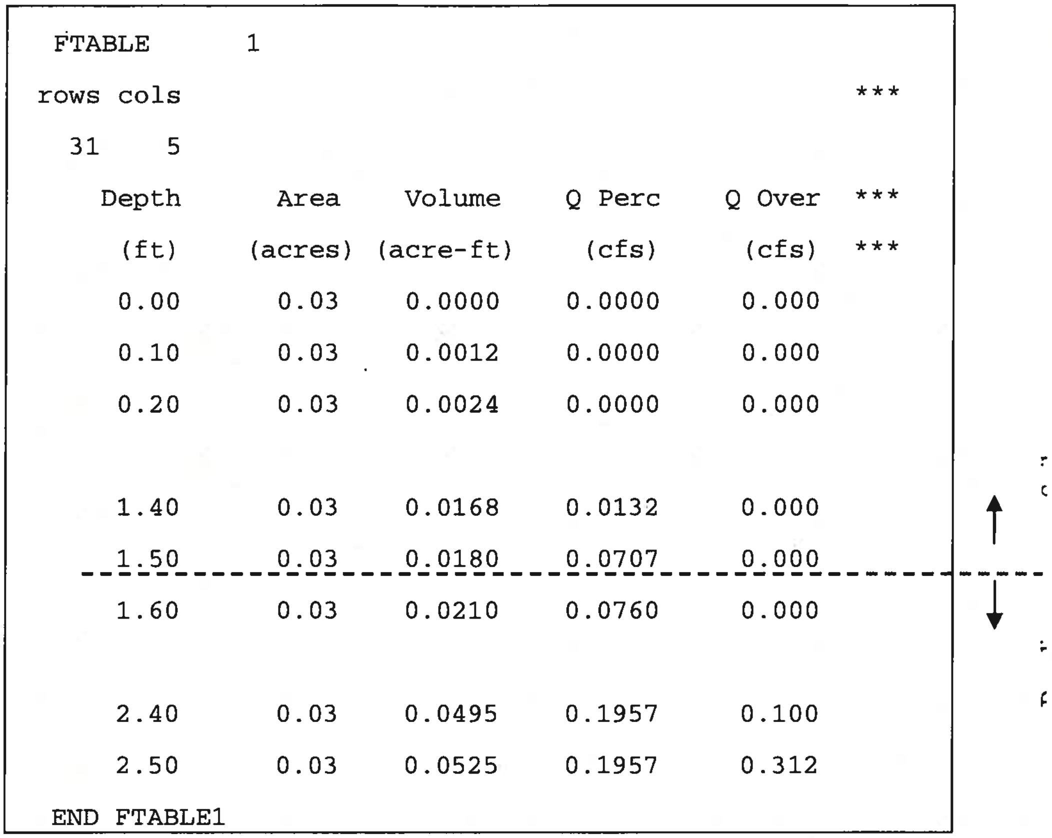
FTABLE 1: Upper Growing medium layer, Ponding Storage and Overflow Outlet

Stormwater routed from impervious surfaces first enters the upper layer of an In-Ground Planter, represented by FTABLE 1 (Figure 4). 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 ft 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 ft, 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 pipe, which is calculated using a weir equation (see Appendix A). Outflow through the overflow pipe does not occur until the depth of storage in the ponding reservoir is above the pipe inlet.



```
  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

      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

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

Figure 4. Example FTABLE Describing Upper Layer of In-Ground Planter

FTABLE 2: Lower Gravel Layer, Percolation to Surrounding Soils, Underdrain Outlet

The second FTABLE represents the lower gravel layer and the underdrain. Percolation outflow from the first FTABLE is routed as inflow to the second FTABLE (Figure 5). This FTABLE represents the lower gravel layer, which has a depth of 1.5 ft. Water is stored as volumetric water content with a maximum storage limited to saturation of the gravel medium. 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).

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 control rate 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 5. Example FTABLE Describing Lower Gravel Layer of In-Ground Planter

3.1.2 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) the pre-project runoff from a pervious land surface and (b) the 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 0.05 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 with each 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.

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. Dry well
6. Vegetated bioswale (for water quality treatment only)

Non-structural strategies for stormwater management, such as pervious pavement, self-retaining areas, and self-treating areas will be described in separate memoranda.

4.1 Bioretention

The bioretention facility consists of a surface ponding layer, a growing medium layer, and a below ground storage layer (Figure 6). 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, we will simulate the bioretention BMP using separate a) ponding layer, b) growing medium, and c) storage layer components. We will assume 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 40 percent porosity
- **Storage layer:** 30-inches of gravel at 40 percent porosity

As described above in Section 3.1.2,the plan area of the BMP will be iteratively sized until the BMP controls limit outflows to levels that are 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 will be 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.

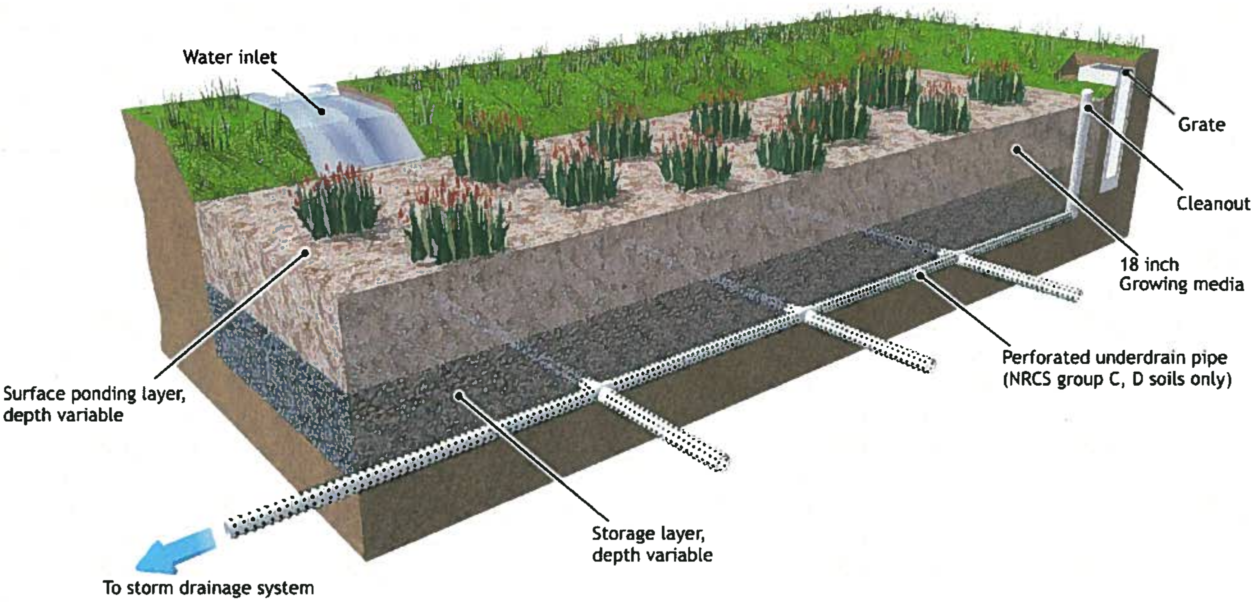


Figure 6. Bioretention BMP Example Illustration

4.2 Cistern with Bioretention

The cistern with bioretention BMP is a flow-control and treatment train BMP. There is no water quality treatment-only option. 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 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.

For the HMP, we will simulate the performance of the cistern with bioretention BMP using the following key assumptions:

- **Cistern configuration:** The cistern is modeled as a 4-foot tall vessel. However, designers could use other configurations, so long as the lower outlet orifice is sized to properly restrict outflows.
- **Cistern upper outlet:** The upper outlet from the cistern would consist of a weir or other flow control structure set at an elevation of 7/8th of the way to the top of the cistern (see Figure 7). The overflow weir would be sized to pass approximately 1 cfs per acre of tributary impervious area.
- **Bioretention configuration:** The bioretention needs only a small depression/ponding area to settle inflows prior to infiltration. For water quality treatment, the bioretention 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.

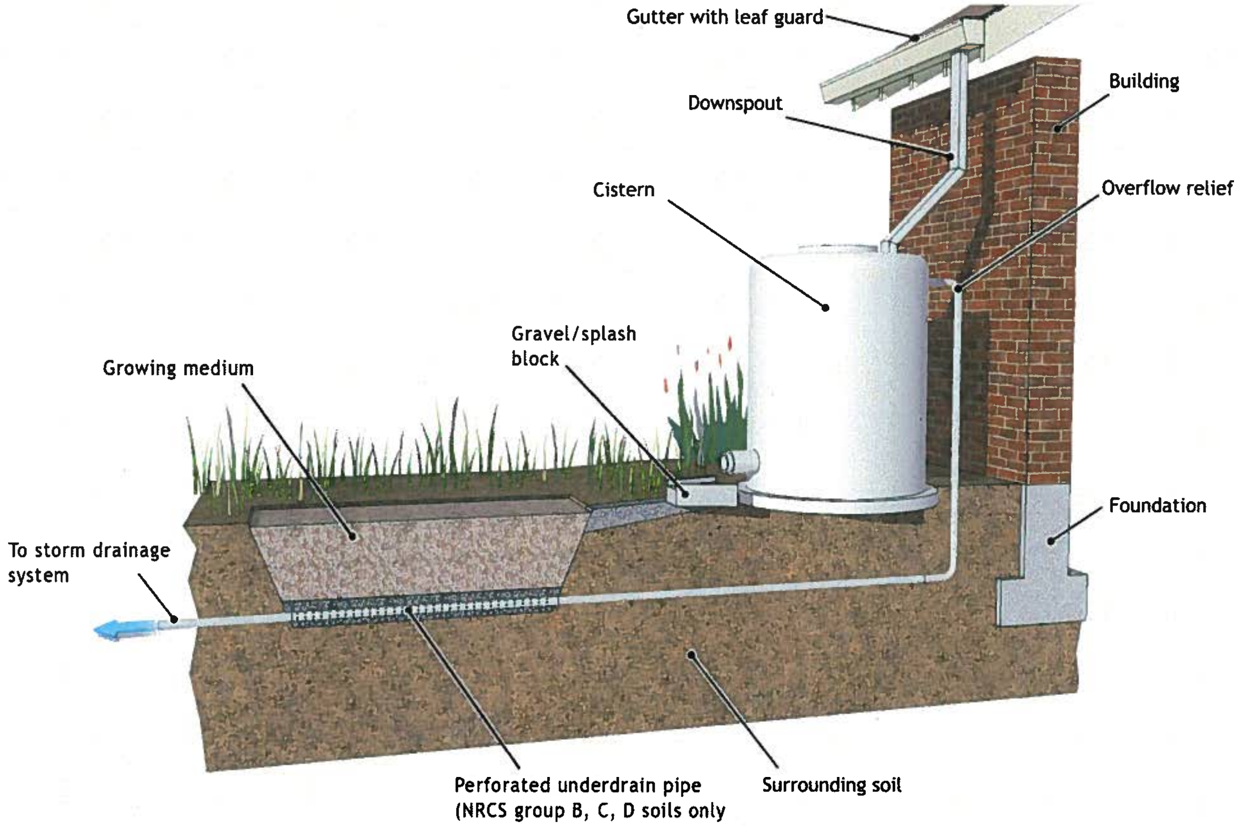


Figure 7. Cistern with Bioretention BMP Example Illustration

4.3 Bioretention with Vault

This BMP configuration would route stormwater through a bioretention basin for water quality treatment, and then discharge water to a nearby vault for detention and release (Figure 8). The vault would contain 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 not water quality treatment-only option.

For the HMP, we will simulate the performance of the bioretention with vault BMP using the following key assumptions:

- **Bioretention configuration:** The bioretention portion of this BMP would be designed similarly to the bioretention BMP, except that the storage layer would be only deep enough to contain a perforated underdrain pipe that would convey treated runoff to the vault portion of the BMP.
- **Vault configuration:** The vault would contain concrete side wall and top, as well as an access hatch for inspection and maintenance. The bottom of the vault would be 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 would contain two outlets. The lower outlet would be a flow control orifice that would release 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 would be located at 80 percent of the vault's height and would have a capacity of approximately 1 cfs per acre of tributary impervious area. The overflow relief should be located no lower than the elevation of the vault's inlet pipe.

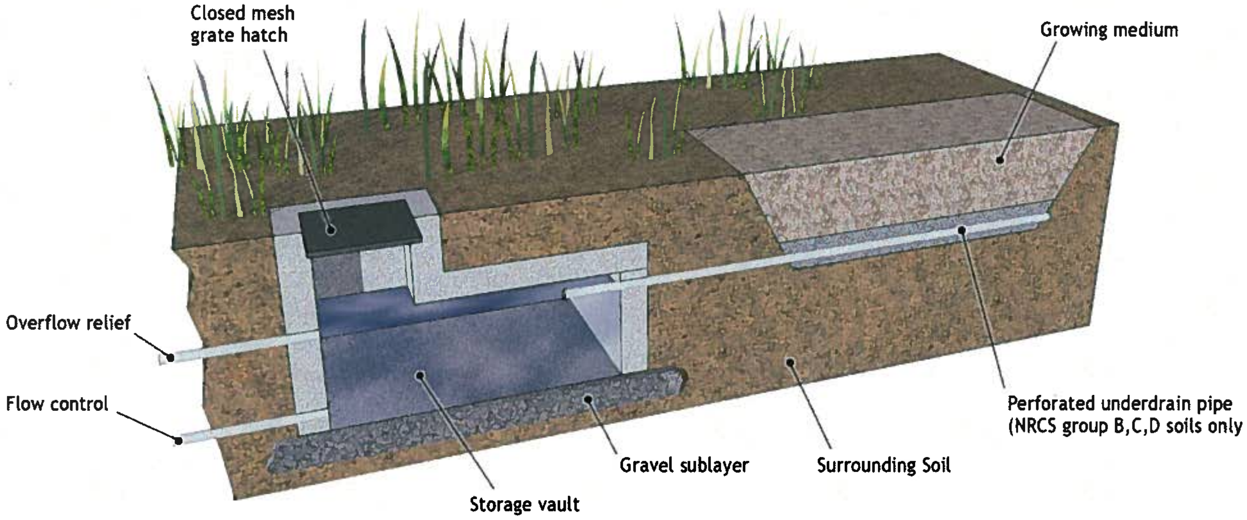


Figure 8. Bioretention with Vault BMP Example Illustration

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 (Figure 9). 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.

For the HMP, we will simulate the flow through planter BMP using separate a) ponding layers, b) growing medium, and c) storage layer components. We will assume 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 40 percent porosity
- **Storage layer:** 30-inches of gravel at 40 percent porosity

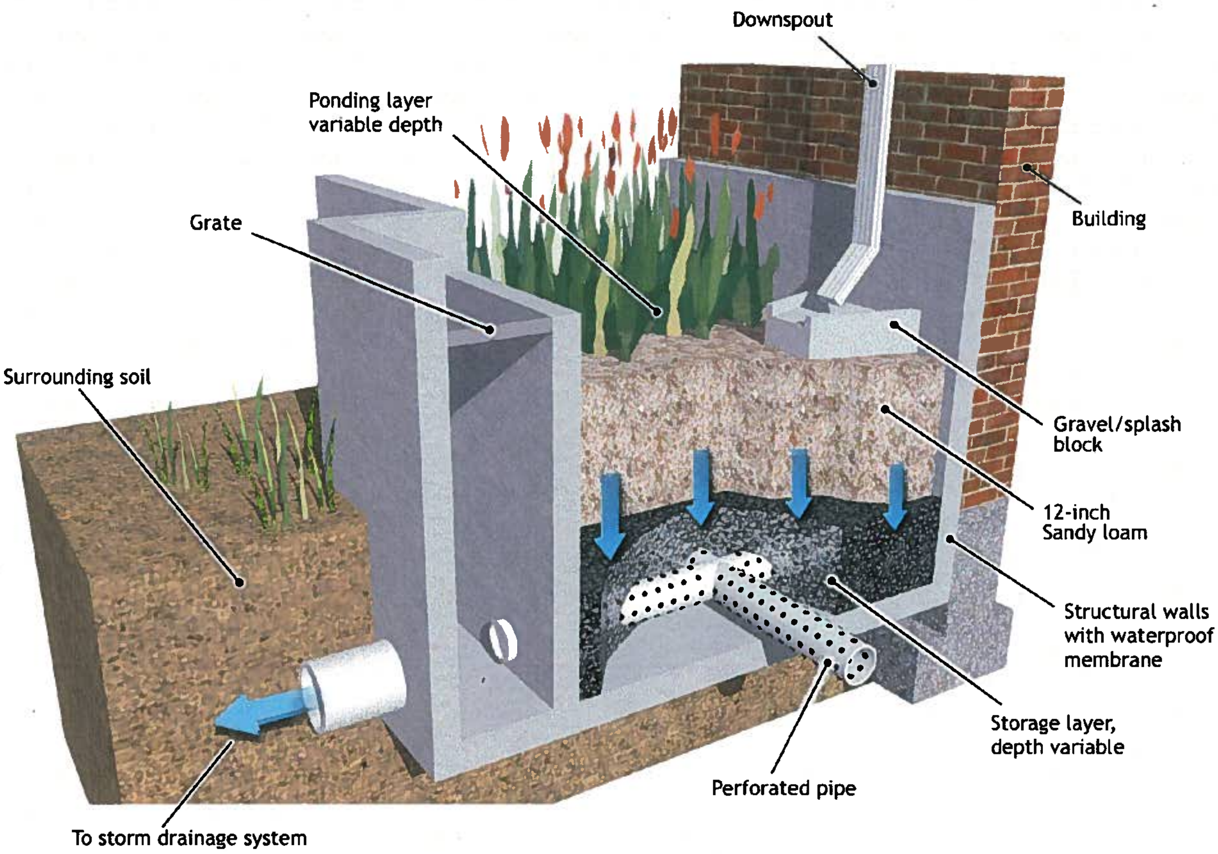


Figure 9. Flow Through BMP Example Illustration

4.5 Drywell

The drywell 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 drywell consists of an initial soil layer to trap pollutants underlain with gravel, drain rock or some other free draining material (Figure 10). The dry well should have an access hatch to limit access.

For the HMP, we will simulate the drywell BMP 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 drywells.

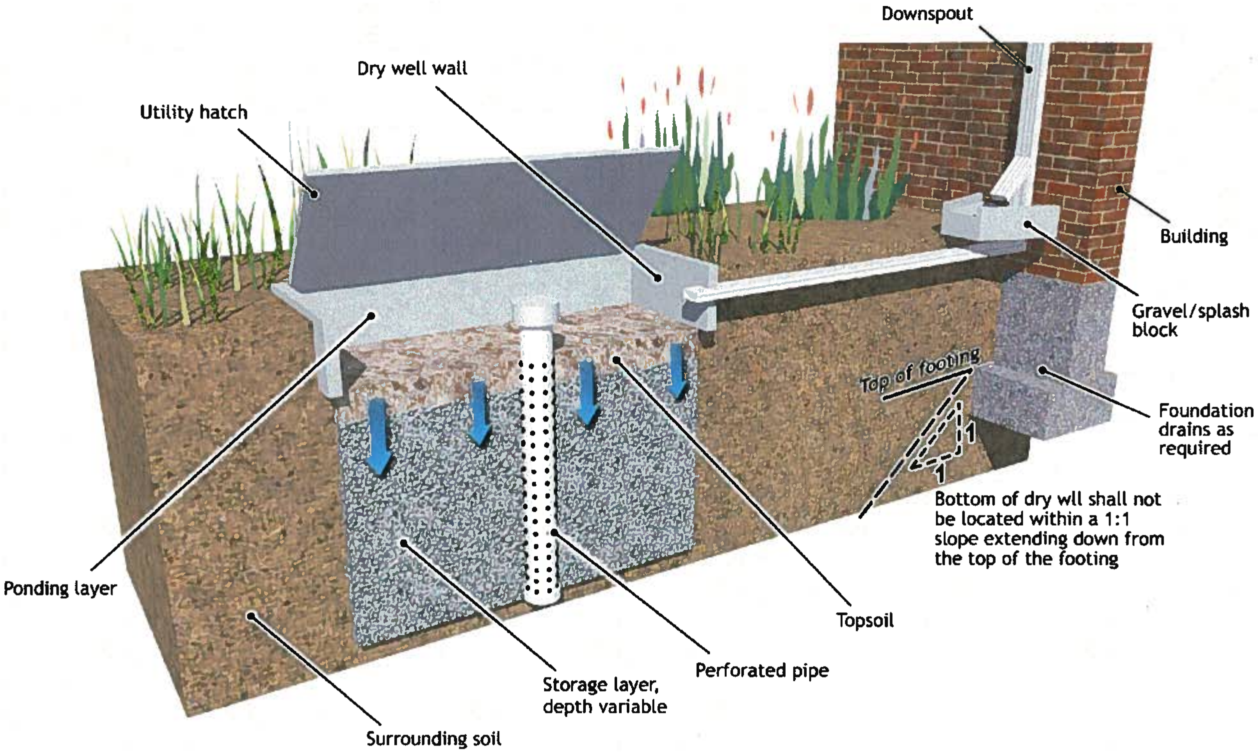


Figure 10. Dry Well BMP Example Illustration

4.6 Vegetated Bioswale

The vegetated bioswale BMP could be used to provide water quality treatment but not to provide stormwater flow control (Figure 11). The conventional swale design uses available on-site soils and does not include an underdrain system. Where soils are clayey, there is little infiltration. Treatment occurs as runoff flows through grass or other vegetation before exiting at the downstream end.

For the simulations, the vegetated bioswale will be sized to meet the minimum detention time specified in the Model SUSMP. If the bioswale is designed to pass stormwater through at a steady rate, its length will be computed based on flow velocities (i.e., slope and dimensions). If the vegetated bioswale is designed with a check dam structure to hold water, its size will be computed based on the volume provided by the swale.

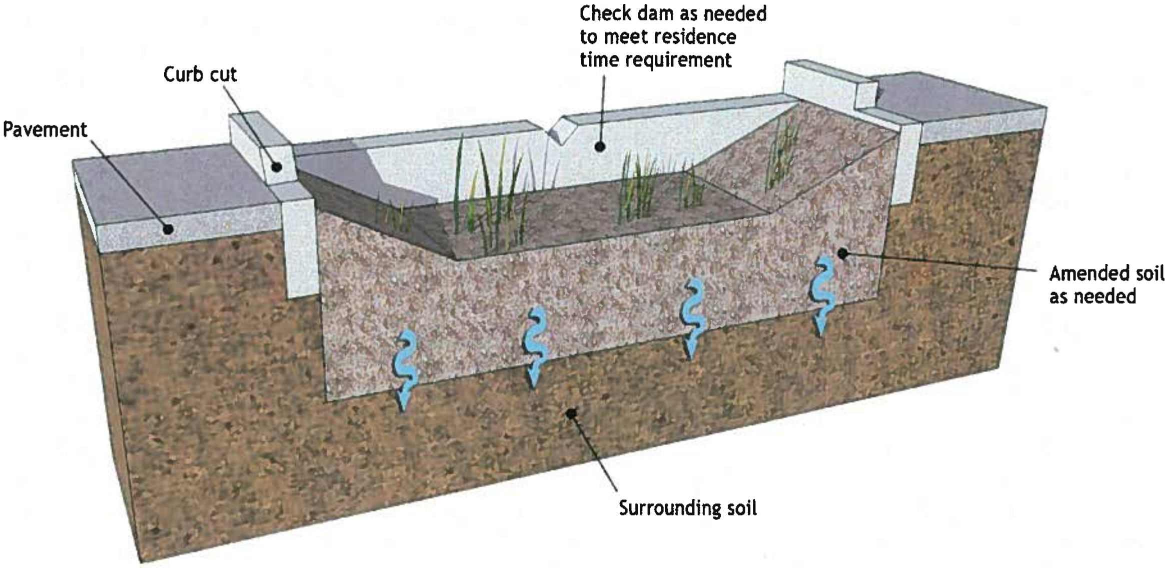


Figure 11. Vegetated Bioswale BMP Example Illustration