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Technical Memorandum

Date: 12 June 2011

To: Orange County Watersheds Program

From: Geosyntec Consultants

Subject: **Assistance in Implementation of the South Orange County Hydromodification Standard: Project-Specific Alternatives to the Interim Sizing Tool**

1. INTRODUCTION

The South Orange County Hydromodification Best Management Practices (BMP) Sizing Tool (Sizing Tool) was developed by the County of Orange, in cooperation with the incorporated Cities of South Orange County, to aid agency staff and project proponents with sizing hydromodification control BMPs to meet the Interim Hydromodification Criteria (IHC) in the South Orange County Municipal Separate Storm Sewer (MS4) Permit (Order No. R9-2009-0002). Although the Sizing Tool provides a straightforward means for sizing hydromodification control BMPs to meet the IHC, project applicants may prefer to conduct their own sizing analysis in order to: 1) best reflect specific hydrologic conditions at the project site; 2) use a type of BMP that is not included in the Sizing Tool; and/or 3) optimize a BMP design to reduce storage and footprint requirements.

This Technical Memorandum describes alternative methods to the use of the Sizing Tool for meeting the IHC. The memorandum is organized as follows:

- Section 2 provides background on hydromodification control requirements in the South Orange County MS4 Permit Requirements (Order No. R9-2009-0002). This section differentiates hydromodification requirements from flood control objectives and summarizes hydromodification control options.

- Section 3 describes the steps required for sizing hydromodification control facilities using a Unit Based Nomograph or a Site Specific System Based approach. The Unit Based process described in this memo is similar to procedures used in developing the Sizing Tool, but may be developed for a specific site using local data. For each step of the Unit Based approach, the assumptions used in the development of the Sizing Tool are documented. The Site Specific System Based approach focuses on modeling the actual project drainage system instead of using a generic Unit Based approach.

Guidance for instream control measures and/or addressing changes in sediment supply is not provided in this memorandum. While the IHC focuses solely on hydrologic changes, a more comprehensive Hydromodification Management Plan, which the Copermittees will submit to the Regional Board by December 16, 2011, is anticipated to provide guidance on these issues.

2. BACKGROUND

2.1 South Orange County MS4 Permit Requirements

Hydromodification refers to changes in the quantity and timing of stormwater runoff caused by changes in land use. Land development is the most significant cause of hydromodification, as impervious surfaces prevent rainfall infiltration and decrease sediment delivery to stream systems. In developed areas, stormwater runs off quickly from roofs, roadways, and parking lots, increasing flows in creeks and streams. In combination with sediment supply reductions, these increased flows alter stream stability. Hydromodification impacts are caused by the combined effects of frequently occurring small storms. In contrast, flood damage is caused by large, infrequent storm events. Hydromodification impacts are similar to flood damage and include increased erosion, unstable stream banks, damage to property and infrastructure, loss of habitat, and water quality degradation.

The South Orange County MS4 permit defines hydromodification as a "change in the natural watershed hydrologic processes and runoff characteristics (i.e., interception, infiltration, overland flow, interflow, and groundwater flow) caused by urbanization or other land use changes that result in increased stream flows and sediment transport." Unless managed, hydromodification can cause excessive channel erosion, sedimentation, planform migration, alteration to baseflow, or changes in bed material composition, as well as biologic impacts to streams. A basic concept in hydromodification impact management is to design hydromodification control BMPs such that the magnitude and flow duration of runoff from a project does not exceed the baseline condition. Thus, the intent of the IHC is to mitigate potential increases in the magnitude and duration of runoff caused by new and re-constructed impervious surfaces associated with new development and redevelopment projects[1]. The IHC, as stated in Order No. R9-2009-0002, is:

[1] The IHC applies to new impervious surface and reconstructed impervious surfaces associated with Priority Development Projects. Per section number F.1.d.1.b of Order No. R9-2009-0002: Where redevelopment results in an increase of less than fifty percent of the impervious surfaces of a previously existing development, and the

Within one year of adoption of this Order, each Copermittee must ensure that all Priority Development Projects are implementing the following criteria by comparing the pre-development (naturally occurring) and post-project flow rates and durations using a continuous simulation hydrologic model such as US EPA's Hydrograph Simulation Program-Fortran (HSPF):

(a) For flow rates from 10 percent of the 2-year storm event to the 5 year storm event, the post-project peak flows shall not exceed predevelopment (naturally occurring) peak flows.

(b) For flow rates from the 5 year storm event to the 10 year storm event, the post-project peak flows may exceed pre-development (naturally occurring) flows by up to 10 percent for a 1-year frequency interval.

The interim hydromodification criteria do not apply to Priority Development Projects where the project discharges (1) stormwater runoff into underground storm drains discharging directly to bays or the ocean, or (2) storm water runoff into conveyance channels whose bed and bank are concrete lined all the way from the point of discharge to ocean waters, enclosed bays, estuaries, or water storage reservoirs and lakes.

The IHC is not limited to matching peak flows of a specific design storm, but more broadly requires matching pre-developed (naturally occurring) and post-developed flow rates and durations over a range of flows. The range of flows that is specified in the IHC is from 10 percent of the 2-year storm to the 10-year storm event.

2.2 Flow Duration Control

The concept of flow duration control is derived from the goal of maintaining pre-development sediment transport capacity by matching pre-project runoff for the cumulative runoff events reflected in a historical record. This means matching the pre-development runoff in terms of flow magnitudes, volumes and durations. In this context, duration does not refer to the time of a single runoff event; instead, it refers to the cumulative time for which a given flow rate occurs over the long term (20 to 30 years). Flow duration control calls for a new design paradigm, requiring fairly sophisticated continuous rainfall-runoff modeling and the design of fairly complex multi-

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existing development was not subject to SSMP requirements, [the IHC] applies only to the addition or replacement, and not to the entire development. Where redevelopment results in an increase of more than fifty percent of the impervious surfaces of a previously existing development, [the IHC] applies to the entire development.

stage outlet structures that result in matching the pre-development flow duration statistics. A key issue for flow duration control is the range of flows which need to be matched to maintain channel stability. This represents a significant departure from the event-based approaches taken in the North Orange County MS4 Permit hydromodification control standard, in that the focus is now on a range of flows referred to as “geomorphically significant” – flows capable of transporting sediment within the channel and yet occurring frequently enough to have influence over long-term stream morphology. On the upper end, this range is often considered to be no greater than the 10-year event. The lower end is understood to be controlled by the dominant materials in the channel, resulting in the need to potentially control flow durations for a low as 10 percent of the 2-year event in the case of sand-bedded streams. Flow duration control has been adopted in Washington State, San Francisco Bay Area, San Diego County, and Sacramento HMPs. This approach can be readily translated into easy-to-use sizing tools for developers and implementing agencies.

The IHC requires Priority Development Projects to incorporate hydromodification control BMPs such that the flow durations from a project do not differ significantly (less than 10 percent for larger flows) from the baseline case over the specified range of flows. The plots showing flow versus duration which are produced by continuous simulation models are referred to as “flow duration curves”, examples of which are shown in Figure 1. On the flow duration curve, the hours on the x-axis represent the cumulative duration at which a given flowrate is equaled or exceeded in the continuous simulation over the entire rainfall record. In Figure 1, the flow duration curve associated with the mitigated condition (dotted blue line) indicates that the IHC is met because it agrees with the baseline condition curve over the range of flows of interest.

The goal of the IHC is to integrate hydrologic controls into a proposed project such that the flow duration curve corresponding to the post-project (proposed) condition agrees with (i.e., is below or within the specified tolerance of 10 percent) the baseline (natural) condition curve over the specified range of flows. When this is accomplished, runoff from the proposed development is considered to not contribute additional erosive forces in the receiving stream channel, assuming the other key factors to channel form (sediment supply, channel geometry, and bed/bank material) do not change from the baseline condition.

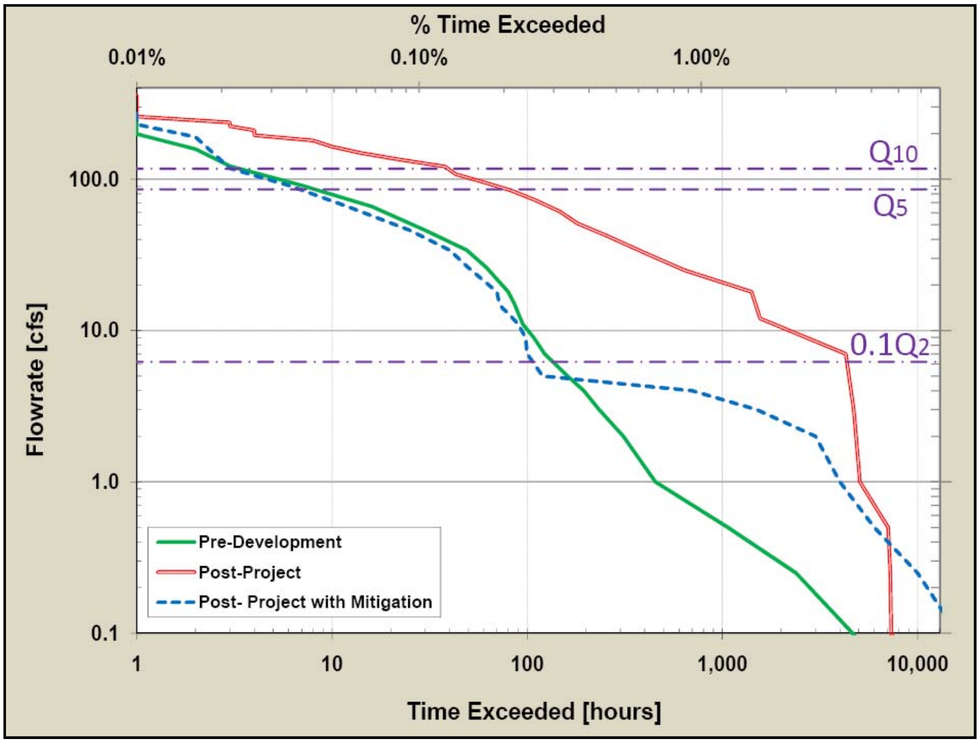


Figure 1. Example Flow Duration Curve Comparison

Hydromodification control BMPs sized to meet a flow duration control standard will be much larger than BMPs sized to meet the LID (or treatment control) standard in the South Orange County MS4 Permit or the event-based hydromodification control standard in the North Orange County MS4 Permit. For example, a case study conducted on a 7.6 acre multi-family residential project (80 percent imperviousness, soil type B, and site slope of 0.04 ft/ft) found that the North Orange County hydromodification control design volume was 53 percent larger than the required LID design volume, and the South Orange County hydromodification control volume was approximately 250 percent to 600 percent larger than the LID design volume.

2.3 Hydromodification Control BMP Options

Excess runoff volume (post-developed minus pre-developed runoff volume) must be managed to achieve flow duration control. Excess runoff volume can be managed through infiltration, evapotranspiration, storage and use, discharge at a flow rate below 10 percent of the 2-year event flow rate, and/or discharge to a non-sensitive water body. Site design and low impact development (LID) BMPs will help to reduce the excess runoff volume and will reduce the necessary size of hydromodification control BMPs.

A variety of hydromodification control BMPs are available. Distributed BMPs are small scale facilities, typically treating runoff from less than ten acres. Example distributed BMPs include bioretention areas, underground vaults or pipes, planter boxes, infiltration trenches, and cisterns. Distributed BMPs are also typically used to meet the MS4 Permit's LID performance standard and can be enlarged to meet the IHC. An alternative to distributed BMPs is the use of regional facilities that can be designed to mitigate the effects of multiple developments in a watershed. Advantages to these systems include the ability to design more complex outlet structures to better duplicate pre-development flow durations, as well as ease of public agency maintenance and monitoring and potential cost savings. Such facilities can also be designed for multiple purposes, including flood protection and water quality management.

2.4 Hydromodification Control vs. Flood Control

This section discusses the differences between flood control and hydromodification control relative to the control concepts and analysis methodologies applicable to each. Flood control and hydromodification control are inherently different in their objectives as well as methods of analysis. The objective of flood control is to prevent flood inundation of property from high magnitude and rare storm events (e.g., the 100-year event). The objective of hydromodification management is to prevent excessive long-term erosion and deposition in natural channels from a range of channel flows that are typically much lower than flood design flow rates (e.g., from 10 percent of the 2-year storm to the 10-year storm event).

While hydrologic analyses for flood control, such as those contained in the Orange County Hydrology Manual, are based on evaluating the magnitude of one large discrete event (on the order of hours to days), hydromodification analysis focuses on continuous simulations (spanning over several decades) which take into account both flow magnitude and duration. Because hydromodification analysis looks at both magnitude and duration of the long-term flow record, the large but rare events that are crucial to flood control can be relatively insignificant when considering sediment transport and changes in channel form. In fact, geomorphic research has found that for most stream channels, the most important range of flows from the perspective of affecting channel form are the relatively frequent flows that are contained primarily within the active channel and not the rare, high magnitude flows which exceed the rate of flow that can be contained in the normally wetted perimeter of the channel.

Flows which create high enough shear stresses to initiate sediment transport within the channel and which occur frequently enough to have influence over long-term stream morphology are considered "geomorphically-significant" flows. To provide perspective on the timescales of interest, a peak storm event may result in a bed scour hole, which slowly fills in with sediment over days to months after the event takes place. But if the time scale considered for stream stability is on the order of several decades, that scour hole may be a negligible perturbation on the overall record of channel form.

3. STEPS FOR SIZING HYDROMODIFICATION CONTROL BMPS

This section describes two alternative methods for sizing structural hydromodification control BMPs: a Unit Based Nomograph (Unit Based) method and a Site Specific System (System Based) approach.

The Unit Based approach is useful in the planning stage of a project, where exact system configurations are not yet established and a planning level estimate of the size of hydromodification control BMPs for a range of BMP types and catchment impervious area fractions is desired. The Unit Based approach generally involves conducting simulations of fixed increments of imperviousness (e.g., 25%, 50%, 75%, and 100%) for fixed BMP design criteria and interpolating a nomograph line between these points. This approach was used to develop the Sizing Tool. While this approach requires more simulation time up front, it allows flexibility for the designer to quickly select a number of BMPs for a range of impervious areas representing different drainage areas on the project. It also generally requires system configurations to be simpler so that many sets of results can be efficiently generated.

The System Based approach models the actual drainage system and BMP(s) tributary to the point of compliance. The System Based approach allows for a more complex BMP configuration and outlet structure; it is effectively equivalent to developing one point on the nomograph. The System-Based approach is useful for a project that has drainage management area(s) and BMP location(s) firmly defined and wishes to simulate each explicitly to size the BMPs instead of generating a design nomograph.

The benefit of the Unit Based approach is that it is relatively simple to model and allows project proponents to easily determine the necessary BMP storage volume and footprint area for flow duration control as a function of the proposed level of imperviousness and onsite soils. Because BMP footprint and storage requirements are normalized by catchment area in the Unit Based approach, the project proponent has the flexibility to strategically situate many small scale distributed facilities or fewer larger facilities, depending on site constraints. The benefit of the Site Specific System approach is that it can result in the most space efficient BMP design; however, it does require a greater investment in modeling because the analysis is more detailed.

Each approach is based on the same general principles and involves similar steps. This memorandum focuses more extensively on the Unit Based Nomograph Approach.

3.1 Unit Based Nomograph Approach

The Unit Based approach relies on hydrologic simulations of a generic watershed to create BMP sizing relationships, which are then applied to actual site conditions. This approach was used to generate the sizing relationships programmed into the Sizing Tool. The steps for performing the Unit Based approach are to:

(1) characterize site specific hydrologic conditions,
(2) establish hydrologic modeling parameters,
(3) define the flow range of interest,
(4) establish a structural BMP configuration,
(5) iteratively size BMP footprints for a range of imperviousness values,
(6) create sizing relationships based on generic modeling results, and
(7) iteratively situate and size BMPs.

Step-by-step instructions for the Unit Based approach are provided below. The specific assumptions used and results obtained for the Sizing Tool are provided in the attachment to this memorandum.

3.1.1 Step 1: Characterize Site Specific Hydrologic Conditions

The first step is to characterize the natural (pre-development) and proposed (post-development) hydrologic conditions in order to qualitatively understand the land use changes associated with the project. This characterization also forms the basis for input parameters used in continuous simulations (Step 2). At a minimum, the characterization should identify the following hydrologic factors: drainage catchments, soil types, vegetation cover, pre-development impervious cover, and overland slope. A discussion of each of these hydrologic factors is provided below.

Drainage Catchments should be delineated, at a minimum, into areas tributary to each discharge location from the site. The same delineations used for the project's flood control analyses, which take into account existing and proposed storm drain systems, should be used here. Although the proposed catchment delineation may differ from that of the natural condition[2], the proposed delineation is the one which governs BMP sizing and location, unless the site discharges to separate receiving streams in either the natural or proposed conditions. In this case, both delineations will affect BMP sizing.

[2] It is considered best practice to maintain the natural catchment delineation to the extent practical.

Soil Type or Hydrologic Soil Group (i.e. Type A, B, C, and D) associated with the natural and proposed conditions should be summarized by acreage and percentage for the site. While the Orange County Hydrology Manual Soils Map (OCEMA 1986) can be used for this summary, site specific data based on infiltration testing or boring logs is preferred and takes precedence for characterizing soil type. It is important to evaluate potential changes in soil conditions from natural to proposed conditions. Changes may occur from compaction, importation and fill with non-native soils, and grading that will alter the surface soil type and properties.

Vegetation Type should be characterized for pervious areas associated with the natural and proposed condition. Historical aerial imagery, geospatial data, or geographically similar reference sites can be used to characterize vegetation type in the natural condition. Proposed vegetation will depend on the landscaping plan.

Pre-Development Impervious Cover should be summarized by area and by percentage of the site. The pre-development condition is considered to be the natural condition, unless the conditions identified in Section F.1.d.1.b[3] of the MS4 permit apply. Section F.1.d.1.b states that:

> *"Where redevelopment results in an increase of less than fifty percent of the impervious surfaces of a previously existing development, and the existing development was not subject to SSMP requirements, [the IHC] applies only to the addition or replacement, and not to the entire development. Where redevelopment results in an increase of more than fifty percent of the impervious surfaces of a previously existing development, [the IHC] applies to the entire development."*

In the case that the redevelopment project results in an increase in impervious area of less than 50 percent of the previously existing impervious area and the existing impervious area is not replaced, the previously existing impervious area of the project can be considered as part of the pre-development condition.

For example, if a project is 10 acres at 50 percent imperviousness in the existing condition and proposes to leave the existing development in place and add 2 acres of new impervious area, this

[3] Section F.1.d.1.b states that "Where redevelopment results in an increase of less than fifty percent of the impervious surfaces of a previously existing development, and the existing development was not subject to SSMP requirements, [the IHC] applies only to the addition or replacement, and not to the entire development. Where redevelopment results in an increase of more than fifty percent of the impervious surfaces of a previously existing development, [the IHC] applies to the entire development."

would constitute an increase in impervious area of 40 percent. This is less than a 50 percent increase in impervious surface; therefore the IHC only applies to the new 2 acres of impervious area, not the entire 10 acre project. The existing impervious area would be included as impervious in the "pre-development" condition. This provision does not apply if the 5 acres of imperviousness was removed and replaced. Impervious area that is removed and replaced is considered to be new impervious area and is subject to the IHC, therefore should be considered as the natural condition for the predevelopment condition in modeling.

The range of **Overland Slope** for the site should be characterized for the natural and proposed conditions. The slopes should be based on topographic maps and grading plans. Slope may decrease from the natural to proposed condition if the site is graded into a flatter pad for development.

3.1.2 Step 2: Establish Hydrologic Modeling Parameters

Continuous hydrologic simulation is conducted to construct a continuous record of natural and proposed runoff conditions from which flow duration curves are developed. For each combination of BMP type and soil type, five generic hydrologic simulations are performed to generate long term flow records. One simulation is associated with the baseline natural condition and the other four represent a range of impervious cover for the proposed post-developed condition (e.g., 25%, 50%, 75%, and 100% imperviousness). Before these simulations can be run, however, input parameters for the model must be established.

The site information collected in Step 1 should be used to establish appropriate input parameters for the continuous hydrologic simulations of a generic watershed. These parameters will differ depending on the modeling program used, but the most essential input assumptions, described in subsequent paragraphs, include: (1) precipitation record, (2) BMP catchment area, (3) soil and vegetation parameters that affect the infiltration properties, and (4) connectivity of impervious cover. No one hydrologic modeling software program is preferred, however, the program used must be capable of simulating continuous hourly runoff over a period of several decades. Publicly available software programs commonly used to perform continuous hydrologic simulations include HSPF, SWMM, and HEC-HMS.

As a practical matter, the longer the **Precipitation Record** the better, but at a minimum, a record of at least 20 years with an hourly time interval of rainfall readings should be used. Upwards of 50 years is preferred if the data is available. Quality assurance of the precipitation record used is of utmost importance to ensure that excessive data gaps or errors in the record are rectified. Two precipitation gages in South Orange County, the Trabuco and Laguna Beach National Climatic Data Center (NCDC) gages, have been identified as appropriate for hydromodification analysis.

While the Laguna gage is most appropriate for projects near the coast, Trabuco is most appropriate for inland projects at higher elevation. The representativeness of the record to the project site is important, as the depth and intensity of rainfall can vary significantly depending on location and elevation. The lack of representative rainfall data may be a key limitation that will dictate a decision to conduct site specific modeling.

The assumed BMP Catchment Area should be justified in a logical fashion based on anticipated BMP locations, associated tributary areas, and the proposed storm drain system. The objective is to demonstrate that the assumed catchment area accurately reflects the eventual site conditions. Assumed catchment shape and flow path is also a key input parameter which is parameterized differently according to the modeling software program used.

The assumed soil infiltration parameters (e.g., hydraulic conductivity) should be provided for each soil type associated with the site and justified in a logical fashion for the natural and proposed conditions. If the proposed condition includes compacted fill, then a reduction in hydraulic conductivity should be assumed (e.g., 75% of natural). In order to represent the infiltration and storage properties associated with vegetative cover, assumed depression storage and overland roughness parameters should be provided for natural and proposed conditions. The parameterization of vegetation effects will differ according to the software program used.

The Connectivity of Impervious Cover will affect how the proposed condition hydrologic simulations are modeled. Impervious cover can be defined as either connected, meaning it is routed directly to the storm drain system, or disconnected, meaning it is routed through a pervious area prior to entering the storm drain system. Disconnecting an impervious area is a non-structural approach for reducing the footprint and storage requirements of structural BMPs.

3.1.3 Step 3: Define the Flow Range of Interest (0.1Q_2, Q_5, and Q_{10})

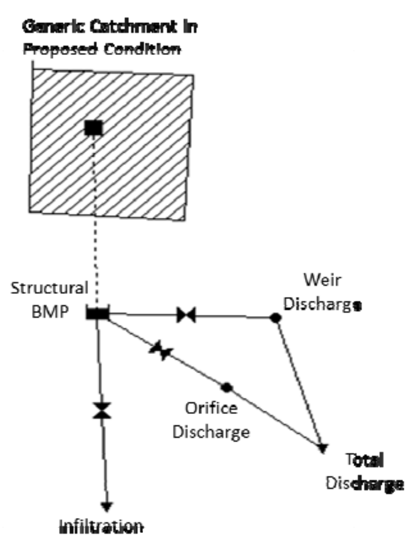
In order to establish the flow range specified in the IHC, the 2-year (Q_2), 5-year (Q_5), and 10-year (Q_{10}) return period discharges for the natural condition must be calculated. This should be done by constructing a partial-duration series from the natural condition simulation output as follows:

- The entire runoff time series generated by the natural hydrologic simulation is divided into a set of discrete events based on independence criteria.

- Unless other independence criteria are shown to be more appropriate for the project site, the independence criteria described in the San Diego County Hydromodification Management Plan[4] shall be used to separate discrete events as follows:
  - Flow events should be considered separate when the flow rate drops below a threshold value of 0.002 cfs/acre for a period of at least 24 hours.
- The peak flows from each discrete event are ranked and the return intervals are computed using plotting position methods to establish the Q_2, Q_5, and Q_{10}. The low flow discharge is simply 10 percent of the computed Q_2 ($0.1Q_2$).

3.1.4 Step 4: Establish a Structural BMP Configuration

For each type of structural BMP, a hydraulic outlet configuration, infiltration rate, and geometric configuration must be assumed so that the BMP can be modeled as a storage unit with a specific stage-storage, stage-discharge, and stage-infiltration relationship. This generic modeling setup is represented in Figure 2. The theory is that if the basic configuration is held constant, only the footprint needs to be iteratively adjusted (Step 5) to achieve flow duration control, per the IHC.



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[4] Brown and Caldwell, 2009. Final Hydromodification Management Plan Prepared for County of San Diego, California. Available at: http://www.projectcleanwater.org/pdf/susmp/hmp_final_san_diego_hmp_mar2011_wappendices.pdf.

Figure 2. Example Modeling Configuration for a Proposed Condition Hydrologic Simulation

The **Hydraulic Outlet Configuration** dictates the stage-discharge relationship entered into the proposed scenario models for the BMP. One simple outlet configuration is to have a low flow orifice at the bottom of the BMP and an overflow weir at the top, as shown in Figure 3. While the orifice should be sized to discharge the $0.1Q_2$ at the pressure head associated with the overflow weir crest, the weir itself should be designed to convey the peak discharge per the OC Hydrology Manual with sufficient freeboard.

Discharge from an orifice can be calculated using the equation $Q = 3.78\ D^2\ H^{1/2}$,where: Q = discharge (cfs); D = diameter (ft); and H = head above the orifice center (ft). Discharge from a rectangular weir can be calculated using the equation $Q = 3.33\ L\ H^{1.5}$ if the weir is suppressed and $Q = 3.33\,(L - 0.2H)\ H^{1.5}$ if the weir is contracted, where: Q = discharge (cfs); L = crest length (ft); and H = head above weir crest (ft).

If infiltration is great enough, a low flow orifice may not be necessary. Additional intermediate orifices or more complicated compound weirs can be part of the hydraulic control as well, but their sizes (e.g., orifice diameter and weir crest length) should be scalable by catchment area so that they can be applied to a range of tributary acreages. For the example model shown in Figure 2, the stage-discharge relationship has been split into two components, one for low flow control and one for overflow so that the runoff volume routed through each component can be quantified.

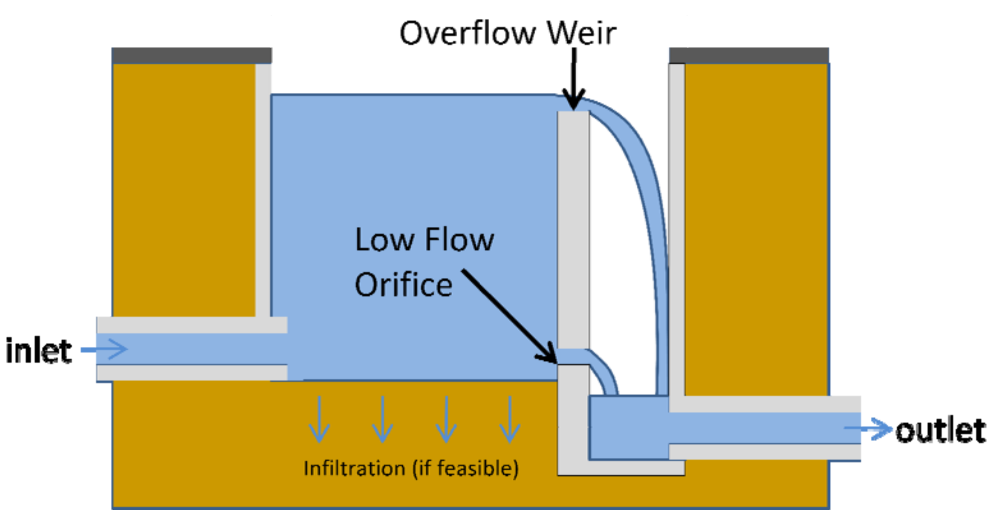

Figure 3. Schematic of a Simple Hydraulic Outlet Configuration

The **Infiltration Rate** can be assumed to be constant or increase as the stage and resulting pressure head increases. Ideally, the infiltration rate assumed should relate to site specific infiltration testing data. Infiltrating runoff through the bottom of a BMP may not be feasible if the subsoil has low permeability, the groundwater table is too high, a contaminated groundwater plume is nearby, a drinking water well is nearby, or if the site is in a designated liquefaction or landslide zone.

The **Geometric Configuration** dictates the stage-storage relationship entered into the proposed scenario models. It also affects the stage-infiltration curve, since a shallow BMP will infiltrate runoff at a greater rate than a deep BMP with a smaller footprint. The simplest BMP geometry to model is one with a rectangular footprint and vertical side walls. If media such as sand or gravel will be placed in the BMP, then the stage-storage curve should account for only the storage capacity within the media and not include the volume of the grains.

3.1.5 Step 5: Iteratively Size the BMP Footprints

Once the BMP configuration is established, the BMP footprint area can be iteratively adjusted for a range of impervious values (e.g., 25%, 50%, 75%, and 100% imperviousness) such that the simulated BMP discharge record meets the flow duration control criteria with a minimum footprint. The resulting BMP footprints[5] and capture volumes[6] should be normalized and summarized in a table. Normalizing the BMP footprint entails dividing the footprint by the assumed BMP catchment area to get a percentage. Normalizing the BMP capture volume involves converting the capture volume into watershed inches. For instance, a capture volume expressed in cubic feet can be converted to watershed inches by dividing it by the square footage of the tributary catchment and multiplying by 12 to convert feet to inches.

To demonstrate that the IHC is met, a graphical comparison should be made of the baseline (natural) flow duration curve to that of the proposed condition (see Figure 1). In order to plot a flow duration curve, a table of flow rates and corresponding cumulative durations (hours), at which the specified flow rate is equaled or exceeded in the simulation record, is required. Comparing these flow duration tables can be helpful in confirming that the proposed flows and durations do not exceed those of the natural condition. There are a number of ways of

[5] BMP footprint area is defined as the area, in square feet, of the BMP at the overflow weir crest.

[6] BMP capture volume is the storage capacity, in cubic feet, of the BMP below the overflow weir crest.

establishing the flow values used in the flow duration table[7]. The method used should be documented and should provide a relatively smooth flow duration curve, without too many steps, indicating that the distribution of flows is well represented.

According to the IHC, the proposed condition flow duration curve, with mitigation, should be below the natural flow duration curve between $0.1Q_2$ and Q_5. If the proposed flow duration curve is above the natural curve between Q_5 and Q_{10}, then it should be demonstrated, using flow frequency statistics, that the proposed peak flows only exceed the natural peak flows by up to 10% for a 1-year frequency interval. The same partial duration methodology used to calculate the flow range of interest for the natural scenario (Step 3) can also be used here. Figure 4 provides an example of a graphical means of comparing peak flow frequencies.

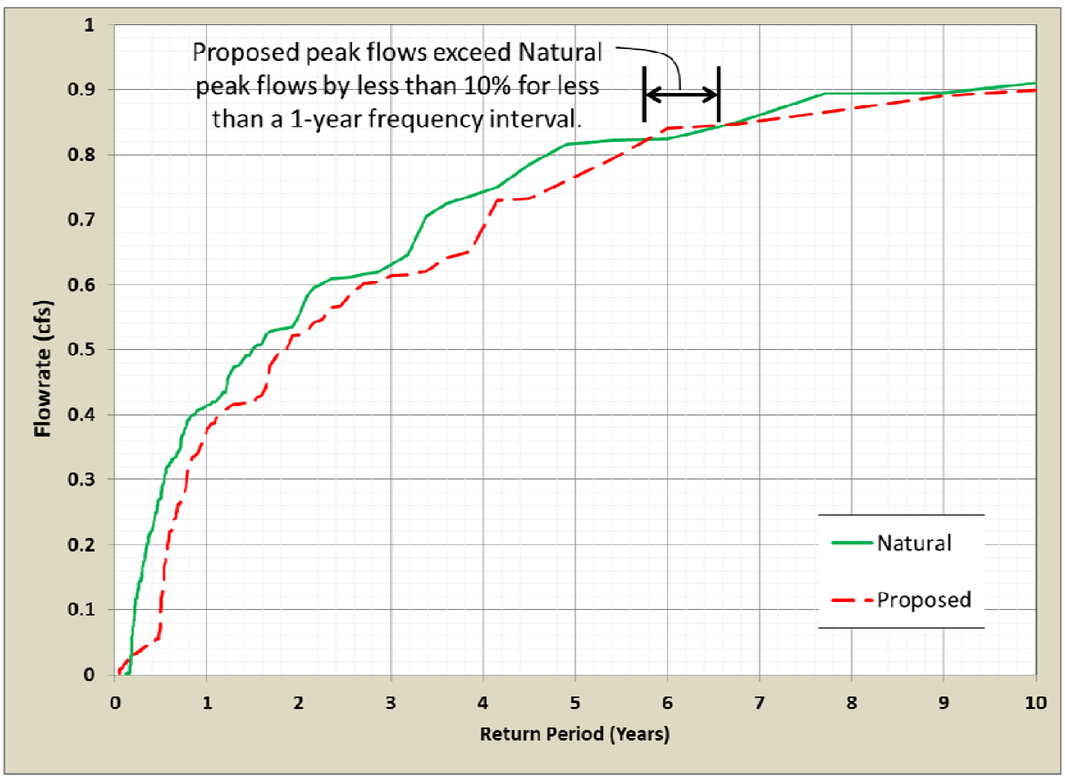

Figure 4. Example Peak Flow Frequency Comparison

[7] One method is to create a flow bin for every output flow generated from the simulation. Another method is to set up a generic channel geometry and increment the flow bins according to increments of flow stage using Manning's normal depth equation.

3.1.6 Step 6: Create Sizing Relationship

With different BMP sizes associated with five different imperviousness values (no BMP is needed for 0% imperviousness), a best fit function should be created for these five data points. These sizing relationships should be documented as equations and as nomographs, which plot BMP capture volume and footprint area on the y-axis and imperviousness on the x-axis (see Sizing Tool Results). A site specific sizing tool, similar to the Interim South Orange County Hydromodification BMP Sizing Tool, can also be prepared to help apply the sizing relationships to site BMPs. If the BMP cannot feasibly infiltrate runoff into the subsoil, then only the capture volume sizing relationship is required because without infiltration, BMP sizing does not significantly change when footprint and depth vary.

3.1.7 Step 7: Iteratively Situate and Size BMPs within the Project

Coming up with a final BMP plan requires an iterative process of: (1) situating BMPs within the project; (2) delineating drainage management areas tributary to those BMPs; (3) calculating the acreage associated with all combinations of soil type and cover type (i.e., pervious or impervious) for each drainage management area[8]; (4) sizing the BMPs by using the soil and imperviousness information as inputs to the BMP sizing relationship; and (5) evaluating whether the resulting BMP sizes can fit in their assumed locations. If the resulting BMP sizes cannot be accommodated in their assumed locations, the process should be repeated for a different BMP plan until one is found that will work for the site.

The final BMP plan should be documented with: (1) a map showing BMP locations, BMP catchments, soil boundaries, and impervious surfaces for the project; (2) a summary of BMP sizing inputs (soil type, % imperviousness, and catchment area) and outputs (capture volume and footprint area); (3) a demonstration that the proposed BMP locations can accommodate the calculated sizing; and (4) a summary of the hydraulic outlet control dimensions for each BMP[9].

3.2 Site Specific System Based Approach

Instead of, or in addition to, a Unit-based Nomograph Approach, a project proponent may wish to perform an explicit System Based modeling analysis of the proposed system. Rather than analyzing a range of BMP types and impervious surface permutations to develop a “design

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[8] Using GIS is ideal for this spatial calculation.

[9] The low flow orifice diameter should be sized to discharge the $0.1Q_2$ at the pressure head associated with the overflow weir crest. The overflow weir crest length and depth should be designed to convey the peak design discharge per the OC Hydrology Manual with sufficient freeboard.

chart" that is applicable across the project (as in the Unit Based Nomograph Approach), the System Based approach focuses on designing a specific system to provide flow duration control only at the project discharge locations. This approach may be preferable where the project has only one possible BMP location and constraints are well defined. The approach used for this case would be analogous to developing one solution point in the Unit Based Nomograph Approach, therefore would be more efficient than developing all points necessary to develop the nomograph. In addition, this approach can provide more optimized BMP storage requirements and, consequently, lower construction costs. However, this process can be highly iterative and is generally prohibitive where constraints are not well defined and the proponent wishes to evaluate many potential scenarios involving different BMP types and locations.

The first three steps of the System Based analysis are essentially the same[10] as the Unit Based approach (site characterization, model parameter selection, and calculation of the flow range of interest). After these steps, the Systems Based Approach involves characterizing the control system and iteratively sizing and designing to find a solution that meets the IHC criteria. This step is analogous to steps 4 and 5 in the Unit Based Nomograph Approach (hydraulic representation and iterative sizing), but may be more site-specific and complex.

One method of implementing the System Based approach in an organized way is to initially use the Unit Based approach to generally locate BMPs, and then use a System Based model to fine tune the BMP configurations, such that their sizes are reduced.

[10] The only difference is that Steps 2 and 3 are performed for a generic catchment in the Unit Based approach and a site specific catchment for the System Based approach.

Attachment

This attachment summarizes the specific assumptions used and results obtained for the Sizing Tool for each general step of the Unit Based Nomograph approach.

Step 1: Characterize Site Specific Hydrologic Conditions

The Sizing Tool was not created for a specific project location, so a site drainage delineation map cannot be provided. However, Table A-1 summarizes the general hydrologic conditions assumed for South Orange County Priority Development Projects during the interim period (12/16/10 to 12/16/11).

Table A-1. Assumed South Orange County Hydrologic Characteristics

Hydrologic Characteristic	Natural (Pre-Development)	Proposed (Post-Development)
Drainage Catchments	5,000 sq ft to 50 acres	5,000 sq ft to 50 acres
Soil Types	A/B, C/D	A/B, C/D
Vegetation Cover	Native grassland, shrub, & chaparral	Landscaped areas with similar native species as the natural condition
Impervious Cover	1%	1% to 100% (directly connected)
Overland Slope	Wide range (5% assumed average)	Wide range (5% assumed average)

Step 2: Establish Hydrologic Modeling Parameters

Table A-2. SWMM Catchment Parameters

Parameter	Unit	Value A/B Soils	Value C/D Soils
Subcatchment SWMM Parameters			
Precipitation Gage	--	Trabuco	Trabuco
Outlet	--	N/A	N/A
Area	Acres	10, 1, 0.25	10, 1, 0.25
Width	Feet	660, 209, 104	660, 209, 104
% Slope	%	5	5

Parameter	Unit	Value A/B Soils	Value C/D Soils
% Imperv	%	1, 25, 50 75, & 100	1, 25, 50 75, & 100
N-Imperv	--	0.012	0.012
N-Perv	--	0.15	0.15
Dstore-Imperv	Inches	0.02	0.02
Dstore-Perv	Inches	0.1	0.1
%Zero-Imperv	%	25	25
Subarea Routing	--	OUTLET	OUTLET
Percent Routed	%	100	100
Infiltration	Method	GREEN_AMPT	GREEN_AMPT
Suction Head	Inches	1.5	8
Undeveloped Conductivity	in/hr	0.3	0.05
Developed Conductivity	in/hr	0.23	0.04
Initial Deficit	Fraction	0.33	0.30
Groundwater	yes/no	NO	NO
Climatology SWMM Parameters			
Temperature	--	N/A	N/A
Evaporation	Monthly Averages	CIMIS Zone 4	CIMIS Zone 4
Wind Speed	--	N/A	N/A
Snow Melt	--	N/A	N/A
Areal Depletion	--	N/A	N/A
Simulation Options			
Infiltration Model	--	Green Ampt	Green Ampt
Routing Method	--	None	None
Reporting Time Step	Days:Hr:Min:Sec	1 hour	1 hour
Dry Weather Time Step	Days:Hr:Min:Sec	4 hours	4 hours
Wet Weather Time Step	Days:Hr:Min:Sec	15 minutes	15 minutes
Routing Time Step	Seconds	60	60
Dynamic Wave Inertial Terms	--	Dampen	Dampen
Define Supercritical Flow By	--	Both	Both
Force Main Equation	--	Hazen-Williams	Hazen-Williams
Variable Time Step Adjustment Factor	%	75	75
Conduit Lengthening	Seconds	0	0
Minimum Surface Area	Square Feet	0	0

The following information provides justification for the parameters in Table A-2:

- **Precipitation Data**: The Trabuco precipitation record was used because the rainfall intensity is greater than that measured at the Laguna gage, which is the other long-term precipitation record in South Orange County. By using a more intense rainfall record, this results in more conservative BMP sizes.

- **Catchment Dimensions**: The assumed generic catchment width is square.

- **Slope**: A typical South Orange County terrain is assumed to have a 5% catchment slope.

- **Infiltration Parameters**: The assumed pre-development hydraulic conductivity is based on typical values associated with Soil Types A/B and C/D, as referenced in *SWMM Hydrology: Runoff and Service Modules* (James et al, 2002)[11]. The post-development hydraulic conductivity was assumed to be 75% of the pre-development hydraulic conductivity, in order to account for disturbance and compaction. The post-development hydraulic conductivity was also used as the infiltration rate within the BMPs.

Step 3: Define the Flow Range of Interest (0.1Q_2, Q_5, and Q_{10})

Table A-3. Partial Duration Series Results for Natural Condition Simulations

Flow/Area (cfs/acre)	**A/B Soils**			**C/D Soils**		
Acres	*0.25*	*1*	*10*	*0.25*	*1*	*10*
Q_{10}	0.679	0.660	0.521	0.912	0.906	0.822
Q_5	0.600	0.571	0.409	0.817	0.808	0.702
Q_2	0.328	0.302	0.209	0.552	0.552	0.495

Step 4: Establish a Structural BMP Configuration

The structural BMP configuration assumptions made for the Sizing Tool and schematics of the configurations are provided below.

[11] James W., Huber W.C., Pitt R.E., Dickinson R.E., James W.R.C. 2002. SWMM Hydrology: Runoff and Service Modules.

<u>Bioretention Facility Assumptions (See Figure A-1)</u>

Hydraulic Outlet Configuration

- An underdrain and low flow orifice is used for C/D Soils, but not for A/B Soils.
- Low flow orifice is sized to discharge the low flow threshold at the head associated with the overflow weir elevation (C/D Soils only).
- Slotted underdrain pipe capacity and infiltration rate through media is significantly greater than the low flow threshold of $0.1Q_2$ (C/D Soils only).
- Overflow weir crest length is sized to convey the peak design flowrate determined from the Orange County flood control standards.
- Slotted underdrain pipe invert and low flow orifice @ 0.5-ft from bottom of facility (C/D Soils only).
- Overflow weir @ 6.25-ft from bottom of facility.
- 0.5-ft of depth above the weir crest to convey overflows.

Infiltration Rate

- Infiltration rate into A/B soils = 0.23 inches/hour. Infiltration rate into C/D Soils = 0.04 inches/hour.

Geometric Configuration

- Media storage capacity = porosity – field capacity. This assumes that only freely drained storage is considered. The storage capacity used for gravel and choke stone is 0.4, for sand and plant media is 0.26, and for mulch is 0.5.Top of Media @ 4.75-ft from bottom of facility.
- Vertical walls between the bottom of facility and top of media.
- 3:1 side slopes above top of media.

<u>Underground Vault with Open Bottom Assumptions (See Figure A-2)</u>

Hydraulic Outlet Configuration

- Low flow orifice is included for C/D Soils, not for A/B Soils.
- Low flow orifice is sized to discharge the low flow threshold at the head associated with the overflow weir elevation (C/D Soils only).
- Overflow weir crest length is sized to convey the peak design flow rate determined from Orange County flood control standards.
- Low flow orifice discharge @ 0.5-ft from bottom of facility (C/D Soils only).
- Overflow weir @ 7.0-ft from bottom of facility.
- 1.0-ft of depth above the weir crest to convey overflows.

Infiltration Rate

- Infiltration rate into A/B soils = 0.23 inches/hour. Infiltration rate into C/D Soils = 0.04 inches/hour.

Geometric Configuration

- Vertical walls throughout.

<u>Underground Vault with Closed Bottom Assumptions (See Figure A-3)</u>

Hydraulic Outlet Configuration

- Low flow orifice is included for C/D and A/B Soils.
- Low flow orifice is sized to discharge the low flow threshold at the head associated with the overflow weir elevation.
- Overflow weir crest length is sized to convey the peak design flow rate determined from Orange County flood control standards.
- Low flow orifice discharge is located at same elevation as the bottom of vault. (Note: sediment storage capacity should be provided below the low flow orifice plate as shown

on Figure A-3; this can be accomplished by placing the outlet structure in a separate manhole or lowering the vault floor below the outlet. Any added storage below the outlet does not count towards the BMP Capture Volume.)

Infiltration Rate

- No infiltration into soils.

Geometric Configuration

- Vertical walls throughout.
- Overflow weir @ 7.0-ft from bottom of facility.
- 1.0-ft of depth above the weir crest to convey overflows.

<u>Planter Box Assumptions (See Figure A-4)</u>

Hydraulic Outlet Configuration

- An underdrain and low flow orifice is used for C/D and A/B Soils.
- Low flow orifice is sized to discharge the low flow threshold at the head associated with the overflow weir elevation.
- Slotted underdrain pipe capacity and infiltration rate through media is significantly greater than the low flow threshold of $0.1Q_2$.
- Overflow weir crest length is sized to convey the peak design flowrate determined from the Orange County flood control standards.
- Slotted underdrain pipe invert and low flow orifice @ bottom of facility.
- Overflow weir @ 5.25-ft from bottom of facility.
- 0.25-ft of depth above the weir crest to convey overflows.

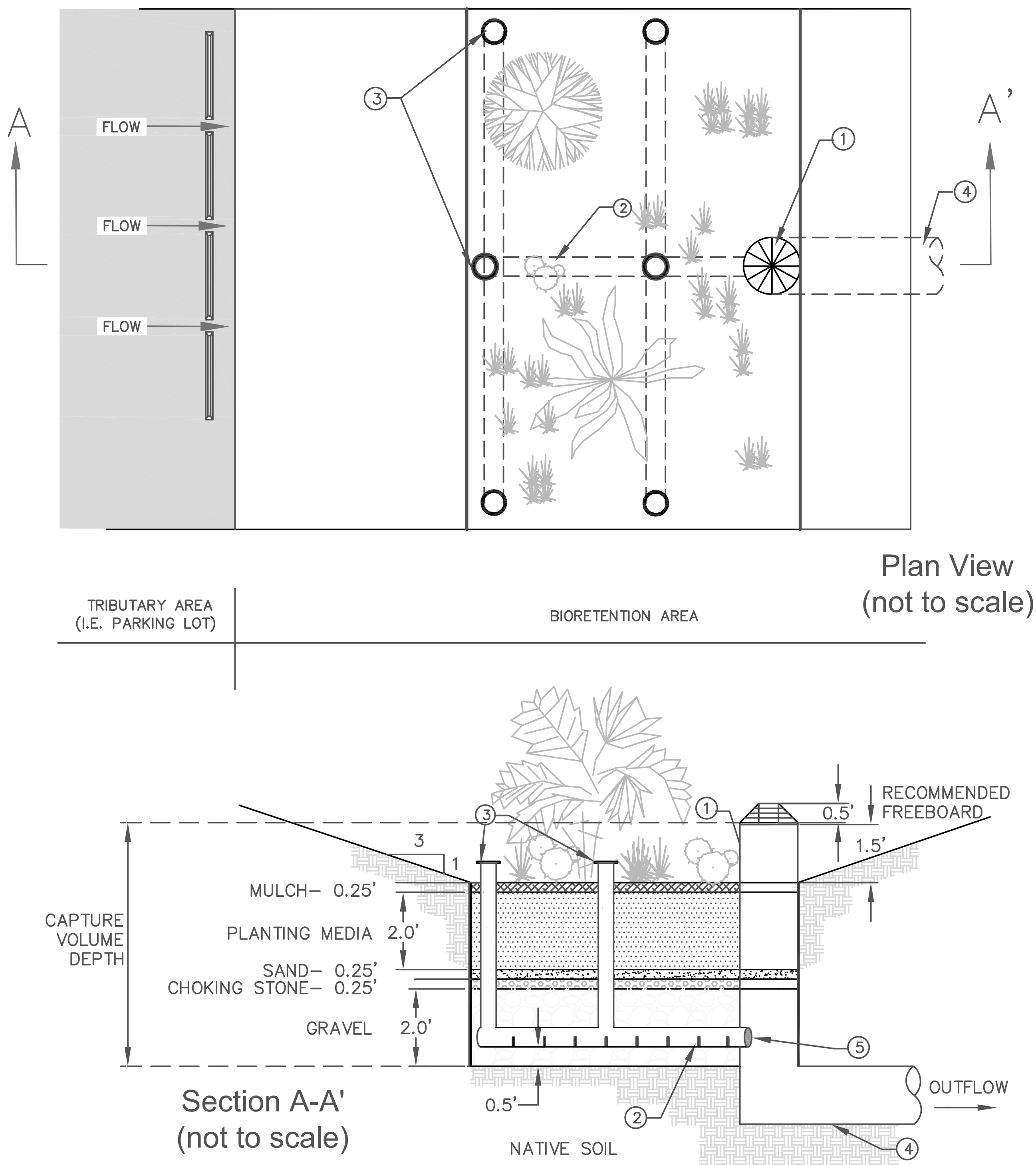
Infiltration Rate

- No infiltration into soils.

Geometric Configuration

- Media storage capacity = porosity – field capacity. This assumes that only freely drained storage is considered. The storage capacity used for gravel and choke stone is 0.4, for sand and planting media is 0.26, and for mulch is 0.5.Top of Media @ 4.25-ft from bottom of facility.

- Vertical walls throughout.



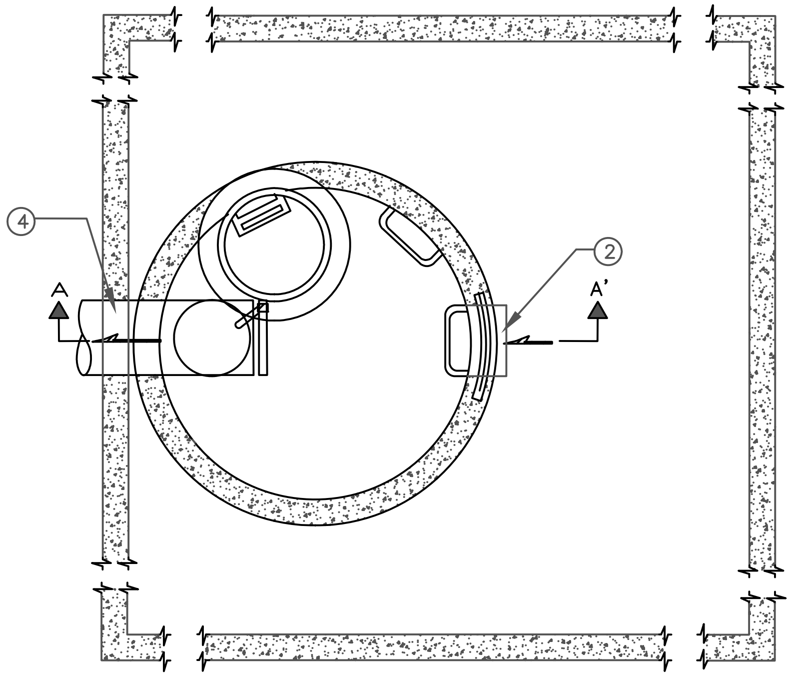
NOTES:

1. OVERFLOW DEVICE WITH WEIR LENGTH SIZED TO CONVEY THE DESIGN DISCHARGE AS REQUIRED BY THE ORANGE COUNTY LOCAL DRAINAGE MANUAL AND HYDROLOGY MANUAL OR THE LOCAL PERMITTING AUTHORITY
2. SLOTTED 6” MIN PVC PIPE UNDERDRAIN (C/D SOILS ONLY)
3. 6” MIN PVC PIPE CLEANOUT (C/D SOILS ONLY)
4. OUTLET PIPE SIZED TO CONVEY THE DESIGN DISCHARGE AS REQUIRED BY THE ORANGE COUNTY LOCAL DRAINAGE MANUAL AND HYDROLOGY MANUAL OR THE LOCAL PERMITTING AUTHORITY
5. BLIND FLANGE AT END OF SLOTTED UNDERDRAIN DRILLED TO SPECIFIC ORIFICE DIAMETER (C/D SOILS ONLY)

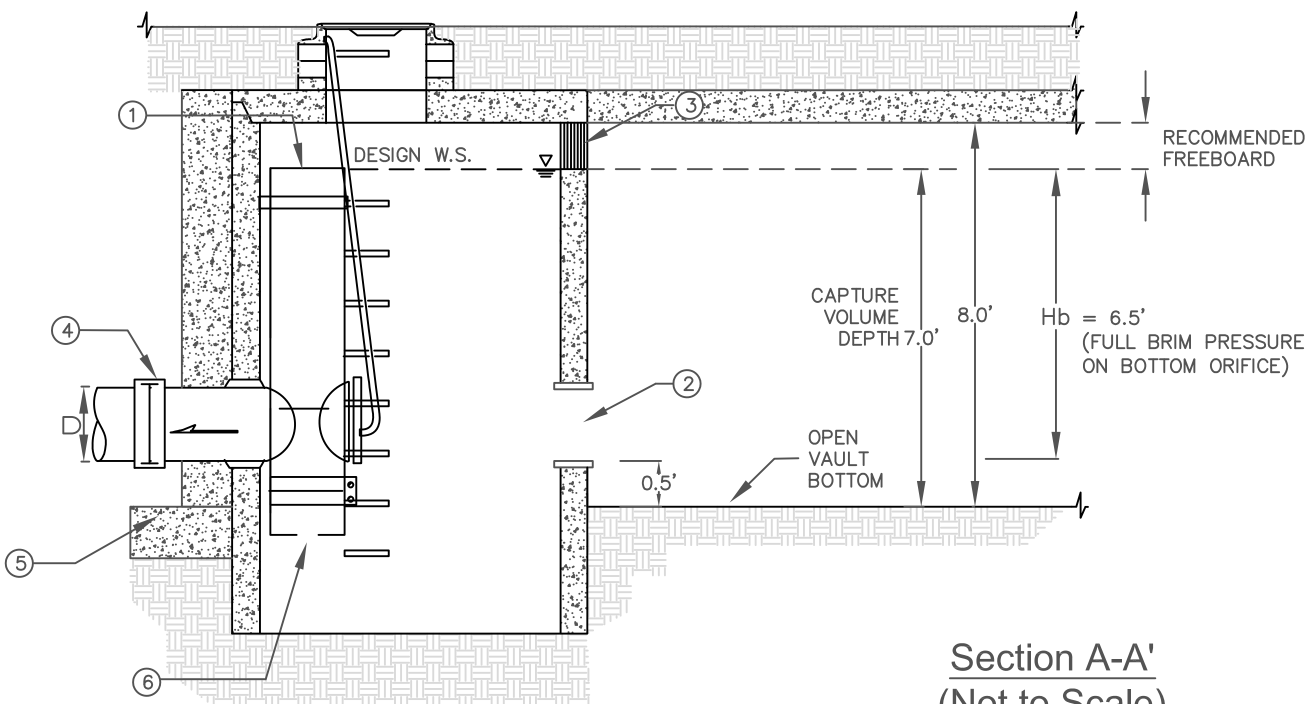
Geosyntec consultants

Bioretention Facility

Figure A-1. Bioretention Facility Schematic



Underground Vault Outlet
Plan View



Section A-A'
(Not to Scale)

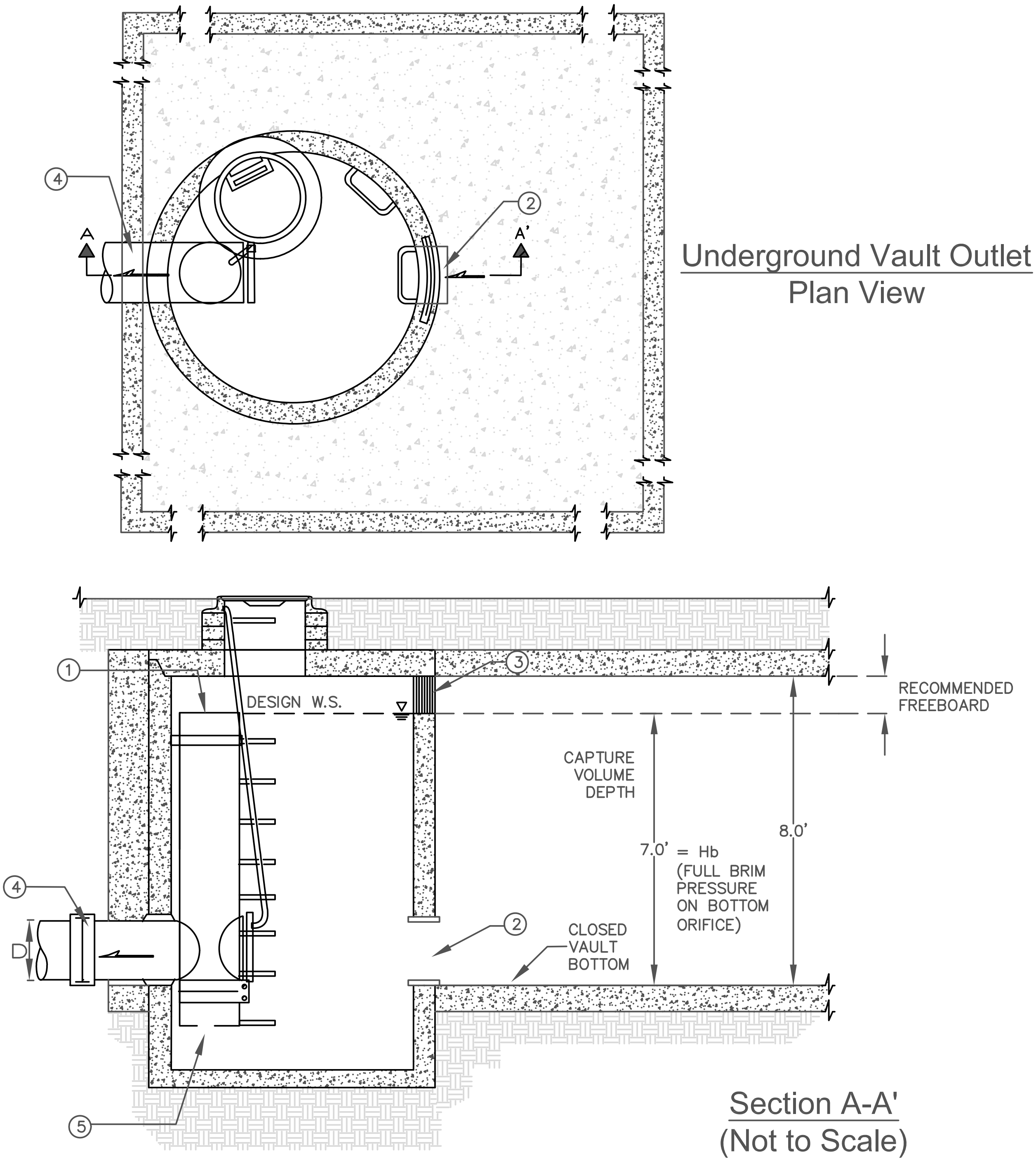
NOTES:

1. OVERFLOW DEVICE WITH WEIR LENGTH SIZED TO CONVEY THE DESIGN DISCHARGE AS REQUIRED BY THE ORANGE COUNTY LOCAL DRAINAGE MANUAL AND HYDROLOGY MANUAL OR THE LOCAL PERMITTING AUTHORITY
2. PRIMARY INLET
3. SECONDARY INLET
4. OUTLET PIPE SIZED TO CONVEY THE DESIGN DISCHARGE AS REQUIRED BY THE ORANGE COUNTY LOCAL DRAINAGE MANUAL AND HYDROLOGY MANUAL OR THE LOCAL PERMITTING AUTHORITY
5. FOOTING FOUNDATION TO PROMOTE INFILTRATION WITHIN THE VAULT
6. RESTRICTOR PLATE WITH ORIFICE DIAMETER (C/D SOILS ONLY)

Geosyntec consultants

Vault- Open Bottom

Figure A-2. Open-Bottom Underground Vault Schematic



NOTES:

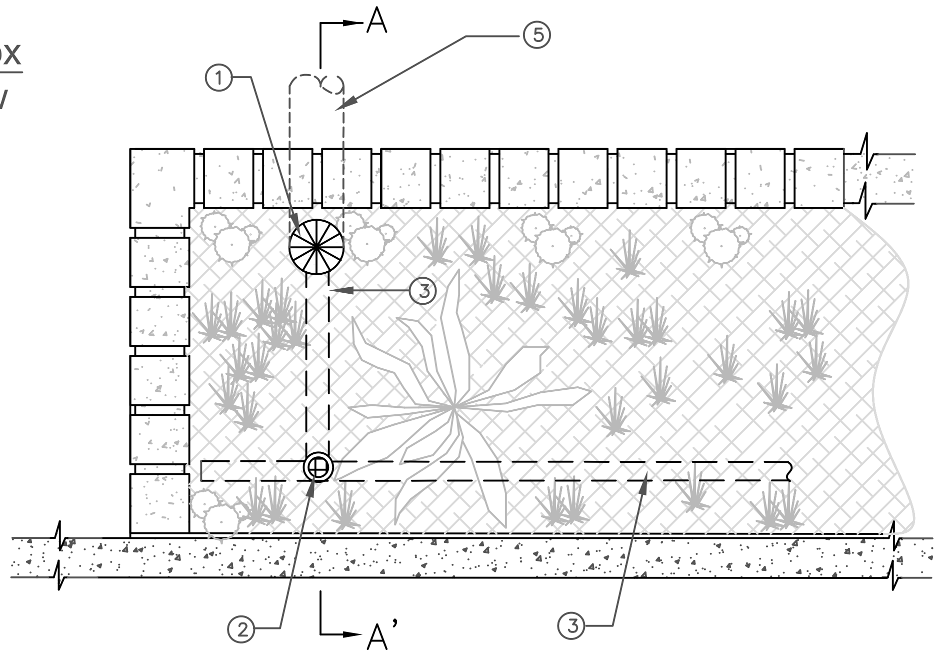
1. OVERFLOW DEVICE WITH WEIR LENGTH SIZED TO CONVEY THE DESIGN DISCHARGE AS REQUIRED BY THE ORANGE COUNTY LOCAL DRAINAGE MANUAL AND HYDROLOGY MANUAL OR THE LOCAL PERMITTING AUTHORITY
2. PRIMARY INLET
3. SECONDARY INLET
4. OUTLET PIPE SIZED TO CONVEY THE DESIGN DISCHARGE AS REQUIRED BY THE ORANGE COUNTY LOCAL DRAINAGE MANUAL AND HYDROLOGY MANUAL OR THE LOCAL PERMITTING AUTHORITY
5. RESTRICTOR PLATE WITH ORIFICE DIAMETER

Geosyntec consultants

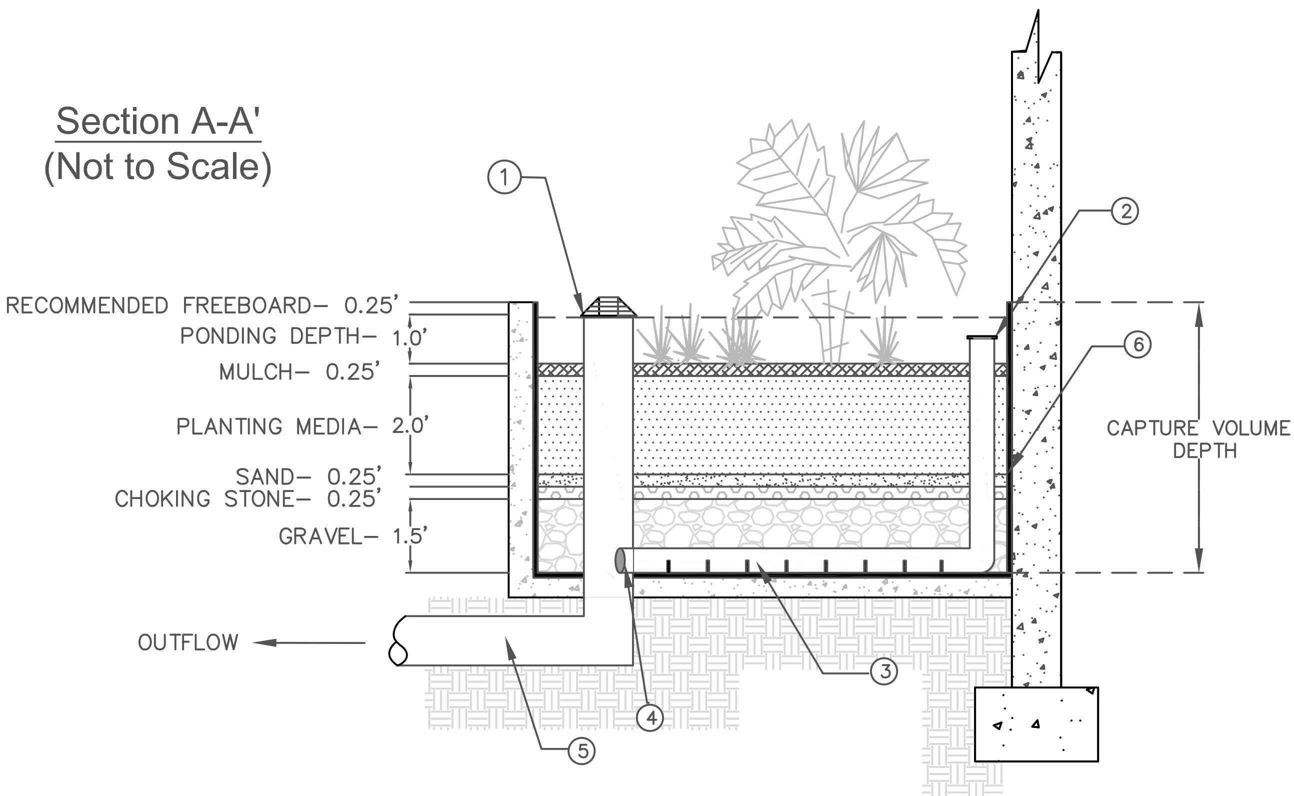
Vault- Closed Bottom

Figure A-3. Closed-Bottom Underground Vault Schematic

Planter Box
Plan View



Section A-A'
(Not to Scale)



NOTES:

1. OVERFLOW DEVICE WITH WEIR LENGTH SIZED TO CONVEY THE DESIGN DISCHARGE AS REQUIRED BY THE ORANGE COUNTY LOCAL DRAINAGE MANUAL AND HYDROLOGY MANUAL OR THE LOCAL PERMITTING AUTHORITY
2. 6” MIN PVC PIPE CLEANOUT
3. SLOTTED 6” MIN PVC PIPE UNDERDRAIN
4. BLIND FLANGE AT END OF SLOTTED UNDERDRAIN DRILLED TO SPECIFIC ORIFICE DIAMETER
5. OUTLET PIPE SIZED TO CONVEY THE DESIGN DISCHARGE AS REQUIRED BY THE ORANGE COUNTY LOCAL DRAINAGE MANUAL AND HYDROLOGY MANUAL OR THE LOCAL PERMITTING AUTHORITY
6. WATERPROOF BARRIER

Geosyntec consultants

Planter Box

Figure A-4. Planter Box Schematic

Step 5: Iteratively Size the BMP Footprints

The BMP capture volumes and footprint areas resulting from the iterative sizing are provided below in Table A-4. Flow duration curve comparisons associated with these BMPs are provided in Figures A-5 to A-12. Flow values used to plot the flow duration curves were established by setting up a generic channel geometry and incrementing the flow bins according to increments of flow stage using Manning's normal depth equation. Peak flow frequency comparisons are not provided because all proposed condition flow duration curves are below the natural curve between Q_5 and Q_{10}.

Table A-4. BMP Sizing Results

BMP Type	Soils	Imperviousness (%)	Capture Volume (Watershed inches)	Footprint @ Overflow Weir (% of Catchment)
Bioretention	C/D	100	1.944	6.9%
	C/D	75	1.511	5.5%
	C/D	50	1.222	4.6%
	C/D	25	0.884	3.5%
	A/B	100	5.120	16.4%
	A/B	75	3.732	12.3%
	A/B	50	2.697	9.2%
	A/B	25	1.411	5.2%
Open Vault	C/D	100	2.919	3.5%
	C/D	75	2.112	2.5%
	C/D	50	1.783	2.1%
	C/D	25	1.043	1.2%
	A/B	100	7.133	8.5%
	A/B	75	5.370	6.4%
	A/B	50	3.481	4.1%
	A/B	25	1.944	2.3%
Closed Vault	C/D	100	2.468	2.9%
	C/D	75	1.999	2.4%
	C/D	50	1.680	2.0%
	C/D	25	0.964	1.1%
	A/B	100	9.147	10.9%
	A/B	75	5.835	6.9%
	A/B	50	3.124	3.7%
	A/B	25	1.435	1.7%

BMP Type	Soils	Imperviousness (%)	Capture Volume (Watershed inches)	Footprint @ Overflow Weir (% of Catchment)
Planter Box	C/D	100	1.917	6.6%
	C/D	75	1.580	5.5%
	C/D	50	1.360	4.7%
	C/D	25	1.156	4.0%
	A/B	100	5.784	20.0%
	A/B	75	3.872	13.4%
	A/B	50	2.342	8.1%
	A/B	25	1.195	4.1%

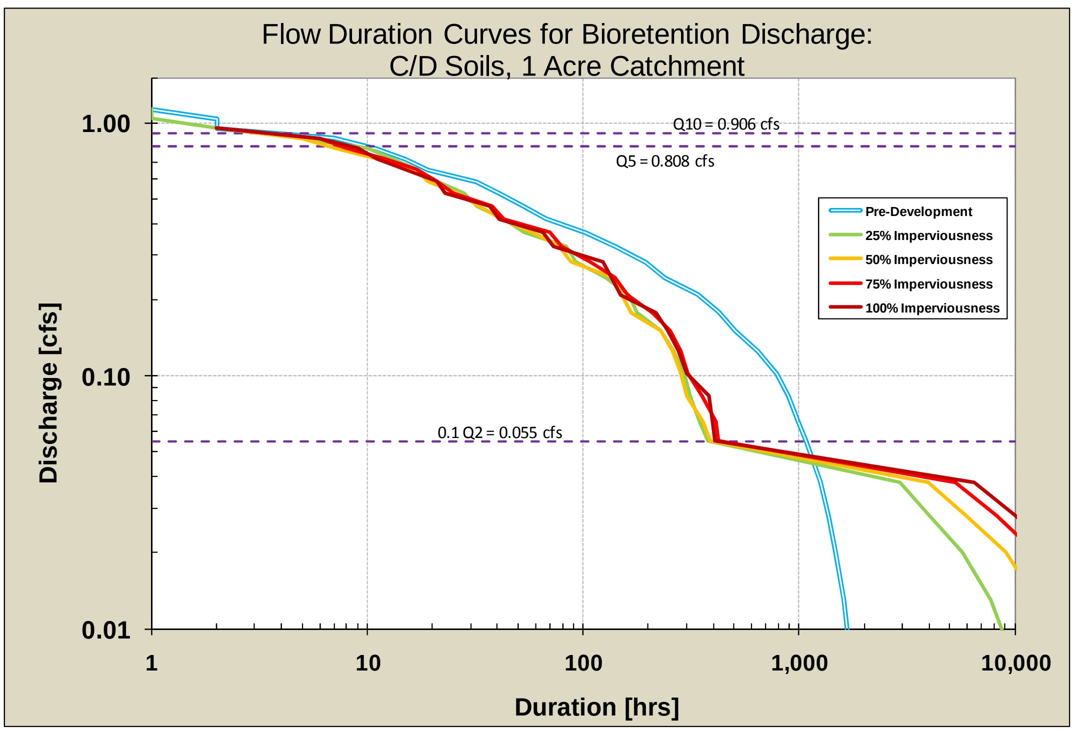


Figure A-5. Flow Duration Results for Bioretention BMP with C/D Soils

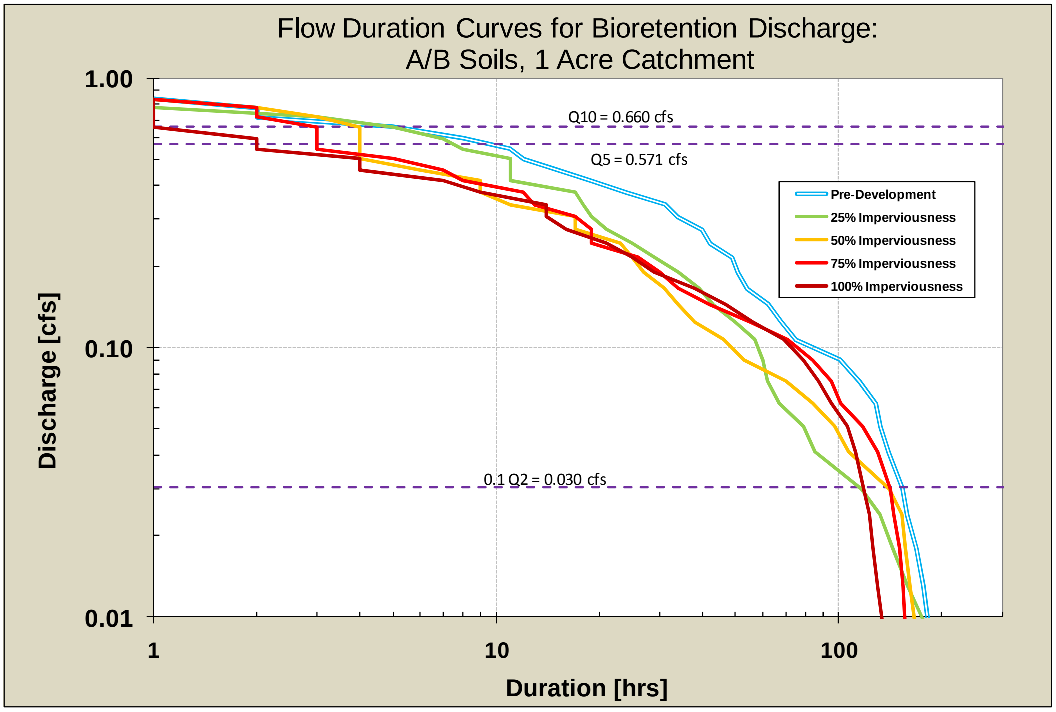


Figure A-6. Flow Duration Results for Bioretention BMP with A/B Soils

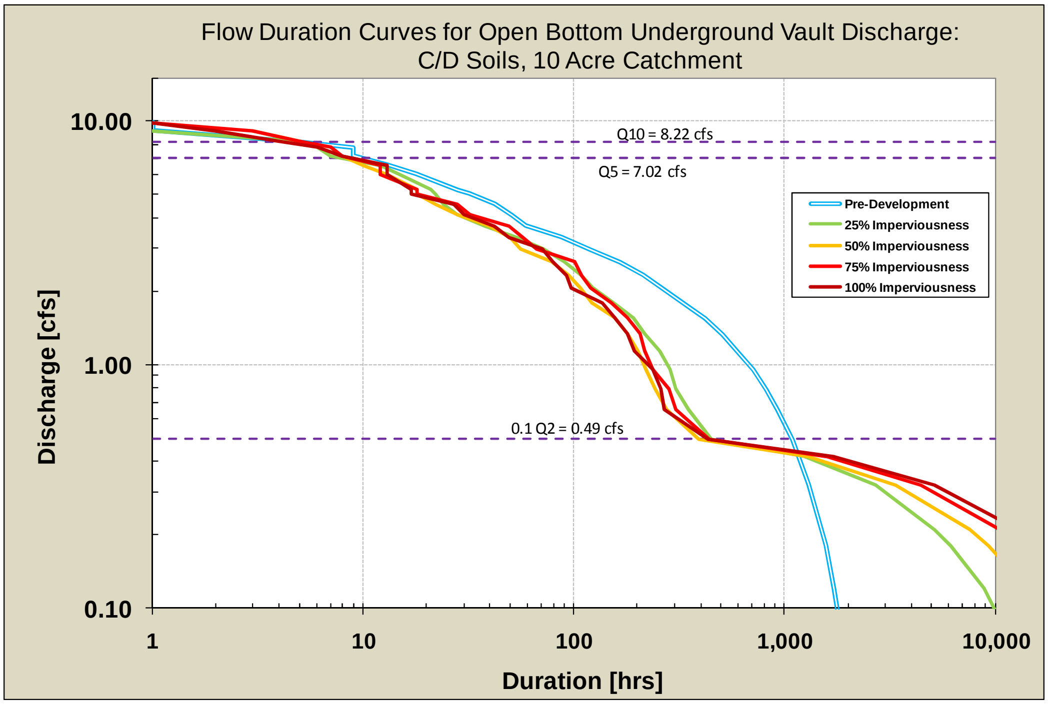


Figure A-7. Flow Duration Results for Open Bottom Underground Vault BMP with C/D Soils

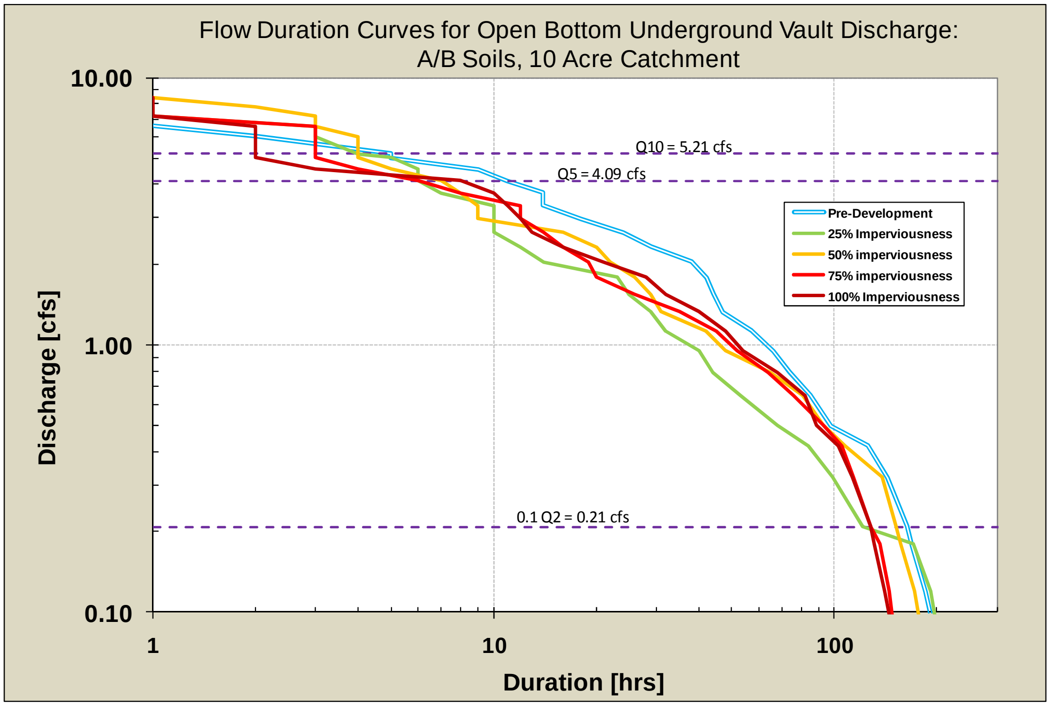


Figure A-8. Flow Duration Results for Open Bottom Underground Vault BMP with A/B Soils

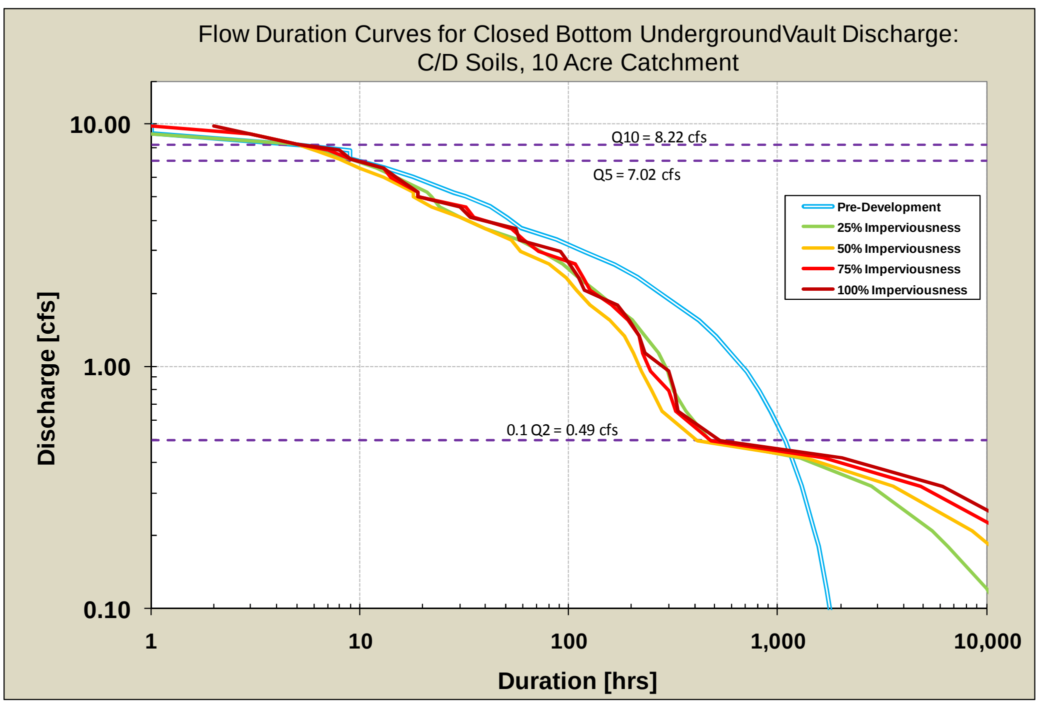


Figure A-9. Flow Duration Results for Closed Bottom Underground Vault with C/D Soils

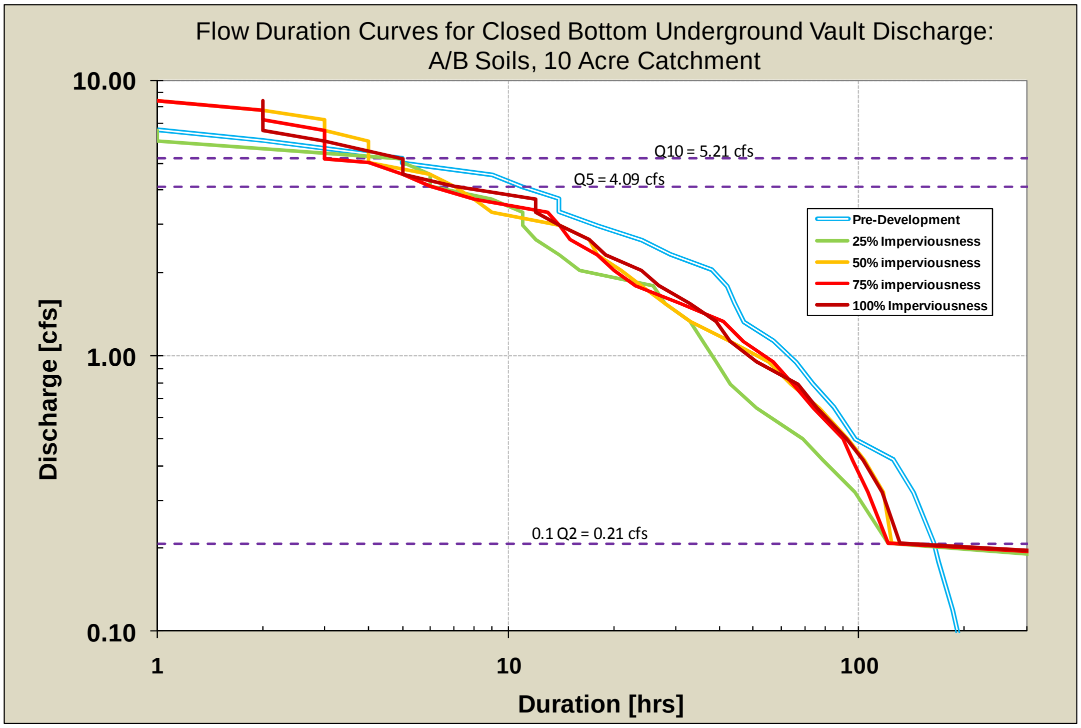


Figure A-10. Flow Duration Results for Closed Bottom Underground Vault with A/B Soils

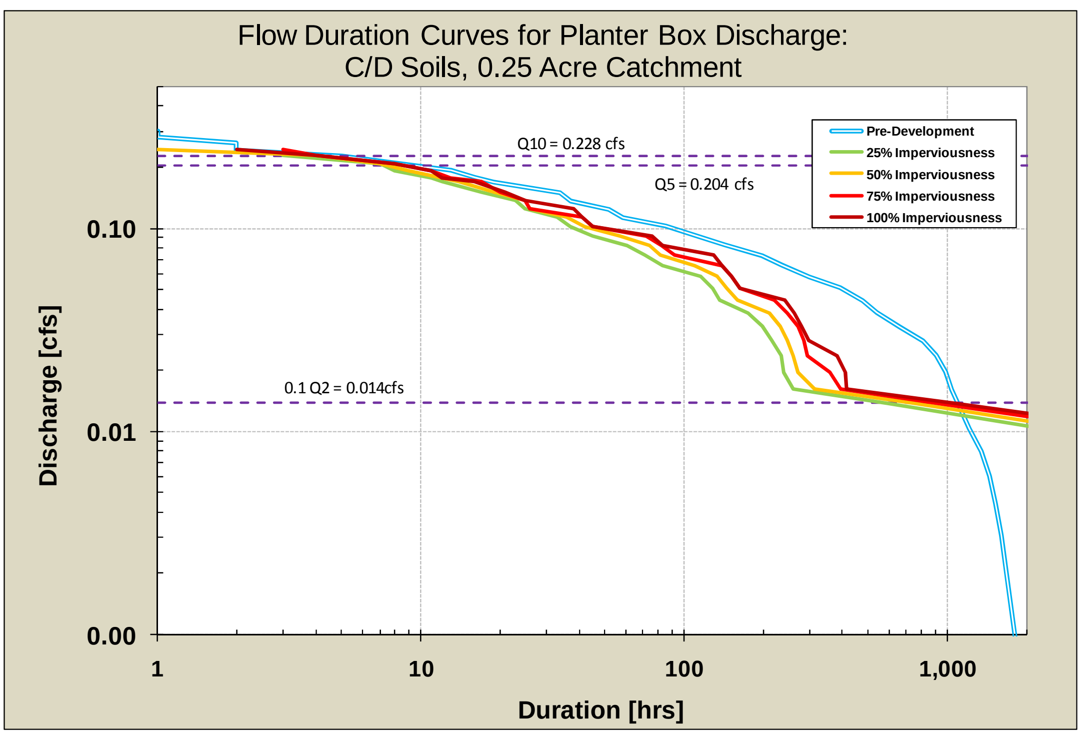


Figure A-11. Flow Duration Results for Planter Box BMP with C/D Soils

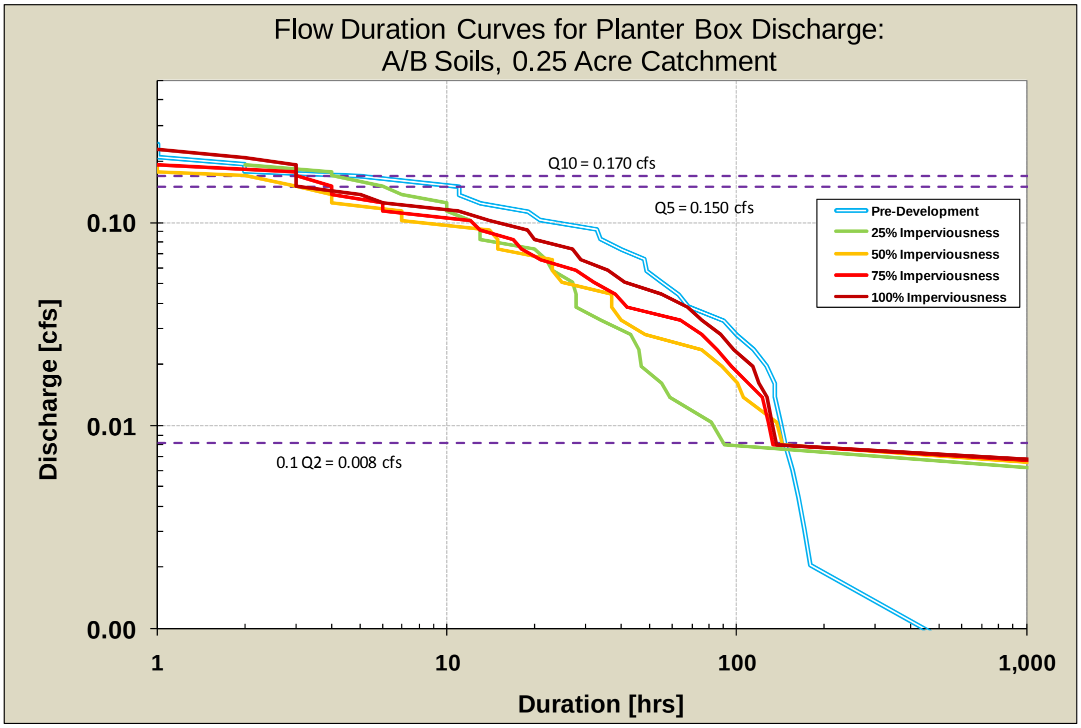


Figure A-12. Flow Duration Results for Planter Box BMP with A/B Soils

Step 6: Create Sizing Relationship

The sizing relationships for both BMP capture volume and BMP footprint area are provided below.

Table A-5. Best Fit Equations for BMP Capture Volume

BMP Type	Soil Type	Capture Volume Function (watershed inches)
Bioretention	C/D	y = (3.707*10^(-6)*x^3)-(6.656*10^(-4)*x^2)+(4.897*10^(-2)*x)
Bioretention	A/B	y = (2.492*10^(-6)*x^3)-(4.054*10^(-4)*x^2)+(6.671*10^(-2)*x)
Open Bottom Vault	C/D	y = (4.088*10^(-6)*x^3)-(7.108*10^(-4)*x^2)+(5.925*10^(-2)*x)
Open Bottom Vault	A/B	y = (1.597*10^(-6)*x^3)-(2.447*10^(-4)*x^2)+(8.001*10^(-2)*x)
Closed Bottom Vault	C/D	y = (2.069*10^(-6)*x^3)-(4.666*10^(-4)*x^2)+(5.055*10^(-2)*x)
Closed Bottom Vault	A/B	y = (1.943*10^(-6)*x^3)+(2.503*10^(-4)*x^2)+(4.717*10^(-2)*x)
Planter Box	C/D	y = (5.761*10^(-6)*x^3)-(1.052*10^(-3)*x^2)+(6.691*10^(-2)*x)
Planter Box	A/B	y = (2.328*10^(-6)*x^3)-(1.430*10^(-4)*x^2)+(4.892*10^(-2)*x)

Note: independent variable “x” represents % imperviousness

Table A-6. Best Fit Equations for BMP Footprint Area

BMP Type	Soil Type	Footprint Area Function (% of catchment)
Bioretention	C/D	y = (1.535*10^(-7)*x^3)-(2.822*10^(-5)*x^2)+(1.977*10^(-3)*x)
Bioretention	A/B	y = (1.181*10^(-7)*x^3)-(2.119*10^(-5)*x^2)+(2.573*10^(-3)*x)
Open Bottom Vault	C/D	y = (4.867*10^(-8)*x^3)-(8.462*10^(-6)*x^2)+(7.053*10^(-4)*x)
Open Bottom Vault	A/B	y = (1.902*10^(-8)*x^3)-(2.913*10^(-6)*x^2)+(9.525*10^(-4)*x)
Closed Bottom Vault	C/D	y = (2.463*10^(-8)*x^3)-(5.554*10^(-6)*x^2)+(6.018*10^(-4)*x)
Closed Bottom Vault	A/B	y = (2.313*10^(-8)*x^3)+(2.98*10^(-6)*x^2)+(5.616*10^(-4)*x)
Planter Box	C/D	y = (1.992*10^(-7)*x^3)-(3.638*10^(-5)*x^2)+(2.314*10^(-3)*x)
Planter Box	A/B	y = (1.000*10^(-7)*x^3)-(7.631*10^(-6)*x^2)+(1.764*10^(-3)*x)

Note: independent variable “x” represents % imperviousness

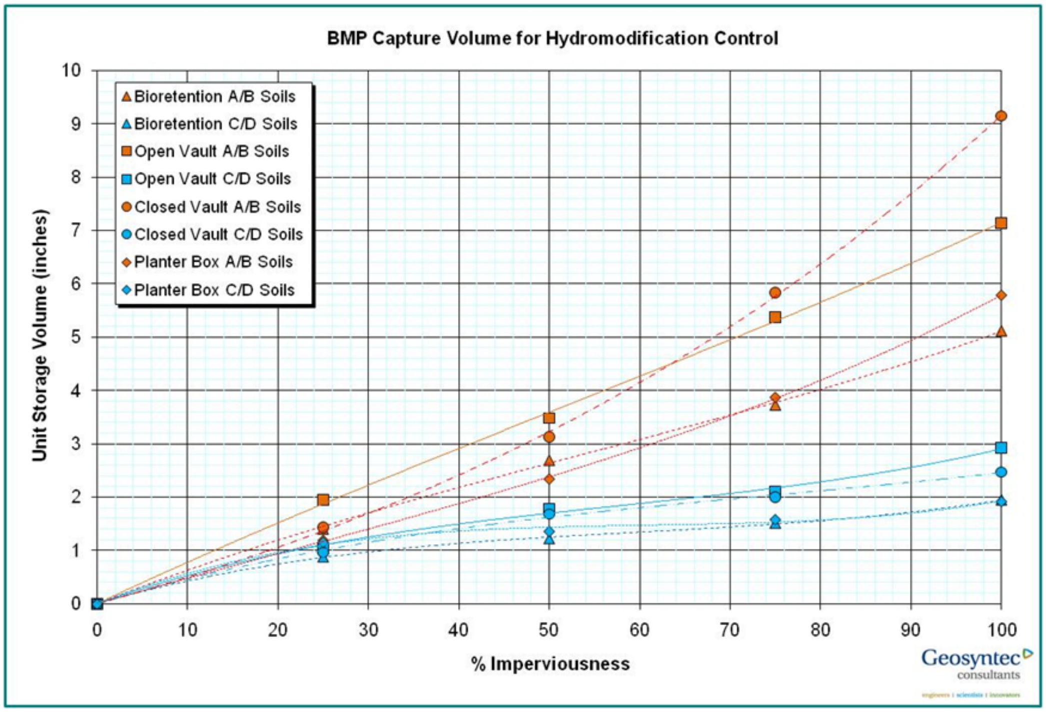


Figure A-13. Sizing Nomograph for BMP Capture Volume

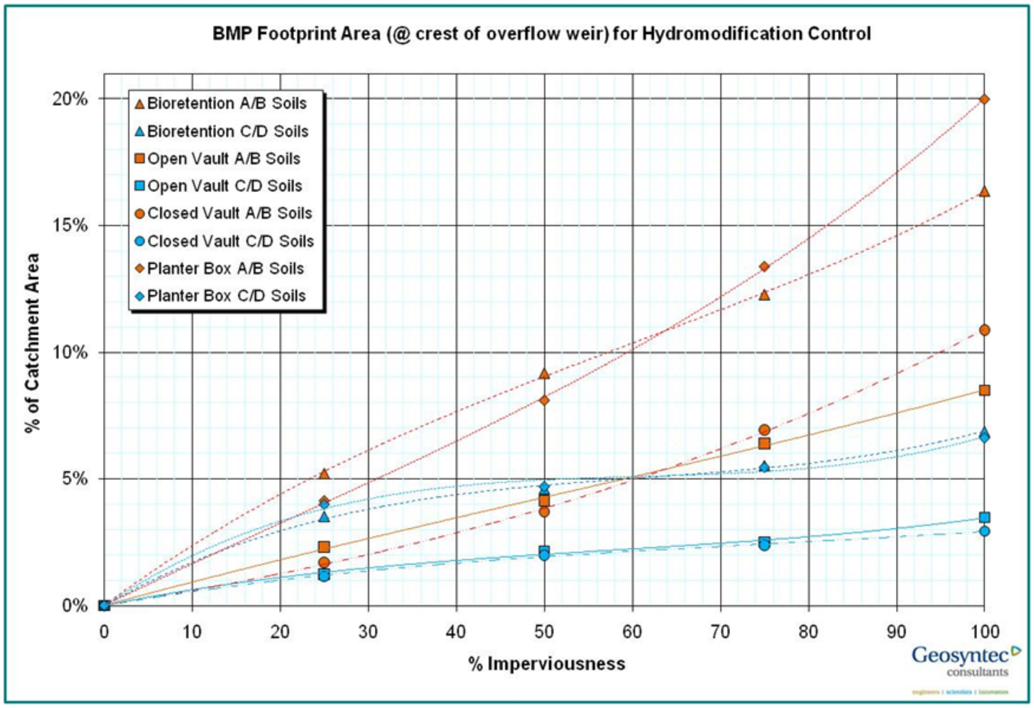


Figure A-14. Sizing Nomograph for BMP Footprint Area

Step 7: Iteratively Situate and Size BMPs within the Project

Although the Sizing Tool was not created for a particular project, an example BMP sizing and hydraulic design summary is provided below. A site map and demonstration that the site can accommodate the BMP size is not provided because the example is hypothetical.

Table A-7. BMP Sizing and Hydraulic Design Summary

INPUT					OUTPUT				
BMP Type	**Soil Type**	**Trib Area (acres)**	**Imperv Cover (%)**	**Depth to Orifice (ft)**	**Footprint Area (sq ft)**	**Capture Volume (cu ft)**	**Orifice Diameter (in)**	**Weir Crest Length (ft)**	**Weir Depth (ft)**
Bio-retention	C/D	2	65.0	5.75	4,481	10,084	1 5/16	9.42	0.5