Ventura County Technical Guidance Manual for Stormwater Quality Control Measures

2025 Reissuance







Ventura Countywide
Stormwater Quality
Management Program

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Ventura Countywide Stormwater Quality Management Program

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Future Updates: Due to the evolving nature of stormwater quality management, this 2025 *Technical Guidance Manual for Stormwater Quality Control Measures* may continue to be updated to correct errors, to incorporate new and innovative control measures, or to add Ventura County's Hydromodification Control Plan. Users should ensure that they are referencing the most current edition by checking http://www.vcstormwater.org or contacting the local permitting agency.

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1 INTRODUCTION

This *Technical Guidance Manual for Stormwater Quality Control Measures* (2025 TGM) provides guidance for the implementation of stormwater management control measures in new development and redevelopment projects located in the County of Ventura and the incorporated cities therein. These guidelines have been developed to meet the Planning and Land Development requirements contained in the regional Phase I Municipal Separate Storm Sewer System (MS4) National Pollutant Discharge Elimination System (NPDES) Permit for stormwater and non-stormwater discharges from the MS4 within the coastal watersheds of Los Angeles and Ventura Counties (CAS004004, Order No. R4-2021-0105), henceforth referred to in this document as the 2021 MS4 Permit.

1.1 Regulatory Background

The Ventura County Watershed Protection District, County of Ventura, and the cities of Camarillo, Fillmore, Moorpark, Ojai, Oxnard, Port Hueneme, Santa Paula, Simi Valley, Thousand Oaks, and Ventura collaboratively implement the Ventura Countywide Stormwater Quality Management Program (Program) and are named as co-permittees of the 2021 MS4 Permit, regulated by the Los Angeles Regional Water Quality Control Board. The co-permittees are required to administer, implement, and enforce a Stormwater Quality Management Program to reduce pollutants in urban runoff to the maximum extent possible. The Program focuses on reducing pollution in various ways, such as raising public awareness, controlling pollution sources, enforcing regulations, monitoring water quality, and implementing treatment controls.

1.2 Impacts of Land Development

Land development increases impervious surfaces, leading to more stormwater runoff and pollutants entering drainage systems. This untreated runoff from streets and storm drains is discharged directly into receiving waters such as channels, rivers, and the ocean, causing water pollution.

The measures outlined in this 2025 TGM are designed to reduce the impact of land development by implementing Low Impact Development (LID) strategies. LID is a decentralized approach to stormwater management that works to mimic the natural hydrology of the site by retaining precipitation on-site, to the maximum extent practicable. Stormwater quality control measures that incorporate LID principles are placed throughout the site in small, discrete units and distributed near the source of impacts. LID strategies help protect surface and groundwater quality, maintain the integrity of ecosystems, and preserve the physical integrity of receiving waters by managing stormwater runoff at or close to the source.

1.3 Applicability

All Priority Development Projects as well as street and road construction projects, as defined below, are required to comply with the 2021 MS4 Permit and the post-construction specifications in this TGM.

1.3.1 Priority Development Projects

Priority Development Projects are land development projects that fall under a local permitting agency's planning and building authority which must implement LID practices that achieve flow reduction and water quality performance requirements specified in Provision VIII.F.4 of the 2021 MS4 Permit. Priority Development Projects include the following:

i. New development projects that are in any of the following categories:

   a. Projects equal to 1 acre or greater of disturbed area and adding more than 10,000 square feet or more of impervious surface area (collectively over the entire project site)

   b. Industrial parks of 10,000 square feet or more of surface area

   c. Commercial malls of 10,000 square feet or more of surface area

ii. Redevelopment projects that create and/or replace 5,000 square feet or more of impervious surface (collectively over the entire project site) on any of the following:

   a. Existing sites of 10,000 square feet or more of impervious surface area

   b. Industrial parks of 10,000 square feet or more of surface area

   c. Commercial malls of 10,000 square feet or more of surface area

iii. New development and redevelopment projects that create and/or replace 5,000 square feet or more of impervious surface (collectively over the entire project site) and support one or more of the following uses:

   a. Restaurants (Standard Industrial Classification (SIC) code 5812)

   b. Parking lots

   c. Automotive services facilities (SIC codes: 5013, 5014, 5511, 5541, 7532-7534 and 7536-7539)

   d. Retail gasoline outlets

iv. New development and redevelopment projects that create and/or replace 2,500 square feet or more of impervious area; discharge stormwater that is likely to impact a sensitive biological species or habitat; and are located in or directly adjacent to or are discharging directly to an "Environmentally Sensitive Area" in Ventura County (further defined in Section 3.1.7).

1.3.2 Roadway Projects

Street and road construction of 10,000 square feet or more of impervious surface area shall follow United States Environmental Protection Agency (U.S. EPA) guidance regarding Managing Wet Weather with Green Infrastructure: Green Streets (December 2008 EPA-833-F-08-009) to the maximum extent practicable. Street and road construction applies to standalone streets, roads, highways, and freeway projects. Temporary access roads are not subject to this requirement. Projects under this category are exempt from the Priority Development Structural Best Management Practice (BMP) Performance Requirements in Provision VIII.F.4 of the 2021 MS4 Permit. This exemption is solely for standalone road projects and not for projects which are part of larger development or redevelopment projects.

1.3.3 Considerations for Redevelopment Projects

The 2021 MS4 Permit, Provision VIII.F.b., provides the following considerations for redevelopment projects:

i. The structural BMP performance requirements of Provision VIII.F.4 are applicable to redevelopment Priority Development Projects, as follows:

   a. Where redevelopment results in an alteration to more than fifty (50%) percent of impervious surfaces of a previously existing development, the entire project must be mitigated.

   b. Where redevelopment results in an alteration of less than fifty (50%) percent of impervious surfaces of a previously existing development, only the alteration must be mitigated, and not the entire development.

ii. Redevelopment does not include routine maintenance activities that are conducted to maintain original line and grade, hydraulic capacity, original purpose of facility or emergency redevelopment activity required to protect public health and safety. Impervious surface replacement, such as the reconstruction of parking lots and roadways which does not disturb additional area and maintains the original grade and alignment, is considered a routine maintenance activity. Redevelopment does not include the repaving of existing roads to maintain the original line and grade or Americans with Disabilities Act (ADA) upgrade requirements, as long as the sidewalk, road, or parking lot repaving is not part of a larger project that meets the redevelopment thresholds.

1.3.4 Effective Date

When 2021 MS4 Permit Minimum Control Measures (MCMs) are effective, all projects or phases of projects where the project's applications, Master Plan, Specific Plan and/or development agreement have not been "deemed complete for processing", including projects with ministerial approval, by the applicable local permitting agency in accordance with the local permitting agency's applicable rules, and local agency projects for which the governing body or their designee has approved initiation of the project design prior to the effective dates of MCMs, must comply with the requirements of the 2021 MS4 Permit.

Projects for which the applications have been deemed "complete" and have worked with local permitting agency staff to develop a final, or substantially final, drainage concept and site layout that includes water quality treatment, based upon the performance criteria set forth in previous MS4 Permits prior to 2021 MS4 Permit MCMs becoming effective, are not required to redesign their proposed project for the purposes of complying with updated new development and redevelopment requirements. Each local permitting agency has the authority and discretion to make this determination based upon project timelines and submitted materials for review and approval.

2 STORMWATER MANAGEMENT STANDARDS

2.1 Introduction

This section outlines the design process to comply with stormwater control requirements. A flowchart is presented in Figure 2-1 to illustrate a step-by-step process for incorporating these stormwater management control measures.

The selection of appropriate stormwater management control measures should be a collaborative effort between the project proponent and the local permitting agency staff. It is recommended that discussions between project planners, engineers, and local permitting agency staff regarding selection of stormwater management control measures occur very early in the design process.

2.2 Step 1: Determine Project Applicability

New development and redevelopment projects meeting the applicability criteria contained in the 2021 MS4 Permit, Provision VIII.F [presented in Section 1.3] must include control measures specified in this 2025 TGM. These projects should be designed to meet the performance criteria described in the steps below.

The requirements specific for roadway projects are described in further detail in the substeps below. Projects that are not applicable are still subject to stormwater agency review, especially for flood drainage requirements. Stormwater management control measures may be required by the governing agency for non-priority projects, depending on the potential discharge of pollutants in stormwater runoff, impairments in receiving water, or other special conditions that would require increased protection.

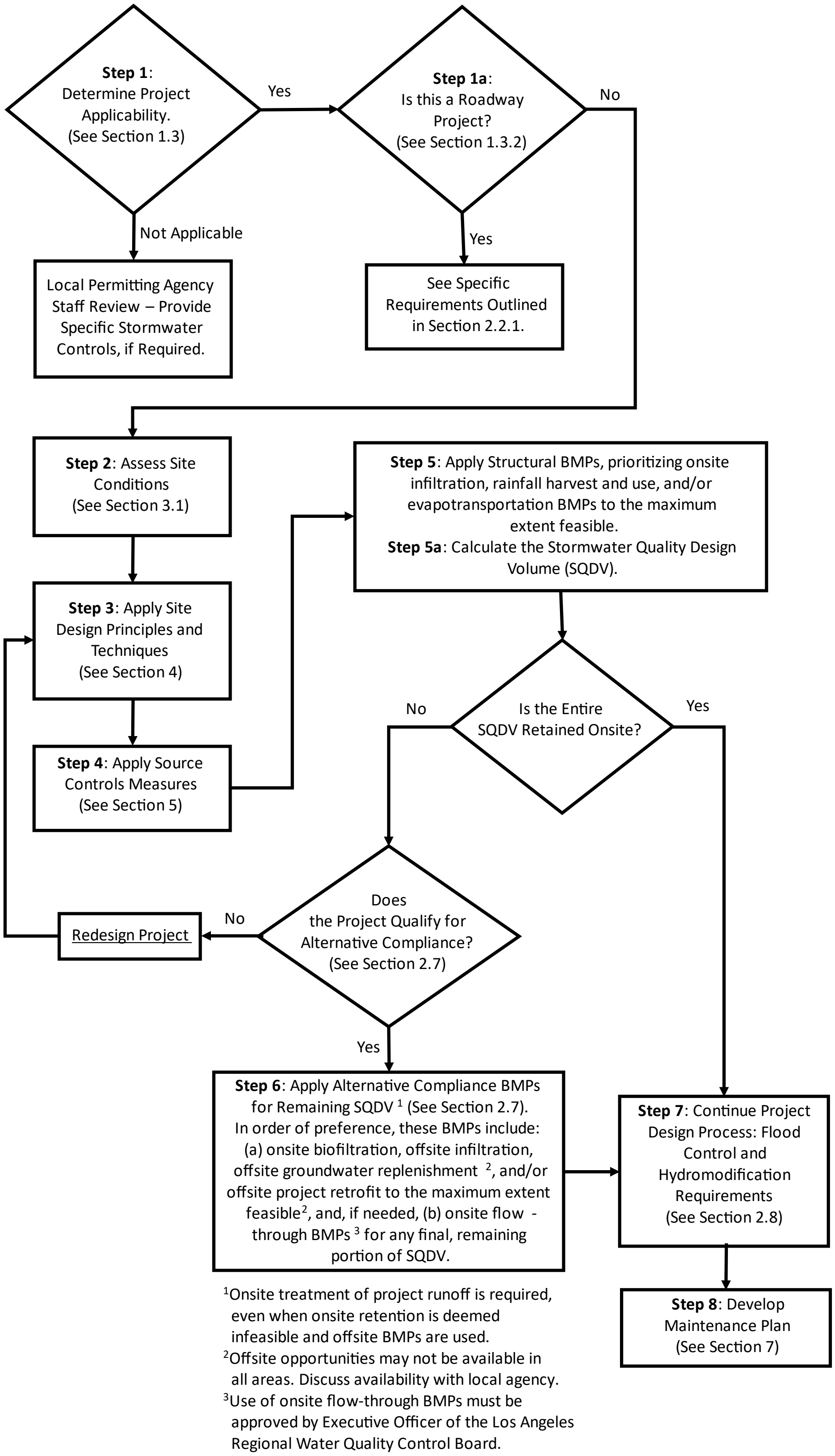


Figure 2-1: Stormwater Management Control Measures Design Decision Flowchart.

2.2.1 Step 1a: Roadway Projects

Roadway projects have specific requirements separate from other new development and redevelopment project categories. Standalone street and road construction projects of 10,000 square feet or more of impervious surface area shall follow U.S. EPA guidance on Managing Wet Weather with Green Infrastructure: Green Streets (December 2008 EPA-833-F-08-009) to the maximum extent practicable. Maximum extent practicable is subject to approval by the local permitting agency and is based upon site specific limitations.

Projects should apply the following measures to the maximum extent practicable and as specified in the local permitting agency's codes and approvals:

- Minimize street width to the appropriate minimum width for maintaining traffic flow and public safety;
- Use porous pavement or pavers for low traffic roadways, on-street parking, shoulders or sidewalks;
- Add tree canopy by planting or preserving trees and shrubs; and
- Add bump-out and sidewalk planters, bioretention curb extensions, sidewalk swales and other vegetated features.

2.3 Step 2: Assess Site Conditions

The next step is to collect site information that is critical for the selection and implementation of Retention BMPs and Biofiltration BMPs. The following information should be documented: topography, soil type and geology, groundwater, geotechnical considerations, offsite drainage, existing utilities, and Environmentally Sensitive Areas. It is imperative that soil analyses and infiltration testing be conducted as soon as possible to understand what soil conditions are present onsite. Detailed guidance on assessing site conditions can be found in Section 3.1.

2.4 Step 3: Apply Site Design Principles and Techniques

The third step is to apply Site Design Principles & Techniques (see Section 4). The implementation of LID requires an integrated approach to site design and stormwater management. It is imperative that planners, engineers, architects and landscape architects meet and discuss site design as early as possible during project development to meet 2021 MS4 Permit requirements. Traditional approaches to stormwater management planning within the site planning process are not likely to achieve the performance standard of the 2021 MS4 Permit. The use of the site planning techniques presented in Section 4 (Site Design Principles & Techniques) will help generate a more hydrologically functional site, maximize the effectiveness of Onsite Retention BMPs, and integrate stormwater management throughout the site.

The following criteria should be considered during the early site planning stages:

- Onsite Retention BMPs should be considered as early as possible in the site planning process. Hydrology should be a key principle that is integrated into the initial site assessment planning phases. Where flexibility exists, conceptual drainage plans should attempt to route water to areas suitable for Onsite Retention BMPs.
- A multidisciplinary approach at the initial phases of the project is recommended and should include planners, engineers, landscape architects, and architects.
- Individual Onsite Retention BMPs should be distributed throughout the project site as feasible and may influence the configuration of roads, buildings and other infrastructure.
- Flood and hydromodification control should be considered early in the design stages. Even sites with Onsite Retention BMPs will still have runoff that occurs during large storm events, but these facilities can have flood and hydromodification control benefits. It may be possible to simultaneously address flood and hydromodification control requirements through an integrated water resources management approach.

Perhaps the most important aspect of site planning is allowing sufficient space for post-construction stormwater treatment BMPs. A simple rule of thumb is to allow 3 to 10 percent of the tributary impervious area (depending on how well the soils drain, allowing for more area with less infiltrative soils) for infiltration BMPs and 3 to 5 percent for biofiltration in preliminary design. Not providing adequate space for post-construction stormwater treatment BMPs should not be used as justification for infeasibility and is at the discretion of local permitting agency.

2.5 Step 4: Apply Source Control Measures

All applicable projects ***must*** implement applicable Source Control Measures. Source Control Measures are operational practices that reduce potential pollutants at the source. They typically do not require maintenance or significant construction. Guidance on Source Control Measures can be found in Section 5.

2.6 Step 5: Apply Onsite Retention Best Management Practices

Provision VIII F.1.d of the 2021 MS4 Permit requires all Priority Development Projects to meet the Structural BMP Performance Requirements in the following order of preference:

i. Onsite infiltration, bioretention and/or rainfall harvest and use;

ii. If subpart i above is infeasible, onsite biofiltration, offsite groundwater replenishment, and/or offsite retrofit; or

iii. If subpart ii above is infeasible, onsite flow-based treatment, where all the above options are infeasible.

Alternative compliance using onsite biofiltration, offsite groundwater replenishment, offsite retrofits and/or onsite flow-based treatment are discussed in Step 6. Use of onsite flow-based treatment best management practices (BMPs) is at discretionary approval of the Executive Officer of the Los Angeles Regional Water Board. Flow-based devices shall be certified for “Enhanced Treatment” under the Washington State of Ecology’s Technology Assessment Protocol - Ecology (TAPE) Program; or an appropriate future BMP certification developed by the State of California. Flow-based devices include proprietary biofiltration BMPs.

2.6.1 Step 5a: Calculate the Volume to be Retained (SQDV)

The 2021 MS4 Permit requires Priority Development Projects to retain the Storm Water Quality Design Volume (SQDV) onsite. The SQDV is defined as the ***greater*** of the following:

a) The runoff from the 0.75-inch, 24-hour rain event; or

b) The runoff from the 85th percentile, 24-hour rain event.

The 85th percentile, 24-hour rain event can be found on the Ventura County Public Works Agency map viewer located at the following link: https://maps.ventura.org/pwagisviewer/. Select the “Map” tab along the top ribbon. Use the “Filter Layer” at the top of the layers list to search for applicable layers. For example, searching for "Rainfall 85th Percentile" will provide the 85th percentile, 24-hour rain event.

The runoff volume that is to be retained onsite should be calculated using Equation 2-1 below:

$$SQDV = 43{,}560 * C * (P/12) * A_{project} \quad \text{(Equation 2-1)}$$

Where:

SQDV = the stormwater quality design volume that must be retained onsite (cu-ft)

C = runoff composite coefficient for the project area (refer to Appendix C-1)

P = the design rainfall depth (in), either the 0.75-inch or the 85th percentile 24-hour rain event, whichever is greater for the project location. Refer to the *Ventura County 85th Percentile Rain Depths* Map in Appendix B-1.

$A_{project}$ = the project area (ac)

2.7 Step 6: Alternative Compliance

In instances of technical infeasibility or where a project has been determined to provide an opportunity to replenish regional ground water supplies at an offsite location within the same sub-watershed (HUC-12) as the new development or redevelopment project, the local permitting agency may allow projects to comply with the 2021 MS4 Permit using alternative compliance measures. The 2021 MS4 Permit (Provision VIII.F.4.b) prescribes very specific requirements for demonstrating technical infeasibility for allowing alternative compliance. These circumstances are detailed below.

2.7.1 Step 6a: Technical Infeasibility Demonstration

Technical infeasibility may be determined by the local permitting agency or demonstrated to the local permitting agency by the project applicant. If a project applicant is demonstrating technical infeasibility, the project applicant must demonstrate that the project cannot reliably retain 100 percent of the SQDV on-site, even with the maximum application of green roofs and/or rainwater harvest and use, and that compliance with the applicable postconstruction requirements would be technically infeasible by submitting a site-specific hydrologic and/or design analysis conducted and endorsed by a registered professional engineer, geologist, architect, and/or landscape architect.

Technical infeasibility may result from conditions including the following:

- The infiltration rate of saturated in-situ soils is less than 0.3 inch per hour (prior to applying the infiltration safety factor), and it is not technically feasible to amend the in-situ soils to attain an infiltration rate necessary to achieve reliable performance of infiltration or bioretention BMPs in retaining the SQDV on-site.
- Locations where seasonal high ground water is less than 5 feet from the bottom of the proposed infiltration basin.
- Locations within 100 feet of a groundwater well used for drinking water.
- Brownfield development sites where infiltration poses a risk of causing pollutant mobilization.

- Other locations where pollutant mobilization is a documented concern.[1]
- Locations with potential geotechnical hazards.
- Smart growth and infill or redevelopment locations where the density and/or nature of the project would create significant difficulty for compliance with the on-site volume retention requirement as determined by the local permitting agency.

2.7.2 Step 6b: Alternative Compliance Options Subject to Local Permitting Agency Approval

When a technical infeasibility demonstration has been made (Step 6a), the local permitting agency may approve use of the following alternative compliance options: onsite biofiltration or, subject to availability, offsite infiltration, groundwater replenishment, or offsite project retrofits. Each of these options is described in i-iv below.

In addition to the requirements listed below, all offsite mitigation and groundwater replenishment projects (ii through iv below), are required to provide treatment of stormwater runoff from the project site using flow-through treatment control BMPs that are certified for "Basic Treatment" under the Washington State Department of Ecology's TAPE Program, or an appropriate future BMP certification developed by the State of California. The sizing of the flow-through treatment device shall be based on a rainfall intensity of:

a) 0.2 inch per hour, or

b) The one year, one-hour rainfall intensity for the project location, *whichever is greater*. To determine the one year, one-hour rainfall for the project site, refer to the NOAA Atlas 14 Point Precipitation Frequency Estimates for California.

i. Onsite biofiltration BMPs. Biofiltration systems need to be designed per specifications in Sections 6.5.1 and 6.5.2 for BIO-1 (Biofiltration) and BIO-2 (Planter Box with Underdrain), respectively. Biofiltration must be sized for 1.5 times the portion of the SQDV that is not reliably retained onsite where Rv = volume reliably retained onsite and Bv is the biofiltration volume.

$$Bv = 1.5(SQDV - Rv) \qquad \text{(Equation 2-2)}$$

In addition, biofiltration systems discharging to water bodies impaired for nitrogen compounds or related effects shall be designed and maintained to achieve enhanced nitrogen removal capacity.

[1]Pollutant mobilization is considered a documented concern at or near properties that are contaminated or store hazardous substances underground.

ii. Offsite Infiltration. Projects may use infiltration or bioretention BMPs to intercept a volume of stormwater runoff equal to the SQDV, less the volume of stormwater runoff reliably retained onsite, at an approved offsite project located within the same subwatershed (HUC-12) as the Priority Development Project, and provide pollutant reduction (treatment) of the stormwater runoff discharged from the project site in accordance with the Water Quality Mitigation Criteria provided in the 2021 MS4 Permit. The required offsite mitigation volume (Mv) shall be calculated by the equation below, where Rv is the volume reliably retained onsite and Bv is the biofiltered volume, if applicable, calculated in Equation 2-2 above:

$$Mv = SQDV - Rv - Bv \qquad \text{(Equation 2-3)}$$

Offsite infiltration opportunities may not be available in all areas of Ventura County. The applicant shall contact the local permitting agency for questions regarding availability of these projects.

iii. Groundwater replenishment. Similarly to offsite infiltration projects, offsite groundwater replenishment opportunities may not be available in all areas of Ventura County. The applicant shall contact the local permitting agency for questions regarding availability of these projects.

In order to use groundwater replenishment at an offsite location, the project applicant shall demonstrate:

- Why it is not advantageous to replenish groundwater at the project site,
- That the offsite location is in the same subwatershed (HUC-12) as the Priority Development Project,
- That groundwater can be used for beneficial purposes at the offsite location, and
- That the alternative measures shall also provide equal or greater water quality benefits to the receiving surface water than the on-site retention of the SQDV.

iv. Off-site Project – Retrofit Existing Development. Project proponents may use infiltration, bioretention, rainfall harvest and use and/or biofiltration BMPs to retrofit an existing development, with similar land uses or land uses associated with comparable or higher stormwater runoff event mean concentrations (EMCs) than the project which did not fully retain the SQDV. Comparison of EMCs for different land uses shall be based on published data from studies performed in southern California.

The retrofit land shall be designed and constructed to intercept a volume of stormwater runoff equal to the mitigation volume (Mv) calculated using the Equation 2-3 above, except biofiltration BMPs shall be designed to meet the biofiltration volume (Bv) calculated using the Equation 2-2.

2.7.3 Step 6c: Alternative Compliance Options Subject to Regional Water Board Approval

If the local permitting agency concurs that onsite biofiltration and offsite alternative compliance measures are not technically feasible, the project applicant must prepare a technical report outlining the technical infeasibility and request the local permitting agency to submit to the Executive Officer of the Regional Water Board to request the use of onsite flow-based BMPs. In the request, the project applicant shall outline why none of the other alternative compliance measures are feasible. The project applicant must provide the local permitting agency with any and all documents that the Executive Officer will require to review the proposed use of onsite flow-based BMPs. Approval will only be granted to areas where other alternative compliance measures are not feasible due to significant technical issues associated with soils contamination and geotechnical hazards and cannot be solely justified based upon building massing and desired densities.

If approved, the project may utilize flow-through BMPs described in Sections 6.6.1 through 6.6.3 (FLO-1 through FLO-3) for onsite treatment. The BMPs must treat runoff leaving the site and mitigate for the design capture volume not reliably retained onsite. Flow-through treatment control BMPs must be sized and designed to:

a. Filter or treat either:

    1. The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or

    2. The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity (for each hour of a storm event), as determined from the local historical rainfall record, *multiplied by a factor of two*;

b. Be certified for “Enhanced Treatment” under the Washington State Department of Ecology’s TAPE Program; or an appropriate future BMP certification developed by the State of California.

Instructions for calculating the SQDF for flow-based BMPs are provided in Appendix C-1 (see Equation C-3).

2.8 Step 7: Continue Project Design Process: Flood Control and Hydromodification Requirements

The Project applicant should continue with the design process to address additional requirements including flood control and hydromodification control criteria.

2.8.1 Step 7a: Flood Control Requirements

Applicants shall comply with Ventura County and local approval agency regulations on floodplain and floodway management, including the Ventura County Hydrology Manual.

2.8.2 Step 7b: Hydromodification (Flow/Volume/Duration) Control Criteria

Priority Development Projects disturbing land areas of 50 acres or greater are required to implement hydrologic control measures to prevent accelerated erosion and to protect stream habitat in downstream natural drainage systems.

Exemptions

The following new development and redevelopment projects are exempt from the hydromodification control criteria:

1) Projects that are replacement, maintenance or repair of a local agency's existing flood control facility, storm drain, or transportation network.

2) Redevelopment Projects in the Urban Core that do not increase the effective impervious area or decrease the infiltration capacity of pervious areas compared to the pre-project conditions.

3) Projects that have any increased discharge directly or via a storm drain to a sump, lake, area under tidal influence, into a waterway that has a 100-year peak flow (Q100) of 25,000 cubic feet per second (cfs) or more, or other receiving water that is not susceptible to hydromodification impacts.

4) Projects that discharge directly or via a storm drain into concrete or otherwise engineered (not natural) channels (e.g., channelized or armored with rip rap, shotcrete, etc.), which, in turn, discharge into receiving water that is not susceptible to hydromodification impacts.

2.8.2.1 Hydromodification Control Measures

The purpose of Hydromodification Control Measures is to minimize changes in post-development stormwater runoff discharge rates, velocities, and durations by maintaining within a certain tolerance, the project's pre-project stormwater runoff flow rates and durations.

Hydromodification requirements are described in the Ventura County Hydromodification Control Plan (HCP) for all projects disturbing an area greater than 1 acre within natural drainage systems. The HCP was developed with the objective of minimizing hydromodification impacts associated with applicable future new development and redevelopment in Ventura County. Until the Ventura County HCP becomes effective, the Interim Hydromodification Control Criteria, described below, apply to applicable, non-exempt new development and redevelopment projects.

2.8.2.2 Interim Hydromodification Control Criteria

1) Projects of all sizes shall comply with local stormwater detention requirements imposed by the local agency having authority.

2) Unless local flood control requirements govern, projects disturbing less than 50 acres must comply with the Stormwater Management Standards contained in this TGM (i.e., implement onsite retention BMPs).

3) Unless local flood control requirements govern, projects disturbing 50 acres or greater must develop and implement a Hydromodification Analysis Study (HAS) that demonstrates one of the following conditions:

   a. The site infiltrates onsite the runoff from a 2-year, 24-hour storm event; or

   b. The runoff flow rate, volume, velocity, and duration for the post-development condition does not exceed the pre-development condition for the 2-year, 24-hour storm event. These conditions must be substantiated by hydrologic modeling acceptable to the Los Angeles Water Board Executive Officer; or

   c. The Erosion Potential (Ep) in the receiving water is approximately 1. The methodology for calculating Erosion Potential is provided in Provision VIII.F.2.c.ii.(c) of the 2021 MS4 Permit.

Project proponents must work with their local permitting authority to ensure that the HAS is correctly prepared.

2.9 Step 8: Develop Maintenance Plan

The Ventura Countywide Stormwater Quality Management Program (Program) requires the submittal of a Maintenance Plan and execution of a Maintenance Agreement with the owner/operator of any stormwater control. Maintenance Plans must include guidelines for how and when inspection and maintenance should occur for each control. Section 7 and Appendix D provide additional information and guidance on compliance with maintenance requirements.

3 SITE ASSESSMENT AND BMP SELECTION

3.1 Assessing Site Conditions and Other Constraints

Assessing a site's potential for implementation of retention BMPs, biofiltration BMPs, and treatment control measures requires both the review of existing information and the collection of site-specific measurements. Available information regarding site layout and slope, soil type, local groundwater conditions, geotechnical conditions, managing offsite drainage, existing utilities, and environmentally sensitive areas should be reviewed as discussed below. In addition, soil and infiltration testing should be conducted to determine if stormwater infiltration is feasible and to determine the appropriate design percolation rates for infiltration-based treatment BMPs.

3.1.1 Site Layout and Slope Considerations

The site's topography should be assessed to evaluate surface drainage and topographic high and low points, as well as to identify the presence of steep slopes that qualify as hillside locations. Use the information to assess what type of retention BMPs, biofiltration BMPs, and treatment control measures will be most beneficial for a given project site, considering the following factors:

- Stormwater infiltration is more effective on level or gently sloping sites.
- Flows on slopes steeper than 15% may runoff as surface flows, rather than infiltrate into the ground. Infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.
- On hillsides, infiltrated runoff may daylight or resurface a short distance downslope, which could cause slope instability depending on the soil or geologic conditions. See the Geotechnical Considerations section below.

3.1.2 Soil Type and Geology Considerations

The site's soil types and geologic conditions should be determined to preliminarily evaluate the site's ability to infiltrate stormwater and to identify suitable, as well as unsuitable, locations for infiltration-based BMPs (e.g., infiltration basins and trenches, bioretention without an underdrain, permeable pavement, and drywells). Soils should have sufficient organic content and sorption capacity to remove certain pollutants, but must be coarse enough to infiltrate runoff in a reasonable amount of time (e.g., < 72 hours for above-ground ponded water to prevent vector breeding).

Using the Soil Survey from the Natural Resource Conservation Service (NRCS) of the U. S. Department of Agriculture, soils in Ventura County were grouped into seven hydrologically homogeneous families [see Ventura County Hydrology Manual (2017); also see Appendix

B]. Preliminary assessment of the suitability for infiltration-based BMPs can be determined as follows:

- Infiltration-based BMPs are likely feasible in areas mapped with Ventura County Soil Numbers 4 through 7.
- Infiltration-based BMPs may be infeasible in Ventura County Soil Numbers 1-3. Local permitting agency will approve infiltration infeasibility and may require infiltration testing to justify infeasibility.

All sites that are considering infiltration-based BMPs require infiltration testing unless it is technically infeasible to retain or infiltrate due to contamination or documented high groundwater table (see Section 3.2 Technical Infeasibility Screening). Guidance for conducting infiltration tests is available in the Los Angeles County Public Works Guidelines for Geotechnical Investigation and Reporting Low Impact Development Stormwater Infiltration (June 30, 2021, and subsequent versions). Soils with infiltration rates of 0.3 in/hr (before applying the reduction factor) or greater are considered feasible for infiltration.

3.1.3 Groundwater Considerations

Site groundwater conditions should be considered prior to BMP siting, selection, sizing, and design. For each site, identify the depth to groundwater, areas of known groundwater pollution, and areas with natural sources of pollutants.

Depth to seasonal high groundwater level shall be estimated as the average of the annual minima (i.e., the shallowest recorded measurements in each water year, defined as October 1 through September 30) for all years on record. If groundwater level data are not available or not considered to be representative, seasonal high groundwater depth can be determined by redoximorphic analytical methods combined with temporary groundwater monitoring for November 1 through April 1 at the proposed project site. Five feet of separation from the proposed BMP invert to the seasonal high ground water level and mounded groundwater level is required.

Due to the risk of groundwater contamination from infiltration BMPs, adequate spacing (100 feet or more) must be provided between these BMPs and potable wells. To minimize the risk of groundwater contamination, infiltration BMPs should not be placed at or near service/gas stations, truck stops, car washes, nurseries, or other areas with pollutant sources that could pose a high threat to water quality, as determined by local permitting agency staff. Infiltration BMPs may be placed in high-risk areas if a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas have little chance of spill migration.

Prior to the use of infiltration BMPs, consult with the local permitting agency to identify if vulnerable unconfined aquifers are located beneath the project to determine the appropriateness of these BMPs.

Infiltration is not allowed in locations with contaminated soils or groundwater where the pollutant(s) could be mobilized as a result of infiltration. Areas with known groundwater pollution include sites listed by the Los Angeles Regional Water Quality Control Board's Leaking Underground Storage Tanks (LUST) program and Site Cleanup Program (SCP). The California State Water Resources Control Board maintains a database of registered contaminated sites through their 'Geotracker' Program. Registered contaminated sites can be identified in the project vicinity when the site address is typed into the "map cleanup sites" field.

Mobilization of groundwater contaminants may also be of concern where contamination from natural sources is prevalent (e.g., marine sediments, selenium rich groundwater, to the extent that data is available). The project applicant shall contact the local permitting agency if contamination from natural sources is suspected at the project site.

Infiltration on sites with contaminated soils or groundwater that could be mobilized or exacerbated by infiltration is not allowed, unless a site-specific analysis determines the infiltration would be beneficial. A site-specific analysis may be conducted where groundwater pollutant mobilization is a concern to allow for infiltration-based BMPs.

3.1.4 Geotechnical Considerations

Water infiltration can cause geotechnical issues, including: (1) settlement through collapsible soil, (2) expansive soil movement, (3) slope instability, and (4) increased liquefaction hazard. Stormwater infiltration temporarily raises the groundwater level near the infiltration facility, such that the potential geotechnical conditions are likely to be of greatest significance near the infiltration area and decrease with distance. A geotechnical investigation should be performed for the infiltration facility to identify potential geotechnical issues and geological hazards that may result from infiltration.

In general, infiltration-based BMPs must be set back from building foundations or steep slopes. The required setback from building foundations is at least ten feet, or as established by the geotechnical expert for the project. Increased water pressure in soil pores reduces soil strength. Decreased soil strength can make foundations more susceptible to settlement and slopes more susceptible to failure. Recommendations for each site should be determined by a licensed geotechnical engineer based on soils boring data, drainage patterns, and the current requirements for stormwater treatment. Implementing the geotechnical engineer's requirements is essential to prevent damage from increased subsurface water pressure on surrounding properties, public infrastructure, sloped banks, and even mudslides.

3.1.4.1 Collapsible Soil

It is important to evaluate the potential for hydrocollapse during the geotechnical investigation. The magnitude of hydrocollapse depends on how thick the soil is where infiltration is occurring. In most instances, the magnitude of hydrocollapse will be small, but the geotechnical engineer should check if hydrocollapse might affect nearby structures and roadways.

To check, put markers around the infiltration site, on roads nearby, and in nearby areas to see if hydrocollapse happens. The markers should be checked before infiltration starts, every month for the first year, and then once a year for about five years after that.

3.1.4.2 Expansive Soil

Expansive soil is generally defined as soil or rock material that has a potential for shrinking or swelling under changing moisture conditions. The effects of expansive soil movement (swelling and shrinking) will be greatest on near surface structures such as shallow foundations, roadways, and concrete walks. Basements or below-grade parking structures can also be affected as additional loads are applied to the basement walls from the large swelling pressures generated by soil expansion. A geotechnical investigation should identify if expandable materials are present near the proposed infiltration facility, and if they are, evaluate if the infiltration will result in wetting of these materials. See Appendix B (expansive soil potential map).

3.1.4.3 Slopes

Slope stability can be impacted by infiltration facilities. A groundwater mounding analysis should be performed to evaluate the rise in groundwater around the facility. If the computed rise in groundwater approaches nearby slopes, then a separate slope stability evaluation should be performed to evaluate the implications of the temporary groundwater level rise. The geotechnical and groundwater mounding evaluations should identify the duration of the elevated groundwater and assign factors of safety consistent with the duration (e.g., temporary or long-term conditions).

3.1.4.4 Liquefaction

Saturation of the subsurface soils above the existing groundwater table may occur as a result of stormwater infiltration, increasing the possibility of soil liquefaction. The groundwater mounding analysis should also evaluate the duration of mounding, as a lengthy duration or long-term rise in groundwater will need to be considered in the evaluation of liquefaction. If the granular soils are sufficiently dense, it is unlikely that liquefaction will be of concern, regardless of the groundwater mounding. If analyses indicate that the potential for liquefaction may be increased from stormwater infiltration, then the analyses will need to evaluate the liquefaction-induced settlement of structures, lateral spreading, and other surface manifestations. See Appendix B (liquefaction potential map).

3.1.5 Managing Offsite Drainage

Locations and sources of offsite run-on onto the site should be identified early in the design process. Offsite drainage should be considered when determining appropriate BMPs so that drainage can be managed. Concentrated flows from offsite drainage may cause extensive erosion, if not properly conveyed through or around the project site or otherwise managed. By identifying the locations and sources of offsite drainage, the volume of water running onto the site may be estimated and factored into the siting and sizing of onsite BMPs.

Vegetated swales or storm drains may be used to intercept, divert, and convey offsite drainage through or around a site to prevent flooding or erosion that might otherwise occur.

3.1.6 Existing Utilities

Existing utility lines that are onsite will limit the possible locations of certain BMPs. For example, infiltration BMPs should not be located near utility lines where the increased amount of water could damage the utilities. Stormwater should be directed away from existing underground utilities. Project designs that require the relocation of existing utilities should be avoided, if possible.

3.1.7 Environmentally Sensitive Areas

The presence of Environmentally Sensitive Areas (ESAs) may limit the siting of certain BMPs. ESAs are typically delineated by and fall under the regulatory oversight of state or federal agencies such as the U.S. Army Corp of Engineers (USACE), California Department of Fish and Wildlife (formerly known as the California Department of Fish and Game), U.S. Fish and Wildlife Service, or the California Environmental Protection Agency. BMPs should be selected and sited to avoid adversely affecting an ESA. The Ventura County ESA map (ESA as defined in Order R4-2010-0108) is provided in Appendix B or may be obtained from the local permitting authority.

3.2 Technical Infeasibility Screening

To use biofiltration BMPs and alternative compliance measures, the project applicant should demonstrate that compliance with the requirement to implement Retention BMPs is technically infeasible by submitting a site-specific hydrologic and/or design analysis conducted and endorsed by a registered professional engineer and/or geologist. Projects seeking to use alternative compliance measures must demonstrate that stormwater runoff has been retained or infiltrated onsite to the maximum extent practicable. As described in Section 2.7: Step 6: Alternative Compliance, technical infeasibility may be determined by the local permitting agency or demonstrated by the project applicant.

For Smart Growth projects, technical infeasibility may result where the density and/or nature of the project would create significant difficulty for compliance with the requirement. Smart Growth projects, which are defined as new development and redevelopment projects that occur within existing urban areas and designated by the local agency are typically designed to achieve the majority of the following principles:

i. Create a range of housing opportunities and choices;

ii. Create walkable neighborhoods;

iii. Mix land uses;

iv. Preserve open space, natural beauty, and critical areas;

1. Farmland preservation may also be considered for projects occurring outside existing urban areas (as defined by the Appendix B maps).

v. Provide a variety of transportation choices;

vi. Includes transit-oriented development (development located within an average 2,000-foot walk to a bus or train station).

vii. Strengthen and direct development towards existing communities (as defined by Appendix B maps); and

viii. Take advantage of compact building design.

4) The City or County Planning Division in which a project is proposed will ultimately determine whether a project meets these Smart Growth criteria and are allowable to utilize alternative compliance. For most projects, failure to designate sufficient site area to accommodate BMPs is generally not an acceptable justification for alternative compliance.

Table 3-1 provides recommended minimum percentages of a site that are feasible to be dedicated to biofiltration BMPs by project type. If the project has not provided these portions of the project site for siting biofiltration BMPs, an attempt should be made to improve site design to provide more area until it is either infeasible to provide more area or design requirements are met. The criteria provided in Table 3-1 are guidance; each project will be individually evaluated by the local permitting authority to determine if good site practices have been integrated into the project to provide the maximum pervious area feasible for siting biofiltration BMPs. Note that in cases where subsurface BMPs are used, the dedicated BMP area may have other surface land uses which do not structurally impact the subsurface BMP (see INF-6: Proprietary Infiltration)

Table 3-1: Recommended Criteria for Percent of Site Feasible to Dedicate to Biofiltration BMPs

Project Type		Percent of Site
New Development	SF/MF Residential < 7 du/ac	10
	SF/MF Residential 7 – 18 du/ac	7
	SF/MF Residential > 18 du/ac	5
	Mixed Use, Commercial, Institutional/Industrial w/ FAR < 1.0	10
	Mixed Use, Commercial, Institutional/Industrial w/ FAR 1.0 – 2.0	7
	Mixed Use, Commercial, Institutional/Industrial w/ FAR > 2.0	5
	Podium (parking under > 75% of project)	3
	Projects with zoning allowing development to lot lines	2
	Transit Oriented Development	5
	Parking	5
Redevelopment	SF/MF Residential < 7 du/ac	5
	SF/MF Residential 7 – 18 du/ac	4
	SF/MF Residential > 18 du/ac	3
	Mixed Use, Commercial, Institutional/Industrial w/ FAR < 1.0	5
	Mixed Use, Commercial, Institutional/Industrial w/ FAR 1.0 – 2.0	4
	Mixed Use, Commercial, Institutional/Industrial w/ FAR > 2.0	3
	Podium (parking under > 75% of project)	2
	Projects with zoning allowing development to lot lines	1
	Transit Oriented Development	3
	Projects in Historic Districts	3

Key: SF = Single Family, MF = Multi Family, du/ac = dwelling units per acre, FAR = Floor Area Ratio = ratio of gross floor area of building to gross lot area.

4 SITE DESIGN PRINCIPLES AND TECHNIQUES

4.1 Introduction

Stormwater design needs to be incorporated into site design as early as possible, such as the discretionary permitting phase of the project. The Site Design Principles and Techniques described in this section are required to be considered for all new development and redevelopment projects subject to conditioning and approval for the design and implementation of post-construction stormwater management control measures (as defined in Section 1.3). The applicability of specific controls outlined within this section should be confirmed with the local government.

Site Design Principles and Techniques include the following design features and considerations:

- Site planning,
- Protect and restore natural areas,
- Minimize land disturbance,
- Minimize impervious cover,
- Apply Low Impact Development best management practices (LID BMPs) at various scales, and
- Implement Integrated Water Resource Management Practices.

Detailed descriptions and design criteria for each of the Site Design Principles and Techniques are presented in the following section.

4.2 Site Planning

4.2.1 Purpose

LID requires a holistic approach to site design and stormwater management. *The use of site planning techniques presented here will generate a more hydrologically functional site, help to maximize the effectiveness of Retention BMPs, and integrate stormwater management throughout the site.*

4.2.2 Design Criteria

The following criteria should be considered during the early site planning stages:

1) Retention BMPs should be considered as early as possible in the site planning process.

2) Project applicants should plan for space requirements of Retention and Biofiltration BMPs as generally summarized in Table 4-1.

Table 4-1: Rule of Thumb Space Requirements for BMPs[2]

BMP Type	% of Contributing Drainage Area
Infiltration	3 to 10
Rainwater Harvesting (Cistern)	0 to 10
Evapotranspiration (Green Roof)	1 to 1 ratio of impervious cover treated
Biofiltration	3 to 5
Dry Extended Detention Basin	1 to 3
Wet Detention Basin	1 to 3
Cartridge Media Filter	0 to 5

3) Site planning should use a multidisciplinary approach that includes planners, engineers, landscape architects, and architects at the initial phases of the project.

4) Individual Retention BMPs should be distributed throughout the project site and may influence the configuration of roads, buildings, and other infrastructure.

5) Consider flood control early in the design stages.

6) Avoid the use of roofing, gutters, and trim made of copper and galvanized (zinc) roofs, gutters, chain link fences and siding.

7) Consider the latest Green Building Code requirements during the site planning stages.

4.3 Protect and Restore Natural Areas

4.3.1 Purpose

Sensitive areas that should be protected and/or restored include streams and their buffers, floodplains, wetlands, steep slopes, and high permeability soils. Locating development on the least sensitive portion of a site and conserving naturally vegetated areas can minimize environmental impacts and stormwater runoff.

4.3.2 Design Criteria

The following site design features or elements are required and should be included in the project site layout, if feasible:

[2] Modified from Schueler, T., D. Hirschman, M. Novotney, and J. Zielinski. 2007. Urban Stormwater Retrofit Practices. Manual 3 in the Urban Subwatershed Restoration Manual Series. Center for Watershed Protection. Ellicott City, MD.

1) Identify and cordon off streams and their buffers, floodplains, wetlands, and steep slopes.

2) Reserve areas with high permeability soils for either open space or Infiltration BMPs.

3) Incorporate existing trees into site layout.

4) Identify areas that may be restored or revegetated either during or post-construction.

5) Identify and avoid and/or stabilize areas susceptible to erosion and sediment loss.

6) Concentrate or cluster development on the least-sensitive portions of a site, while leaving the remaining land in a natural undisturbed state.

7) Slopes must be protected from erosion by safely conveying runoff from the tops of slopes.

8) Limit clearing and grading of native vegetation at the project site to the minimum amount needed to build lots, allow access, and provide fire protection.

9) Maintain existing topography and existing drainage divides to encourage dispersed flow.

10) Maximize trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native and/or drought-tolerant plants.

11) Promote natural vegetation by using parking lot islands and other landscaped areas. Integrate vegetated BMPs within parking lot islands and landscaped areas.

4.4 Minimize Land Disturbance

4.4.1 Purpose

By designing a site layout to preserve the natural hydrology and drainageways on the site, it reduces the need for grading the disturbance of vegetation and soils (GSMM, 2001). By siting buildings and impervious surfaces away from steep slopes, drainageways, and floodplains, it limits the amount of grading, clearing and distance and reduces the hydrologic impact.

4.4.2 Design Criteria

1) Delineate and flag the development envelope for the site. Concentrate buildings and paved areas on the least permeable soils, with the least intact habitats.

2) Plan clearing and grading to minimize the compaction of infiltrative soils.

3) Restrict equipment access and storage of construction equipment to the development envelope.

4) Restrict storage of construction equipment within the development envelope.

5) Avoid the removal of existing trees and valuable vegetation, as feasible.

6) Consider soil amendments to restore permeability and organic content especially for infill and redevelopment projects to avoid soil disturbance.

4.5 Minimize Impervious Cover

4.5.1 Purpose

Minimizing impervious area through site design is an important means of minimizing stormwater pollutants of concern. In addition to the environmental and aesthetic benefits, a highly pervious site may allow reduction in the size of downstream conveyance and treatment systems, yielding savings in development costs.

4.5.2 Design Criteria

Suggested strategies for minimizing impervious surfaces through site design include the following:

1) Use minimum allowable roadway cross sections, driveway lengths, and parking stall widths and lengths.

2) Minimize or eliminate the use of curbs and gutters, and maximize the use of Retention BMPs, where slope and density permit.

3) Use two-track/ribbon alleyways/driveways or shared driveways.

4) Include landscape islands in cul-de-sac streets. Consider alternatives to cul-de-sacs to increase connectivity.

5) Reduce the footprints of building and parking lots. Building footprints may be reduced by building taller.

6) Use permeable pavement to accommodate overflow parking (if overflow parking is needed).

7) Cluster buildings and paved areas to maximize pervious area.

8) Maximize tree preservation or tree planting.

9) Avoid compacting or paving over soils with high infiltration rates (see Minimize Land Disturbance).

10) Use pervious pavement materials where appropriate, such as modular paving blocks, turf blocks, porous concrete and asphalt, brick, and gravel or cobbles.

11) Use grass-lined channels or surface swales to convey runoff instead of paved gutters (see BIO-3: Vegetated Swale).

12) Build more compactly in infill and redevelopment site to avoid disturbing natural and agricultural lands. Per capita impacts can be significantly reduced by building more compactly in infill and redevelopment areas.

4.6 Apply LID at Various Scales

4.6.1 Purpose

To realize the full benefits of water quality protection and runoff volume reduction, LID should be planned at the regional and watershed scale and the site scale.

4.6.2 Design Criteria

4.6.2.1 Regional/Watershed

The following design criteria should be considered at the regional/watershed level:

1) Consider Development Density,
2) Identify and Preserve Contiguous Open Space,
3) Make use of Previously Developed Sites, and
4) Locate Compact Development within Close Proximity to Mass Transit.

4.6.2.2 Site

The following design criteria should be considered at the site level:

1) Maintain and Restore Natural Flowpaths for Runoff,
2) Maximize Use of Existing Impervious Cover,
3) Design Public Spaces and Common Areas to Minimize Stormwater Runoff,
4) Compact Project Design, and
5) Encourage Use of Multiple Modes of Transportation.

4.7 Implement Integrated Water Resource Management Practices

4.7.1 Purpose

Integrated Water Resource Management (IWRM) is a process which promotes the coordinated development and management of water, land, and related resources. The Permit promotes the use of IWRM to help guide the selection of BMPs. Many of the concepts of IWRM are documented in the County's IRWM Plan (IRWMP).

4.7.2 Design Criteria

The goals of the 2025 TGM and the new development and redevelopment requirements contained within the Permit, complement the goals of the IRWMP. Development projects should strive to select BMPs that meet the following multiple objectives (Watershed Coalition of Ventura County, 2019):

1) Conserve and Augment Water Supplies,

2) Protect People, Property and the Environment from Adverse Flooding Impacts,

3) Protect and Restore Habitat and Ecosystems in Watersheds, and

4) Provide Water-related Recreational, Public Access and Educational Opportunities.

5 SOURCE CONTROL MEASURES

5.1 Introduction

Source Control Measures are low-technology practices designed to prevent pollutants from contacting stormwater runoff and prevent discharge of contaminated runoff to the storm drainage system.

This section describes structural-type Source Control Measures for specific types of sites or activities that have been identified as potential significant sources of pollutants in stormwater. Each of the measures specified in this section should be implemented in conjunction with appropriate non-structural Source Control Measures to optimize pollution prevention. Non-structural type Source Control Measures; such as good housekeeping and employee training, are not included in the 2025 TGM. The project applicant can consult the California Industrial Best Management Practice Manual for this type of practice (SWQTF, 1993). The governing stormwater agency may require additional Source Control Measures not included in the 2025 TGM for specific pollutants, activities, or land uses.

It is important to note that though parking lot design needs to incorporate source control measures, these projects are not covered in this section. Requirements for proper design of parking lots are covered by requirements for General Site Design Principles and Techniques (see Section 4) and Treatment Control Measures (see Section 6).

Some of the measures presented in this section require connection to the sanitary sewer system. It is prohibited to connect and discharge to the sanitary sewer system without prior approval or obtaining the required permits. Contact staff of the local permitting agency about obtaining sanitary sewer permits within Ventura County. Discharges of certain types of flows to the sanitary sewer system may be cost prohibitive. The designer is urged to contact the appropriate agency prior to completing site and equipment design of the facility.

5.2 Description

Table 5-1 summarizes site-specific Source Control Measures and associated design features specified for various sites and activities. Fact Sheets are presented in this section for each source control measure. These sheets include design criteria established by the local permitting agencies to ensure effective implementation of the required Source Control Measures:

Table 5-1: Summary of Site-Specific Source Control Measure Design Features

Site-Specific Source Control Measure [1]	DESIGN FEATURE OR ELEMENT						
	Signs, placards, stencils	Surfacing (compatible, impervious)	Covers, screens	Grading/berming to prevent run-on	Grading/berming to provide secondary containment	Sanitary sewer connection	Emergency Storm Drain Seal
Storm Drain Message and Signage (S-1)	X						
Outdoor Material Storage Area Design (S-2)		X	X	X	X		X
Outdoor Trash Storage and Waste Handling Area Design (S-3)		X	X	X		X	
Outdoor Loading/Unloading Dock Area Design (S-4)		X	X	X	X		
Outdoor Repair/Maintenance Bay Design (S-5)		X	X	X	X		X
Outdoor Vehicle/Equipment/ Accessory Washing Area Design (S-6)		X	X	X	X	X	X
Fueling Area Design (S-7)		X	X	X	X		X
Parking Lot Design [2]							

1 Refer to Fact Sheets in Section 6 for detailed information and design criteria and Appendix C for BMP sizing worksheets

2 Requirements for proper design of parking lots are covered by requirements for General Site Design Principles and Techniques (see Section 4) and Treatment Control Measures (see Section 6).

5.3 Site-Specific Source Control Measures

5.3.1 S-1: Storm Drain Message and Signage

5.3.1.1 Purpose

Waste materials dumped into storm drain inlets can have severe impacts on receiving and ground waters. Posting notices regarding discharge prohibitions at storm drain inlets can deter waste dumping. This Fact Sheet contains details on the installation of storm drain messages at storm drain inlets located in new or redeveloped commercial, industrial, and residential sites.

5.3.1.2 Design Criteria

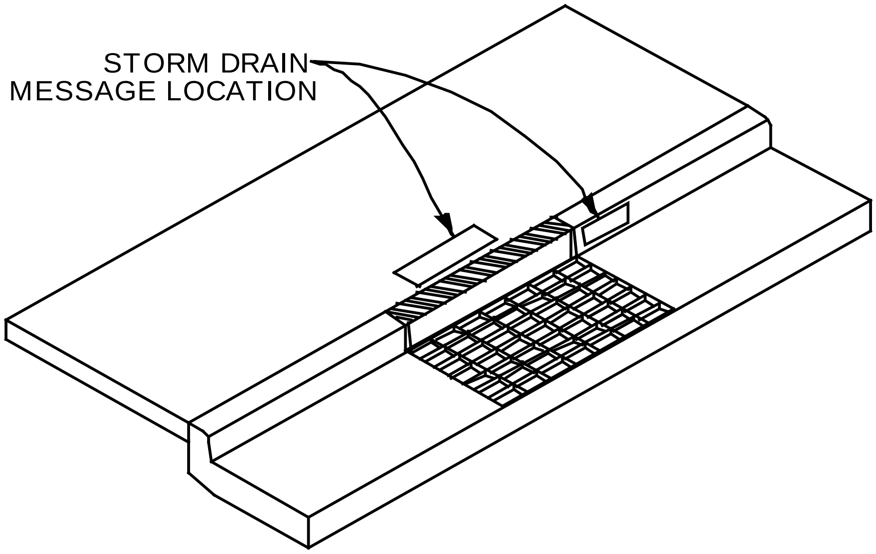
Storm drain messages have become a popular method of alerting the public to the effects of and the prohibitions against waste disposal into the storm drain system. The signs are typically stenciled or affixed near the storm drain inlet. The message simply informs the public that dumping of wastes into storm drain inlets is prohibited and/or the drain discharges to a receiving water.

Storm drain message markers or placards are required at all storm drain inlets within the boundary of the development project. The marker should be placed in clear sight facing anyone approaching the inlet from either side (see Figure 5-1). All storm drain inlet locations must be identified on the development site map.

Some local agencies within the County have approved storm drain message placards for use. Signs with language and/or graphical icons, which prohibit illegal dumping, should be posted at designated public access points along channels and streams within a project area. Consult local permitting agency stormwater staff to determine specific requirements for placard types and installation methods.

5.3.1.3 Maintenance Requirements

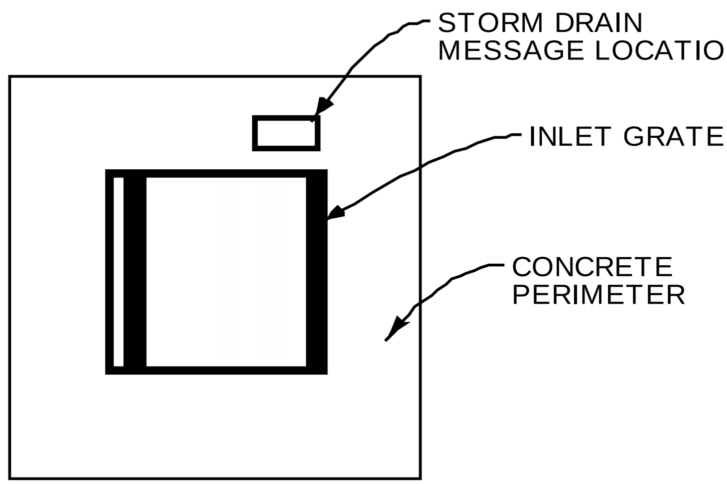
Legibility of markers and signs should be maintained. If required by the agency with jurisdiction over the project, the owner/operator or homeowner's association shall enter into a Maintenance Agreement with the agency or record a deed restriction upon the property title to maintain the legibility of placards and signs.



CURB TYPE INLET

NOTES:

1. **STORM DRAIN MESSAGE SHALL BE APPLIED IN SUCH A WAY AS TO PROVIDE A CLEAR, LEGIBLE IMAGE.**
2. **STORM DRAIN MESSAGE SHALL BE PERMANENTLY APPLIED DURING THE CONSTRUCTION OF THE CURB AND GUTTER USING A METHOD APPROVED BY THE LOCAL AGENCY.**



AREA TYPE INLET

Figure 5-1: Storm Drain Message Location

5.3.2 S-2: Outdoor Material Storage Area Design

5.3.2.1 Purpose

Materials that are stored outdoors could become sources of pollutants in stormwater runoff if not handled or stored properly. Materials could be in the form of raw products, by-products, finished products, and waste products. The type of pollutants associated with the materials will vary depending on the type of commercial or industrial activity.

Some materials are more of a concern than others. Toxic and hazardous materials must be prevented from coming in contact with stormwater. Non-toxic or non-hazardous materials do not have to be prevented from stormwater contact but cannot be allowed to runoff with the stormwater. These materials may have toxic effects on receiving waters. Accumulated material on an impervious surface could result in significant debris and sediment being discharged with stormwater runoff causing a significant impact on the rivers or streams that receive the runoff.

Materials may be stored in a variety of ways, including bulk piles, containers, shelving, stacking, and tanks. Stormwater contamination may be prevented by eliminating the possibility of stormwater contact with the material storage areas through a combination of diversion, cover, and/or capture of the stormwater. Control measures may also include minimizing the storage area. Control measures are site-specific and must meet local permitting agency requirements.

5.3.2.2 Design Criteria

Design requirements for material storage areas are governed by Building and Fire Codes and by current City or County ordinances and zoning requirements. Source Control Measures described in the Fact Sheet are intended to enhance and be consistent with these code and ordinance requirements. The following design features should be incorporated into the design of a material storage area when storing materials outside could contribute significant pollutants to the storm drain.

Table 5-2: Design Criteria for Outdoor Material Storage Area Design

Source Control Design Feature	Design Criteria
Surfacing	• Construct the storage area base with a material impervious to leaks and spills.
Covers	• Install a cover that extends beyond the storage area, or use a manufactured storage shed for small containers.
Grading/Containment	• Minimize the storage area. • Slope the storage area towards a dead-end sump to contain spills. • Grade or berm storage areas to prevent run-on from surrounding areas. • Direct runoff from downspouts/roofs away from storage areas.

5.3.2.3 Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

5.3.3 S-3: Outdoor Trash Storage Area Design

5.3.3.1 Purpose

Stormwater runoff from areas where trash is stored or disposed of can be polluted. In addition, loose trash and debris can be easily transported by water or wind into nearby storm drain inlets, channels, and/or creeks. Waste handling operations may be sources of stormwater pollution and include dumpsters, litter control, and waste piles. This fact sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff associated with trash storage and handling.

5.3.3.2 Design Criteria

Design requirements for waste handling areas are governed by Building and Fire Codes, and by current local permitting agency ordinances and zoning requirements. The design criteria described in the Fact Sheet are meant to enhance and be consistent with these code and ordinance requirements. Hazardous waste should be handled in accordance with legal requirements established in Title 22, California Code of Regulations.

Wastes from commercial and industrial sites are typically hauled by either public or commercial carriers that may have design or access requirements for waste storage areas. The design criteria listed below are recommendations and are not intended to be in conflict with requirements established by the waste hauler. The waste hauler should be contacted prior to the design of your site trash collection area to obtain established and accepted guidelines for designing trash collection areas. Conflicts or issues should be discussed with the local permitting agency.

The following trash storage area design controls were developed to enhance the local permitting agency codes and ordinances and should be implemented depending on the type of waste and the type of containment.

Table 5-3: Design Criteria for Outdoor Trash Storage Areas

Source Control Design Feature	Design Criteria
Surfacing	• Construct the storage area base with a material impervious to leaks and spills.
Screens/Covers	• Install a screen or wall around trash storage area to prevent offsite transport of loose trash. • Use lined bins or dumpsters to reduce leaking of liquid wastes. • Use water-proof lids on bins/dumpsters or provide a roof to cover enclosure (local permitting agency discretion) to prevent rainfall from entering containers.
Grading/Contouring	• Berm or grade the waste handling area to prevent run-on of stormwater. • Do not locate storm drains in immediate vicinity of the trash storage area.
Signs	• Post signs on all dumpsters informing users that hazardous materials are not to be disposed of therein.

5.3.3.3 Maintenance Requirements

The owner/operator must maintain the integrity of structural elements that are subject to damage (e.g. screens, covers and signs). Maintenance Agreements between the local permitting agency and the owner/operator may be required. Some agencies will require maintenance deed restrictions to be recorded on the property title. If required by the local permitting agency, Maintenance Agreements or deed restrictions processes will be established by the local permitting agency.

5.3.4 S-4: Outdoor Loading/Unloading Dock Area Design

5.3.4.1 Purpose

Materials spilled, leaked, or lost during loading or unloading may collect on impervious surfaces or in the soil and be carried away by runoff or when the area is cleaned. Rainfall may also wash pollutants from machinery used to load or unload materials. Depressed loading docks (truck wells) are contained areas that can accumulate stormwater runoff. Discharge of spills or contaminated stormwater to the storm drain system is prohibited. This Fact Sheet contains details on specific measures recommended to prevent or reduce pollutants in stormwater runoff from outdoor loading or unloading areas.

5.3.4.2 Design Criteria

Design requirements for outdoor loading and unloading of materials are governed by Building and Fire Codes, and by current local permitting agency ordinances and zoning requirements. Source Control Measures described in this Fact Sheet are meant to enhance and be consistent with these code and ordinance requirements. Companies may have their own design or access requirements for loading docks. The design criteria listed below are not intended to be in conflict with requirements established by individual companies. Conflicts or issues should be discussed with the local permitting agency.

The following design criteria should be followed when developing construction plans for material loading and unloading areas:

Table 5-4: Design Criteria for Outdoor Loading/ Unloading Areas

Source Control Design Feature	Design Criteria
Surfacing	• Construct floor surfaces with materials that are compatible with materials being handled in the loading/unloading area.
Covers	• Cover loading/unloading areas to a distance of at least 3 feet beyond the loading dock or install a seal or door skirt to be used for all material transfers between the trailer and the building.
Grading/Contouring	• Grade or berm storage areas to prevent run-on from surrounding areas. • Direct runoff from downspouts/roofs away from loading areas.
Emergency Storm Drain Seal	• Do not locate storm drains in the loading dock area. Direct connections to storm drains from depressed loading docks are prohibited. • Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

5.3.4.3 Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces, such as depressed loading docks. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

5.3.5 S-5: Outdoor Repair/Maintenance Bay Design

5.3.5.1 Purpose

Activities that can contaminate stormwater include engine repair, service, and parking (i.e. leaking engines or parts). Oil and grease, solvents, car battery acid, coolant and gasoline from the repair/maintenance bays can severely impact stormwater if allowed to come into contact with stormwater runoff. This Fact Sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment maintenance and repair areas.

5.3.5.2 Design Criteria

Design requirements for vehicle maintenance and repair areas are governed by Building and Fire Codes, and by current local permitting agency ordinances, and zoning requirements. The design criteria described in this Fact Sheet are meant to enhance and be consistent with these code requirements.

The following design criteria are required for vehicle and equipment maintenance, and repair. All wash water, hazardous and toxic wastes must be prevented from entering the storm drainage system.

Table 5-5: Outdoor Repair/Maintenance Bay Design

Source Control Design Feature	Design Criteria
Surfacing	• Construct the vehicle maintenance/repair floor area with Portland cement concrete.
Covers	• Cover or berm areas where vehicle parts with fluids are stored. • Cover or enclose all vehicle maintenance/repair areas.
Grading/ Contouring	• Berm or grade the maintenance/repair area to prevent run-on and runoff of stormwater or runoff of spills. • Direct runoff from downspouts/roofs away from maintenance/repair areas. • Grade the maintenance/repair area to drain to a dead-end sump for collection of all wash water, leaks and spills. Direct connection of maintenance/repair area to storm drain system is prohibited. • Do not locate storm drains in the immediate vicinity of the maintenance/repair area.
Emergency Storm Drain Seal	• Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

5.3.5.3 Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

5.3.6 S-6: Outdoor Vehicle/Equipment/Accessory Washing Area Design

5.3.6.1 Purpose

Washing vehicles and equipment in areas where wash water flows onto the ground can pollute stormwater. Wash waters are not allowed in the storm drain system. They can contain high concentrations of oil and grease, solvents, phosphates and high suspended solids loads. Sources of washing contamination include outside vehicle/equipment cleaning or wash water discharge to the ground. This Fact Sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment washing areas.

5.3.6.2 Design Criteria

Design requirements for vehicle maintenance and repair areas are governed by Building and Fire Codes, and by current local permitting agency ordinances, and zoning requirements. The design criteria described in this Fact Sheet are meant to enhance and be consistent with these code requirements.

The following design criteria are required for vehicle and equipment washing areas. All hazardous and toxic wastes must be prevented from entering the storm drain system.

Table 5-6: Outdoor Vehicle/Equipment/Accessory Washing Area Design

Source Control Design Feature	Design Criteria
Surfacing	• Construct the vehicle/equipment wash area floors with Portland cement concrete.
Covers	• Provide a cover that extends over the entire wash area.
Grading/ Contouring	• Berm or grade the maintenance/repair area to prevent run-on and runoff of stormwater or runoff of spills. • Grade or berm the wash area to contain the wash water within the covered area and direct the wash water to treatment and recycle or pretreatment and proper connection to the sanitary sewer system. Obtain approval from the governing agency before discharging to the sanitary sewer. • Direct runoff from downspouts/roofs away from wash areas. • Do not locate storm drains in the immediate vicinity of the wash area.
Emergency Storm Drain Seal	• Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

5.3.6.3 Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

5.3.7 S-7: Fueling Area Design

5.3.7.1 Purpose

Spills at vehicle and equipment fueling areas can be a significant source of pollution because fuels contain toxic materials and heavy metals that are not easily removed by stormwater treatment devices. When stormwater mixes with fuel spilled or leaked onto the ground, it becomes polluted by petroleum-based materials that are harmful to humans, fish, and wildlife. This could occur at large industrial sites or at small commercial sites such as gas stations and convenience stores. This Fact Sheet contains details on specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment fueling areas, including retail gas stations.

5.3.7.2 Design Criteria

Design requirements for fueling areas are governed by Building and Fire Codes and by current local permitting agency ordinances and zoning requirements. The design requirements described in this Fact Sheet are meant to enhance and be consistent with these code and ordinance requirements.

Table 5-7: Fueling Area Design

Source Control Design Feature	Design Criteria
Surfacing	• Fuel dispensing areas must be paved with Portland cement concrete. The fuel dispensing area is defined as extending 6.5 feet from the corner of each fuel dispenser or the length at which the hose and nozzle assemble may be operated plus 1 foot, whichever is less. The paving around the fuel dispensing area may exceed the minimum dimensions of the "fuel dispensing area" stated above. • Use asphalt sealant to protect asphalt paved areas surrounding the fueling area.
Covers	• The fuel dispensing area must be covered [1], and the cover's minimum dimensions must be equal to or greater than the area within the grade break or the fuel dispensing area, as defined above. The cover must not drain onto the fuel dispensing area.
Grading/ Contouring	• The fuel dispensing area should have a 2% to 4% slope to prevent ponding and must be separated from the rest of the site by a grade break that prevents run-on of stormwater to the extent practicable. • Grade the fueling area to drain toward a dead-end sump. • Direct runoff from downspouts/roofs away from fueling areas. • Do not locate storm drains in the immediate vicinity of the fueling area.
Emergency Storm Drain Seal	• Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

1. If fueling large equipment or vehicles that would prohibit the use of covers or roofs, the fueling island should be designed to sufficiently accommodate the larger vehicles and equipment and to prevent run-on and runoff of stormwater. Grade to direct stormwater to a dead-end sump.

5.3.7.3 Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

5.3.8 S-8: Proof of Control Measure Maintenance

5.3.8.1 Purpose

Continued effectiveness of control measures specified in the TGM depends on diligent ongoing inspection and maintenance. To ensure that such maintenance is provided, the local permitting agency will require both a Maintenance Agreement and a Maintenance Plan from the owner/operator of stormwater control measures.

Maintenance Agreement

Onsite Treatment Control Measures are to be maintained by the owner/operator. Maintenance Agreements between the local permitting agency and the owner/operator may be required. A Maintenance Agreement with the local permitting agency must be executed by the owner/operator before occupancy of the project is approved.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the local permitting agency's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility; and
- Responsible party for operation and maintenance.

Additional guidelines for Maintenance Plans are provided in Appendix D.

6 STORMWATER BMP DESIGN

6.1 Introduction

Retention BMPs or, in certain circumstances, alternative compliance BMPs are required to augment Site Design Principles and Techniques and Source Control Measures to reduce pollution from stormwater discharges to the maximum extent practicable. Retention BMPs are engineered facilities that are designed to retain surface runoff on the project site. If retention BMPs are technically infeasible, alternative compliance using onsite biofiltration may be used. Onsite biofiltration BMPs are vegetated stormwater BMPs that remove pollutants by filtering stormwater through vegetation and soils. In situations specifically approved by the Regional Water Board, Alternative Compliance using Onsite Flow-Based BMPs may be used. Flow-based BMPs are engineered BMPs that provide a reduction of pollutant loads and concentrations in stormwater runoff. Opportunities for other Alternative Compliance BMPs such as off-site infiltration, groundwater replenishment project(s), and/or off-site project retrofit of an existing development, may be available on a case-by-case basis in discussion with the local permitting agency.

Unlike flood control measures that are designed to handle peak flows, these stormwater BMPs are designed to retain or treat the more frequent, lower-flow storm events, or the first flush runoff from larger storm events. Small, frequent storm events represent most of the total average annual rainfall for the area. It's the volume from such small events, referred to as the Stormwater Quality Design Volume (SQDV), that is targeted for retention onsite in Retention BMPs. Alternative Compliance BMPs can be sized to capture either the SQDV for biofiltration or the Stormwater Quality Design Flow (SQDF) when flow-based BMPs are approved by the Executive Officer of the Los Angeles Regional Water Quality Control Board (Regional Water Board). Calculation methods for the SQDV and the SQDF are presented in Section 2 and Appendix C.

6.2 General Considerations

All BMP types (retention, alternative compliance using onsite biofiltration, alternative compliance using onsite flow-based BMPs, other alternative compliance using offsite BMPs) are designed to remove pollutants contained in stormwater runoff. The BMPs are also designed to reduce runoff volume, thereby reducing pollutant loading to receiving waters.

6.2.1 BMP Selection

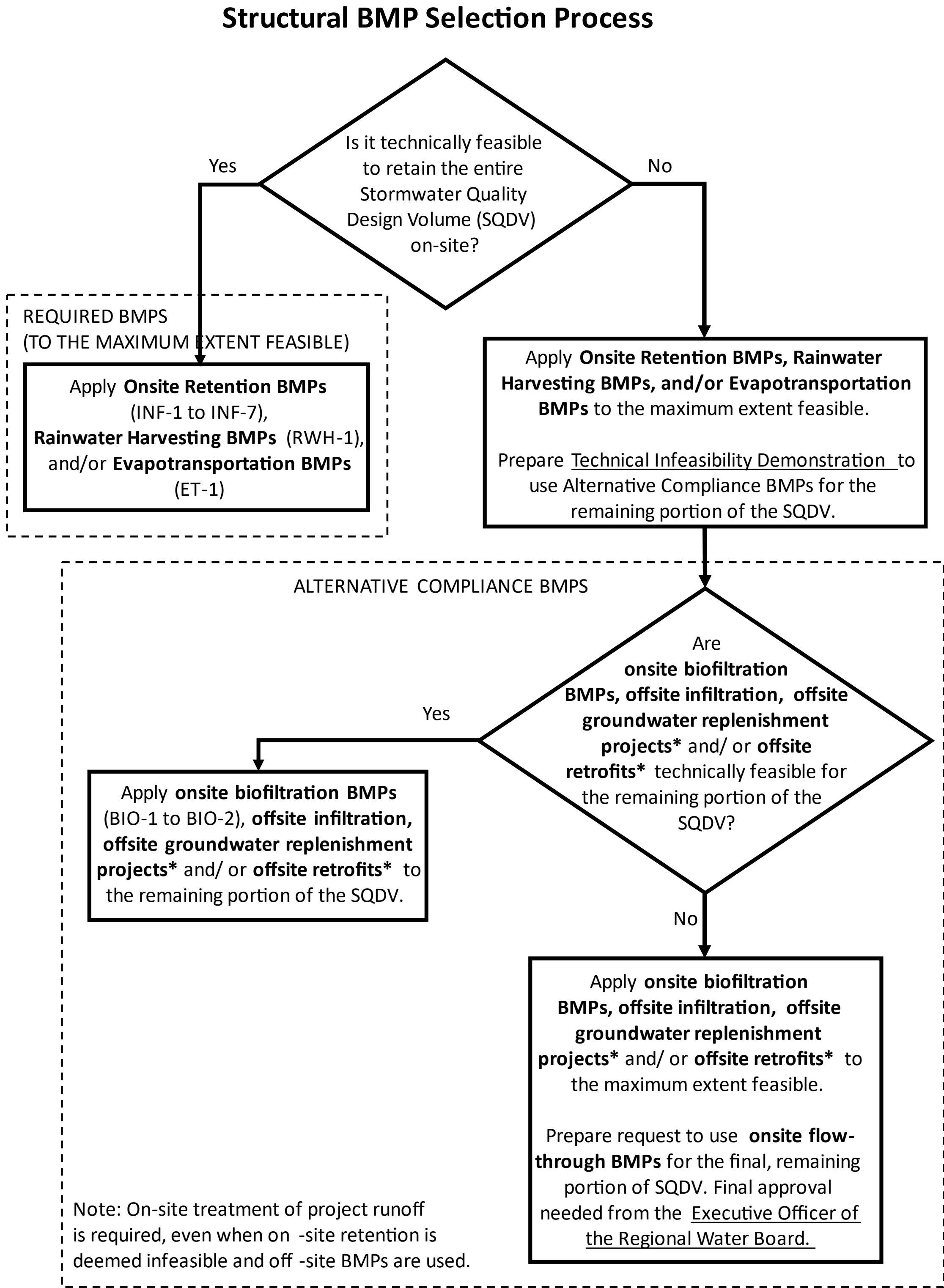
Onsite retention of the SQDV is required for all projects and onsite retention BMPs are mandated by the 2021 MS4 Permit. In the following rare circumstances, compliance may be achieved through alternative types of BMPs using onsite biofiltration BMPs, offsite BMPs, or onsite flow-based BMPs:

- Alternative compliance using onsite biofiltration BMPs may be used when onsite infiltration is technically infeasible (see Section 2.7 for technical infeasibility criteria).

- In situations where onsite retention and onsite biofiltration are both technically infeasible, compliance may be met using offsite BMPs such as off-site infiltration, groundwater replenishment project(s), and/or off-site project retrofit of an existing development. Off-site projects require prior approval and discussion with the local permitting agency, as off-site opportunities may not be available in all areas. It is important to note that on-site treatment of project runoff is required, even when on-site retention is deemed infeasible and off-site BMPs are used.

- If off-site BMPs are not feasible, compliance may be achieved using onsite flow-based BMPs. This final option requires prior approval from the Executive Officer of the Regional Water Board. A direct request must be made by the project proponent and shall include why none of the other alternative compliance measures are feasible. Approval will only be granted to areas where other alternative compliance measures are not feasible due to significant technical issues and not justified by site design or desired building densities.

The chart below summarizes the process for identifying types of BMPs that are suitable to each project based on site conditions, constraints, and technical infeasibility.



*Offsite BMPs may not be available in all areas. Discuss availability with local agency.

Figure 6-1: BMP Selection Process

6.2.2 Pretreatment

Pretreatment must be provided for filtration and infiltration facilities and other facilities whose function could be adversely affected by sediment or other pollutants. Pretreatment selection may be determined by the local governing agency depending on the type of project and its siting. The local government agency reserves the right to condition a project to use a more stringent pre-treatment requirement than what is being specified by the TGM. Pretreatment BMPs cannot be used as standalone BMPs and are to be utilized in combination with onsite retention BMPs or alternative compliance BMPs. Fact Sheets for pretreatment BMPs are included in Section 6.3.

6.2.3 Onsite Retention BMPs

Onsite retention BMPs are engineered facilities that are designed to retain surface runoff on the project site. The most common of these employ infiltration techniques, but other measures for onsite retention, such as rainwater harvesting and green roofs, also fall in this category. A geotechnical investigation must be conducted when evaluating infiltration to determine the suitability of the site soil and if it is adequately addressing groundwater protection.

6.2.4 Alternative Compliance using Onsite Biofiltration BMPs

Biofiltration refers to a set of onsite alternative compliance BMPs that use vegetation and soil media for treatment of stormwater runoff. These options include biofiltration and planter boxes with underdrains. As runoff passes through the vegetation and soil media, the combined effects of filtration, adsorption, and biological uptake remove pollutants. As noted in Section 2.7, onsite biofiltration BMPs must be sized to treat 1.5 times the portion of SQDV that is not retained on-site. As with all alternative compliance BMPs, technical infeasibility for onsite retention must be demonstrated.

6.2.5 Alternative Compliance using Offsite Projects

When onsite retention and biofiltration BMPs have been used to the maximum extent feasible, the project applicant may opt for use of offsite opportunities: offsite infiltration, offsite groundwater replenishment, or retrofit of an existing development. As with all alternative compliance BMPs, a technical infeasibility for onsite retention must be demonstrated. Offsite infiltration opportunities may not be available in all areas of Ventura County. The applicant shall contact the local permitting agency for questions regarding availability of these projects.

Regardless of the type of offsite project being pursued, onsite treatment of stormwater runoff from the project site is required. The type of treatment BMPs and the volume required to be treated is noted in Section 2.7.2.

6.2.6 Alternative Compliance using Onsite Flow-Based BMPs

If approved for use by the Executive Officer of the Regional Water Board, and all other types of BMPs have been used to the maximum extent feasible, the project may provide alternative compliance using onsite flow-based BMPs. These are cartridge media filter and proprietary biofiltration BMPs. The volume required to be treated is noted in Section 2.7 and in individual Fact Sheets in Appendix C.

6.2.7 Maintenance Responsibility

Unless otherwise agreed to by the governing stormwater agency, the landowner, site operator, or homeowner's association is responsible for the operation and maintenance of the BMP facilities and a Maintenance Plan must be developed and implemented. Section 7 and Appendices F and G provide additional information and guidance on compliance with maintenance requirements. The local permitting agency may also require water quality monitoring agreements to help evaluate the effectiveness of the BMPs in reducing pollutants in stormwater runoff.

6.3 Structural BMP Fact Sheets

This section provides fact sheets with recommended criteria for the design and implementation of Structural BMPs, such as onsite retention BMPs, alternative compliance using onsite biofiltration BMPs, and onsite flow-based BMPs, as well as a section of hydromodification BMPs and pretreatment BMPs. The siting, design, and maintenance requirements in the fact sheets are intended to ensure optimal performance of the measures.

The TGM also contains calculation worksheets to aid in the design of these BMPs in Appendix C.

Fact sheets are provided for the BMPs listed below:

On-site Retention BMPs

Infiltration BMPs

INF-1: Infiltration Basin
INF-2: Subsurface Infiltration
INF-3: Bioretention
INF-4: Drywell
INF-5: Permeable Pavement
INF-6: Proprietary Infiltration
INF-7: Bioinfiltration

On-site Retention BMPs (continued)

Rainwater Harvesting BMPs

RWH-1: Rainwater Harvesting

Evapotranspiration BMPs

ET-1: Green Roof

Alternative Compliance using Onsite Biofiltration BMPs

BIO-1: Biofiltration
BIO-2: Planter Box with Underdrain

Alternative Compliance using Onsite Flow-Based BMPs

FLO-1: Cartridge Media Filter
FLO-2: Proprietary Biofiltration
FLO-3: Other TAPE-Certified Enhanced Treatment BMPs

Hydromodification BMPs

HM-1: Dry Extended Detention Basin
HM-2: Wet Detention Basin
HM-3: Constructed Wetland

Pretreatment/Gross Solids Removal BMPs

Note: Pretreatment BMPs are not stand alone BMPs; they must be used in combination with other BMP(s) noted above. Pretreatment selection may be determined by the local governing agency depending on the type of project and its siting.

PT-1: Hydrodynamic Separator
PT-2: Catch Basin Insert
PT-3: Vegetated Swale
PT-4: Vegetated Filter Strip

6.4 On-site Retention BMPs

6.4.1 INF-1: Infiltration Basin

An infiltration basin consists of an earthen basin constructed in naturally pervious soils (soil numbers 4 to 7) with a flat bottom and an inlet structure to dissipate energy of incoming flow and an emergency spillway to control excess flows. Pretreatment must be provided. An infiltration basin functions by retaining the SQDV in the basin and allowing the retained runoff to percolate into the underlying native soils over a specified period of time. The bottoms of infiltration basins are typically vegetated with dry-land grasses or irrigated turf grass. A typical layout of an infiltration basin system is shown in Figure 6-2.

Application

- Mixed-use and commercial
- Roads and parking lots
- Parks and open spaces
- Single and multi-family residential
- Can integrate with parks

Routine Maintenance

- Removal trash, debris, and sediment at inlet and outlets
- Wet weather inspection to ensure drain time
- Remove weeds
- Inspect for mosquito breeding

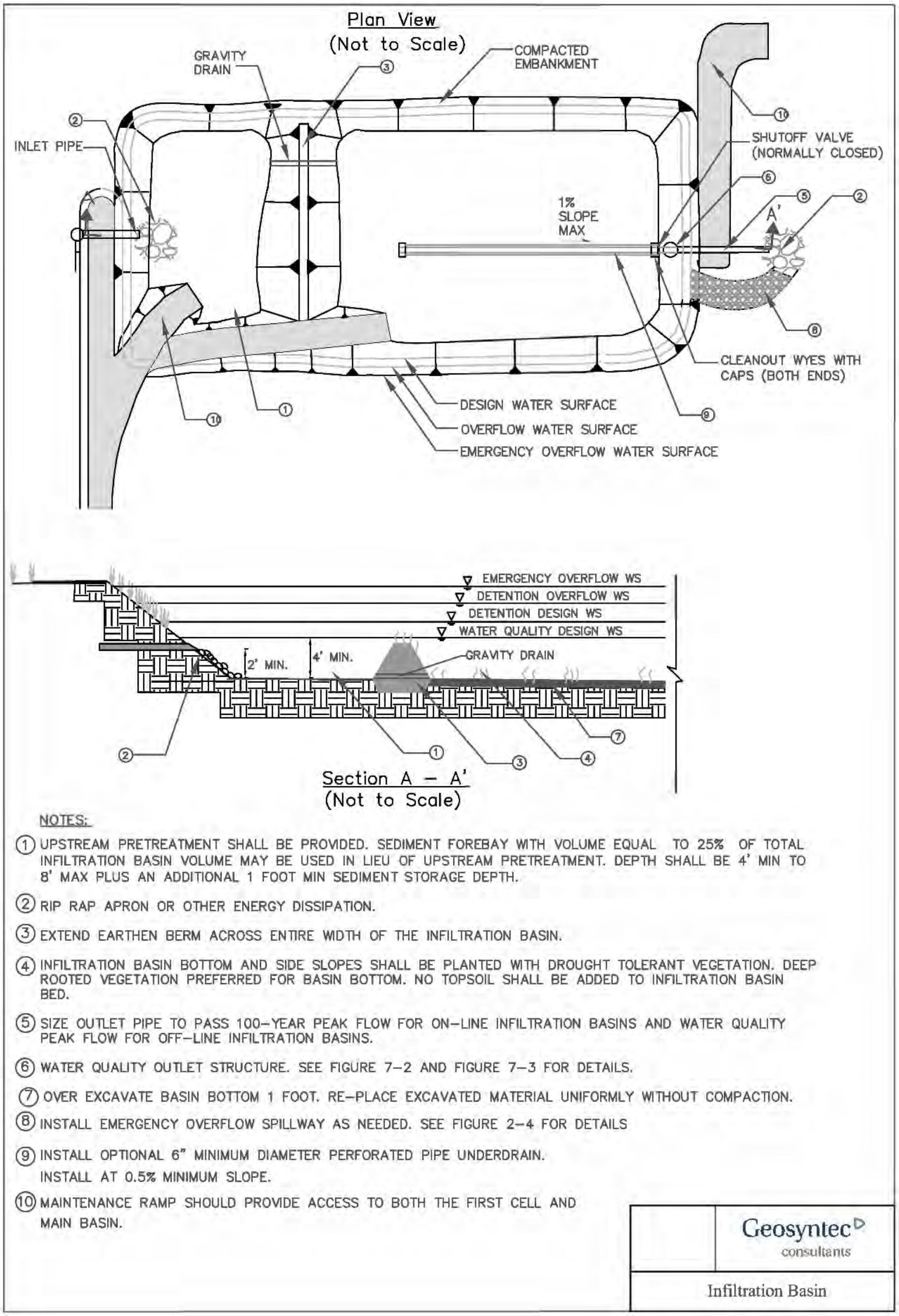


Figure 6-2: Infiltration Basin Design Schematic

6.4.1.1 Limitations

The following limitations should be considered before choosing to use an infiltration basin:

- Native soil infiltration rate - permeability of soils at the infiltration basin location must be at least 0.3 inches per hour.

- Depth to groundwater, bedrock, or low permeability soil layer – 5 feet vertical separation is required between the bottom of the infiltration basin and the seasonal high groundwater level or mounded groundwater level, bedrock, or other barrier to infiltration to ensure that the facility will completely drain between storms and that infiltrating water will receive adequate treatment through the soils before it reaches the groundwater.

- Slope stability - infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.

- Setbacks - a minimum setback (100 feet) must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields, and springs. Infiltration BMPs must be setback at least ten feet from building foundations or have an alternative setback established by the geotechnical expert for the project.

- Groundwater contamination - the application of infiltration BMPs should include significant pretreatment in an area identified as an unconfined aquifer to ensure groundwater is protected for pollutants of concern.

- Contaminated soils or groundwater plumes - infiltration BMPs are not allowed at locations with contaminated soils or groundwater, where the pollutants could be mobilized or exacerbated by infiltration, unless a site-specific analysis determines the infiltration would be beneficial.

- High pollutant land uses - infiltration BMPs should not be placed in high-risk areas such as at/near service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk unless a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas have little chance of spill migration.

- High sediment loading rates – infiltration BMPs may clog quickly if sediment loads are high (e.g., unstabilized site) or if flows are not adequately pretreated.

6.4.1.2 Additional Control Functions

Infiltration basins can be designed for flow control by providing storage capacity in excess of that provided by infiltration and incorporating outlet controls. Note that the selected outlet structure should not be designed to drain the design volume intended for infiltration and should be similar to outlet structures that accommodate ponding (see HM-1: Wet Detention Basin).

6.4.1.3 Multi-Use Opportunities

Infiltration basins may be integrated into the design of a park or playfield. Recreational multi-use facilities should be inspected after every storm and may require a greater maintenance frequency than dedicated infiltration basins to ensure aesthetics and public safety are not compromised. Any planned multi-use facility must obtain approval by the affected City and County departments.

6.4.1.4 Design Criteria

The main challenge associated with infiltration basins is preventing system clogging and subsequent infiltration inhibition. Infiltration basins should be designed according to the requirements listed in Table 6-1 and outlined in the section below. Detailed design procedures and an example are included in Appendix C.

Table 6-1: Infiltration Basin Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2.6 and Appendix C for calculating SQDV
Design drawdown time	hr	72 (See Appendix C, Section C.2)
Bottom basin elevation	feet	5 feet above seasonally high groundwater table or mounded groundwater
Setbacks	feet	100 feet from wells, fields, and springs; 20 feet downslope of 100 feet upslope of foundations; Geotechnical expert should establish the setback requirement from building foundations that must be ≥ 10 ft.
Pretreatment	-	Sedimentation forebay or other Pretreatment BMPs shall be provided as pretreatment for all tributary surfaces other than roofs.
Design percolation rate (P_{design})	in/hr	Measured soil infiltration rate must be corrected based on site suitability assessment and design related considerations described in this fact sheet.

Design Parameter	Unit	Design Criteria
Facility geometry	-	Forebay (if applicable): 25% of facility volume; flat bottom slope
Freeboard (minimum)	ft	1.0
Inlet/ Outlet erosion control	-	Energy dissipater to reduce velocity
Overflow device	-	Required if system is on-line

6.4.1.5 Geotechnical Considerations

An extensive geotechnical site investigation must be undertaken early in the site planning process to verify site suitability for the installation of infiltration facilities, due to the potential to contaminate groundwater, cause slope instability, impact surrounding structures, and have insufficient infiltration capacity. Soil infiltration rates and the water table depth should be evaluated to ensure that conditions are satisfactory for proper operation of an infiltration facility. See the Los Angeles County Public Works Guidelines for Geotechnical Investigation and Reporting Low Impact Development Stormwater Infiltration (June 30, 2021, and subsequent versions)for guidance on infiltration testing.

The project designer must demonstrate through infiltration testing, soil logs, and the written opinion of a licensed civil and/or geotechnical engineer that sufficiently permeable soils exist onsite to allow the construction of a properly functioning infiltration facility.

1) Infiltration facilities require a minimum soil infiltration rate of 0.3 inches/hour. Pretreatment is required in all instances.

2) Groundwater separation must be at least 5 feet from the basin bottom to the measured Seasonal High Groundwater Elevation or estimated high groundwater mounding elevation. Groundwater levels measurements must be made during the time when water level is expected to be at a maximum (i.e., toward the end of the wet season).

3) Potential BMP sites with a slope greater than 25% (4:1) should be excluded. A geotechnical analysis and report addressing slope stability are required if located within 50 feet of slopes greater than 15%.

6.4.1.5.1 Soil Assessment and Site Geotechnical Investigation Reports

The soil assessment report should:

- State whether the site is suitable for the proposed infiltration basin;

- Recommend a design percolation rate (see Appendix C.2 *Design Percolation Rate Corrections Safety Factors for Infiltration BMPs*);
- Identify the seasonally high depth to groundwater table surface elevation;
- Provide a good understanding of how the stormwater runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water; and
- If a geotechnical investigation and report are required, the report should:
  - Provide a written opinion by a professional civil and/or geotechnical engineer describing whether the infiltration basin will compromise slope stability; and
  - Identify potential impacts to nearby structural foundations.

6.4.1.6 Setbacks

1) Infiltration facilities shall be setback a minimum of 100 feet from proposed or existing potable wells, non-potable wells, septic drain fields, and springs.
2) Infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.
3) The geotechnical expert shall establish the setback requirement from building foundations that must be ≥ 10 ft.

6.4.1.7 Pretreatment

Pretreatment is required for infiltration basins in order to reduce the sediment load entering the facility and maintain the infiltration rate of the facility. Pretreatment refers to design features that provide settling of large particles before runoff reaches a management practice; easing the long-term maintenance burden. Pretreatment is important for all structural stormwater BMPs, but it is particularly important for infiltration BMPs. To ensure that pretreatment mechanisms are effective, designers should incorporate sediment reduction practices. Sediment reduction BMPs may include sedimentation basins or forebays, sedimentation manholes, hydrodynamic separation devices, catch basin inserts, vegetated swales, vegetated filter strips, or media cartridge filters.

For design specification of selected pretreatment devices, refer to:

- PT-1: Hydrodynamic Separator
- PT-2: Catch basin insert
- PT-3: Vegetated swales

- PT-4: Vegetated filter strips
- FLO 1 – Cartridge media filter

6.4.1.8 Sizing Criteria

Detailed sizing procedures are provided in Appendix C.3.

6.4.1.8.1 Geometry and Sizing

1) Infiltration basins should be designed and constructed with the flattest bottom slope possible to promote uniform ponding and infiltration across the facility.
2) A sediment forebay is required unless adequate pretreatment is provided in a separate pretreatment unit (e.g., vegetated swale, filter strip, hydrodynamic separator) to reduce sediment loads entering the infiltration basin. The sediment forebay, if present, should have a volume equal to 25% of the total infiltration basin volume.
3) The forebay should be designed with a minimum length to width ratio of 2:1 and should completely drain to the main basin through an 8-inch minimum low-flow outlet within 10 minutes.
4) All inlets should enter the sediment forebay. If there are multiple inlets, the length-to-width ratio should be based on the average flowpath length for all inlets.
5) Embankments should be designed to conform to requirements of the State of California Division of Safety of Dams, if the basin dimensions cause it to fall under that agency's jurisdiction.

6.4.1.8.2 Drainage

1) The bottom of the infiltration bed should be native soil, over-excavated to at least one foot in depth, and replaced uniformly without compaction.
2) The hydraulic conductivity of the subsurface layers should be sufficient to ensure a maximum 72-hr drawdown time. An observation well shall be incorporated to allow observation of drain time.

6.4.1.8.3 Emergency Overflow

1) There should be an overflow route for stormwater flows that overtop the facility or in case the infiltration facility becomes clogged.
2) The overflow channel should be able to safely convey flows from the peak design storm to the downstream stormwater conveyance system or other acceptable discharge point.

3) Spillway and overflow structures should be designed in accordance with applicable standards of the Ventura County Flood Control District or local jurisdiction.

6.4.1.9 Vegetation

1) A thick mat of drought tolerant grass should be established on the basin floor and side-slopes following construction. Grasses can help prevent erosion and increase evapotranspiration and their roots discourage compaction helping to maintain the surface infiltration rates. Additionally, the active growing vegetation can help break up surface layers that accumulate fine particulates.

2) Grass may need to be irrigated during establishment.

3) For infiltration basins, landscaping of the area surrounding the basin should adhere to the following criteria so as not to hinder maintenance operations:

    a. No trees or shrubs may be planted within 10 feet of inlet or outlet pipes or manmade drainage structures such as spillways, flow spreaders, or earthen embankments. Species with roots that seek water, such as willow or poplar, should not be used within 50 feet of pipes.

    b. Prohibited non-native plant species will not be permitted. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.

6.4.1.10 Maintenance Access

1) Maintenance access road(s) shall be provided to the drainage structures associated with the basin (e.g., inlet, emergency overflow, or bypass structures). Manhole and catch basin lids should be in or at the edge of the access road.

2) An access ramp to the basin bottom is required to facilitate the entry of sediment removal and vegetation maintenance equipment without compaction of the basin bottom and side slopes.

6.4.1.11 Construction Considerations

To preserve and avoid the loss of infiltration capacity, the following construction guidelines are specified:

1) The entire area draining to the facility should be stabilized before construction begins. If this is impossible, a diversion berm should be placed around the perimeter of the infiltration site to prevent sediment entrance during construction.

2) Infiltration basins should not be hydraulically connected to the stormwater conveyance system until all contributing tributary areas are stabilized as shown on

the Contract Plans and to the satisfaction of the Engineer. Infiltration basins should not be used as sediment control facilities.

3) Compaction of the subgrade with heavy equipment should be minimized to the maximum extent possible. If the use of heavy equipment on the base of the facility cannot be avoided, the infiltrative capacity should be restored by tilling or aerating prior to placing the infiltrative bed.

4) The exposed soils should be inspected by a civil and/or geotechnical engineer after excavation to confirm that soil conditions are suitable.

6.4.1.12 Operations and Maintenance

Infiltration facility maintenance should include frequent inspections to ensure that surface ponding infiltrates into the subsurface completely within the design infiltration time after a storm (see Appendix D for an infiltration BMP inspection and maintenance checklist).

Maintenance and regular inspections are of primary importance if infiltration BMPs are to continue to function as originally designed. A specific maintenance plan shall be formulated specifically for each facility outlining the schedule and scope of maintenance operations, as well as the data handling and reporting requirements. The following are general maintenance requirements:

1) Regular inspection should determine if the pretreatment sediment removal BMPs require routine maintenance.

2) If water is noticed in the basin more than 72 hours after a major storm the infiltration facility may be clogged. Maintenance activities triggered by a potentially clogged facility include:

    a. Check for debris/sediment accumulation, rake surface, and remove sediment (if any) and evaluate potential sources of sediment and debris (e.g., embankment erosion, channel scour, overhanging trees, etc.). If suspected upland sources are outside of the immediate jurisdiction, additional pretreatment operations (e.g., trash racks, vegetated swales, etc.) may be necessary.

    b. For basins, removal of the top layer of native soil may be required to restore infiltrative capacity.

    c. Any debris or algae growth located on top of the infiltration facility should be removed and disposed of properly.

    d. Facilities shall be inspected annually. Trash and debris should be removed as needed, but at least annually prior to the beginning of the wet season.

3) Site vegetation should be maintained as frequently as necessary to maintain the aesthetic appearance of the site, and as follows:

    a. Vegetation, large shrubs, or trees that limit access or interfere with basin operation should be pruned or removed.

    b. Slope areas that have become bare should be revegetated and eroded areas should be re-graded prior to being revegetated.

    c. Grass should be mowed to 4" - 9" high and grass clippings should be removed.

    d. Fallen leaves and debris from deciduous plant foliage should be raked and removed.

    e. Invasive vegetation, such as Alligatorweed (Alternanthera philoxeroides), Halogeton (Halogeton glomeratus), Spotted Knapweed (Centaurea maculosa), Giant Reed (Arundo donax), Castor Bean (Ricinus communis), Perennial Pepperweed (Lepidium latifolium), and Yellow Starthistle (Centaurea solstitalis) should be removed and replaced with non-invasive species. Invasive species should never contribute more than 25% of the vegetated area. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.

    f. Dead vegetation should be removed if it exceeds 10% of area coverage. Vegetation should be replaced immediately to maintain cover density and control erosion where soils are exposed.

4) For infiltration basins, sediment build-up exceeding 50% of the forebay capacity should be removed. Sediment from the remainder of the basin should be removed when 6 inches of sediment accumulates. Sediments should be tested for toxic substance accumulation in compliance with current disposal requirements if land uses in the catchment include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed. If toxic substances are encountered at concentrations exceeding thresholds of Title 22, Section 66261 of the California Code of Regulations, the sediment should be disposed of in a hazardous waste landfill and the source of the contaminated sediments should be investigated and mitigated to the extent possible.

5) Following sediment removal activities, replanting and/or reseeding of vegetation may be required for reestablishment.

6.4.2 INF-2: Subsurface infiltration

Subsurface infiltration facilities are facilities with the majority of runoff is stored in the void space within the gravel or subsurface drainage structure and infiltrated through the sides and the bottom of the facility.

Rural Highway Infiltration Subsurface

http://stormwater.wordpress.com/2007/05/23/infiltration--trenches/

Application

- At level or underneath open areas adjacent to parking lots, driveways, and buildings
- At level or underneath roadway medians and shoulders

Routine Maintenance

- Removal trash, debris, and sediment at inlet and outlets
- Wet weather inspection to ensure drain time
- Remove weeds
- Inspect for mosquito breeding

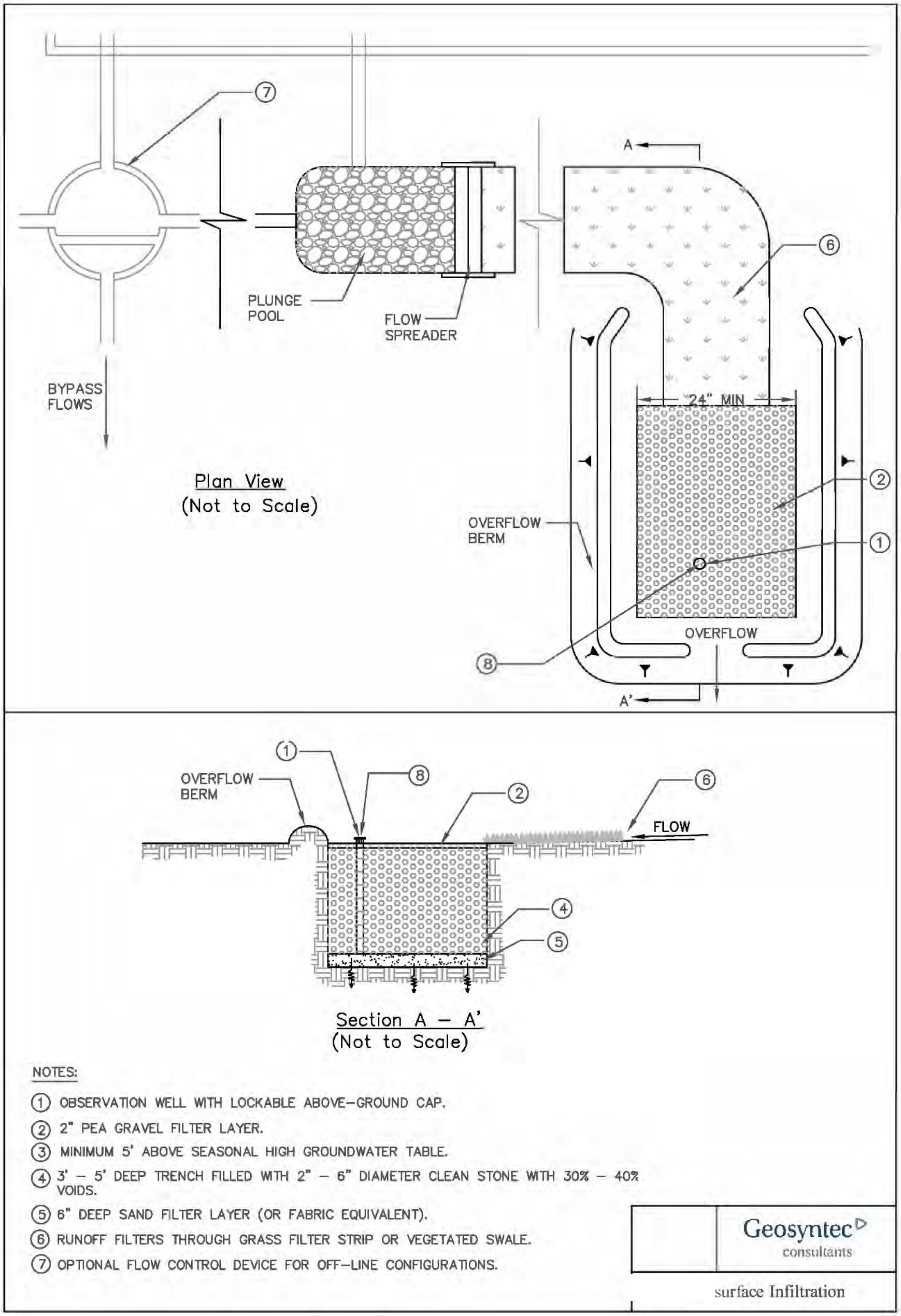


Figure 6-3: Subsurface infiltration Design Schematic

6.4.2.1 Limitations

The following limitations should be considered before choosing to use a subsurface infiltration BMP:

- Native soil infiltration rate – soil permeability at the infiltration trench location must be at least 0.3 inches per hour.
- Depth to groundwater, bedrock, or low permeability soil layer – 5 feet vertical separation is required between the bottom of the infiltration trench and the seasonal high groundwater level or mounded groundwater level, bedrock, or other barrier to infiltration to ensure that the facility will completely drain between storms and that infiltrating water will receive adequate treatment though the soils before it reaches the groundwater.
- Slope stability - infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.
- Setbacks - a minimum setback (100 feet or more) must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields and springs. Infiltration BMPs must be setback from building foundations at least ten feet or an alternative setback established by the geotechnical expert for the project.
- Groundwater contamination - the application of infiltration BMPs should include significant pretreatment in an area identified as an unconfined aquifer to ensure groundwater is protected for pollutants of concern.
- Contaminated soils or groundwater plumes - infiltration BMPs are not allowed at locations with contaminated soils or groundwater where the pollutants could be mobilized or exacerbated by infiltration, unless a site-specific analysis determines that infiltration would be beneficial.
- High pollutant land uses - infiltration BMPs should not be placed in high-risk areas such as at/near service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk unless a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas have little chance of spill migration.
- High sediment loading rates – infiltration BMPs may clog quickly if sediment loads are high (e.g., unstabilized site) or if flows are not adequately pretreated.

6.4.2.2 Design Criteria

The main challenge associated with subsurface infiltration BMPs is preventing system clogging and subsequent infiltration inhibition. Subsurface infiltration should be designed according to the requirements listed in Table 6-2 and outlined in the section below. BMP sizing worksheets are presented in Appendix C.

Table 6-2: Subsurface Infiltration Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2 and Appendix C for calculating SQDV.
Design drawdown time	hr	72, see Appendix C, Section C.2
Trench bottom elevation	feet	5 feet from seasonally high groundwater table
Setbacks	feet	100 feet from wells, fields, springs Geotechnical expert should establish the setback requirement from building foundations that must be ≥ 10 ft Do not locate under tree driplines
Pretreatment	-	Sedimentation forebay or pretreatment BMPs for all surfaces other than roofs
Design percolation rate, (P_{design})	in/hr	Measured soil infiltration rate must be corrected based on site suitability assessment and design related considerations described in this fact sheet
Maximum depth of facility (d_{max})	feet	8.0; Defined by the design percolation rate and the design drawdown time (includes ponding depth and depth of media)
Surface area of facility (A)	square feet	Based on depth of ponding (if applicable) and depth of trench media
Facility geometry	-	Minimum 24 inches wide and maximum 5 feet deep; max 3% bottom slope
Filter media diameter	inches	1 – 3 (gravel); prefabricated media and chamber/pipe system may also be used to increase void space
Trench lining material	-	Geotextile fabric
Overflow device	-	Required if system is on-line

6.4.2.3 Geotechnical Considerations

An extensive geotechnical site investigation must be undertaken early in the site planning process to verify site suitability for the installation of infiltration facilities due to the potential to contaminate groundwater, cause slope instability, impact surrounding structures, and have insufficient infiltration capacity. Soil infiltration rates and the water table depth should be evaluated to ensure that conditions are satisfactory for proper operation of an infiltration facility. See the Los Angeles County Public Works Guidelines for Geotechnical Investigation and Reporting Low Impact Development Stormwater Infiltration (June 30, 2021, and subsequent versions) for guidance on infiltration testing.

The project designer must demonstrate through infiltration testing, soil logs, and the written opinion of a licensed civil and/or geotechnical engineer that sufficiently permeable soils exist onsite to allow the construction of a properly functioning infiltration facility.

1) Infiltration facilities require a minimum soil infiltration rate of 0.3 inches/hour. If infiltration rates exceed 2.4 inches/hour, then the runoff should be fully treated in an upstream BMP prior to infiltration to protect groundwater quality. Pretreatment for coarse sediment removal is required in all instances. Additional pretreatment selection may be required by the local governing agency depending on the type of project and its siting.

2) Groundwater separation must be at least 5 feet from the trench bottom to the measured season high groundwater elevation or estimated high groundwater mounding elevation. Groundwater level measurements must be made during the time when water level is expected to be at a maximum (i.e., toward the end of the wet season).

3) Sites with a slope greater than 25% (4:1) should be excluded. A geotechnical analysis and report addressing slope stability are required if located on slopes greater than 15%.

6.4.2.3.1 Soil Assessment and Site Geotechnical Investigation Reports

The soil assessment report should:

- State whether the site is suitable for the proposed subsurface infiltration;
- Recommend a design percolation rate (see Appendix C.2 *Design Percolation Rate Corrections Safety Factors for Infiltration BMPs*);
- Identify the seasonally high depth to groundwater table surface elevation.
- Provide a good understanding of how the stormwater runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water; and
- If a geotechnical investigation and report are required, the report should:

- Provide a written opinion by a professional civil and/or geotechnical engineer describing whether the subsurface infiltration will compromise slope stability; and
- Identify potential impacts to nearby structural foundations.

6.4.2.3.2 Setbacks

1) Infiltration facilities shall be setback a minimum of 100 feet from proposed or existing potable wells, non-potable wells, septic drain fields, and springs.

2) Infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.

3) Infiltration BMPs must be setback from building foundations at least 10 feet or an alternative setback established by the geotechnical expert for the project.

6.4.2.4 Pretreatment

Pretreatment is required for subsurface infiltration BMPs in order to reduce the sediment load entering the facility and maintain the infiltration rate of the facility. Pretreatment refers to design features that provide settling of large particles before runoff reaches a management practice; easing the long-term maintenance burden. Pretreatment is important for all structural stormwater BMPs, but it is particularly important for infiltration BMPs. To ensure that pretreatment mechanisms are effective, designers should incorporate sediment reduction practices. Sediment reduction BMPs may include sedimentation basins or forebays, sedimentation manholes, hydrodynamic separation devices, catch basin inserts, vegetated swales, vegetated filter strips, or media cartridge filters. If runoff is piped into the subsurface infiltration, the design shall include a sump structure to allow the subsurface facility to be inspected and accessed for incoming flow and maintenance.

For design specification of selected pre-treatment devices, refer to:

- PT-1: Hydrodynamic separator
- PT-2: Catch basin insert
- PT-3: Vegetated swales
- PT-4: Vegetated filter strips
- FLO-1: Cartridge media filters

6.4.2.5 Sizing Criteria

Sizing Criteria are provided in Appendix C, Section C.3.

6.4.2.5.1 Geometry and Sizing

1) Subsurface infiltration BMPs should be at least 2 feet wide and 3 to 5 feet deep.

2) The longitudinal slope of the trench should not exceed 3%.

3) The filter bed media layers should have the following composition and thickness:

    a. Top layer – If stormwater runoff enters the top of the trench via sheet flow at the ground surface, then the top 2 inches should be pea gravel with a thin 2 to 4-inch layer of pure sand and 2-inch layer of chocking stone (e.g., #8) to capture sediment before entering the trench. If stormwater runoff enters the trench from an underground pipe, pretreatment prior to entry into the trench is required.

    b. Middle layer (3 to 5 feet of washed, 1.5 to 3-inch gravel or encapsulated chamber system). Void space for gravel is 35% and as specified by the manufacturer for underground chamber system.

    c. Bottom layer (6 inches of clean, washed sand to encourage drainage and prevent compaction of the native soil while the stone aggregate is added).

4) For gravel filled system, one or more observation wells should be installed, depending on trench length, to check for water level, drawdown time, and evidence of clogging. A typical observation well consists of a slotted PVC well screen, 4 to 6 inches in diameter, capped with a lockable, above-ground lid.

5) For gravel encapsulated manufactured system, a sump should be installed at the intake junction for maintenance and to check for water level, drawdown time and evidence of clogging. The sump structure should be designed as the lowest point in the system to allow sediments and debris to gravitate towards it.

6.4.2.5.2 Drainage

1) The bottom of the infiltration bed must be native soil, over-excavated to at least one foot in depth and replaced uniformly without compaction.

2) The hydraulic conductivity of the subsurface layers should be sufficient to ensure the design drawdown time. An observation well should be incorporated to allow observation of drain time.

6.4.2.5.3 Emergency Overflow

1) There must be an overflow route for stormwater flows that overtop the facility or in case the infiltration facility becomes clogged.

2) The overflow channel or drainage system must be able to safely convey flows from the peak design storm to the downstream stormwater conveyance system or other acceptable discharge point.

6.4.2.6 Vegetation

1) Trees and other large vegetation should be planted away from trenches such that drip lines do not overhang infiltration beds.

6.4.2.7 Maintenance Access

1) The facility and outlet structures must all be safely accessible during wet and dry weather conditions.

2) Access to the subsurface infiltration is required. For manufactured chamber systems, all components of the infiltration facility shall be accessible for maintenance. Accessibility to each chamber is required for inspections to ensure proper operation, cleaning, and repairs to ensure the systems operate at design specifications.

6.4.2.8 Construction Considerations

To preserve and avoid the loss of infiltration capacity, the following construction guidelines are specified:

1) The entire area draining to the facility must be stabilized before construction begins. If this is impossible, a diversion berm should be placed around the perimeter of the infiltration site to prevent sediment entering during construction.

2) The subsurface facility should not be hydraulically connected to the stormwater conveyance system until all contributing tributary areas are stabilized as shown on the Contract Plans and to the satisfaction of the Engineer. Subsurface infiltration facilities should not be used as sediment control facilities.

3) Compaction of the subgrade with heavy equipment should be minimized to the maximum extent possible. If the use of heavy equipment on the base of the facility cannot be avoided, the infiltrative capacity should be restored by tilling or aerating prior to placing the infiltrative bed.

4) The exposed soils should be inspected by a civil and/or geotechnical engineer after excavation to confirm that soil conditions are suitable.

6.4.2.9 Operations and Maintenance

Infiltration facility maintenance should include frequent inspections to ensure that water infiltrates into the subsurface completely within the design drawdown time after a storm.

Maintenance and regular inspections are of primary importance if subsurface infiltration BMPs are to continue to function as originally designed. A specific maintenance plan shall be developed specifically to each facility outlining the schedule and scope of maintenance operations, as well as the documentation and reporting requirements. The following are general maintenance requirements:

1) Regular inspection should determine if the sediment pretreatment structures require preventive maintenance. Inspect a minimum of twice a year, before and after the rainy season, after large storms, or more frequently if needed.

2) If water is noticed in the observation well of the subsurface infiltration facility more than 72 hours after a major storm, the subsurface infiltration facility may be clogged. Maintenance activities triggered by a potentially clogged facility include:

    a. For trenches, assess the condition of the top aggregate layer for sediment buildup and crusting. Remove top layer of pea gravel and replace. If slow draining conditions persist, entire trench may need to be excavated and replaced.

    b. For underground subsurface facility, assess the condition of the undergrounding chamber and perform sediment removal per the manufacturer's recommendations.

3) Any debris or algae growth located on top of the infiltration facility should be removed and disposed of properly.

4) Inspect a minimum of twice a year, before and after the rainy season, after large storms, or more frequently if needed.

5) Clean when loss of infiltrative capacity is observed. If drawdown time is observed to have increased significantly over the design drawdown time, removal of sediment may be necessary. This is an expensive maintenance activity and the need for it can be minimized through prevention of upstream erosion.

6) Mow as appropriate for vegetative cover species.

7) Monitor health of vegetation and replace as necessary.

8) Control mosquitoes as necessary.

9) Remove litter and debris from trench area as required.

6.4.3 INF-3: Bioretention

Bioretention stormwater treatment facilities are landscaped shallow depressions that capture and filter stormwater runoff. These facilities function as a soil and plant-based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. The facilities normally consist of a ponding area, mulch layer, planting soils, and plantings. An optional gravel layer can be added below the planting soil to provide additional storage volume for infiltration. As stormwater passes down through the planting soil, pollutants are filtered, adsorbed, and biodegraded by the soil and plants. For areas with low permeability native soils or steep slopes, see section INF-7: Bioinfiltration or BIO-1: Biofiltration for relevant design specifications.

Bioretention in Parkway and Parking Lots

Photo Credits: Top – Geosyntec Consultants; Bottom – County of Ventura

Application

- Commercial, residential, mixed use, institutional, and recreational uses
- Parking lot islands, traffic circles
- Road parkways & medians

Preventive Maintenance

- Repair small eroded areas
- Remove trash and debris and rake surface soils
- Remove accumulated fine sediments, dead leaves and trash
- Remove weeds and prune back excess plant growth
- Remove sediment and debris accumulation near inlet and outlet structures
- Periodically observe function under wet weather conditions

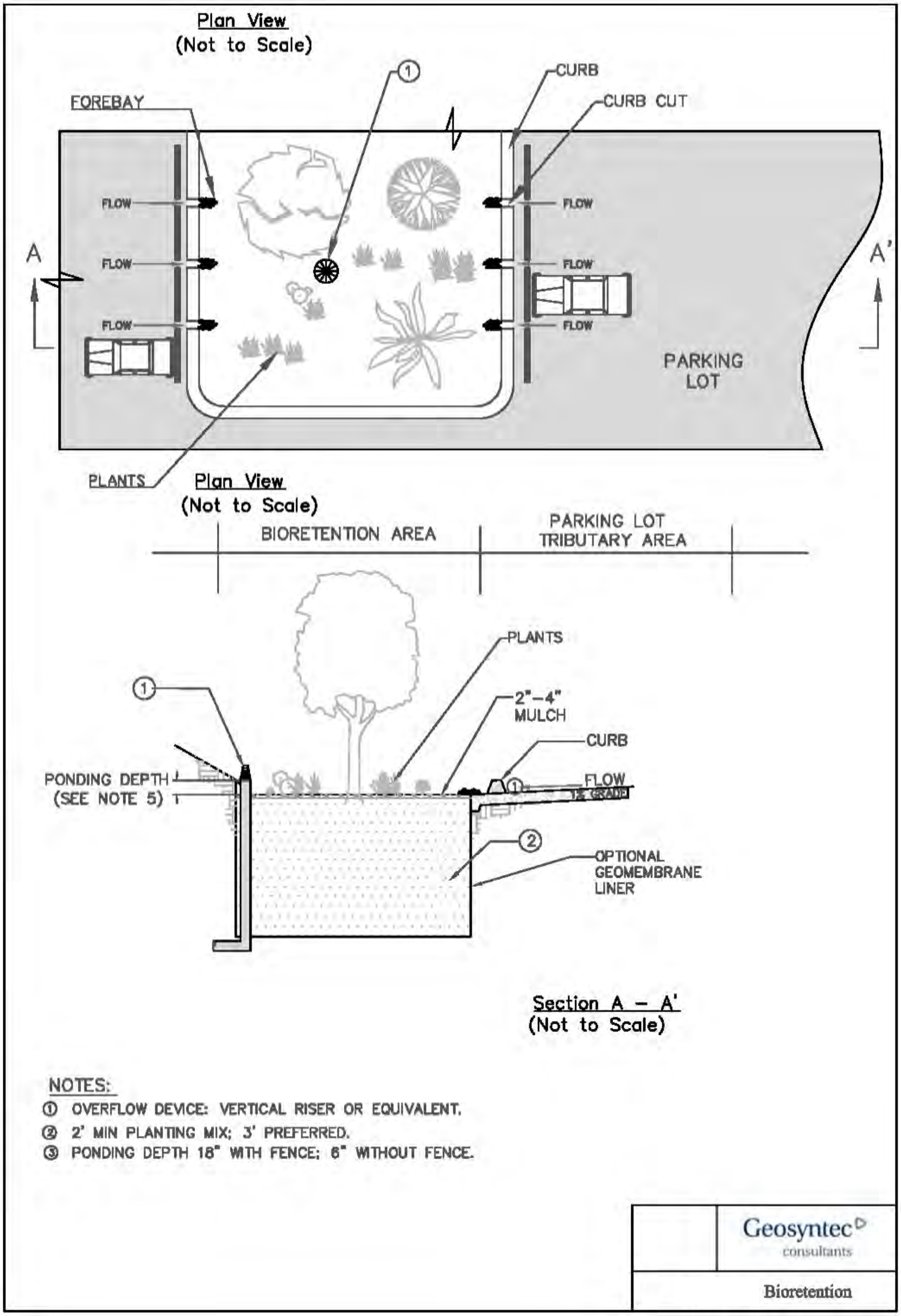


Figure 6-4: Bioretention Design Schematic

6.4.3.1 Limitations

The following limitations should be considered before choosing to use bioretention:

1) Native soil infiltration rate - soil permeability at the bioretention location must be at least 0.3 inches per hour.

2) Depth to groundwater, bedrock, or low permeability soil layer – 5 feet vertical separation is required between the bottom of the subsurface infiltration BMP and the seasonal high groundwater level or mounded groundwater level, bedrock, or other barrier to infiltration to ensure that the facility will completely drain between storms and that infiltrating water will receive adequate treatment through the soils before it reaches the groundwater.

3) Slope stability - infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.

4) Setbacks - a minimum setback (100 feet or more) must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields, and springs. Infiltration BMPs must be setback from building foundations at least ten feet or have an alternative setback established by the geotechnical expert for the project.

5) Groundwater contamination - the application of infiltration BMPs should include significant pretreatment in an area identified as an unconfined aquifer to ensure groundwater is protected for pollutants of concern.

6) Contaminated soils or groundwater plumes - infiltration BMPs are not allowed at locations with contaminated soils or groundwater where the pollutants could be mobilized or exacerbated by infiltration, unless a site-specific analysis determines that infiltration would be beneficial.

7) High pollutant land uses - infiltration BMPs should not be placed in high-risk areas such as at/or near service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk unless a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas have little chance of spill migration.

8) High sediment loading rates – infiltration BMPs may clog quickly if sediment loads are high (e.g., unstabilized site) or if flows are not adequately pretreated.

9) Vertical relief and proximity to storm drain - site must have adequate relief between the land surface and storm drain to permit vertical percolation through the soil media and collection.

6.4.3.2 Design Criteria

Bioretention should be designed according to the requirements listed in Table 6-3 and outlined in the section below. BMP sizing worksheets are presented in Appendix C.

Table 6-3: Bioretention Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2 and Appendix C for calculating SQDV.
Pretreatment	-	Sedimentation forebay or pretreatment BMPs for all surfaces other than roofs are required. Forebays should be designed to prevent standing water during dry weather and should be planted with a plant palette that is tolerant of wet conditions.
Maximum drawdown time of water ponded on surface	hours	48
Maximum drawdown time of surface ponding plus subsurface pores	hours	72
Maximum ponding depth	inches	18
Minimum thickness of amended soil	feet	2
Minimum thickness of stabilized mulch	inches	2 to 3
Planting mix composition	-	60 to 80% fine sand, 20 to 40% compost
Overflow device	-	Required

6.4.3.3 Sizing Criteria

Sizing Criteria are provided in the fact sheet for INF-3 Bioretention in Appendix C.4.

6.4.3.3.1 Geometry

1) Bioretention areas shall be sized to capture and treat the stormwater quality design volume (See Section 2 and Appendix C for calculating SQDV) with an 18-inch maximum ponding depth. *The intention is that ponding depth be limited to a depth that will allow for a health vegetation layer.*

2) Minimum planting soil depth must be at least 2 feet. The depth of planting soils may be increased by the designer to provide additional volume. *The intention is that the*

minimum planting soil depth should provide a beneficial root zone for the chosen plant palette and adequate water storage for the SQDV.

3) A gravel storage layer below the bioretention soil media to promote infiltration into the native soil is optional.

4) Bioretention should be designed to drain below the planting soil in less than 48 hours and completely drain in less than 72 hours. *The intention is that soils must be allowed to dry out periodically in order to restore hydraulic capacity needed to receive flows from subsequent storms, maintain infiltration rates, maintain adequate soil oxygen levels for healthy soil biota and vegetation, and to provide proper soil conditions for biodegradation and retention of pollutants.*

6.4.3.3.2 Flow Entrance and Energy Dissipation

The following types of flow entrance can be used for bioretention cells:

5) Dispersed, low velocity flow across a landscape area. Dispersed flow may not be possible given space limitations or if the facility is controlling roadway or parking lot flows where curbs are mandatory.

6) Dispersed flow across pavement or gravel and past wheel stops for parking areas.

7) Curb cuts for roadside or parking lot areas: curb cuts should include rock or other erosion protection material in the channel entrance to dissipate energy. Flow entrance should drop 2 to 3 inches from curb line and it should provide a settling area and periodic sediment removal of coarse material before flow dissipates to the remainder of the cell.

8) Pipe flow entrance: Piped entrances, such as roof downspouts, should include rock, splash blocks, or other appropriate measures at the entrance to dissipate energy and disperse flows.

Woody plants (trees, shrubs, etc.) can restrict or concentrate flows and can be damaged by erosion around the root ball and should not be placed directly in the entrance flow path.

6.4.3.3.3 Overflow

An overflow device is required at the ponding depth, per the design criteria, with 18 inches as the maximum ponding depth. The overflow structure(s) should be 6 inches or greater in diameter and be fitted with a trash/grate device to prevent floating mulch and debris from discharging with overflowed stormwater.

6.4.3.3.4 Hydraulic Restriction Layers

Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mils.

6.4.3.3.5 Planting/Storage Media

1) The planting media placed in the cell should achieve a long-term, in-place infiltration rate of at least 1 inch per hour. Higher infiltration rates are permissible. If the design long-term, in-place infiltration rate of the soil exceeds 12 inches per hour, documentation should be provided to demonstrate that the media will adequately address pollutants of concern at a higher flowrate. Bioretention soil shall also support vigorous plant growth.

2) Planting media should consist of 60 to 80% fine sand and 20 to 40% compost.

3) Sand should be free of wood, waste, coating such as clay, stone dust, carbonate, etc., or any other deleterious material. All aggregate passing the No. 200 sieve size should be non-plastic. Sand for bioretention should be analyzed by an accredited lab using #200, #100, #40, #30, #16, #8, #4, and 3/8 sieves (American Society for Testing and Materials (ASTM) D 422 or as approved by the local permitting agency) and meet the following gradation (Note: all sands complying with ASTM C33 for fine aggregate comply with the gradation requirements below):

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
3/8 inch	100	100
#4	90	100
#8	70	100
#16	40	95
#30	15	70
#40	5	55
#100	0	15
#200	0	5

Note: the gradation of the sand component of the media is believed to be a major factor in the hydraulic conductivity of the media mix. If the desired hydraulic conductivity of the media cannot be achieved within the specified proportions of sand and compost (#2), then it may be necessary to utilize sand at the coarser end of the range specified in above ("minimum" column).

4) Compost should be a well decomposed, stable, weed free organic matter source derived from waste materials including yard debris, wood wastes, or other organic materials not including manure or biosolids meeting standards developed by the US Composting Council (USCC). The product shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program). Compost quality should be verified via a lab analysis to be:

- Feedstock materials shall be specified and include one or more of the following: landscape/yard trimmings, grass clippings, food scraps, and agricultural crop residues.
- Organic matter: 35-75% dry weight basis.
- Carbon and Nitrogen Ratio: 15:1 < C:N < 25:1
- Maturity/Stability: shall have dark brown color and a soil-like odor. Compost exhibiting a sour or putrid smell, containing recognizable grass or leaves, or is hot (120 degrees Fahrenheit) upon delivery or rewetting is not acceptable.
- Toxicity: any one of the following measures is sufficient to indicate non-toxicity:
    - NH4:NH3 < 3
    - Ammonium < 500 ppm, dry weight basis
    - Seed Germination > 80% of control
    - Plant trials > 80% of control
    - Solvita® > 5 index value
- Nutrient content:
    - Total Nitrogen content 0.9% or above preferred
    - Total Boron should be <80 ppm, soluble boron < 2.5 ppm
- Salinity: < 6.0 mmhos/cm
- pH between 6.5 and 8 (may vary with plant palette)

Compost for bioretention should be analyzed by an accredited lab using #200, ¼ inch, ½ inch, and 1-inch sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation:

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
1 inch	99	100
½ inch	90	100
¼ inch	40	90
#200	2	10

Tests should be sufficiently recent to represent the actual material that is anticipated to be delivered to the site. If processes or sources used by the supplier have changed significantly since the most recent testing, new tests should be requested.

Note: the gradation of compost used in bioretention media is believed to play an important role in the saturated hydraulic conductivity of the media. To achieve a higher saturated hydraulic conductivity, it may be necessary to utilize compost at the coarser end of this range (“minimum” column). The percent passing the #200 sieve (fines) is believed to be the most important factor in hydraulic conductivity.

In addition, a coarser compost mix provides more heterogeneity of the bioretention media, which is believed to be advantageous for more rapid development of soil structure needed to support health biological processes. This may be an advantage for plant establishment with lower nutrient and water input.

5) The bioretention area should be covered with 2 to 4 inches (average 3 inches) of mulch at the start and an additional placement of 1 to 2 inches of mulch should be added annually. *The intention is to help sustain the nutrient levels, suppress weeds, retain moisture, and maintain infiltration capacity*.

6) Gravel section, if used for additional storage volume, must be constructed out of Caltrans Class 2 permeable material.

6.4.3.4 Plants

1) Plant materials should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 48 to 72 hours.

2) It is recommended that a minimum of three types of tree, shrubs, and/or herbaceous groundcover species be incorporated to protect against facility failure due to disease and insect infestations of a single species.

3) Native plant species and/or hardy cultivars that are not invasive and do not require chemical inputs should be used to the maximum extent practicable.

6.4.3.5 Operations and Maintenance

Bioretention areas require annual plant, soil, and mulch layer maintenance to ensure optimum infiltration, storage, and pollutant removal capabilities. In general, bioretention maintenance requirements are typical landscape care procedures and include:

1) Watering: Plants should be drought-tolerant. Watering may be required during prolonged dry periods after plants are established.

2) Erosion control: Inspect flow entrances, ponding area, and surface overflow areas periodically, and replace soil, plant material, and/or mulch layer in areas if erosion has occurred (see Appendix D for a bioretention inspection and maintenance checklist). Properly designed facilities with appropriate flow velocities should not have erosion

problems, except perhaps in extreme events. If erosion problems occur, the following should be reassessed: (1) flow velocities and gradients within the cell, and (2) flow dissipation and erosion protection strategies in the pretreatment area and flow entrance. If sediment is deposited in the bioretention area, immediately determine the source within the contributing area, stabilize, and remove excess surface deposits.

3) Plant material: Depending on aesthetic requirements, occasional pruning and removing of dead plant material may be necessary. Replace all dead plants and if specific plants have a high mortality rate, assess the cause and, if necessary, replace with more appropriate species. Periodic weeding is necessary until plants are established. The weeding schedule should become less frequent if the appropriate plant species and planting density have been used and, as a result, undesirable plants excluded.

4) Nutrients and pesticides: The soil mix and plants should be selected for optimum fertility, plant establishment, and growth. Nutrient and pesticide inputs should not be required and may degrade the pollutant processing capability of the bioretention area, as well as contribute pollutant loads to receiving waters. By design, bioretention facilities are located in areas where phosphorous and nitrogen levels are often elevated, and these should not be limiting nutrients. If in question, have soil analyzed for fertility.

5) Mulch: Replace mulch annually in bioretention facilities where heavy metal deposition is likely (e.g., contributing areas that include industrial and auto dealer/repair parking lots and roads). In residential lots or other areas where metal deposition is not a concern, replace or add mulch as needed to maintain a 2 to 3-inch depth at least once every two years.

6) Soil: Soil mixes for bioretention facilities are designed to maintain long-term fertility and pollutant processing capability. Estimates from metal attenuation research suggest that metal accumulation should not present an environmental concern for at least 20 years in bioretention systems. Replacing mulch in bioretention facilities where heavy metal deposition likely provides an additional level of protection for prolonged performance. If in question, have soil analyzed for fertility and pollutant levels.

6.4.4 INF-4: Drywell

A drywell is defined as a bored, drilled, or driven shaft or hole whose depth is greater than its width. A drywell is designed specifically for flood alleviation and stormwater disposal. A drywell may be either a small, excavated pit filled with aggregate or a prefabricated storage chamber or pipe segment.

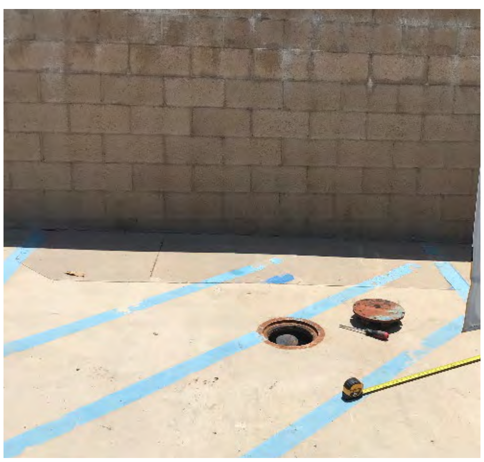
Drywells can be used to reduce the increased volume of stormwater runoff generated from impervious areas. Forebays and other forms of pretreatment are extremely important for this type of infiltration BMPs.

Application

- Infiltration of runoff

Preventive Maintenance

- Remove trash, debris, and sediment at outlets and pretreatment inlets
- Wet weather inspection to ensure drain time
- Inspect for mosquito breeding



Drywell Examples

Photo Credit: Left – County of Ventura; Bottom – Canale Landscaping

Drywell Installation

Photo Credit: Torrent Resources

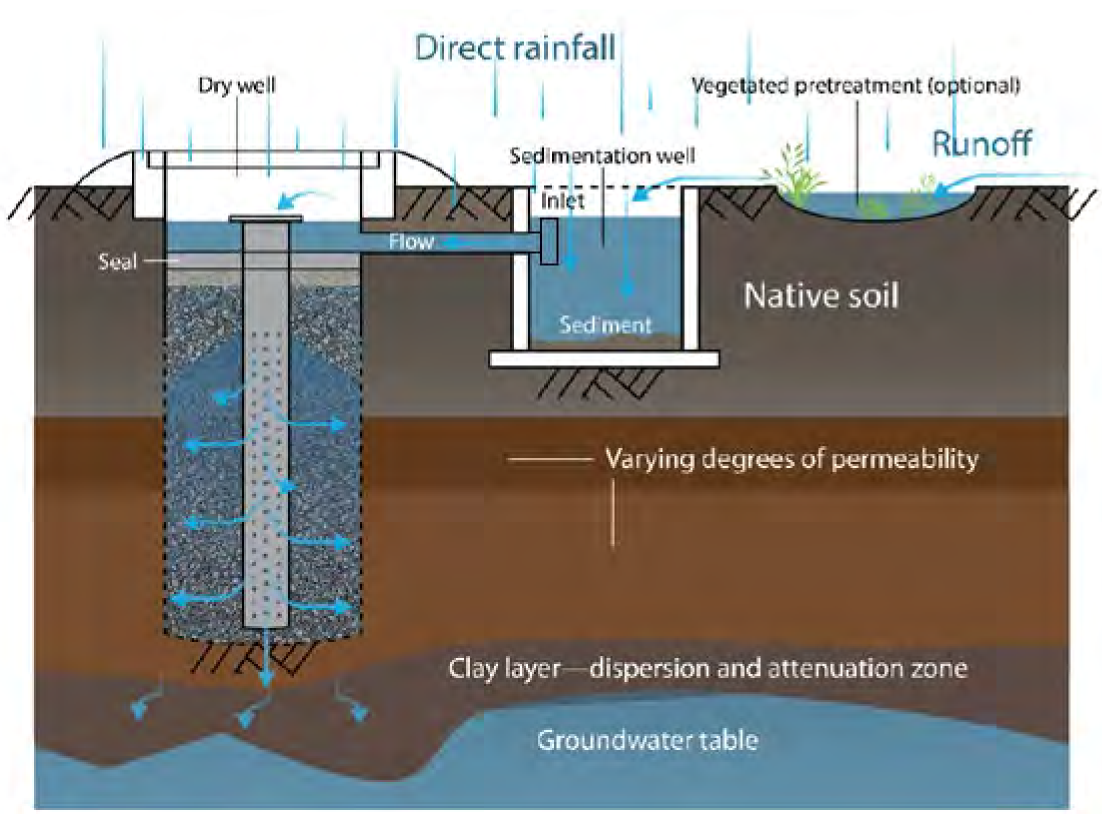


Figure 6-5: Drywell Schematic

(Reference: Guidance for Stormwater and Dry Weather Runoff Capture at Schools, 2018)

6.4.4.1 Limitations

The following limitations shall be considered before choosing to use a drywell:

- Native soil infiltration rate – soil permeability at the drywell location must be at least 0.3 inches per hour.

- Depth to groundwater, bedrock, or low permeability soil layer – 5 feet vertical separation is required between the bottom of the drywell and the seasonal high groundwater level or mounded groundwater level, bedrock, or other barrier to infiltration to ensure that the facility will completely drain between storms and that infiltrating water will receive adequate treatment though the soils before it reaches the groundwater.

- Slope stability - infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.

- Setbacks - a minimum setback (100 feet or more) must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields, and springs. Infiltration BMPs must be setback from building foundations at least ten feet or have an alternative setback established by the geotechnical expert for the project.

- Groundwater contamination - the application of infiltration BMPs should include significant pretreatment particularly in an area identified as an unconfined aquifer, to ensure groundwater is protected from pollutants of concern.

- Contaminated soils or groundwater plumes - infiltration BMPs are not allowed at locations with contaminated soils or groundwater where the pollutants could be mobilized or exacerbated by infiltration, unless a site-specific analysis determines the infiltration would be beneficial.

- High pollutant land uses - infiltration BMPs should not be placed in high-risk areas such as at or near service/gas stations, truck stops, and heavy industrial sites due to groundwater contamination risk unless a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas have little chance of spill migration.

- High sediment loading rates – infiltration BMPs may clog quickly if sediment loads are high (e.g., unstabilized site) or if flows are not adequately pretreated.

- Drywells shall not receive untreated stormwater runoff. Pretreatment of runoff from other surfaces is necessary to prevent premature failure that results from clogging with fine sediment, and to prevent potential groundwater contamination due to nutrients, salts, and hydrocarbons. Drywells are often designed with a pretreatment chamber to address these pollutants prior to entering the drywell.

- Infiltration structures cannot be used to treat runoff from portions of the site that are not stabilized.
- Rehabilitation of failed drywells requires complete reconstruction.

6.4.4.2 Design Criteria

The main challenge associated with drywells, as with other infiltration BMPs, is the prevention of system clogging and subsequent infiltration inhibition. Drywells should be designed according to the requirements listed in Table 6-4 and outlined in the section below. BMP sizing worksheets are presented in Appendix C.

Table 6-4: Infiltration BMP Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2 and Appendix C for calculating SQDV.
Design drawdown time	hour	72
Pretreatment	-	PT-3: Vegetated Swale, PT-4: Filter Strip, proprietary device, or equivalent. Pretreatment is required.
Design percolation rate (k_{design})	in/hr	0.5, minimum. Shall be corrected for testing method, potential for clogging and compaction over time, and facility geometry.
Maximum depth of facility (d_{max})	feet	Defined by the design percolation rate and the design drawdown time (includes depth of media). Must be at least 5 feet above seasonal high groundwater elevation.
Surface area of facility (A)	ft^2	Based on depth of and size drywell. Includes bottom and sidewall surface area.
Facility geometry	-	Geometry varies; flat bottom.
Gravel rock diameter	inches	3/8 – 3 (washed gravel)
Overflow device	-	Required if system is on-line

6.4.4.3 Geotechnical Considerations

An extensive geotechnical site investigation must be undertaken early in the site planning process to verify site suitability for the installation of drywells, due to the potential to contaminate groundwater, cause slope instability, impact surrounding structures, and have insufficient infiltration capacity. Soil infiltration rates and the water table depth should be evaluated to ensure that conditions are satisfactory for proper operation of a drywell. See the Los Angeles County Public Works Guidelines for Geotechnical

Investigation and Reporting Low Impact Development Stormwater Infiltration (June 30, 2021, and subsequent versions) for guidance on infiltration testing.

The project designer must demonstrate through infiltration testing, soil logs, and the written opinion of a licensed civil and/or geotechnical engineer that sufficiently permeable soils exist on site to allow the construction of a properly functioning drywell.

1) Infiltration facilities require a minimum soil infiltration rate of 0.3 inches/hour. If infiltration rates exceed 2.4 inches/hour, then the runoff should be fully-treated in an upstream BMP prior to infiltration to protect groundwater quality. Pretreatment for coarse sediment removal is required in all instances.

2) Groundwater separation must be at least 5 feet from the drywell bottom to the measured seasonal high groundwater elevation or estimated high groundwater mounding elevation. Measurements of groundwater levels must be made during the time when water level is expected to be at a maximum (i.e., toward the end of the wet season).

3) Sites with a slope greater than 25% (4:1) should be excluded. A geotechnical analysis and report addressing slope stability are required if located on slopes greater than 15%.

6.4.4.3.1 Soil Assessment and Site Geotechnical Investigation Reports

The soil assessment report should:

- State whether the site is suitable for the proposed drywell;
- Recommend a design percolation rate (see Appendix C.2 *Design Percolation Rate Corrections Safety Factors for Infiltration BMPs*);
- Identify the seasonal high depth to groundwater table surface elevation;
- Provide a good understanding of how the stormwater runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water; and
- If a geotechnical investigation and report are required, the report should:
    - Provide a written opinion by a professional civil and/or geotechnical engineer describing whether the drywell will compromise slope stability; and
    - Identify potential impacts to nearby structural foundations.

6.4.4.3.2 Setbacks

1) Infiltration facilities shall be setback a minimum of 100 feet from proposed or existing potable wells, non-potable wells, septic drain fields, and springs.

2) Infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.

3) Infiltration BMPs must be setback from building foundations at least ten feet or have an alternative setback established by the geotechnical expert for the project.

6.4.4.4 Pretreatment

Though roofs are generally not a significant source of runoff pollution, they can still be source of particulates and organic matter. At a minimum, a removable filter with a screened bottom should be installed in the roof leader below the surcharge pipe in order to screen out leaves and other debris. Other measures such as roof gutter guards, roof leader clean-out with sump, or an intermediate sump box are also appropriate for roof runoff.

For all other types of runoff, forebays and more substantial pretreatment are required and extremely important to preserve the long-term infiltration capabilities of the drywell. Refer to the pretreatment BMPs: PT-1 to Pt-4.

6.4.4.5 Sizing Criteria

Sizing Criteria are provided in Appendix C.3.

6.4.4.5.1 Geometry and Sizing

1) Drywell configurations vary, but generally they have a small footprint and are deeper than they are wide. Pre-fabricated dry-wells are often cylindrical with a typical diameter of 18-72 inches and a flat bottom. The surface area of the drywell must be large enough to infiltrate the storage volume within 72 hours.

2) The porosity of gravel media systems is generally 30 to 40%.

3) An observation well should be installed to check for water levels, drawdown time, and evidence of clogging. A typical observation well consists of a slotted PVC well screen, 4 to 6 inches in diameter, capped with a lockable, above-ground lid.

6.4.4.5.2 Drainage

1) The drywell shall be constructed on top of native soil, without compaction.

2) The hydraulic conductivity of the subsurface layers should be sufficient to ensure a maximum 72-hour drawdown time. An observation well should be incorporated to allow observation of drain time.

6.4.4.5.3 Emergency Overflow

1) There must be an overflow route for stormwater flows that overtop the facility or in case the infiltration facility becomes clogged.

2) The overflow channel must be able to safely convey flows from the peak design storm to the downstream stormwater conveyance system or other acceptable discharge point.

6.4.4.6 Vegetation

1) Drywells should be kept free of vegetation.

2) Trees and other large vegetation should be planted away from drywells such that drip lines do not overhang infiltration beds.

6.4.4.7 Maintenance Access

1) The facility and outlet structures must all be safely accessible during wet and dry weather conditions.

2) Maintenance access is required.

6.4.4.8 Construction Considerations

To preserve and avoid the loss of infiltration capacity, the following construction guidelines should be specified:

1) The entire area draining to the facility must be stabilized before construction begins. If this is impossible, a diversion berm should be placed around the perimeter of the infiltration site to prevent sediment entering during construction.

2) Drywells should not be hydraulically connected to the stormwater conveyance system until all contributing tributary areas are stabilized as shown on the Contract Plans and to the satisfaction of the Engineer. Drywells should not be used as sediment control facilities.

3) Compaction of the subgrade with heavy equipment should be minimized to the maximum extent possible. If the use of heavy equipment on the base of the facility cannot be avoided, the infiltration capacity should be restored by tilling or aerating prior to placing the infiltrative bed.

4) The exposed soils should be inspected by a civil and/or geotechnical engineer after excavation to confirm that soil conditions are suitable.

6.4.4.9 Operations and Maintenance

Drywell maintenance should be performed frequently to ensure that water infiltrates into the subsurface completely within the recommended infiltration time (or drain time if a drywell receives runoff from an underground pipe) of 72 hours or less after a storm.

Maintenance and regular inspections are important for the proper functioning of drywells. A specific maintenance plan shall be developed specifically for each facility outlining the schedule and scope of maintenance operations, documentation, and reporting needs.

6.4.5 INF-5: Permeable Pavement

Permeable pavements contain small voids that allow water to pass through to a stone base. They come in a variety of forms; they may be a modular paving system (concrete pavers, grass-pave, or gravel-pave) or a poured-in-place solution (porous concrete or permeable asphalt). All permeable pavements with a stone reservoir base treat stormwater and remove sediments and metals to some degree. While conventional pavement results in increased rates and volumes of surface runoff, porous pavements when properly constructed and maintained, allow some of the stormwater to percolate through the pavement and enter the soil below. This facilitates groundwater recharge while providing the structural and functional features needed for the roadway, parking lot, or sidewalk.

The paving surface, subgrade, and installation requirements of permeable pavements are more complex than those for conventional asphalt or concrete surfaces. For porous pavements to function properly over an expected life span of 15 to 20 years, they must be properly sited and carefully designed and installed, as well as periodically maintained. Failure to protect paved areas from construction-related sediment loads can result in their premature clogging and failure. Note that the TGM does not provide specific instructions on how to design and construct pavement.

Permeable Pavement Applications

Photo Credits: County of Ventura

Application

- Parking lots
- Driveways
- Sidewalks and walkways
- Outdoor athletic courts

Preventive Maintenance

- Trash removal
- Post-rain inspections
- Vacuum sweeping
- Vegetation inspection and removal

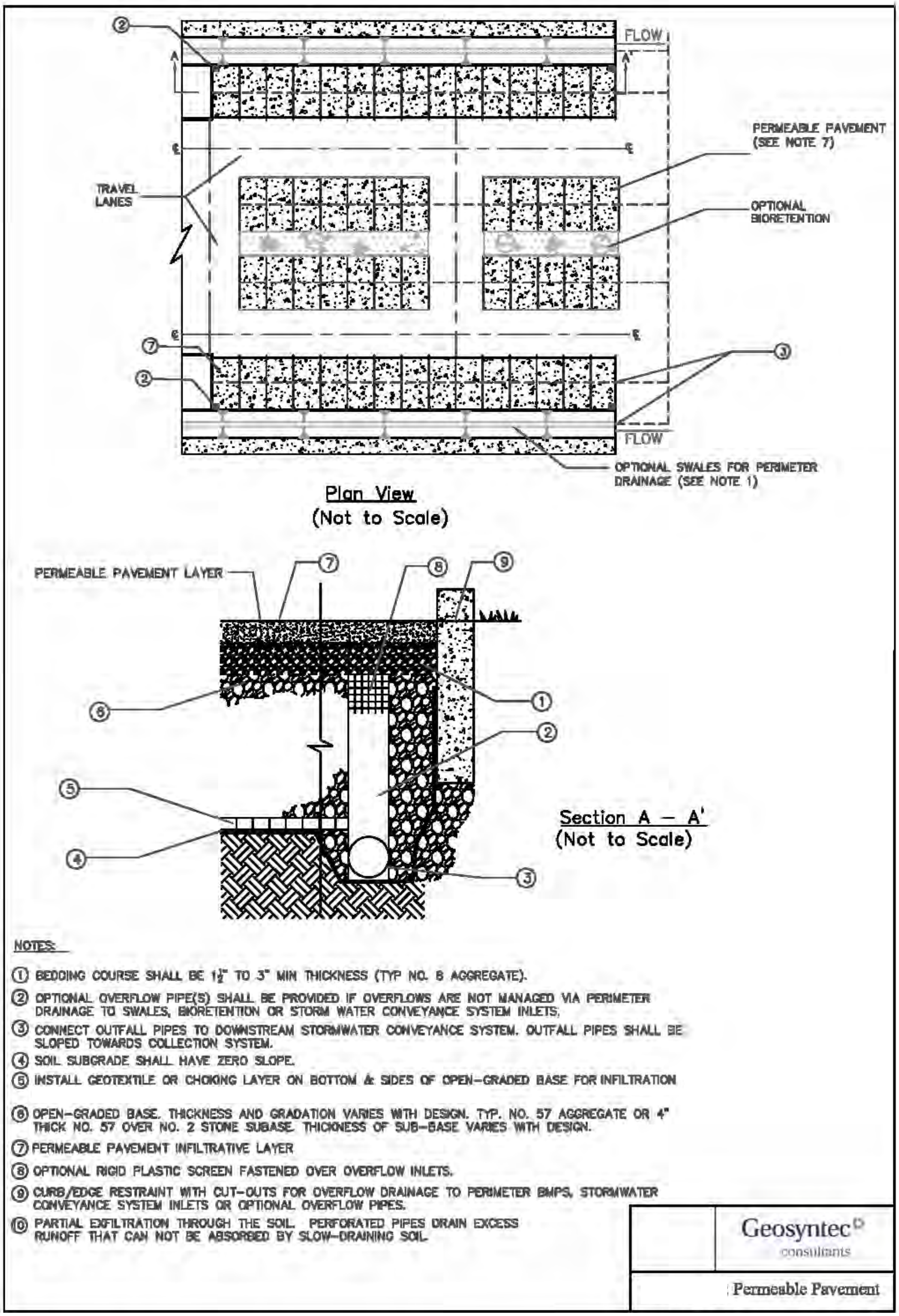


Figure 6-6: Permeable Pavement Design Schematic

6.4.5.1 Limitations

The following describes limitations for the use of permeable pavement.

- Native soil infiltration rate - permeability of soils at the BMP location must be at least 0.3 inches per hour.

- Depth to groundwater, bedrock, or low permeability soil layer – 5 feet vertical separation is required between the bottom of the infiltration trench and the seasonal high groundwater level or mounded groundwater level, bedrock, or other infiltration barrier to ensure that the facility will completely drain between storms and that infiltrating water will receive adequate treatment though the soils before it reaches the groundwater.

- Slope stability - infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.

- Setbacks - a minimum setback (100 feet or more) must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields, and springs. Infiltration BMPs must be setback from building foundations at least ten feet or an alternative setback established by the geotechnical expert for the project.

- Groundwater contamination - the application of infiltration BMPs should include significant pretreatment in an area identified as an unconfined aquifer, to ensure groundwater is protected for pollutants of concern.

- Contaminated soils or groundwater plumes - infiltration BMPs are not allowed at locations with contaminated soils or groundwater where the pollutants could be mobilized or exacerbated by infiltration, unless a site-specific analysis determines the infiltration would be beneficial.

- High pollutant land uses - infiltration BMPs should not be placed in high-risk areas such as at or near a service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk unless a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas that have little chance of spill migration.

- High sediment loading rates – infiltration BMPs may clog quickly if sediment loads are high (e.g., unstabilized site) or if flows are not adequately pretreated. For this reason, the maximum ratio of impervious area to permeable pavement should be no greater than 2:1 to minimize sediment loading. Additional pretreatment should be implemented when the ratio exceeds 2:1 to reduce excessive sediment loading and ensure the long-term surface permeability performance of the permeable pavement.

- Permeable pavement cannot receive untreated stormwater runoff from other surfaces. Pretreatment of run-on from other surfaces is necessary to prevent premature failure that results from clogging with fine sediment.
- Permeable pavement cannot be used to treat runoff from portions of the site that are not stabilized.
- Pretreatment must be provided for runoff routed to the permeable pavement through a storm drainpipe. The permeable pavement system designed with this type of stormwater intake will be treated similarly to an underground infiltration basin.

6.4.5.2 Design Criteria

Permeable pavement should be designed according to the requirements listed in Table 6-5 and outlined in the section below.

Table 6-5: Permeable Pavements Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater Quality Design Volume (SQDV)	acre-feet	See Section 2 and Appendix C for calculating SQDV.
Pretreatment	-	Runoff from pervious areas should not drain directly to the permeable pavement. The ratio of impervious to permeable pavement should not be greater than 2:1. Additional pretreatment should be implemented when the ratio exceeds 2:1 to reduce excessive sediment loading and ensure the long-term surface permeability performance of the permeable pavement.
Drawdown time of gravel drainage layer	hrs	12 - 72
Porous Pavement Infill		ASTM No. 9 or as specified by the permeable pavement manufacturer
Minimum depth to bedrock	ft	2 (without underdrains)
Minimum depth to seasonal high water table	ft	2 (with underdrains); 5 (without underdrains)
Infiltration rate of subsoil	in/hr	0.3 (minimum without an underdrain)
Overflow device	-	Required

6.4.5.3 Geotechnical Considerations

An extensive geotechnical site investigation must be undertaken early in the site planning process to verify site suitability for the installation of infiltration facilities, due to the potential to contaminate groundwater, cause slope instability, impact surrounding structures, and have insufficient infiltration capacity. Soil infiltration rates and the water table depth should be evaluated to ensure that conditions are satisfactory for proper operation of an infiltration facility. See the Los Angeles County Public Works Guidelines for Geotechnical Investigation and Reporting Low Impact Development Stormwater Infiltration (June 30, 2021, and subsequent versions) for guidance on infiltration testing.

The project designer must demonstrate through infiltration testing, soil logs, and the written opinion of a licensed civil and/or geotechnical engineer that sufficiently permeable soils exist onsite to allow the construction of a properly functioning infiltration facility.

1) Permeable pavement facilities require a minimum native soil infiltration rate of 0.3 inches/hour.

2) Groundwater separation must be at least 5 feet from the subbase invert to the measured season high groundwater elevation or estimated high groundwater mounding elevation. Groundwater levels measurements must be made during the time when the water level is expected to be at a maximum (i.e., toward the end of the wet season).

3) Sites with a slope greater than 25% (4:1) should be excluded. A geotechnical analysis and report addressing slope stability are required if located on slopes greater than 15%.

6.4.5.3.1 Soil Assessment and Site Geotechnical Investigation Reports

The soil assessment report should:

- State whether the site is suitable for the proposed permeable pavement;
- Recommend a design percolation rate (see Appendix C.2 *Design Percolation Rate Corrections Safety Factors for Infiltration BMPs*);
- Identify the seasonal high depth to groundwater table surface elevation;
- Provide a good understanding of how the stormwater runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water; and
- If a geotechnical investigation and report are required, the report should:
    - Provide a written opinion by a professional civil and/or geotechnical engineer describing whether the permeable pavement will compromise slope stability; and
    - Identify potential impacts to nearby structural foundations.

6.4.5.3.2 Setbacks

1) Infiltration facilities shall be setback a minimum of 100 feet from proposed or existing potable wells, non-potable wells, septic drain fields, and springs.

2) Infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.

3) Infiltration BMPs must be setback from building foundations at least ten feet or have an alternative setback established by the geotechnical expert for the project.

6.4.5.4 Pretreatment

1) The design of the permeable pavement shall not receive runoff from landscape areas. Incidental landscape areas, such as an island planter, shall be designed so that the soils and sediments are contained inside the planter.

2) Protection of permeable pavement is essential during installation. Failure to protect paved areas from construction-related sediment loads can result in their premature clogging and failure.

6.4.5.5 Sizing Criteria

Permeable pavement must be designed to meet Ventura County codes and/or applicable local permitting authority codes. These sizing criteria are meant to provide guidance for runoff volume storage only. See Appendix C, Section C.5 INF-5 Fact Sheet for a design Work Sheet and Examples.

6.4.5.5.1 Geometry and Size

1) Permeable pavement shall be sized to capture and treat the stormwater quality design volume (SQDV).

2) If permeable pavement is located on a site with a slope greater than 2%, the permeable pavement area should be terraced to prevent lateral flow through the subsurface. Permeable pavement cannot be located on a site with a slope greater than 5%.

3) Porous pavement systems generally consist of at least four different layers of material:

    a. The top or wearing layer consists of either asphalt or concrete with a greater than normal percentage of voids (typically 12 to 20 percent in the case of asphalt). The wearing layer may also be comprised of lattice-type pavers (either hollow concrete blocks or paving stones made from solid conventional concrete or stone), which are set in a bedding material (sand, pea-sized gravel or turf grass). See the Interlocking Concrete Pavement Institute (ICPI) for further guidance.

    b. Below the wearing layer, a stone reservoir layer or a thick layer of aggregate (e.g., 2-inch stone) provides the bulk of the water storage capacity for a porous pavement system. In the pavement design, it is important to ensure that this reservoir layer retains its load bearing capacity under saturated conditions, because it may take several days for complete drainage to occur.

c. Typically, porous pavement designs include two (or more) transition layers that can be constructed from 1 to 2-inch diameter stone. One transition layer separates the top wearing layer from the underlying stone reservoir layer. Another transition layer is used to separate the stone reservoir from the undisturbed subgrade soil. Some designs also add a geotextile layer to this bottom layer or some combination of stones and geotextiles.

d. Porous asphalt pavement, for example, consists of open grade asphalt mixture ranging in depth from 2 to 4 inches with 16 percent voids. The thickness selected depends on bearing strength and pavement design requirements. This layer sits on a 2 to 4-inch transition layer located over a stone reservoir. The bottom layer completes the transition to the underlying undisturbed soil using a combination transition/filter fabric layer.

e. The depth of each layer should be determined by a licensed civil and/or geotechnical engineer based on analyses of the hydrology, hydraulics, and structural requirements of the site.

4) Modular paving stones are also used to create porous pavements. These pavements can be constructed in situ by pouring concrete into special frames or by using preformed blocks. The top layer of these porous pavements consists of conventional concrete, with the intervening void areas filled with either turf or sand. A transition or bedding layer is used to make the transition to the reservoir layer. These lattice-type pavers or hollow concrete blocks are often used in conjunction with turf grasses and are used in low-traffic parking lots, lanes, or driveways. Porous pavements using paving stones have similar construction but can be designed to have a much higher load bearing capacity, and therefore have more widespread applicability. Construction guidelines and design specifications are available from the manufacturers of these products.

5) Permeable pavement (including the base layers) should be designed to drain in less than 72 hours. The basis for this is that soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive flows from subsequent storms, maintain infiltration rates, maintain adequate subsoil oxygen levels for healthy soil biota, and to provide proper soil conditions for biodegradation and retention of pollutants.

6) The percolation rate will decline as the surface becomes occluded and particulates accumulate in the infiltration layer. It is important that adequate conservatism is incorporated in the selection of design percolation rates.

6.4.5.5.2 Overflow

An overflow mechanism is required. The design should include an overflow facility where excess runoff can be collected and safely discharged.

6.4.5.6 Construction Considerations

1) Permeable pavement should be laid close to level and the bottom of the base layers must be level to ensure uniform infiltration.

2) Permeable pavement surfaces should not be used to store site materials, unless the surface is well protected from accidental spillage or other contamination.

3) To prevent/minimize soil compaction in the area of the permeable pavement installation, use light equipment with tracks or oversized tires.

4) Include a layer of open geogrid on top of the subgrade for added structural strength.

5) Divert stormwater from the area as needed (before and during installation).

6) The pavement should be the last installation done at a development site. Landscaping should be completed and adjacent areas stabilized, before pavement installation to minimize the risk of clogging.

7) Vehicular traffic should be prohibited for at least 2 days after installation.

6.4.5.7 Operations and Maintenance

Permeable pavement mainly requires vacuuming and management of adjacent areas to limit sediment contamination and prevent clogging by fine sediment particles. Therefore, little special training is needed for maintenance crews. The following maintenance concerns and maintenance activities shall be considered and provided:

1) Trash tends to accumulate in paved areas, particularly in parking lots and along roadways. The need for litter removal should be determined through periodic inspection.

2) Regularly (e.g., monthly for a few months after initial installation, then quarterly) inspect pavement for pools of standing water after rain events, this could indicate surface clogging.

3) Actively (3 to 4 times per year, or more frequently depending onsite conditions) vacuum sweep the pavement to reduce the risk of clogging by frequently removing fine sediments before they can clog the pavement and subsurface layers. This also helps to prolong the functional period of the pavement.

4) If clogging occurs, a combination of pressure washing and vacuuming should be used to dislodge fine sediments.

5) Inspect for vegetation growth on pavement and remove when present.

6) Inspect for missing sand/gravel in spaces between pavers and replace as needed.

7) Activities that lead to ruts or depressions on the surface should be prevented or the integrity of the pavement should be restored by patching or repaving. Examples are vehicle tracks and utility maintenance.

8) Spot clogging of porous concrete may be remedied by drilling 0.5-inch holes every few feet in the concrete.

9) Interlocking pavers that are damaged should be replaced.

10) Maintain landscaped areas and reseed bare areas.

6.4.6 INF-6: Proprietary Infiltration

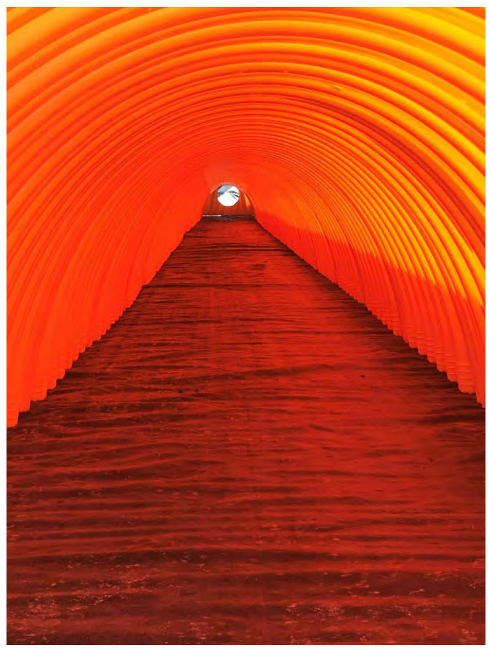
A number of vendors offer proprietary infiltration products that allow for similar or enhanced rates of infiltration and subsurface storage while offering durable prefabricated structures. There are many varieties of proprietary infiltration BMPs.

Application

- Mixed-use and commercial
- Roads and parking lots
- Parks and open spaces
- Single and multi-family residential

Routine Maintenance

- Removal trash, debris, and sediment at inlet and outlets
- Wet weather inspection to ensure drain time
- Inspect for mosquito breeding



Proprietary Infiltration BMPs

Photo Credits: County of Ventura

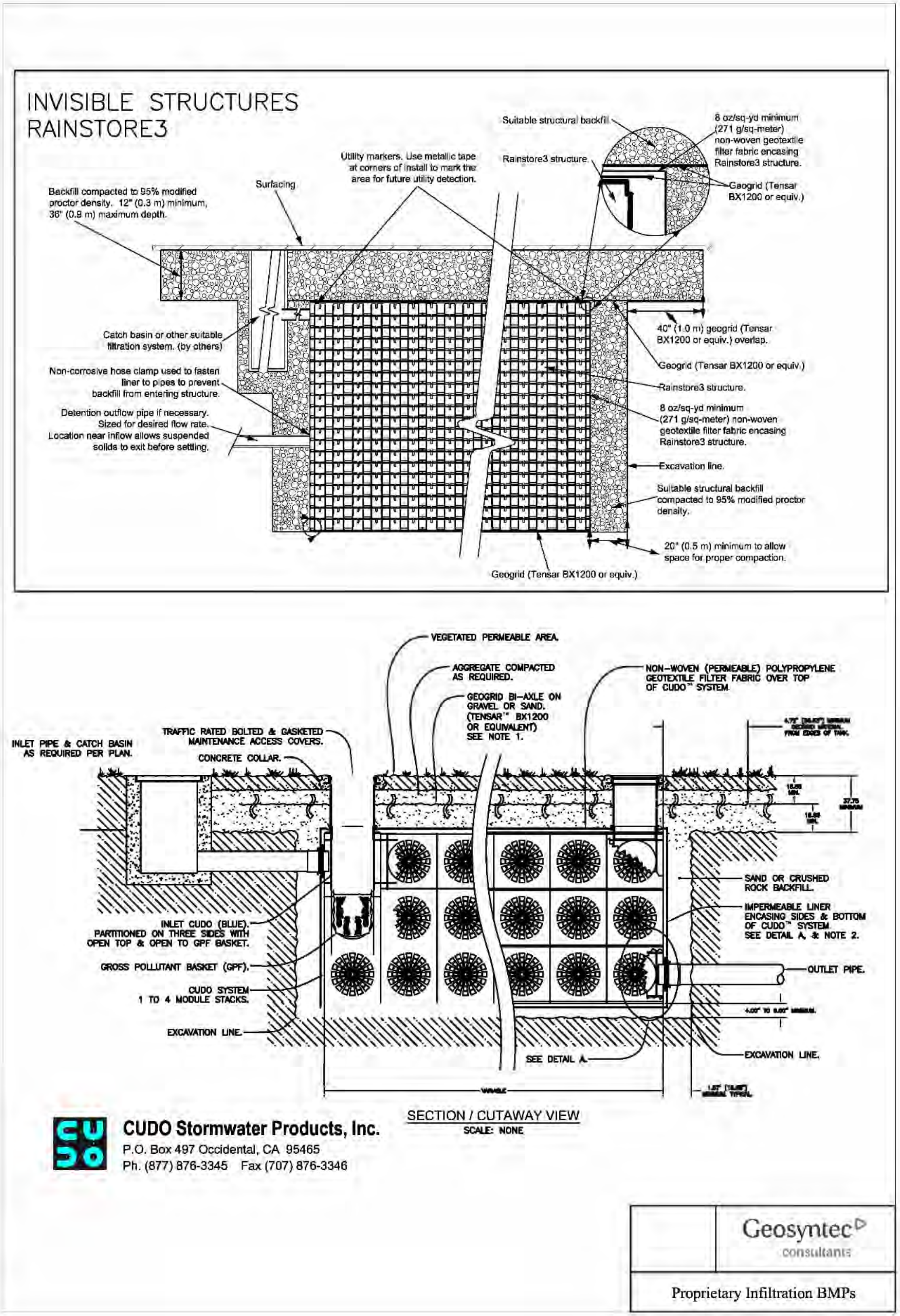


Figure 6-7. Proprietary Infiltration Design Schematic Example

6.4.6.1 Limitations

Limitations will be similar to those for other infiltration BMPs. See *Limitations* listed for other infiltration BMPs (*e.g.*, Section 6.4.1.1 under INF-1) and also consult with the device manufacturer.

6.4.6.2 Geotechnical Considerations

As with all infiltration facilities, an extensive geotechnical site investigation must be undertaken early in the site planning process to verify site suitability for the installation of infiltration facilities, due to the potential to contaminate groundwater, cause slope instability, impact surrounding structures, and have insufficient infiltration capacity. See Geotechnical Considerations listed for other infiltration BMPs (e.g., Section 6.4.1.5 under INF-1) and also consult with the device manufacturer.

6.4.6.3 Pretreatment

Pretreatment is required for proprietary infiltration BMPs in order to reduce the sediment load entering the facility and maintain the infiltration rate of the facility. Pretreatment is important for all stormwater treatment BMPs, but it is particularly important for infiltration BMPs. To ensure that pretreatment mechanisms are effective, designers should incorporate sediment reduction practices. Sediment reduction BMPs may include vegetated swales, vegetated filter strips, sedimentation basins, sedimentation manholes and hydrodynamic separation devices.

6.4.6.4 Sizing

1) Proprietary infiltration BMPs shall be sized to capture and treat the stormwater quality design volume (SQDV). See Section 2 and Appendix C for further detail.

2) The percolation rate will decline as the surface becomes occluded and particulates accumulate in the infiltrative layer. It is important that adequate conservatism is incorporated in the selection of design percolation rates.

3) For the sizing guidelines, refer to the manufacturer's website.

6.4.6.5 Operations and Maintenance

See device specification for maintenance requirements. If the facility is a subsurface system, all components of the infiltration facility shall be accessible for maintenance. Accessibility to each element is required for inspections to ensure proper operation, cleaning, and repairs to ensure the systems operate at design specifications.

6.4.7 INF-7: Bioinfiltration

Bioinfiltration facilities are designed for partial infiltration of runoff and partial biotreatment. These facilities are similar to bioretention devices with underdrains, but the underdrain is raised above the gravel sump to facilitate infiltration. These facilities can be used in areas where there are no hazards associated with infiltration, but infiltration of the full SQDV may not be feasible due to low infiltration rates, below 0.3 in/hr or high depths of fill. These facilities may not result in retention of the SQDV, but they can be used to meet the MEP standards.

Application

- Commercial, residential, mixed use, institutional, and recreational uses
- Parking lot islands, traffic circles
- Road parkways & medians

Preventive Maintenance

- Repair small eroded areas
- Remove trash and debris and rake surface soils
- Remove accumulated fine sediments, dead leaves and trash
- Remove weeds and prune back excess plant growth
- Remove sediment and debris accumulation near inlet and outlet structures
- Periodically observe function under wet weather conditions

Bioretention in Parkway and Parking Lots

Photo Credits: Geosyntec Consultants

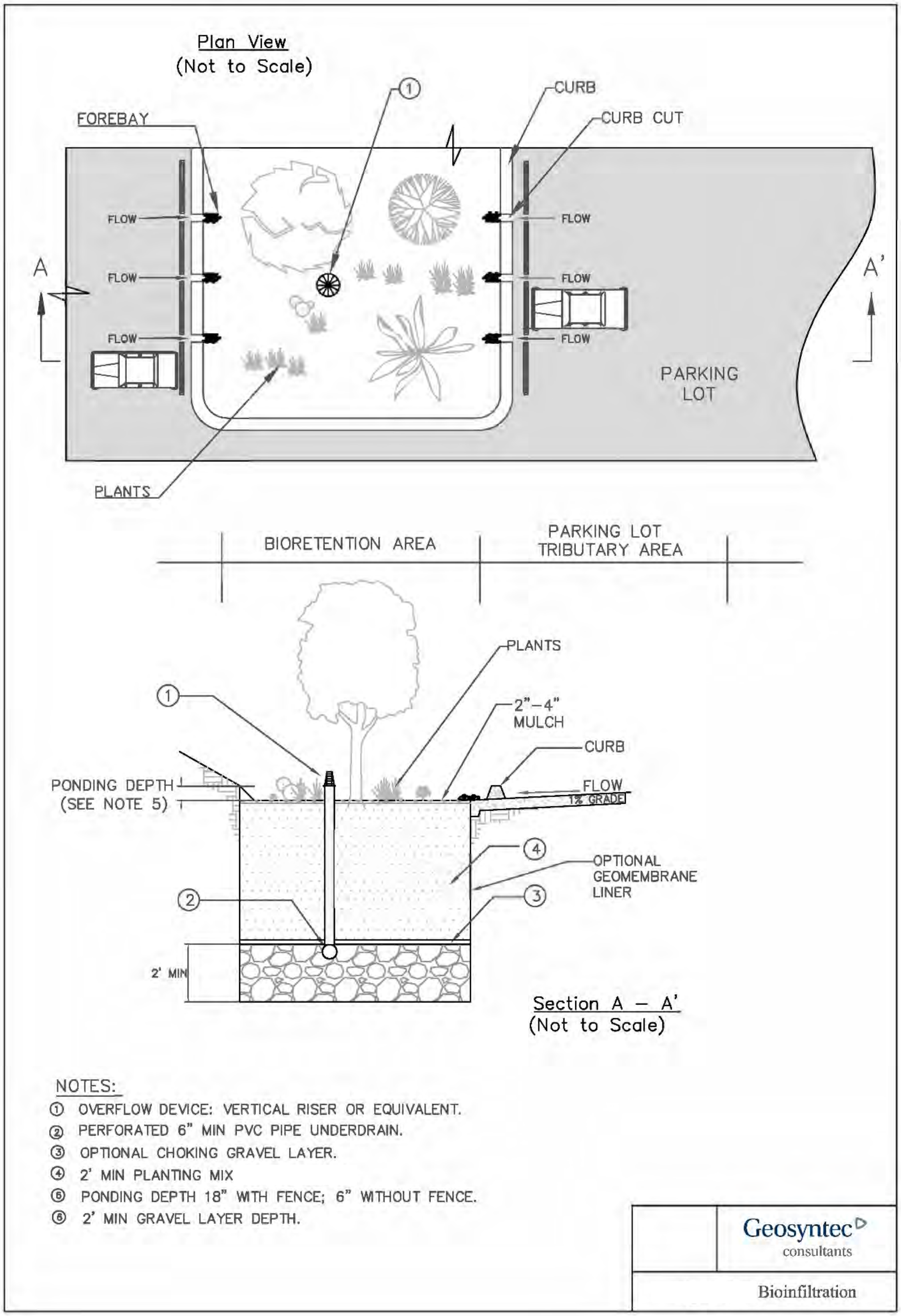


Figure 6-8: Bioinfiltration Design Schematic

6.4.7.1 Limitations

The following limitations should be considered before choosing to use bioinfiltration:

1) Native soil infiltration rate - soil infiltration at the bioinfiltration location must be no less than 0.3 inches per hour.

2) Depth to groundwater, bedrock, or low permeability soil layer – 5 feet vertical separation is required between the bottom of the infiltration trench and the seasonal high groundwater level or mounded groundwater level, bedrock, or other barrier to infiltration to ensure that the facility will completely drain between storms and that infiltrating water will receive adequate treatment though the soils before it reaches the groundwater.

3) Slope stability - infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.

4) Setbacks - a minimum setback (100 feet or more) must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields, and springs. Infiltration BMPs must be setback from building foundations at least ten feet or have an alternative setback established by the geotechnical expert for the project.

5) Groundwater contamination - the application of infiltration BMPs should include significant pretreatment in an area identified as an unconfined aquifer to ensure groundwater is protected for pollutants of concern.

6) Contaminated soils or groundwater plumes - infiltration BMPs are not allowed at locations with contaminated soils or groundwater where the pollutants could be mobilized or exacerbated by infiltration, unless a site-specific analysis determines that infiltration would be beneficial.

7) High pollutant land uses - infiltration BMPs should not be placed in high-risk areas such as at/near service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk unless a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas have little chance of spill migration.

8) High sediment loading rates – infiltration BMPs may clog quickly if sediment loads are high (e.g., unstabilized site) or if flows are not adequately pretreated.

9) Vertical relief and proximity to storm drain - site must have adequate relief between the land surface and storm drain to permit vertical percolation through the soil media and collection.

6.4.7.2 Design Criteria

Bioinfiltration should be designed according to the requirements listed in Table 6-6 and outlined in the section below.

Table 6-6: Bioretention Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2 and Appendix C for calculating SQDV.
Pretreatment	-	Sedimentation forebay or pretreatment BMPs for all surfaces other than roofs are required. Forebays should be designed to prevent standing water during dry weather and should be planted with a plant palette that is tolerant of wet conditions.
Maximum drawdown time of water ponded on surface	hours	48
Maximum drawdown time of surface ponding plus subsurface pores	hours	72
Maximum ponding depth	inches	18
Minimum thickness of amended soil	feet	2
Minimum thickness of stabilized mulch	inches	2 to 4
Planting mix composition	-	60 to 80% fine sand, 20 to 40% compost
Underdrain sizing	-	Underdrain should be installed below the choking stone; 4-inch minimum diameter; 0.5% minimum slope; slotted, polyvinyl chloride (PVC) pipe (PVC SDR 35 or approved equivalent); spacing shall be determined to provide capacity for maximum rate filtered through amended media.
Minimum thickness of gravel layer	feet	2 of Caltrans Class 2 permeable material
Overflow device	-	Required

6.4.7.3 Sizing Criteria

Bioinfiltration facilities can be sized using a simple sizing method. The SQDV volume must be completely infiltrated within 72 hours (including subsurface pore space), and surface ponding must be infiltrated within 48 hours. The sizing procedure is provided in Appendix C, Section C.6.

6.4.7.3.1 Geometry

1) Minimum planting soil depth should be 2 feet minimum.

   The intention is that the minimum planting soil depth should provide a beneficial root zone for the chosen plant palette and adequate water storage for the stormwater quality design volume. A deeper soil depth will provide a smaller surface area footprint.

2) Minimum gravel layer depth is 2 feet and must be constructed out of Caltrans Class 2 permeable material.

   The intention is that the gravel sump provides partial retention of captured water.

3) Bioinfiltration should be designed to drain below the planting soil in less than 48 hours and completely drain from the gravel layer within 72 hours (both starting from the end of inflow).

   The intention is that soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive flows from subsequent storms, maintain infiltration rates, maintain adequate soil oxygen levels for healthy soil biota and vegetation, and to provide proper soil conditions for biodegradation and retention of pollutants.

6.4.7.3.2 Flow Entrance and Energy Dissipation

The following types of flow entrance can be used for bioinfiltration cells:

1) Dispersed, low velocity flow across a landscape area. Dispersed flow may not be possible given space limitations or if the facility is controlling roadway or parking lot flows where curbs are mandatory.

2) Dispersed flow across pavement or gravel and past wheel stops for parking areas.

3) Curb cuts for roadside or parking lot areas: curb cuts should include rock or other erosion protection material in the channel entrance to dissipate energy. Flow entrance should drop 2 to 3 inches from curb line and it should provide a settling area and periodic sediment removal of coarse material before flow dissipates to the remainder of the cell.

4) Pipe flow entrance: Piped entrances, such as roof downspouts, should include rock, splash blocks, or other appropriate measures at the entrance to dissipate energy and disperse flows.

Woody plants (trees, shrubs, etc.) can restrict or concentrate flows, can be damaged by erosion around the root ball, and should not be placed directly in the entrance flow path.

6.4.7.3.3 Underdrains

Underdrains should meet the following criteria:

1) 6-inch minimum diameter.

2) Underdrains should be made of slotted, polyvinyl chloride (PVC) pipe (PVC SDR 35 or approved equivalent). *The intention is that compared to round-hole perforated pipe, slotted underdrains provide greater intake capacity, clog resistant drainage, and reduced entrance velocity into the pipe, thereby reducing the chances of solids migration.*

3) Slotted pipe should have 2 to 4 rows of slots cut perpendicular to the axis of the pipe or at right angles to the pitch of corrugations. Slots should be 0.04 to 0.1 inches and should have a length of 1 to 1.25 inches. Slots should be longitudinally spaced such that the pipe has a minimum of one square inch of slot per lineal foot of pipe and should be placed with slots facing the bottom of the pipe.

4) Underdrains should be sloped at a minimum of 0.5%.

5) Underdrains shall be embedded in a gravel layer to reduce sediment discharge and shall not be wrapped in filter fabric.

6) Rigid non-perforated observation pipes with a diameter equal to the underdrain diameter should be connected to the underdrain every 100 feet to provide a clean-out port as well as an observation well to monitor dewatering rates. The wells/cleanouts should be connected to the perforated underdrain with the appropriate manufactured connection(s). The wells/cleanouts should extend 6 inches above the top elevation of the bioinfiltration facility mulch, and should be capped with a lockable screw cap. The end of an underdrain pipe not terminating in an observation well/cleanout should also be capped.

6.4.7.3.4 Gravel Layer

1) Caltrans Class 2 permeable material should be used for any gravel layer below the underdrain pipe. Place the underdrain below the choking stone, within the top 6 inches of the gravel layer.

2) Bioinfiltration facilities have the added benefit of enhanced nitrogen removal due to the elevated underdrain to be at least 12 inches above the bottom of the facility. This allows for a fluctuating anaerobic/aerobic zone below the drainpipe. *The intention is that denitrification within the anaerobic/anoxic zone is facilitated by microbes using forms of nitrogen (NO_2 and NO_3) instead of oxygen for respiration.*

3) The underdrain should drain freely to an acceptable discharge point. The underdrain can be connected to a downstream open conveyance (vegetated swale), to another bioinfiltration cell as part of a connected treatment system, to a storm drain, daylight to a vegetated dispersion area using an effective flow dispersion device, or to a storage facility for harvesting.

6.4.7.3.5 Overflow

An overflow device is required at the 18-inch ponding depth. The following, or equivalent, should be provided:

1) A vertical PVC pipe (SDR 35) to act as an overflow riser.

2) The overflow riser(s) should be 6 inches or greater in diameter, so it can be cleaned without damage to the pipe.

The inlet to the riser should be at the ponding depth (18 inches for fenced bioinfiltration areas and 6 inches for areas that are not fenced) and be capped with a spider cap to exclude floating mulch and debris. Spider caps should be screwed in or glued (i.e., not removable).

6.4.7.3.6 Hydraulic Restriction Layers

Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mils.

6.4.7.3.7 Planting/Storage Media

1) The planting media placed in the cell should achieve a long-term, in-place infiltration rate of at least 1 inch per hour. Higher infiltration rates are permissible. If the design long-term, in-place infiltration rate of the soil exceeds 12 inches per hour, documentation should be provided to demonstrate that the media will adequately address pollutants of concern at a higher flowrate. Bioinfiltration soil shall also support vigorous plant growth.

2) Planting media should consist of 60 to 80% fine sand and 20 to 40% compost.

3) Sand should be free of wood, waste, coating such as clay, stone dust, carbonate, etc., or any other deleterious material. All aggregate passing the No. 200 sieve size should be non-plastic. Sand for bioinfiltration should be analyzed by an accredited lab using #200, #100, #40, #30, #16, #8, #4, and 3/8 sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation (Note: all sands complying with ASTM C33 for fine aggregate comply with the gradation requirements below):

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
3/8 inch	100	100
#4	90	100
#8	70	100
#16	40	95
#30	15	70
#40	5	55
#100	0	15
#200	0	5

Note: the gradation of the sand component of the media is believed to be a major factor in the hydraulic conductivity of the media mix. If the desired hydraulic conductivity of the media cannot be achieved within the specified proportions of sand and compost (#2), then it may be necessary to utilize sand at the coarser end of the range specified in above (“minimum” column).

4) Compost should be a well decomposed, stable, weed free organic matter source derived from waste materials including yard debris, wood wastes, or other organic materials not including manure or biosolids meeting standards developed by the US Composting Council (USCC). The product shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program). Compost quality should be verified via a lab analysis to be:

- Feedstock materials shall be specified and include one or more of the following: landscape/yard trimmings, grass clippings, food scraps, and agricultural crop residues.
- Organic matter: 35-75% dry weight basis.
- Carbon and Nitrogen Ratio: 15:1 < C:N < 25:1
- Maturity/Stability: shall have dark brown color and a soil-like odor. Compost exhibiting a sour or putrid smell, containing recognizable grass or leaves, or is hot (120 F) upon delivery or rewetting is not acceptable.
- Toxicity: any one of the following measures is sufficient to indicate non-toxicity:
    - NH_4:NH_3 < 3
    - Ammonium < 500 ppm, dry weight basis
    - Seed Germination > 80% of control
    - Plant trials > 80% of control

- e. Solvita® > 5 index value
- Nutrient content:
  - Total Nitrogen content 0.9% or above preferred
  - Total Boron should be <80 ppm, soluble boron < 2.5 ppm
- Salinity: < 6.0 mmhos/cm
- pH between 6.5 and 8 (may vary with plant palette)

Compost for bioinfiltration should be analyzed by an accredited lab using #200, ¼ inch, ½ inch, and 1-inch sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation:

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
1 inch	99	100
½ inch	90	100
¼ inch	40	90
#200	2	10

Tests should be sufficiently recent to represent the actual material that is anticipated to be delivered to the site. If processes or sources used by the supplier have changed significantly since the most recent testing, new tests should be requested.

Note: the gradation of compost used in bioinfiltration media is believed to play an important role in the saturated hydraulic conductivity of the media. To achieve a higher saturated hydraulic conductivity, it may be necessary to utilize compost at the coarser end of this range ("minimum" column). The percent passing the #200 sieve (fines) is believed to be the most important factor in hydraulic conductivity.

In addition, a coarser compost mix provides more heterogeneity of the bioinfiltration media, which is believed to be advantageous for more rapid development of soil structure needed to support health biological processes. This may be an advantage for plant establishment with lower nutrient and water input.

5) The bioinfiltration area should be covered with 2 to 4 inches (average 3 inches) of mulch at the start and an additional placement of 1 to 2 inches of mulch should be added annually. *The intention is to help sustain the nutrient levels, suppress weeds, retain moisture, and maintain infiltration capacity*.

6.4.7.3.8 Planting/Storage Media Design for Nutrient Sensitive Receiving Waters

1) Where the BMP discharges to receiving waters with nutrient impairments or nutrient TMDLs, the planting media placed in the cell should be designed with the specific goal

of minimizing the potential for initial and long-term leaching of nutrients from the media.

2) In general, the potential for leaching of nutrients can be minimized by:

    a. Utilizing stable, aged compost (as required of media mixes under all conditions).

    b. Utilizing other sources of organic matter, as appropriate, that are safe, non-toxic, and have lower potential for nutrient leaching than compost.

    c. Reducing the content of compost or other organic material in the media mix to the minimum amount necessary to support vigorous plant growth and healthy biological processes.

3) A landscape architect should be consulted to assist in the design of planting/storage media to balance the interests of plant establishment, water retention capacity (irrigation demand), and the potential for nutrient leaching. The following practices should be considered in developing the media mix design:

    a. The actual nutrient content and organic content of the selected compost source should be considered when specifying the proportions of compost and sand. The compost specification allows a range of organic content over approximately a factor of 2 and nutrient content may vary more widely. Therefore, determining the actual organic content and nutrient content of the compost expected to be supplied is important in determining the proportion to be used for amendment.

    b. A commitment to periodic soil testing for nutrient content and a commitment to adaptive management of nutrient levels can help reduce the amount of organic amendment that must be provided initially. Generally, nutrients can be added to planting areas through the addition of organic mulch but cannot be removed.

    c. Plant palettes and the associated planting mix should be designed with native plants where possible. Native plants generally have a broader tolerance for nutrient content and can be longer lived in leaner/lower nutrient soils. An additional benefit of lower nutrient levels is that native plants will generally have less competition from weeds.

    d. Nutrients are better retained in soils with higher cation exchange capacity (CEC). CEC can be increased through selection of organic material with naturally high CEC, such as peat, and/or selection of inorganic material with high CEC such as some sands or engineered minerals (e.g., low P-index sands, zeolites, rhyolites, etc.). Including higher CEC materials would tend to reduce the net leaching of nutrients.

e. Soil structure can be more important than nutrient content in plant survival and biologic health of the system. If a good soil structure can be created with very low amounts of compost, plants survivability should still be provided. Soil structure is loosely defined as the ability of the soil to conduct and store water and nutrients as well as the degree of aeration of the soil. While soil structure generally develops with time, planting/storage media can be designed to promote earlier development of soil structure. Soil structure is enhanced by the use of amendments with high hummus content (as found in well-aged organic material). In addition, soil structure can be enhanced through the use of compost/organic material with a distribution of particle sizes (i.e., a more heterogeneous mix). Finally, inorganic amendments such as polymer beads may be useful for promoting aeration and moisture retention associated with a good soil structure. An example of engineered soil to promote soil structure can be found here:

   http://www.hort.cornell.edu/uhi/outreach/pdfs/custructuralsoilwebpdf.pdf

f. Younger plants are generally more tolerant of lower nutrient levels and tend to help develop soil structure as they grow. Starting plants from smaller transplants can help reduce the need for organic amendments and improve soil structure. The project should be able to accept a plant mortality rate that is somewhat higher than starting from larger plants and providing high organic content.

g. With these considerations, it is anticipated that less than 10 percent compost amendment could be used, while still balancing plant survivability and water retention.

6.4.7.4 Plants

1) Plant materials should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 48 to 72 hours.

2) It is recommended that a minimum of three types of tree, shrubs, and/or herbaceous groundcover species be incorporated to protect against facility failure due to disease and insect infestations of a single species.

3) Native plant species and/or hardy cultivars that are not invasive and do not require chemical inputs should be used to the maximum extent practicable.

6.4.7.5 Operations and Maintenance

Bioinfiltration areas require annual plant, soil, and mulch layer maintenance to ensure optimum infiltration, storage, and pollutant removal capabilities. In general, bioinfiltration maintenance requirements are typical landscape care procedures and include:

1) Watering: Plants should be drought-tolerant. Watering may be required during prolonged dry periods after plants are established.

2) Erosion control: Inspect flow entrances, ponding area, and surface overflow areas periodically, and replace soil, plant material, and/or mulch layer in areas if erosion has occurred (see Appendix D for a bioinfiltration inspection and maintenance checklist). Properly designed facilities with appropriate flow velocities should not have erosion problems, except perhaps in extreme events. If erosion problems occur, the following should be reassessed: (1) flow velocities and gradients within the cell, and (2) flow dissipation and erosion protection strategies in the pretreatment area and flow entrance. If sediment is deposited in the bioinfiltration area, immediately determine the source within the contributing area, stabilize, and remove excess surface deposits.

3) Plant material: Depending on aesthetic requirements, occasional pruning and removing of dead plant material may be necessary. Replace all dead plants and if specific plants have a high mortality rate, assess the cause and, if necessary, replace with more appropriate species. Periodic weeding is necessary until plants are established. The weeding schedule should become less frequent if the appropriate plant species and planting density have been used and, as a result, undesirable plants excluded.

4) Nutrients and pesticides: The soil mix and plants should be selected for optimum fertility, plant establishment, and growth. Nutrient and pesticide inputs should not be required and may degrade the pollutant processing capability of the bioinfiltration area, as well as contribute pollutant loads to receiving waters. By design, bioinfiltration facilities are located in areas where phosphorous and nitrogen levels are often elevated, and these should not be limiting nutrients. If in question, have soil analyzed for fertility.

5) Mulch: Replace mulch annually in bioinfiltration facilities where heavy metal deposition is likely (e.g., contributing areas that include industrial and auto dealer/repair parking lots and roads). In residential lots or other areas where metal deposition is not a concern, replace or add mulch as needed to maintain a 2 to 3-inch depth at least once every two years.

6) Soil: Soil mixes for bioinfiltration facilities are designed to maintain long-term fertility and pollutant processing capability. Estimates from metal attenuation research suggest that metal accumulation should not present an environmental concern for at least 20 years in bioinfiltration systems. Replacing mulch in bioinfiltration facilities where heavy metal deposition is likely providing an additional level of protection for prolonged performance. If in question, have soil analyzed for fertility and pollutant levels.

6.4.8 RWH-1: Rainwater Harvesting

Rainwater harvesting BMPs capture and store stormwater runoff for later use. These BMPs are engineered to store a specified volume of water with no surface discharge until this volume is exceeded. Storage facilities that can be used to harvest rainwater include cisterns (above ground tanks), open storage reservoirs (e.g., ponds and lakes), and underground storage devices (tanks, vaults, pipes, arch spans, and proprietary storage systems). Uses of captured water may potentially include irrigation demand, indoor non-potable demand, industrial process water demand, or other demands. Rainwater harvesting systems typically include several components: (1) methods to divert runoff to the storage device, (2) an overflow for when the storage device is full, and (3) a distribution system to get the water to where it is intended to be used. Harvesting systems typically include pretreatment to remove large sediment and vegetative debris. Systems used for internal uses may require an additional level of treatment prior to use.

Application

- Any type of land use, provided adequate water demand

Preventive Maintenance

- Debris and sediment removal
- After-rain inspections

Rainwater Harvesting

Photo Credit: County of Ventura

6.4.8.1 Limitations

Rainwater harvesting may be used to meet all of the on-site retention requirement if reliable demand is available. It can be used as the sole onsite retention BMP, if the available demands meet the volume required for 80% capture using a 72-hour drawdown time. Otherwise, rainwater harvesting can be used for partial capture, with the remaining SQDV being captured by other onsite retention BMPs.

6.4.8.2 Design Criteria

Specific considerations for cistern rainwater harvesting systems include:

- Cisterns should include screens on gutters and downspouts to remove vegetative debris and sediment from the runoff prior to entering the cistern.
- Above-ground cisterns should be secured in place.
- Above-ground cisterns should not be located on uneven or sloped surfaces; if installed on a sloped surface, the base where the cistern will be installed should be leveled and designed for the weight of the filled cistern prior to installation.
- Child-resistant covers and mosquito screens should be placed on all water entry holes.
- A first flush diverter may be installed so that initial runoff bypasses the cistern. Where a first flush diverter is used, the diverted flows must be directed to a pervious area so that no runoff is produced, or another form of treatment must be provided for this flow.
- Above-ground cisterns should be installed in a location with easy access for maintenance or replacement.

Specific considerations for underground detention include:

- Access entry covers (36” diameter minimum) should be locking and within 50 feet of all areas of the detention tank.
- In cases where the detention facility provides sediment containment, the facility should be laid flat and there should be at least ½ foot of dead storage within the tank or vault.
- Outlet structures should be designed using the 100-year storm as overflow and should be easily accessible for maintenance activities.
- For detention facilities beneath roads and parking areas, structural requirements should meet H20 load requirements.

- In cases where groundwater may cause flotation, these forces should be counteracted with backfill, anchors, or other measures.
- Underground detention facilities should be installed on consolidated and stable native soil; if the facility is constructed in fill slopes, a geotechnical analysis should be performed to ensure stability.

General considerations include:

- In cases where there is non-potable indoor demand, proper pretreatment measures should be installed such as pre-filtration, cartridge filtration, and/or disinfection (which can also be provided between the cistern and point of use).
- Plumbing systems should be installed in accordance with the current California Building and Plumbing Codes (CBC – part of California Code of Regulations, Title 24).
- Underground detention facilities can be incorporated into a treatment train to provide initial or supplemental storage to other detention storage facilities and/or infiltration BMPs.
- Treatment of the captured rainwater (i.e. disinfection) may be required depending on the end use of the water.

Rainwater harvesting uses include:

- Harvested rainwater can be used for irrigation and other non-potable uses (if local, State, and Federal ordinances allow). The use of captured stormwater allows a reduced demand on the potable water supply. Cross-contamination should be prevented when make-up water is required for rainwater use demand by providing a backflow prevention system on the potable water supply line and/or an air gap.
- Irrigation Use
    - Subsurface (or drip) irrigation should not require disinfection pretreatment prior to use; other irrigation types, such as spray irrigation, may require additional pre-treatment prior to use
    - Selecting native and/or drought tolerant plants for landscaped area will reduce irrigation demand; however, they are still recommended for use.
- Domestic Use
    - Domestic uses may include toilet flushing and clothes washing (if local, State, and Federal ordinances allow).
    - Pretreatment requirements per local, State, or Federal codes and ordinances may apply.

- Other Non-Potable Uses
    - Other potential non-potable uses may include vehicle/equipment washing, evaporative cooling, industrial processes, and dilution water for recycled water systems.

6.4.8.3 Sizing Criteria

The effectiveness of rainwater harvesting (RWH) systems is a function of tributary area, storage volume, demand patterns and magnitudes, and operational regime. If rainwater harvesting is a project's sole onsite retention BMP, a system sized for 80% capture runoff (as determined by continuous modeling), which can draw down within 72 hours, is required. If rainwater harvesting is used in combination with other onsite retention BMPs, it can be a valuable tool towards meeting the SQDV capture requirement. The sizing procedure is provided in Appendix C, Section C.7.

6.4.8.4 Operations and Maintenance

1) Inspect storage facilities, associated pipes, and valve connections for leaks.
2) Clean gutters and filters of debris that has accumulated and is obstructing flow into the storage facility.
3) Clean and remove accumulated sediment annually.
4) Check cisterns for stability and anchor if necessary.
5) If the storage device is underground, ensure that a manhole is accessible, operational, and secure.

6.4.9 ET-1: Green Roof

Green roofs (also known as eco-roofs and vegetated roof covers) are roofing systems that layer a soil/vegetative cover over a waterproofing membrane. Green roofs rely on highly porous media and moisture retention layers to store intercepted precipitation and to support vegetation that can reduce the volume of stormwater runoff via evapotranspiration. There are two types of green roofing systems: extensive, which is a light-weight system; and intensive, which is a heavier system, that allows for larger plants but requires additional structural support.

Application

- Building roofs
- Outdoor eating area roofs
- Parking structure or turnaround roofs

Preventive Maintenance

- Weeding and pruning
- Leaf and debris removal
- Regular membrane inspection
- Drain cleanout

Green Roof Examples

Photo Credits: greenroofs.com; Right – County of Ventura

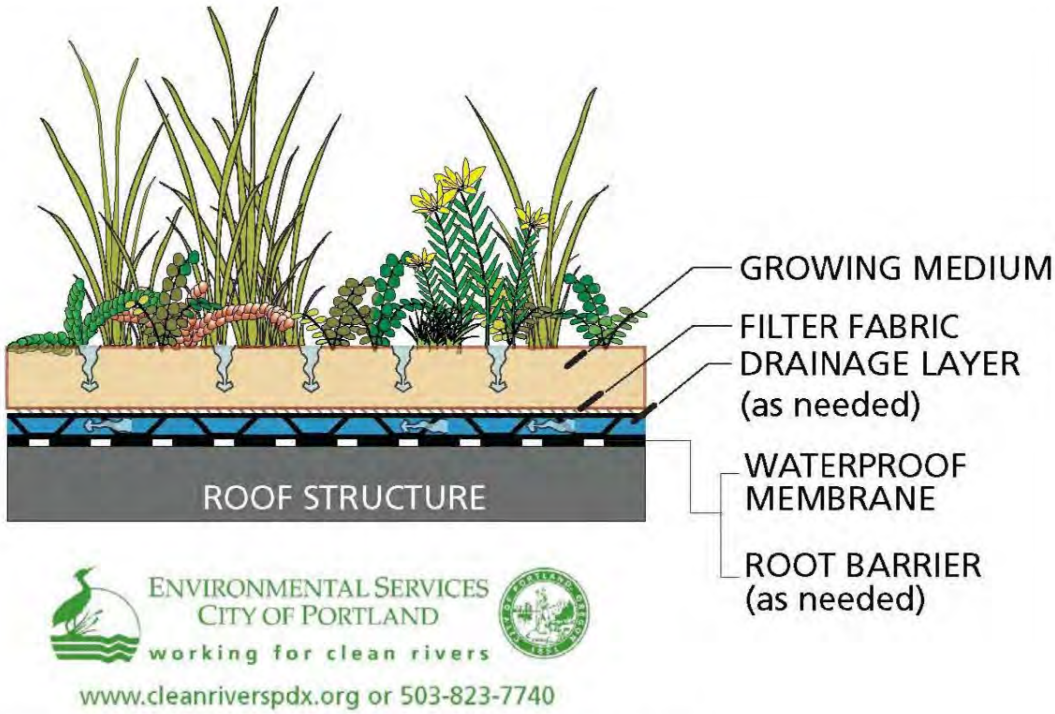


Exhibit A: Green Roof Schematic Courtesy of Portland, OR Environmental Services Department

Exhibit B: Green Roof Schematic Courtesy of American Wick

Geosyntec consultants

Green Roofs

Figure 6-9. Green Roof Design Schematic

6.4.9.1 Limitations

The following describes additional site suitability recommendations and limitations for green roofs.

- Typically not used for steep roofs (>25%); and
- Structural roof support must be sufficient to support additional roof weight.

6.4.9.2 Design Criteria

Green roofs should be designed according to the requirements listed in Table 6-7 and outlined in the section below.

Table 6-7: Green Roof Design Criteria

Design Parameter	Unit	Design Criteria
Soil depth range	inch	2 – 6
Saturated soil weight	lbs. / sq. ft.	10 – 25
Maximum roof slope	%	25
Minimum roof slope	--	Flat
Vegetation type	--	Varies (see vegetation section below)
Vegetation height	--	Varies (see vegetation section below)

6.4.9.2.1 Sizing

Green roofs may provide quantifiable reduction in volume. However, they are not explicitly sized to meet the water quality treatment requirements. Rather, the volume reduction is accounted for implicitly in sizing calculations for the treatment BMPs for the remainder of the site by assuming that the roof area is pervious rather than impervious when calculating a runoff coefficient for the site.

6.4.9.3 Green Roof Components

6.4.9.3.1 Structural Support

The first requirement that must be met before installing a green roof is the structural support of the roof. The roof must be able to support the additional weight of the soil, water, and vegetation. A licensed structural engineer should be consulted to determine the proposed structural support during the design phase.

6.4.9.3.2 Waterproof Roofing Membrane

Waterproof roofing membrane is an integral part of a green roofing system. The waterproof membrane prevents the roof runoff from penetrating and damaging the roofing material. There are many materials available for this purpose and come in various forms (i.e., rolls, sheets, liquid) and exhibit different characteristics (e.g., flexibility, strength, etc.). Depending on the type of membrane chosen a root barrier may be required to prevent roots from compromising the integrity of the membrane.

6.4.9.3.3 Drainage Layer

Depending on the design of the roof, a drainage layer may be required to convey the excess runoff from the roof. If a drainage layer is needed, there are numerous options including a gravel layer (which may require additional structural support), and many styles and types of plastic drainage layers.

6.4.9.3.4 Soil Considerations

The soil layer is an important factor in the construction and operation of green roofs. The soil layer must have excellent drainage, not be too heavy when saturated, and be adequately fertile as a growing medium for plants. Many companies sell their own proprietary soil mixes. However, a simple mix of ¼ topsoil, ¼ compost, and the remainder pumice perlite may be used for many applications. Other soil amendments may be substituted for the compost and the pumice perlite. The soil mix used should not contain any clay.

6.4.9.3.5 Vegetation

Green roofs must be vegetated in order to provide adequate treatment of runoff via filtration and evapotranspiration. Vegetation, when chosen and maintained appropriately, also improves the aesthetics of a site. Green roofs should be vegetated with a mix of erosion-resistant plant species that effectively bind the soil and can withstand the extreme environment of rooftops. A diverse selection of low growing plants that thrive under the specific site, climatic, and watering conditions should be identified. A mixture of drought-tolerant, self-sustaining (perennial or self-sowing without need for fertilizers, herbicides, and/or pesticides) is most effective in the Ventura County region. Plants selected should also be low maintenance and able to withstand heat, cold, and high winds. Native or adapted sedum/succulent plants are preferred because they generally require less fertilizer, limited maintenance, and are more drought resistant than exotic plants. When appropriate, green roofs may be planted with larger plants. However, this depends on structural support and soil depth.

The following provides additional vegetation guidance for green roofs.

1) For extensive roofs, trees or shrubs may be used as long as the increased soil depth required may be supported.

2) Irrigation is required if the seed is planted in spring or summer. The use of a permanent smart (self-regulating) irrigation system or other watering system may help provide maximal water quality performance. Drought-tolerant plants should be specified to minimize irrigation requirements. For projects seeking "High Performance Building" recognition, ASHRAE Standard 189.1 states that potable water cannot be used for irrigating green roofs after they are established.

3) Locate the green roof vegetation in an area without excessive shade to avoid poor vegetative growth. For moderately shaded areas, shade tolerant plants should be used.

4) A relevant plant list should be provided by a landscape professional and used as a guide to support project-specific planting recommendations, including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth.

6.4.9.3.6 Drain

1) There must be a drainpipe (gutter) to convey runoff (both overflow and underdrain flow, if appropriate) safely from the roof to another basic or stormwater runoff BMP, a pervious area, or the stormwater conveyance system.

6.4.9.4 Construction Considerations

1) Building structure must be adequate to hold the additional weight of the soil, retained water, and plants.

2) Plants should be selected carefully to minimize maintenance and function properly.

6.4.9.5 Operations and Maintenance

1) During the establishment period, green roofs may need irrigation and occasional light fertilization until the plants have fully established themselves. Once healthy and fully established, properly selected climate-appropriate plants will no longer need irrigation except during extreme drought.

2) Weeding during the establishment period may be required to ensure proper establishment of the desired vegetation. Once established and assuming proper selection of vegetation, the vegetation should not require any preventive maintenance.

3) The roofing membrane should be inspected routinely, as it is a crucial element of the green roof. In addition, preventive inspection of the drainage paths is required to ensure that there are no clogs in the system. If a green roof is not properly draining, the moisture in the system may cause the roof to leak and/or the plants to drown or rot. Leaks in the roof may occur not only due to improper drainage, but also if the incorrect combination of waterproofing barrier, root barrier, and drainage systems are selected. Leak inspections in the roofing system are advised, especially in locations prone to leaks, such as at all joints.

4) Inspect green roofs for erosion or damage to vegetation after every storm greater than 0.75 inches and at the end of the wet season to schedule summer maintenance and in the fall to ensure readiness for winter. Additional inspection after periods of heavy runoff is recommended. Green roofs should be checked for debris, litter, and signs of clogging.

5) Replanting and/or reseeding of vegetation may be required for reestablishment.

6) Vegetation should be healthy and dense enough to provide filtering while protecting underlying soils from erosion.

7) Fallen leaves and debris from deciduous plant foliage should be removed.

8) Invasive vegetation, such as Alligatorweed (*Alternanthera philoxeroides*), Halogeton (*Halogeton glomeratus*), Spotted Knapweed (*Centaurea maculosa*), Giant Reed (*Arundo donax*), Castor Bean (*Ricinus communis*), Perennial Pepperweed (*Lepidium latifolium*), and Yellow Starthistle (*Centaurea solstitalis*) should be removed and replaced with non-invasive species. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.

9) Dead vegetation should be removed if greater than 10% of the area coverage. Vegetation should be replaced and established before the wet season to maintain cover density and control erosion where soils are exposed.

6.5 Alternative Compliance using Onsite Biofiltration BMPs

6.5.1 BIO-1: Biofiltration

Biofiltration consists of a bioretention facility with an underdrain that is suitable for areas with low permeability native soils or steep slopes. Bioretention may be designed without an underdrain to serve as a retention BMP in areas of high soil permeability (see INF-3 Bioretention) or partial retention/ partial biofiltration BMP (see INF-7: Bioinfiltration). These facilities function as a soil and plant-based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. The facilities normally consist of a ponding area, mulch layer, planting soils, and plantings. As stormwater passes down through the planting soil, pollutants are filtered, adsorbed, and biodegraded by the soil and plants.

Application

- Parking lots
- Roadway parkways and medians
- School entrances, courtyards, and walkways
- Playgrounds and sports fields

Preventive Maintenance

- Repair small eroded areas
- Remove trash and debris and rake surface soils
- Remove accumulated fine sediments, dead leaves, and trash
- Remove weeds and prune back excess plant growth
- Remove sediment and debris accumulation near inlet and outlet structures
- Periodically observe function under wet weather conditions

Biofiltration in Parking Lots

Photo Credits: Top – Geosyntec Consultants; Bottom – County of Ventura

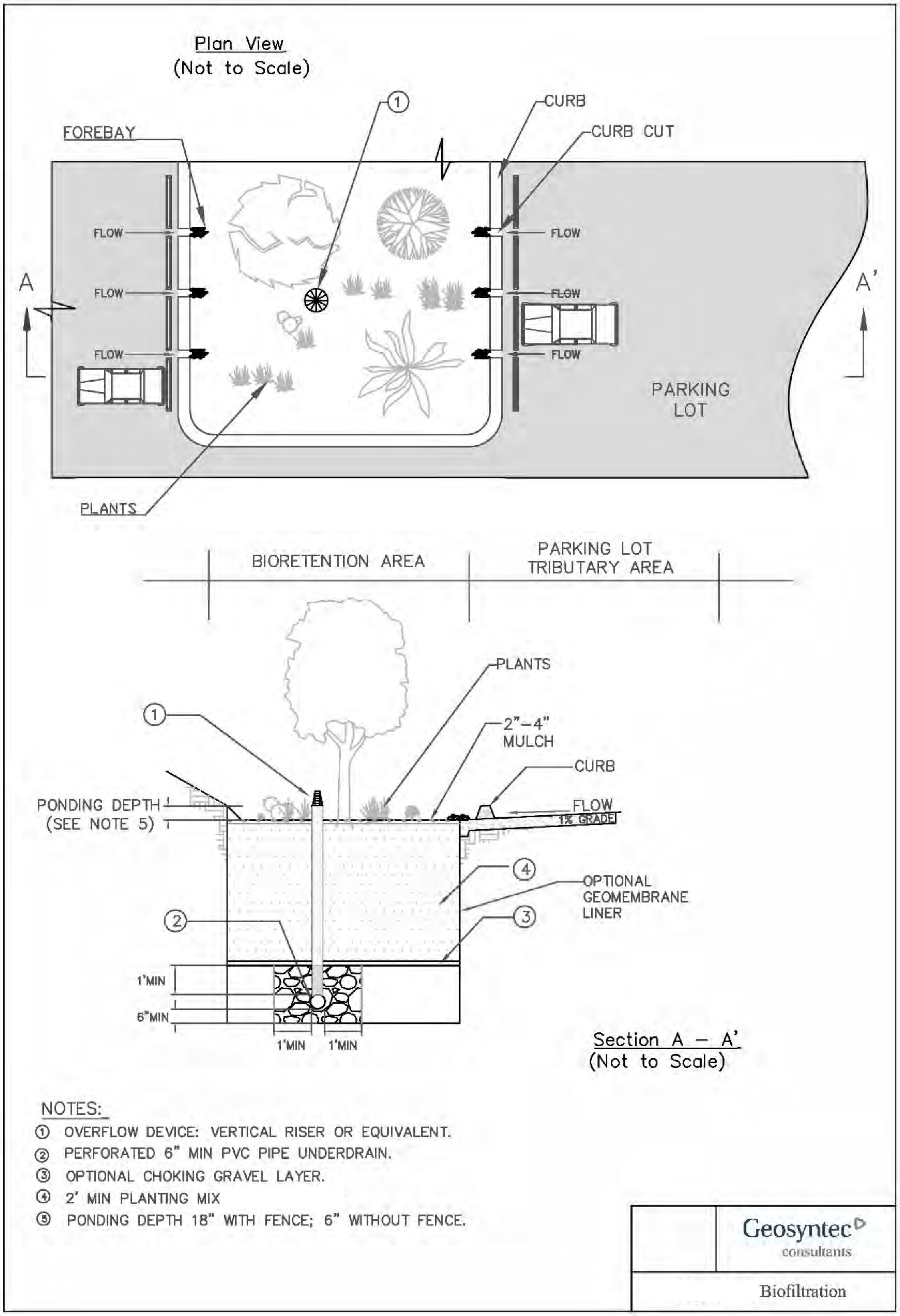


Figure 6-10: Biofiltration Schematic

6.5.1.1 Limitations

1) Vertical relief and proximity to storm drain - site must have adequate relief between land surface and storm drain to permit vertical percolation through the soil media and collection and conveyance in underdrain to storm drain system.

2) Depth to groundwater - shallow groundwater table may not permit complete drawdown between storms.

6.5.1.2 Design Criteria

Biofiltration should be designed according to the requirements listed in Table 6-8 and outlined in the section below. BMP sizing worksheets are presented in Appendix C.

Table 6-8: Bioretention with an Underdrain Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2 and Appendix C for calculating SQDV. As noted in Section 2.6, onsite biofiltration BMPs must be sized to treat 1.5 times the portion of SQDV that is not reliably retained on-site.
Pretreatment	-	Sedimentation forebay or pretreatment BMPs for all surfaces other than roofs are required. Forebays should be designed to prevent standing water during dry weather and should be planted with a plant palette that is tolerant of wet conditions.
Maximum drawdown time of water ponded on surface	hours	48
Maximum drawdown time of surface ponding plus subsurface pores	hours	72
Maximum ponding depth	inches	18 inches
Minimum thickness of amended soils layer	feet	2
Minimum thickness of stabilized mulch	inches	2 to 4
Planting mix composition	-	60 to 80% fine sand, 20 to 40% compost

Design Parameter	Unit	Design Criteria
Underdrain sizing	-	4-inch minimum diameter; 0.5% minimum slope; slotted, polyvinyl chloride (PVC) pipe (PVC SDR 35 or approved equivalent); spacing shall be determined to provide capacity for maximum rate filtered through amended media
Gravel layer	-	A gravel bed should be provided around underdrain. Underdrain should have at least 1 foot of gravel installed to the sides and on top of the underdrain, and at least 0.5 feet of gravel installed below underdrain.
Overflow device	-	Required

6.5.1.3 Sizing Criteria

Biofiltration facilities shall be designed to capture and treat 1.5 times the portion of SQDV that is not reliably retained on-site. Because these systems commonly have a relatively high amended soil infiltration rate and shallow depth, these systems are typically capable of filtering a significant portion of the SQDV during a storm event. Appendix C, Section C.8 describes a simplified routing approach that accounts for the portion of the SQDV that is filtered during the storm event.

6.5.1.3.1 Geometry

1) Minimum planting soil depth should be 2 feet, although 3 feet is preferred.

   The intention is that the minimum planting soil depth should provide a beneficial root zone for the chosen plant palette and adequate water storage for the stormwater quality design volume. A deeper soil depth will provide a smaller surface area footprint.

2) Biofiltration should be designed to drain below the planting soil in less than 48 hours and completely drain from the underdrain within 72 hours (both starting from the end of inflow).

   The intention is that soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive flows from subsequent storms, maintain infiltration rates, maintain adequate soil oxygen levels for healthy soil biota and vegetation, and to provide proper soil conditions for biodegradation and retention of pollutants.

6.5.1.3.2 Flow Entrance and Energy Dissipation

The following types of flow entrance can be used for biofiltration cells:

1) Dispersed, low velocity flow across a landscape area. Dispersed flow may not be possible given space limitations or if the facility is controlling roadway or parking lot flows where curbs are mandatory.

2) Dispersed flow across pavement or gravel and past wheel stops for parking areas.

3) Curb cuts for roadside or parking lot areas: Curb cuts should include rock or other erosion protection material in the channel entrance to dissipate energy. Flow entrance should drop 2 to 3 inches from curb line and provide an area for settling and periodic removal of sediment and coarse material before flow dissipates to the remainder of the cell.

4) Pipe flow entrance: Piped entrances, such as roof downspouts, should include rock, splash blocks, or other appropriate measures at the entrance to dissipate energy and disperse flows.

5) Woody plants (trees, shrubs, etc.) can restrict or concentrate flows and can be damaged by erosion around the root ball and should not be placed directly in the entrance flow path.

6.5.1.3.3 Underdrains

Underdrains should meet the following criteria:

1) 6-inch minimum diameter.

2) Underdrains should be made of slotted, polyvinyl chloride (PVC) pipe (PVC SDR 35 or approved equivalent). *The intention is that compared to round-hole perforated pipe, slotted underdrains provide greater intake capacity, clog resistant drainage, and reduced entrance velocity into the pipe, thereby reducing the chances of solids migration.*

3) Slotted pipe should have 2 to 4 rows of slots cut perpendicular to the axis of the pipe or at right angles to the pitch of corrugations. Slots should be 0.04 to 0.1 inches and should have a length of 1 to 1.25 inches. Slots should be longitudinally spaced such that the pipe has a minimum of one square inch of slot per lineal foot of pipe and should be placed with slots facing the bottom of the pipe.

4) Underdrains should be sloped at a minimum of 0.5%.

5) Rigid non-perforated observation pipes with a diameter equal to the underdrain diameter should be connected to the underdrain every 100 feet to provide a clean-out port as well as an observation well to monitor dewatering rates. The wells/cleanouts should be connected to the perforated underdrain with the appropriate manufactured connections. The wells/cleanouts should extend 6 inches above the top elevation of the bioretention facility mulch, and should be capped with a lockable screw cap. The ends of the underdrain pipes not terminating in an observation well/cleanout should also be capped.

6) Caltrans Class 2 permeable material shall be used for the gravel blanket and bedding for the underdrain pipe. Place the underdrain on a bed of gravel layer for minimum thickness of 6 inches and cover it with the same aggregate to provide a 1-foot minimum

depth around the top and sides of the slotted pipe. The underdrain shall not be wrapped in filter fabric.

7) For biofiltration facilities enhanced to address nitrogen as the primary pollutant class, the underdrain should be elevated from the bottom of the biofiltration facility by at least 6 inches from the bottom and least 6 inches within the gravel blanket to create a fluctuating anaerobic/aerobic zone below the drainpipe. *The intention is that denitrification within the anaerobic/anoxic zone is facilitated by microbes using forms of nitrogen (NO_2 and NO_3) instead of oxygen for respiration.*

8) The underdrain should drain freely to an acceptable discharge point. The underdrain can be connected to a downstream open conveyance (vegetated swale), to another bioretention cell as part of a connected treatment system, to a storm drain, daylight to a vegetated dispersion area using an effective flow dispersion device, or to a storage facility for rainwater harvesting.

6.5.1.3.4 Overflow

An overflow device is required at the maximum ponding depth. The following, or equivalent, should be provided:

1) A vertical PVC pipe (SDR 35) should be connected to the underdrain.

2) The overflow riser(s) should be 4 inches or greater in diameter, so it can be cleaned without damage to the pipe. The vertical pipe will provide access to cleaning the underdrains.

3) The inlet to the riser should be at the ponding depth (maximum 18 inches for fenced bioretention areas and 6 inches for areas that are not fenced) and be capped with a spider cap to exclude floating mulch and debris. Spider caps should be screwed in or glued (i.e., not removable).

6.5.1.3.5 Hydraulic Restriction Layers

Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mils.

6.5.1.3.6 Planting/Storage Media

1) The planting media placed in the cell should achieve a long-term, in-place infiltration rate of at least 1 inch per hour. Higher infiltration rates are permissible. If the design long-term, in-place infiltration rate of the soil exceeds 12 inches per hour, documentation should be provided to demonstrate that the media will adequately address pollutants of concern at a higher flowrate. Bioretention soil shall also support vigorous plant growth.

2) Planting media should consist of 60 to 80% fine sand and 20 to 40% compost.

3) Sand should be free of wood, waste, coating such as clay, stone dust, carbonate, etc., or any other deleterious material. All aggregate passing the No. 200 sieve size should be non-plastic. Sand for bioretention should be analyzed by an accredited lab using #200, #100, #40, #30, #16, #8, #4, and 3/8 sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation (Note: all sands complying with ASTM C33 for fine aggregate comply with the gradation requirements below):

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
3/8 inch	100	100
#4	90	100
#8	70	100
#16	40	95
#30	15	70
#40	5	55
#100	0	15
#200	0	5

Note: the gradation of the sand component of the media is believed to be a major factor in the hydraulic conductivity of the media mix. If the desired hydraulic conductivity of the media cannot be achieved within the specified proportions of sand and compost (#2), then it may be necessary to utilize sand at the coarser end of the range specified in above ("minimum" column).

4) Compost should be a well decomposed, stable, weed free organic matter source derived from waste materials including yard debris, wood wastes, or other organic materials not including manure or biosolids meeting standards developed by the US Composting Council (USCC). The product shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program). Compost quality should be verified via a lab analysis to be:

- Feedstock materials shall be specified and include one or more of the following: landscape/yard trimmings, grass clippings, food scraps, and agricultural crop residues.

- Organic matter: 35-75% dry weight basis.

- Carbon and Nitrogen Ratio: 15:1 < C:N < 25:1

- Maturity/Stability: shall have dark brown color and a soil-like odor. Compost exhibiting a sour or putrid smell, containing recognizable grass or leaves, or is hot (120 F) upon delivery or rewetting is not acceptable.

- Toxicity: any one of the following measures is sufficient to indicate non-toxicity:
    - NH4:NH3 < 3
    - Ammonium < 500 ppm, dry weight basis
    - Seed Germination > 80% of control
    - Plant trials > 80% of control
    - Solvita® > 5 index value
- Nutrient content:
    - Total Nitrogen content 0.9% or above preferred
    - Total Boron should be <80 ppm, soluble boron < 2.5 ppm
- Salinity: < 6.0 mmhos/cm
- pH between 6.5 and 8 (may vary with plant palette)

Compost for bioretention should be analyzed by an accredited lab using #200, ¼ inch, ½ inch, and 1-inch sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation:

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
1 inch	99	100
½ inch	90	100
¼ inch	40	90
#200	2	10

Tests should be sufficiently recent to represent the actual material that is anticipated to be delivered to the site. If processes or sources used by the supplier have changed significantly since the most recent testing, new tests should be requested.

Note: the gradation of compost used in bioretention media is believed to play an important role in the saturated hydraulic conductivity of the media. To achieve a higher saturated hydraulic conductivity, it may be necessary to utilize compost at the coarser end of this range ("minimum" column). The percent passing the #200 sieve (fines) is believed to be the most important factor in hydraulic conductivity.

In addition, a coarser compost mix provides more heterogeneity of the bioretention media, which is believed to be advantageous for more rapid development of soil structure needed to support health biological processes. This may be an advantage for plant establishment with lower nutrient and water input.

5) The bioretention area should be covered with 2 to 4 inches (average 3 inches) of mulch at the start and an additional placement of 1 to 2 inches of mulch should be added annually. *The intention is to help sustain the nutrient levels, suppress weeds, retain moisture, and maintain infiltration capacity*.

6.5.1.4 Plants

Plant materials should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 48 to 72 hours.

It is recommended that a minimum of three types of tree, shrubs, and/or herbaceous groundcover species be incorporated to protect against facility failure due to disease and insect infestations of a single species.

Native plant species and/or hardy cultivars that are not invasive and do not require chemical inputs should be used to the maximum extent practicable.

6.5.1.5 Operations and Maintenance

Biofiltration areas require annual plant, soil, and mulch layer maintenance to ensure optimum infiltration, storage, and pollutant removal capabilities. In general, bioretention maintenance requirements are typical landscape care procedures and include:

1) Watering: Plants should be selected to be drought-tolerant and not require watering after establishment (2 to 3 years). Watering may be required during prolonged dry periods after plants are established.

2) Erosion control: Inspect flow entrances, ponding area, and surface overflow areas periodically, and replace soil, plant material, and/or mulch layer in areas if erosion has occurred (see Appendix D for a bioretention inspection and maintenance checklist). Properly designed facilities with appropriate flow velocities should not have erosion problems except perhaps in extreme events. If erosion problems occur, the following should be reassessed: (1) flow velocities and gradients within the cell, and (2) flow dissipation and erosion protection strategies in the pretreatment area and flow entrance. If sediment is deposited in the bioretention area, immediately determine the source within the contributing area, stabilize, and remove excess surface deposits.

3) Plant material: Depending on aesthetic requirements, occasional pruning and removing of dead plant material may be necessary. Replace all dead plants and if specific plants have a high mortality rate, assess the cause and, if necessary, replace with more appropriate species. Periodic weeding is necessary until plants are established. The weeding schedule should become less frequent if the appropriate plant species and planting density have been used and, as a result, undesirable plants have been excluded.

4) Nutrient and pesticides: The soil mix and plants are selected for optimum fertility, plant establishment, and growth. Nutrient and pesticide inputs should not be required

and may degrade the pollutant processing capability of the bioretention area, as well as contribute pollutant loads to receiving waters. By design, bioretention facilities are located in areas where phosphorous and nitrogen levels are often elevated, and these should not be limiting nutrients. If in question, have soil analyzed for fertility.

5) Mulch: Replace mulch annually in bioretention facilities where high trash, sediment load, and heavy metal deposition is likely (e.g., heavy metal contributing areas include industrial and auto dealer/repair parking lots and roads). In residential lots or other areas where metal deposition is not a concern, replace or add mulch as needed to maintain a 2 to 3-inch depth at least once every two years.

6) Soil: Soil mixes for bioretention facilities are designed to maintain long-term fertility and pollutant processing capability. Replacing mulch in bioretention facilities where high trash, sediment load, and heavy metal deposition are likely providing an additional level of protection for prolonged performance. Estimates from metal attenuation research suggest that metal accumulation should not present an environmental concern for at least 20 years in bioretention systems. However, the saturated hydraulic conductivity should be assessed at least annually to ensure that the design water quality event is being treated. If in question, have soil analyzed for fertility and pollutant levels.

6.5.2 BIO-2: Planter Box with Underdrain

Planter boxes with an underdrain are biofiltration facilities that are completely contained within an impermeable structure with an underdrain (they do not infiltrate). These facilities function as a soil and plant-based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. The facilities normally consist of a ponding area, mulch layer, planting soils, plantings, and an underdrain within the planter box. As stormwater passes down through the planting soil, pollutants are filtered, adsorbed, and biodegraded by the soil and plants. Planter boxes are comprised of a variety of materials, usually chosen to be the same material as the adjacent building or sidewalk.

Planter boxes with underdrains may be placed adjacent to or near buildings, other structures, or sidewalks. They can be used directly adjacent to buildings beneath downspouts as long as the boxes are properly lined on the building side and the overflow outlet discharges away from the building to ensure water does not percolate into footings or foundations. They can also be placed further away from buildings by conveying roof runoff in shallow engineered open conveyances, shallow pipes, or other innovative drainage structures.

Planter Boxes Extending Along a Building Wall

Photo Credit: Geosyntec Consultants

<u>Application</u>

- Areas adjacent to buildings and sidewalks
- Building entrances, courtyards, and walkways

<u>Preventive Maintenance</u>

- Repair small eroded areas
- Remove trash and debris and rake surface soils
- Remove accumulated fine sediments, dead leaves, and trash
- Remove weeds and prune back excess pla growth
- Remove sediment and debris accumulatio inlet and outlet structures
- Periodically observe function under wet weather conditions

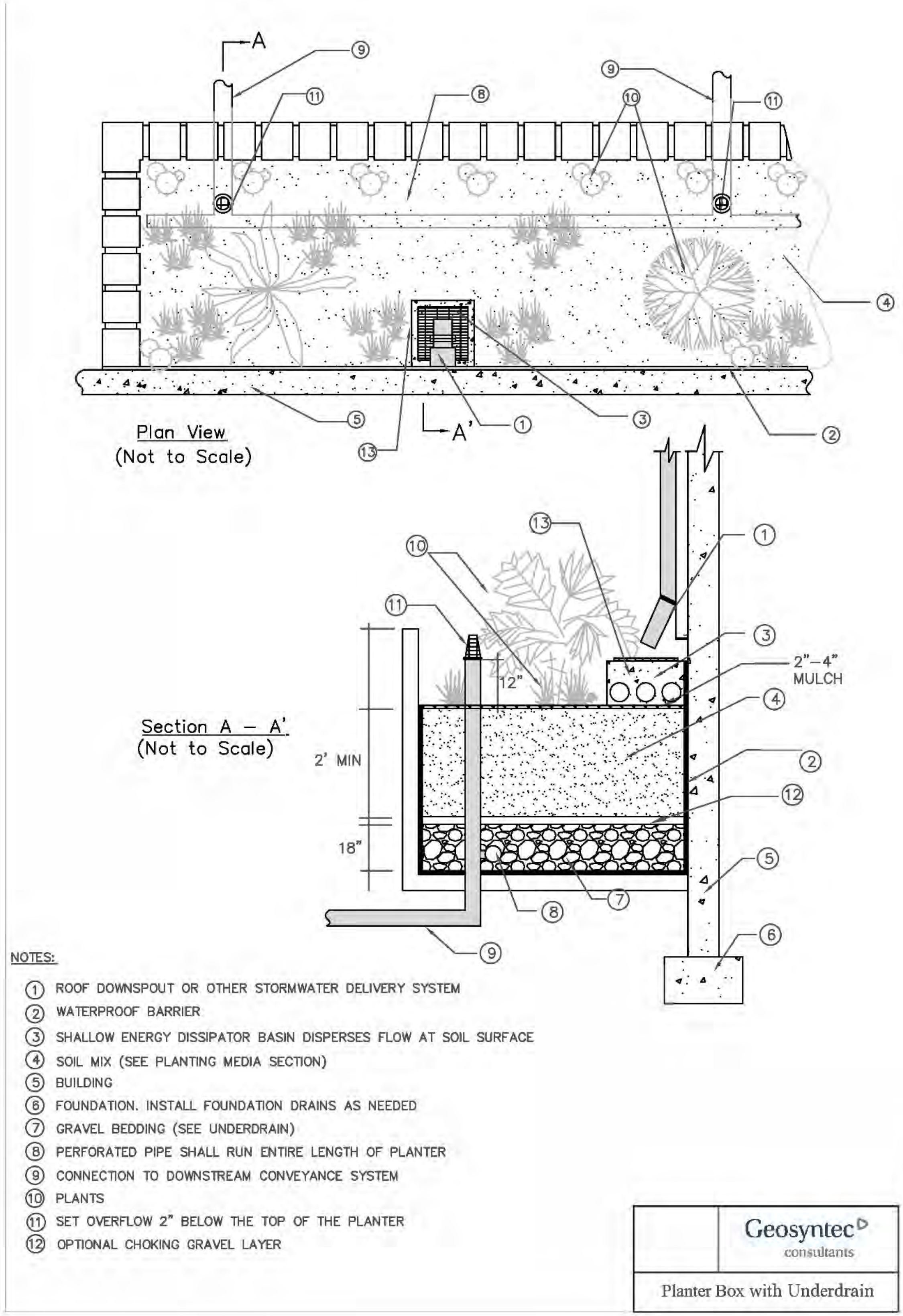


Figure 6-11: Planter Box with Underdrain Design Schematic

6.5.2.1 Limitations

The applicability of stormwater planter boxes with underdrains is limited by the following site characteristics:

1) The tributary area (area draining to the planter box area) should be less than 15,000 ft^2.

2) Groundwater levels should be at least 2 ft lower than the bottom of the planter box.

3) Site must have adequate vertical relief between land surface and the stormwater conveyance system to permit connection of the underdrain to the stormwater conveyance system.

4) Planter boxes should not be located in areas with excessive shade to avoid poor vegetative growth. For moderately shaded areas, shade tolerant plants should be used.

6.5.2.2 Design Criteria

Planter boxes with underdrain should be designed according to the requirements listed in Table 6-9 and outlined in the section below. BMP sizing worksheets are presented in Appendix C.

Table 6-9: Planter Box with Underdrain Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2 and Appendix C for calculating SQDV. As noted in Section 2.6, onsite biofiltration BMPs must be sized to treat 1.5 times the portion of SQDV that is not reliably retained on-site.
Drawdown time of planting soil	hours	12
Maximum ponding depth	inches	12
Minimum soil depth	feet	2
Stabilized mulch depth	inches	2 to 3
Planting soil composition	-	60 to 70% sand, 30 to 40% compost
Underdrain	-	4-inch minimum diameter; 0.5% minimum slope; slotted, polyvinyl chloride (PVC) pipe (PVC SDR 35 or approved equivalent)
Overflow device	-	Required

6.5.2.3 Sizing Criteria

See Sizing Criteria section in the Appendix C, Section C.8: BIO-1 Biofiltration/BIO-2 Planter Box with Underdrain.

6.5.2.3.1 Geometry and Size

1) Planter boxes areas should be sized to capture and treat the SQDV with a 12-inch maximum ponding depth. The mulch layer should be included as part of the ponding depth.

2) Minimum soil depth should be 2 feet, although 3 feet is preferred. *The intention is that a minimum soil depth should provide a beneficial root zone for the chosen plant palette and adequate water storage for the SQDV. A deeper planting soil depth will provide a smaller surface area footprint.*

3) Planter boxes should be designed to drain to below the planting soil depth in less than 48 hours. *The intention is that soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive flows from subsequent storms, maintain infiltration rates, prevent long periods of saturation for plant health, maintain adequate soil oxygen levels for healthy soil biota and vegetation, reduce potential for vector breeding, and provide proper soil conditions for biodegradation and retention of pollutants.*

4) Any planter box shape configuration is possible as long as other design criteria are met.

5) The distance between the downspouts and the overflow outlet should be maximized. *The intention is to increase the opportunity for stormwater retention and filtration.*

6) Off-line configurations should be considered to minimize the possibility of scouring and resuspension of previously captured pollutants during large storms.

6.5.2.3.2 Structural Materials

1) Planter boxes should be constructed out of stone, concrete, brick, recycled plastic, or other permanent materials. Pressure-treated wood or other materials that may leach pollutants (e.g., arsenic, copper, zinc, etc.) should not be allowed.

2) The structure should be adequately sealed, or a waterproof membrane installed to ensure water only exits the structure via the underdrain.

6.5.2.3.3 Flow Entrance and Energy Dissipation

The following types of flow entrance can be used for planter boxes:

1) Pipe flow entrance: Piped entrances, such as roof downspouts, should include rock, splash blocks, or other appropriate measures at the entrance to dissipate energy and disperse flows.

2) Woody plants (e.g., trees, shrubs, etc.) can restrict or concentrate flows and can be damaged by erosion around the root ball and should not be placed directly in the entrance flow path.

6.5.2.3.4 Underdrains

Underdrains are required and should meet the following criteria:

1) 4-inch minimum diameter.

2) Underdrains should be made of slotted, polyvinyl chloride (PVC) pipe (PVC SDR 35 or approved equivalent). *The intention is that in comparison to round-hole perforated pipe, slotted underdrains provide greater intake capacity, clog resistant drainage, and reduced entrance velocity into the pipe, thereby reducing the chances of solids migration.*

3) Slotted pipe should have 2 to 4 rows of slots cut perpendicular to the axis of the pipe or at right angles to the pitch of corrugations. Slots should be 0.04 to 0.1 inch and should have a length of 1 to 1.25 inches. Slots should be longitudinally spaced such that the pipe has a minimum of one square inch opening per lineal foot and should face down.

4) Underdrains should be sloped at a minimum of 0.5%.

5) Rigid non-perforated observation pipes with a diameter equal to the underdrain diameter should be connected to the underdrain every 100 feet to provide a clean-out port as well as an observation well to monitor dewatering rates. The wells/cleanouts should be connected to the perforated underdrain with the appropriate manufactured connections. The wells/cleanouts should extend 6 inches above the top elevation of the bioretention facility mulch, and should be capped with a lockable screw cap. The ends of underdrain pipes not terminating in an observation well/cleanout should also be capped.

6) Caltrans Class 2 permeable material should be used to provide a gravel blanket and bedding for the underdrain pipe. Place the underdrain on a bed of the gravel at a minimum thickness of 6 inches and cover it with the same aggregate to provide a 1-foot minimum depth around the top and sides of the slotted pipe.

7) The underdrain should be elevated from the bottom of the planter box by 6 inches within the gravel blanket and 12 inches above to create a fluctuating anaerobic/aerobic zone below the drainpipe. *The intention is that denitrification within the anaerobic/anoxic zone is facilitated by microbes using forms of nitrogen (NO_2 and NO_3) instead of oxygen for respiration.*

8) The underdrain must drain freely to an acceptable discharge point. The underdrain can be connected to a downstream open conveyance (vegetated swale), to another bioretention cell as part of a connected treatment system, to a storm drain, daylight to

a vegetated dispersion area using an effective flow dispersion device, or to a storage facility for rainwater harvesting.

6.5.2.3.5 Overflow

An overflow device is required to be set at 2 inches below the top of the planter and no more than 12 inches above the soil surface. The most common option is a vertical riser, described below.

Vertical riser

1) A vertical PVC pipe (SDR 35) should be connected to the underdrain.
2) The overflow riser(s) should be 4 inches or greater in diameter, so it can be cleaned without damage to the pipe. The vertical pipe will provide access to cleaning the underdrains.
3) The inlet to the riser should be a maximum of 12 inches above the planting soil and be capped with a spider cap. Spider caps should be screwed in or glued (i.e., not removable).

6.5.2.3.6 Hydraulic Restriction Layers

A waterproof barrier should be provided to restrict moisture away from foundations. Geomembrane liners should have a minimum thickness of 30 mils. Equivalent waterproofing measures may be used.

6.5.2.3.7 Planting/Storage Media

1) The planting media placed in the cell should achieve a long-term, in-place infiltration rate of at least 1 inch per hour. Higher infiltration rates are permissible. If the design long-term, in-place infiltration rate of the soil exceeds 12 inches per hour, documentation should be provided to demonstrate that the media will adequately address pollutants of concern at a higher flowrate. Planter box soil shall also support vigorous plant growth.
2) Planting media should consist of 60 to 80% fine sand and 20 to 40% compost.
3) Sand should be free of wood, waste, coating such as clay, stone dust, carbonate, etc., or any other deleterious material. All aggregate passing the No. 200 sieve size should be non-plastic. Sand for the planter box should be analyzed by an accredited lab using #200, #100, #40, #30, #16, #8, #4, and 3/8 sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation (Note: all sands complying with ASTM C33 for fine aggregate comply with the gradation requirements below):

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
3/8 inch	100	100
#4	90	100
#8	70	100
#16	40	95
#30	15	70
#40	5	55
#100	0	15
#200	0	5

Note: the gradation of the sand component of the media is believed to be a major factor in the hydraulic conductivity of the media mix. If the desired hydraulic conductivity of the media cannot be achieved within the specified proportions of sand and compost (#2), then it may be necessary to utilize sand at the coarser end of the range specified in above ("minimum" column).

4) Compost should be a well decomposed, stable, weed free organic matter source derived from waste materials including yard debris, wood wastes, or other organic materials not including manure or biosolids meeting standards developed by the US Composting Council (USCC). The product shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program). Compost quality should be verified via a lab analysis to be:

- Feedstock materials shall be specified and include one or more of the following: landscape/yard trimmings, grass clippings, food scraps, and agricultural crop residues.
- Organic matter: 35-75% dry weight basis.
- Carbon and Nitrogen Ratio: 15:1 < C:N < 25:1
- Maturity/Stability: shall have dark brown color and a soil-like odor. Compost exhibiting a sour or putrid smell, containing recognizable grass or leaves, or is hot (120 F) upon delivery or rewetting is not acceptable.
- Toxicity: any one of the following measures is sufficient to indicate non-toxicity:
    - NH4:NH3 < 3
    - Ammonium < 500 ppm, dry weight basis
    - Seed Germination > 80% of control
    - Plant trials > 80% of control

- Solvita® > 5 index value
- Nutrient content:
  - Total Nitrogen content 0.9% or above preferred
  - Total Boron should be <80 ppm, soluble boron < 2.5 ppm
- Salinity: < 6.0 mmhos/cm
- pH between 6.5 and 8 (may vary with plant palette)

Compost for planter box should be analyzed by an accredited lab using #200, ¼ inch, ½ inch, and 1-inch sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation:

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
1 inch	99	100
½ inch	90	100
¼ inch	40	90
#200	2	10

Tests should be sufficiently recent to represent the actual material that is anticipated to be delivered to the site. If processes or sources used by the supplier have changed significantly since the most recent testing, new tests should be requested.

Note: the gradation of compost used in planter box media is believed to play an important role in the saturated hydraulic conductivity of the media. To achieve a higher saturated hydraulic conductivity, it may be necessary to utilize compost at the coarser end of this range ("minimum" column). The percent passing the #200 sieve (fines) is believed to be the most important factor in hydraulic conductivity.

In addition, a coarser compost mix provides more heterogeneity of the planter box media, which is believed to be advantageous for more rapid development of soil structure needed to support health biological processes. This may be an advantage for plant establishment with lower nutrient and water input.

5) The planter box should be covered with 2 to 4 inches (average 3 inches) of mulch at the start and an additional placement of 1 to 2 inches of mulch should be added annually. *The intention is to help sustain the nutrient levels, suppress weeds, retain moisture, and maintain infiltration capacity*.

6.5.2.4 Plants

1) Plant materials should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 48 to 72 hours.

2) It is recommended that a minimum of three types of tree, shrubs, and/or herbaceous groundcover species be incorporated to protect against facility failure due to disease and insect infestations of a single species.

3) Native plant species and/or hardy cultivars that are not invasive and do not require chemical inputs should be used to the maximum extent practicable.

4) Plants should be selected carefully to minimize maintenance and function properly.

6.5.2.5 Operations and Maintenance

Planter boxes require annual plant, soil, and mulch layer maintenance to ensure optimum infiltration, storage, and pollutant removal capabilities. In general, planter box maintenance requirements are typical of landscape care procedures and include:

1) Watering: Plants should be selected to be drought-tolerant and do not require watering after establishment (2 to 3 years). Watering may be required during prolonged dry periods after plants are established.

2) Erosion control: Inspect flow entrances, ponding area, and surface overflow areas periodically, and replace soil, plant material, and/or mulch layer in areas if erosion has occurred (see Appendix D for an inspection and maintenance checklist). Properly designed facilities with appropriate flow velocities should not have erosion problems except perhaps in extreme events. If erosion problems occur, the following should be reassessed: (1) flow velocities and gradients within the cell, and (2) flow dissipation and erosion protection strategies in the flow entrance. If sediment is deposited in the planter box, immediately determine the source within the contributing area, stabilize, and remove excess surface deposits.

3) Plant material: Depending on aesthetic requirements, occasional pruning and removing of dead plant material may be necessary. Replace all dead plants and if specific plants have a high mortality rate, assess the cause and, if necessary, replace with more appropriate species. Periodic weeding is necessary until plants are established. The weeding schedule should become less frequent if the appropriate plant species and planting density have been used and, as a result, undesirable plants have been excluded.

4) Nutrients and pesticides: The soil mix and plants are selected for optimum fertility, plant establishment, and growth. Nutrient and pesticide inputs should not be required and may degrade the pollutant processing capability of the planter box area, as well as contribute pollutant loads to receiving waters. By design, planter boxes are located in areas where phosphorous and nitrogen levels are often elevated, and these should not be limiting nutrients. If in question, have soil analyzed for fertility.

5) Mulch: Replace mulch annually in planter boxes where high trash, sediment load, and heavy metal deposition is likely (e.g., heavy metal contributing areas include industrial, auto dealer/repair, parking lots, and roads). In residential lots or other

areas where metal deposition is not a concern, replace or add mulch as needed to maintain a 2 to 3-inch depth at least once every two years.

6) Soil: Soil mixes for planter boxes are designed to maintain long-term fertility and pollutant processing capability. Replacing mulch in planter boxes where high trash, sediment load, and heavy metal deposition are likely provides an additional level of protection for prolonged performance. Estimates from metal attenuation research suggest that metal accumulation should not present an environmental concern for at least 20 years in planter boxes. However, the saturated hydraulic conductivity should be assessed at least annually to ensure that the design water quality event is being treated. If in question, have soil analyzed for fertility and pollutant levels.

6.6 Alternative Compliance using Onsite Flow-Based BMPs

6.6.1 FLO-1: Cartridge Media Filter

Cartridge media filters are on site flow-based treatment devices that may be used as alternative compliance BMPs with prior approval from the Executive Officer of the Regional Water Board. They are manufactured devices that typically consist of a series of cylindrical vertical filters contained in a catch basin, manhole, or vault that provide treatment through filtration and sedimentation. The manhole or vault may be divided into multiple chambers where the first chamber acts as a pre-settling basin for removal of coarse sediment while another chamber acts as the filter bay and houses the filter cartridges.

Application

- Parking lots
- Roadways
- Playgrounds
- Outdoor eating areas

Preventive Maintenance

- Filter media replacement
- Solids removal from vault, manhole, or catch basin
- Inspect for inlet and outlet for clogging

Example Cartridge Media Filters

Photo Credits: Left – Contech Stormwater Solutions, Inc.;
Right – County of Ventura

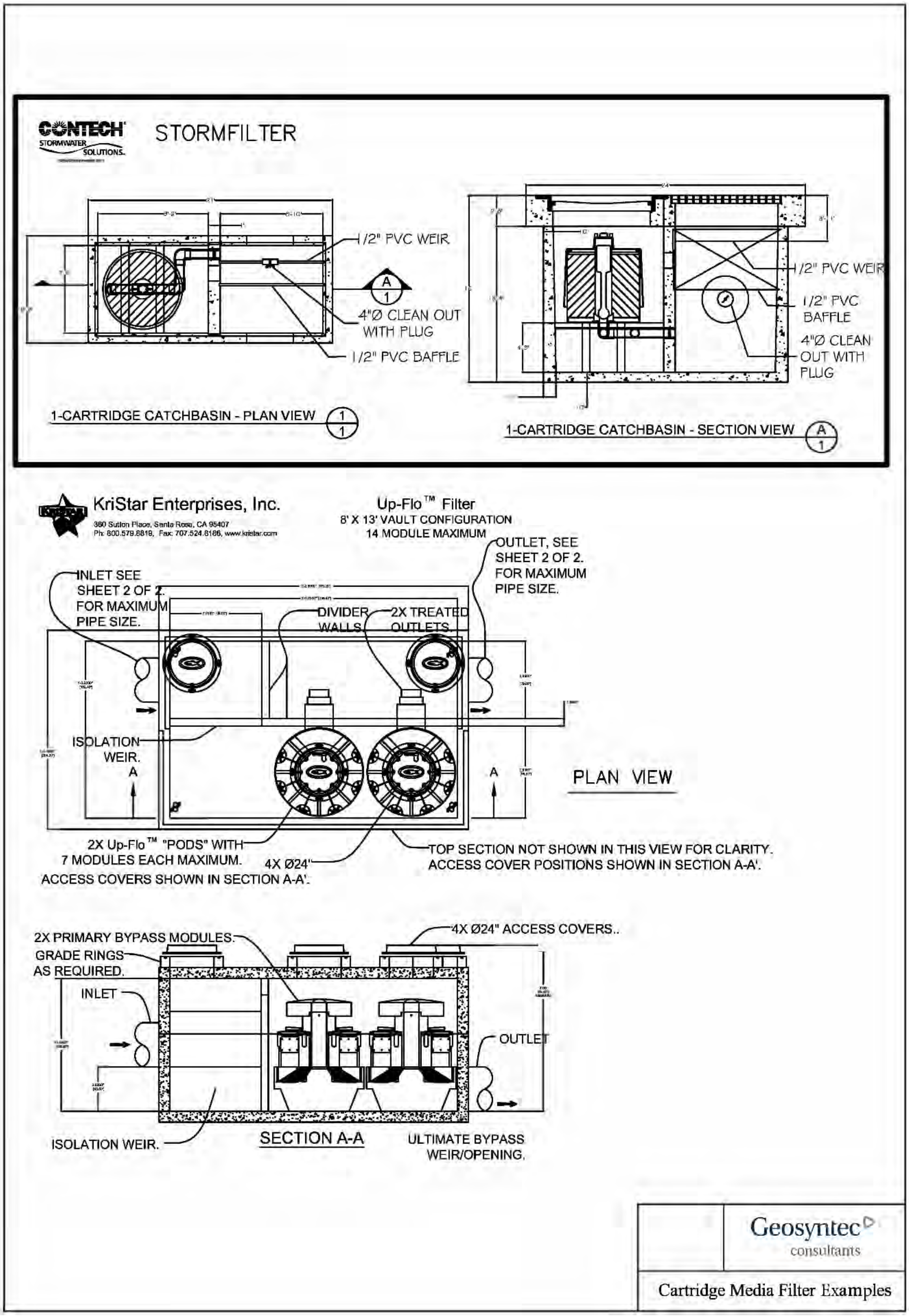


Figure 6-12: Example Cartridge Media Filter Design Schematic

6.6.1.1 Limitations

As with all filtration systems, use in catchments that have significant areas of non-stabilized soils can lead to premature clogging.

6.6.1.2 Design Criteria

1) Cartridge media filter BMP vendors are constantly updating and expanding their product lines. Please refer to the latest design guidance from each of the vendors.

2) Selected filter media should target pollutants of concern. A combination of media is often recommended to maximize pollutant removal. Perlite is effective for removing TSS and oil and grease. Zeolite removes soluble metals, ammonium, and some organics. Vendors also offer proprietary medias (such as leaf compost or activated carbon) that are designed to remove soluble metals, organics, and other pollutants.

3) Manufacturers try to distinguish their products through innovative designs that aim at providing self-cleaning and draining, uniformly loaded, and clog resistant cartridges that functional properly over a wide range of hydraulic loadings and pollutant concentrations.

4) All stormwater vaults containing cartridge filters that have standing water for longer than 72 hours can become a breeding area for mosquitoes. The selected BMP should have a system to completely drain the vault, such as weep holes in the bottom of the vault.

6.6.1.2.1 Sizing

1) Cartridge media filters should be sized to capture and treat the stormwater quality design flow rate.

2) Proprietary cartridge media filter devices, like most proprietary BMPs, and auxiliary components such as media, screens, baffles, and sumps are selected based onsite-specific conditions such as the loading that is expected and the desired frequency of maintenance. Sizing of proprietary devices is reduced to a simple process whereby a model can simply be selected from a table or a chart based on a few known quantities (tributary area, location, design flow rate, etc.). Most of the manufacturers either size the devices for potential clients or offer calculators on their websites that simplify the design process. For the latest sizing guidelines, refer to the manufacturer's website.

6.6.2 FLO-2: Proprietary Biotreatment

Proprietary biotreatment are flow-based, proprietary treatment devices that may be used as alternative compliance BMPs with prior approval from the Executive Officer of the Regional Water Board. They are manufactured treatment BMPs that incorporate plants, soil, and microbes engineered to provide treatment at higher flow rates or volumes and with smaller footprints than their non-proprietary counterparts. Incoming flows are typically pretreated to remove larger particles/debris, filtered through a planting media (mulch, compost, soil, and plants), collected by an underdrain, and delivered to the stormwater conveyance system.

All proprietary biotreatment systems must be certified for "Enhanced Treatment" under the Washington State Department of Ecology's TAPE Program.

Application

- Parking lot islands
- Pickup/drop off turnarounds
- Roadway curbs

Maintenance

- Filter media replacement
- Sediment, trash, and debris removal
- Mulch replacement
- Vegetation upkeep and replacement

Proprietary Biotreatment Examples

Photo Credits: County of Ventura

6.6.2.1 Design Criteria

As proprietary biotreatment BMP vendors are constantly updating and expanding their product lines, refer to the specific vendor for the latest design and sizing guidance. All devices must be able to filter or treat Filter or treat either:

(1) The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or

(2) The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity (for each hour of a storm event), as determined from the local historical rainfall record, multiplied by a factor of two.

6.6.3 FLO-3: Other TAPE-Certified Enhanced Treatment BMPs

The Washington State Department of Ecology's TAPE Program also certifies and sets design standards for non-priopritary biotreatment systems, such as Washington State Department of Transportation's Compost-Amended Biofiltration Swale and Modified Vegetated Filter Strip. Project applicants may propose use of such other TAPE-Certified 'Enhanced Treatment' devices for alternative compliance BMPs with prior approval from the Executive Officer of the Regional Water Board.

All flow-based treatment devices must be able to filter or treat either:

(1) The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or

(2) The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity (for each hour of a storm event), as determined from the local historical rainfall record, *multiplied by a factor of two*.

6.7 Hydromodification BMPs

6.7.1 HM-1: Dry Extended Detention Basin

Dry extended detention (ED) basins are basins whose outlets have been designed to detain the SQDV for 36 to 48 hours to allow sediment particles and associated pollutants to settle and be removed. Dry ED basins do not have a permanent pool. They are designed to drain completely between storm events. They can also be used to provide hydromodification and/or flood control by modifying the outlet control structure and providing additional detention storage. The slopes, bottom, and forebay of dry ED basins are typically vegetated. Without the addition of a sand filter beneath the basin, considerable stormwater volume reduction can still occur, depending on the infiltration capacity of the subsoil.

Application

- Adjacent to parking lots
- Road medians and shoulders
- Within open areas or play fields

Preventive Maintenance

- Remove trash and debris, minor sediment accumulation, and obstructions near inlet and outlet structures
- Replace top 2 to 4 inch of sand
- Mow or weed surface of filter

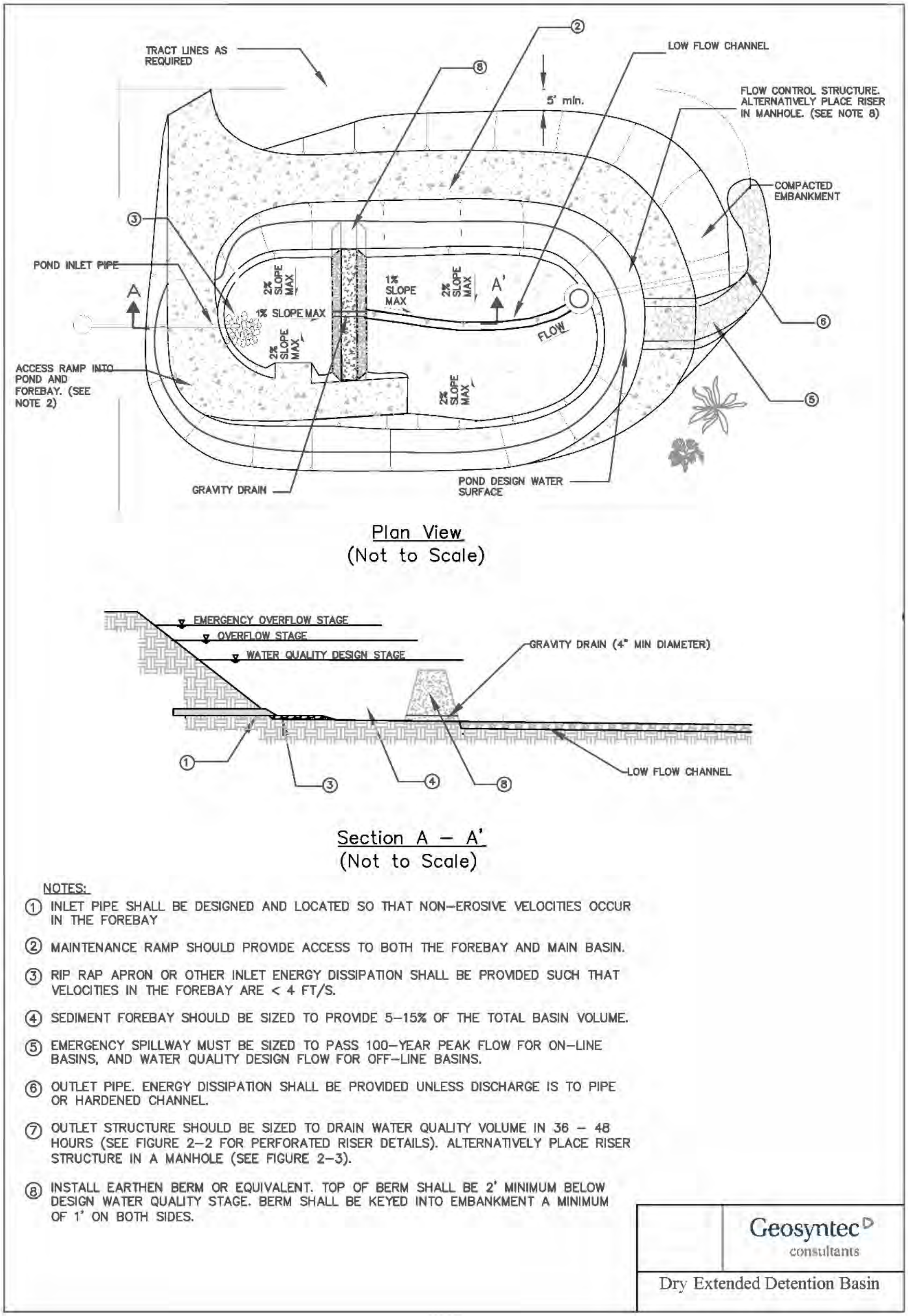
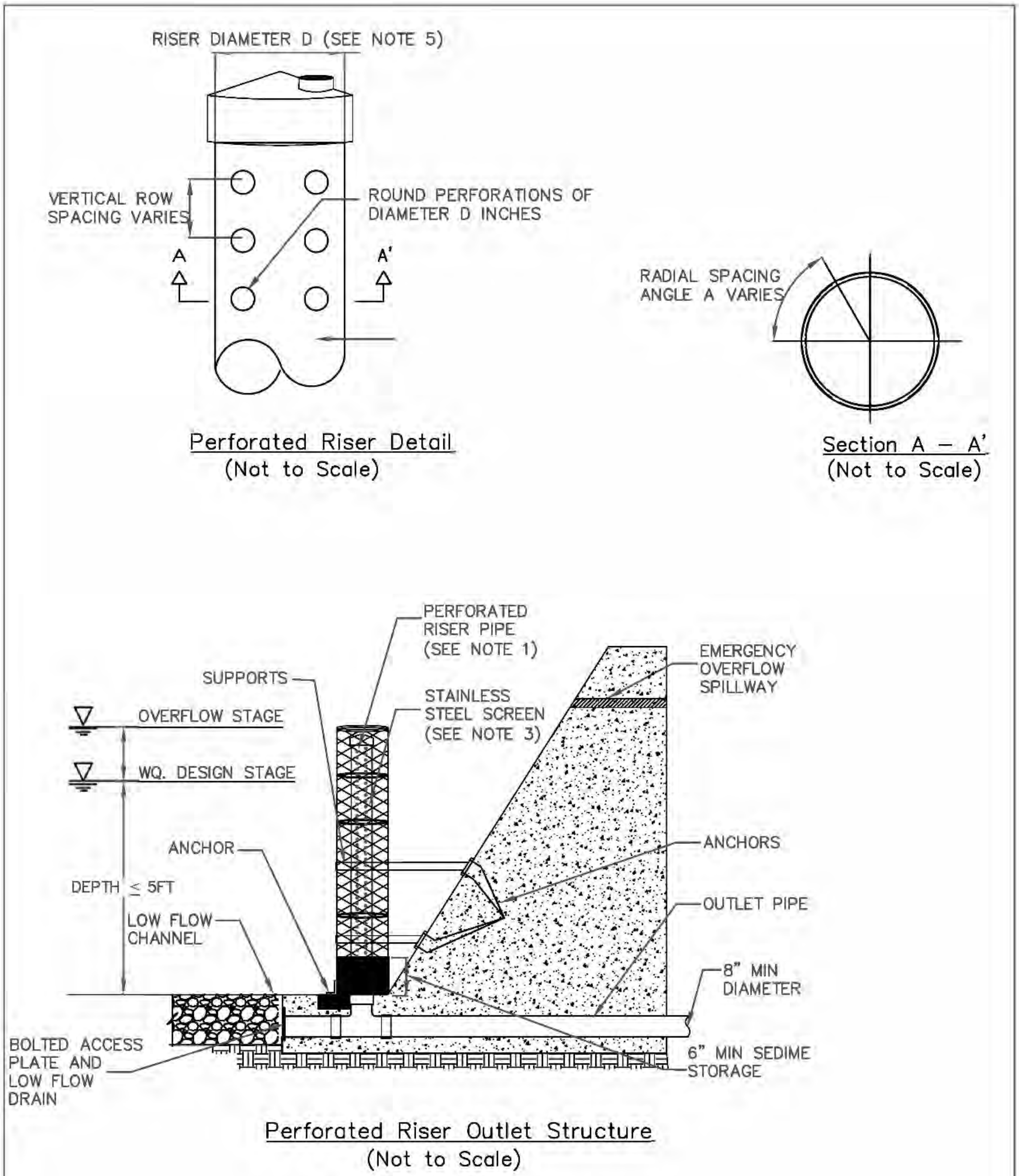


Figure 6-13: Dry Extended Detention Basin Schematic



NOTES:

1. RISER PIPE SHALL BE SIZED TO PROVIDE 36 TO 48–HOUR FULL BRIM DRAW DOWN TIME.
2. TOTAL OUTLET CAPACITY: 100–YEAR PEAK FLOW FOR ON–LINE BASINS AND WATER QUALITY DESIGN FLOW FOR OFF–LINE BASINS.
3. SCREEN OPENINGS SHALL BE AT LEAST ¼" AND SHALL NOT EXCEED THE DIAMETER OF THE PERFORATIONS ON THE RISER.
4. RISER PIPE PERFORATION DIAMETER SHALL BE NO LESS THAN ½" AND NO MORE THAN 2"
5. MINIMUM PIPE DIAMETER (D) IS 2'
6. RISER PIPE MATERIAL IS CMP

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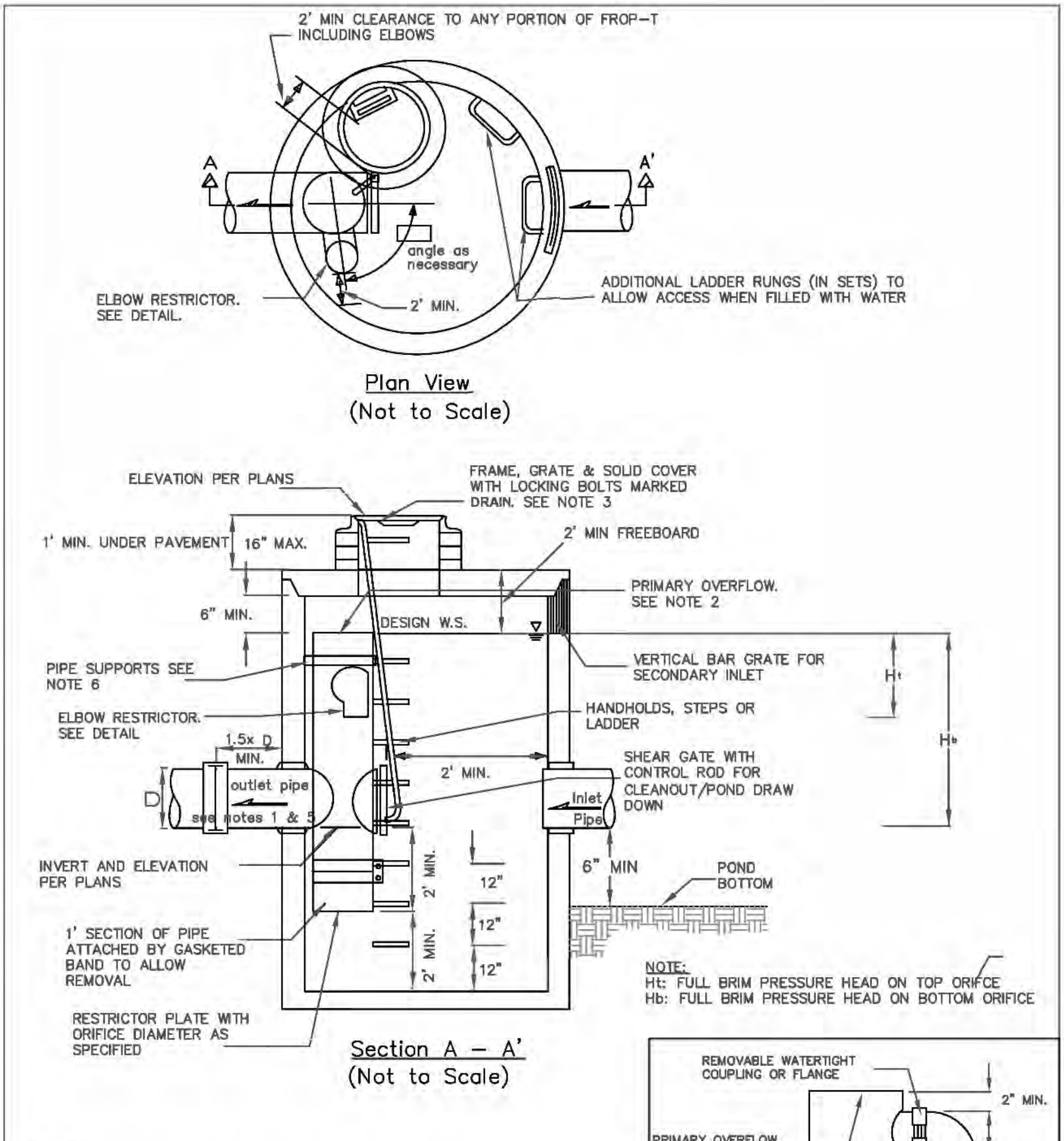
Perforated Riser Outlet

Figure 6-14: Perforated Riser Outlet



NOTES:

1. USE A MINIMUM OF A 54" DIA TYPE 2 CATCH BASIN
2. OUTLET CAPACITY: 100-YEAR PEAK FLOW FOR ON-LINE BASINS.
3. METAL PARTS: CORROSION RESISTANT. NON-GALVANIZED PARTS PERFERRED. GALVANIZED PIPE PARTS TO HAVE ASPHALT TREATMENT.
4. FRAME AND LADDER OR STEPS OFFSET SO:
   A. CLEANOUT GATE IS VISIBLE FROM TOP.
   B. CLIMB-DOWN SPACE IS CLEAR OF RISER AND
   C. FRAME IS CLEAR OF CURB.
5. IF METAL OUTLET PIPE CONNECTS TO CEMENT CONCRETE PIPE: OUTLET PIPE TO HAVE SMOOTH O.D. EQUAL TO CONCRETE PIPE I.D. LESS ¼"
6. PROVIDE AT LEAST ONE 3 X .090 GAGE SUPPORT BRACKET ANCHORED TO CONCRETE WALL. (MAXIMUM 3' VERTICAL SPACING)
7. LOCATE ADDITIONAL LADDER RUNGS IN STRUCTURES USED AS ACCESS TO TANKS OR VAULTS TO ALLOW ACCESS WHEN CATCH BASIN IS FILLED WITH WATER

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Multiple Orifice Outlet

Figure 6-15: Multiple Orifice Outlet

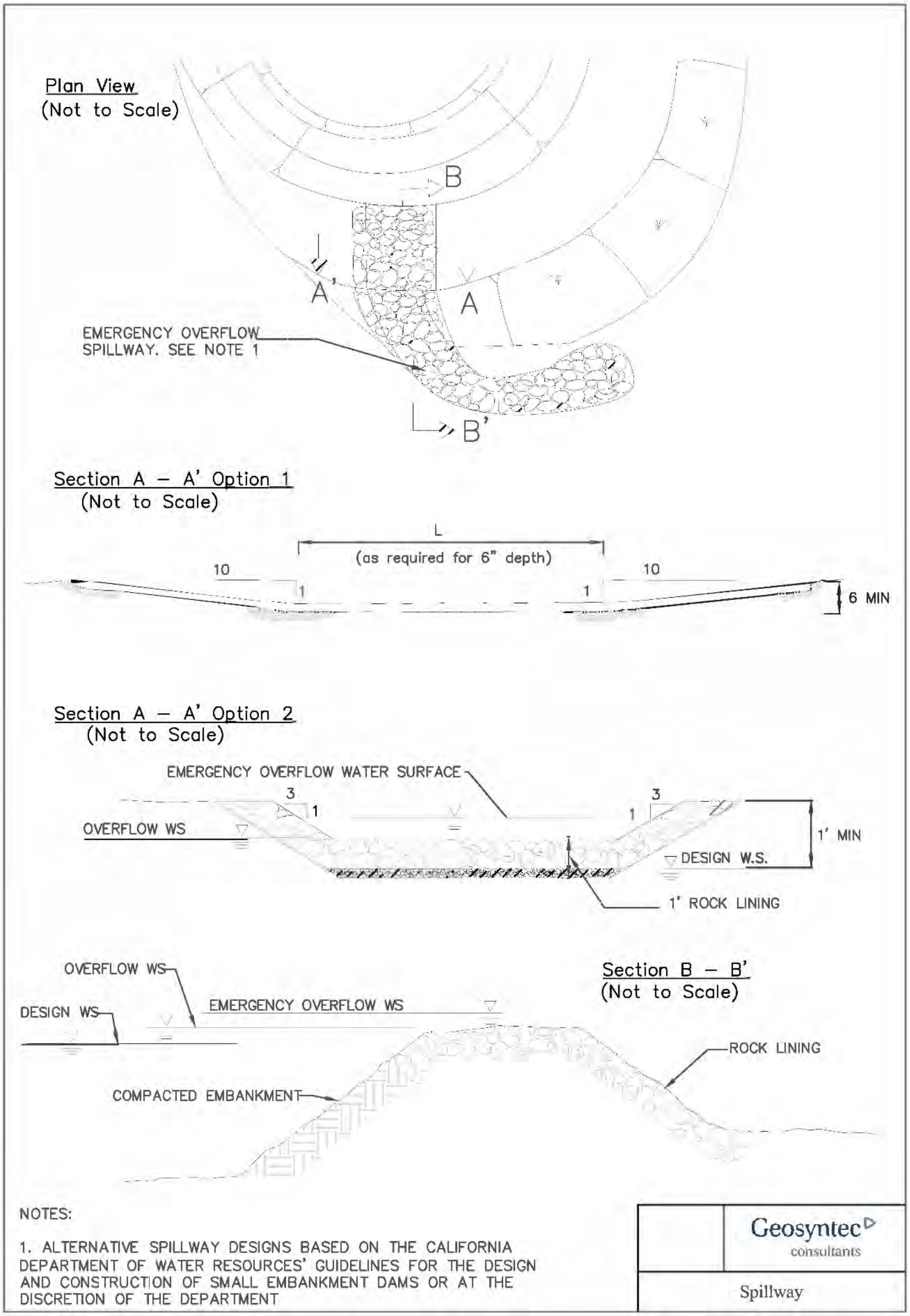


Figure 6-16: Spillway

6.7.1.1 Limitations

Limitations for dry extended detention basins include:

- Surface space availability - typically 0.5 to 2.0 percent of the total tributary development area required.
- Depth to groundwater - bottom of basin should be 2 feet higher than the seasonal high water table elevation.
- Steep slopes - basins placed above slopes greater than 15 percent or within 200 feet from the top of a hazardous slope or landslide area require a geotechnical investigation.
- Compatibility with flood control - basins must not interfere with flood control functions of existing conveyance and detention structures.

6.7.1.2 Design Criteria

Dry extended detention basins should be designed according to the requirements listed in Table 6-10 and outlined in the section below. BMP sizing worksheets are presented in Appendix C.

Table 6-10: Dry Extended Detention Basin Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2 and Appendix C for calculating SQDV
Drawdown time for SQDV	hours	Top 50%: 12 hrs (minimum); Bottom 50%: 36 hrs
Basin Design Volume	acre-ft	1.2 * SQDV
Forebay basin size	acre-feet	5 to 15% of SQDV
Maximum forebay drain time	min	45
Low–flow channel depth	inches	9
Low-flow channel flow capacity		2*forebay outlet rate
Freeboard (minimum)	inches	12
Flow path length to width ratio	L:W	2:1, larger preferred; can be achieved using internal berms
Longitudinal slope	percentage	1 (forebay) and 0-2 (main basin)
Low flow channel geometry	feet	depth of 0.5 and width of 1
Minimum outflow device diameter	inches	18

6.7.1.3 Sizing Criteria

Dry extended detention (ED) basins are basins designed such that the SQDV is detained for 48 hours. This allows sediment particles and associated pollutants to settle and be removed from the stormwater. Procedures for sizing extended detention basins are described in Appendix C. Section C.9. A sizing example is also provided.

6.7.1.3.1 Sizing and Geometry

1) The total basin volume should be increased an additional 20% of the SQDV to account for sediment accumulation, at a minimum. If the basin is designed only for water quality treatment, then the basin volume would be 120% of the SQDV. Freeboard is in addition to the total basin volume.

2) The minimum freeboard should be at least 1 foot above the emergency overflow water surface for dry extended detention basins.

3) The minimum flow-path length to width ratio at half basin height should be a minimum of 3:1 (L:W) and can be achieved using internal berms or other means to prevent short-circuiting. Intent: a long flow length will improve fine sediment removal.

4) The cross-sectional geometry across the width of the basin should be approximately trapezoidal. Shallow side slopes are necessary if the basin is designed to have recreational uses during dry weather conditions.

5) All dry ED basins should be free draining and a low flow channel should be provided. A low flow channel is a narrow, shallow trench filled with pea gravel and encased with filter fabric that runs the length of the basin to drain dry weather flows. The low flow channel should be of sufficient size considering the natural characteristics of the soil and have a positive-draining gradient flowing toward the outlet structure (typically 1 ft wide by 6 inches deep). If infiltration rates of subsurface soils are insufficient, the low flow channel should tie into perforated pipe at the outlet structure. If a sand filter or planting media is provided beneath the dry ED basin for increased volume reduction, it may be designed to take the place of the low flow channel.

6) The basin bottom should have a 1% longitudinal slope (direction of flow) in the forebay and may range from 0 to 2% longitudinal slope in the main basin. The bottom of the basin should slope 2% toward the center low flow channel.

7) A basin should be large enough to allow for equipment access via a graded ramp.

6.7.1.3.2 Soils Considerations

1) The slopes of the detention basin should be analyzed for slope stability using rapid drawdown conditions and should meet the minimum standards set by the Ventura County Flood Control District. A 1.5 static factor of safety should be used. Seismic analysis is not required due to the temporary storage of water in the basin.

2) The infiltration capability of the dry ED basin can be enhanced by incorporating soil amendments.

6.7.1.3.3 Energy Dissipation

1) Energy dissipation controls constructed of sound materials such as stones, concrete, or proprietary devices that are rated to withstand the energy of the influent flow should be installed at the inlet to the sediment forebay. Flow velocity into the basin forebay should be controlled to 4 feet per second (ft/sec) or less.

2) Energy dissipation controls must also be used at the outlet/spillway from the detention basin unless the basin discharges to a storm drain or hardened channel.

6.7.1.3.4 Sediment Forebay

As untreated stormwater enters the dry ED basin, it passes through a sediment forebay for coarse solids removal. The forebay may be constructed using an internal berm constructed out of earthen embankment material, grouted riprap, stop logs, or other structurally sound material.

1) The basin should be sized so that 5 to 15% of the total basin volume is in the forebay and 85 to 95% of the total basin volume is in the main portion of the basin.

2) A gravity drain outlet from the forebay (2 inch minimum diameter) should extend the entire width of the internal berm and be designed to completely drain to the main basin within 10 minutes.

3) The forebay outlet should be offset (horizontally) from the inflow streamline to prevent short-circuiting.

4) Permanent steel post depth markers should be placed in the forebay to define sediment removal limits at 50% of the forebay sediment storage depth.

6.7.1.3.5 Vegetation

Vegetation within the dry ED basin provides erosion protection from wind and water and biofiltration of stormwater. The local permitting authority should review and approve any proposed basin landscape plan prior to implementation and following guidelines should be followed:

1) The bottom and slopes of the dry ED basin should be vegetated. A mix of erosion-resistant plant species that effectively bind the soil should be used on the slopes and a diverse selection of plants that thrive under the specific site, climatic, and watering conditions should be specified for the basin bottom. The basin bottom should not be planted with trees, shrubs, or other large woody plants that may interfere with sediment removal activities. The basin should be free of floating objects. Only native perennial grasses, forbs, or similar vegetation that can be replaced via seeding should be used on the basin bottom.

a. Landscaping outside of the basin is required for all dry ED basins and should adhere to the following criteria so as not to hinder maintenance operations:

b. No trees or shrubs may be planted within 15 feet of inlet or outlet pipes or manmade drainage structures such as spillways, flow spreaders, or earthen embankments. Species with roots that seek water, such as willow or poplar, should not be used within 50 feet of pipes or manmade structures. Weeping willow (Salix babylonica) should not be planted in or near detention basins.

2) Prohibited non-native plant species will not be permitted. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website- or the California Invasive Plant Council website at www.cal-ipc.org.

3) A plant list provided by a landscape professional should be used as a guide only and should not replace project-specific planting recommendations, including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth.

6.7.1.3.6 Sand Filter or Planting Media Layer

For increasing the volume reduction capability of a dry ED basin, an appropriately sized sand filter or planting media layer can be placed beneath the dry ED basin to achieve desired volume reduction goals if soil and slope conditions allow (i.e., infiltration rate greater than 0.5 in/hr but less than 2.4 in/hr; site slope less than 15%). The drawdown time of the sand filter or planting media layer should be less than 72 hours. The base of the sand filter or planting media layer should be level (i.e., zero slope). If a sand filter/planting media layer is provided over the length of the basin, it can take the place of the low-flow channel so long as it is designed to adequately infiltrate dry weather flows. Sizing of the sand filter and planting media layer for dry ED basins is the same as for sand filters and bioretention areas, respectively. The depth of water in the dry ED basin should not exceed 6 feet.

6.7.1.3.7 Outlet Structure and Drawdown Time

A drawdown time of 72 hours shall be provided for the SQDV. This drawdown time is for the volume in the basin above the sand filter layer (if provided) and serves the purpose of water quality treatment. An outflow device should be designed to release the bottom 50% of the detention volume (half-full to empty) over 24 to 32 hours, and the top half (full to half-full) in 12 to 16 hours. *The intention is that the drawdown schemes that detain low flows for longer periods than high flows have the following advantages over outlets that drain the basin evenly:*

- Greater flood control capabilities
- Enhanced treatment of low flows which make up the bulk of incoming flows.

Additional storage, detention, and outlet control is required to achieve pre-development stormwater runoff discharge rates for hydromodification control. The outlet structure can be designed to achieve flow control for meeting the multiple objectives of water quality and flow attenuation.

The outflow device (i.e., outlet pipe) should be oversized (18-inch minimum diameter). There are two options that can be used for the outlet structure:

1) Uniformly perforated riser structures.

2) Multiple orifice structures (orifice plate).

Details on sizing of these options are included in Appendix C. Section C.9.

The outlet structure can be placed in the basin with a debris screen (Figure 6-15) or housed in a standard manhole (Figure 6-16). If a multiple orifice structure is used, an orifice restriction (if necessary) should be used to limit orifice outflow to the maximum discharge rates allowable for achieving the desired water quality and flow control objectives. Orifice restriction plates should be removable for emergency situations. A removable trash rack should be provided at the outlet.

Note that a primary overflow (typically a riser pipe connected to the outlet works) should be sized to pass flows larger than the stormwater quality design storm (if the ED basin is sized only for water quality) or to pass flows larger than the peak flow rate of the maximum design storm to be detained in the basin (e.g., 100-yr, 24-hr). The primary overflow is intended to protect against overtopping or breaching of a basin embankment.

6.7.1.3.8 Emergency Spillway

An emergency overflow spillway in addition to the primary overflow outlet (as described above) is required. The emergency spillway should be sized for flows greater than the peak 100-year 24-hour storm if the basin is designed on-line or, if the basin is designed on-line, the spillway should be sized for flows greater than the basin design volume (e.g., stormwater quality design volume). The spillway should provide adequate energy dissipation downstream. The spillway should allow for at least 12 inches of freeboard above the emergency overflow water surface elevation if the basin is on-line. If the basin is on-line, 2 feet of freeboard is preferable.

Spillways shall meet the California Department of Water Resources, Division of Safety of Dams Guidelines for the Design and Construction of Small Embankment Dams (http://damsafety.water.ca.gov/docs/GuidelinesSmallDams.pdf). *Intent: Emergency overflow spillways are intended to control the location of basin overtopping and safely direct overflows back into the downstream conveyance system or other acceptable discharge point.*

On-line Basins

1) On-line basins must have an emergency overflow spillway to prevent overtopping of walls or berms should blockage of the primary outlet occur based on a downstream risk assessment.

2) The overflow spillway must be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm.

3) The minimum freeboard should be 1 foot (but preferably at least 2 feet) above the maximum water surface elevation over the emergency spillway.

Off-line Basins

1) Off-line basins must have either an emergency overflow spillway or an emergency overflow riser. The emergency overflow must be designed to pass the 100-yr 24-hr post-development peak stormwater runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point. Where an emergency overflow spillway would discharge to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

2) The emergency overflow spillway shall be armored to withstand the energy of the spillway flows.

3) The minimum freeboard should be 1 foot above the maximum water surface elevation over the emergency spillway.

6.7.1.3.9 Side Slopes

1) Interior side slopes above the stormwater quality design depth and up to the emergency overflow water surface steeper than 4:1 (H:V) should be stabilized to prevent erosion with a method approved by the local permitting authority.

2) Exterior side slopes steeper than 2:1 (H:V) should be stabilized to prevent erosion with a method approved by the local permitting authority.

3) For any slope (interior or exterior) greater than 2:1 (H:V), a geotechnical investigation and report must be submitted and approved by the local permitting authority.

4) Landscaped slopes should be no greater than 3:1 (H:V) to allow for maintenance.

5) Basin walls may be vertical retaining walls, provided: (a) they are constructed of reinforced concrete, (b) a fence is provided along the top of the wall (see fencing below) or further back, and (c) the design is stamped by a licensed civil and/or geotechnical engineer and approved by the Local permitting authority.

6.7.1.3.10 Embankments

1) Earthworks and berm embankments should be performed in accordance with the latest edition of the "Greenbook Standard Specifications for Public Works Construction".

2) Embankments are earthen slopes or berms used for detaining or redirecting the flow of water.

3) Top of berm separating forebay and main basin should be 2 feet minimum below the stormwater quality design water surface and should be keyed into embankment a minimum of 1 foot on both sides.

4) Typically, the top width of berm embankments are at least 20 feet, but narrower embankments may be plausible if approved by the civil and/or geotechnical engineer and the local permitting authority.

5) Basin berm embankments should be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a licensed civil and/or geotechnical engineer) free of loose surface soil materials, roots, and other organic debris.

6) The berm embankment should be constructed of compacted soil (95% minimum dry density, modified proctor method per ASTM D1557), placed in 6-inch lifts.

7) Basin berm embankments greater than 4 feet in height should be constructed by excavating a key equal to 50% of the berm embankment cross-sectional height and width. This requirement may be waived if specifically recommended by a licensed civil and/or geotechnical engineer.

8) The berm embankment should be constructed of compacted soil (95% minimum dry density, modified proctor method per ASTM D1557), placed in 6-inch lifts.

9) Low growing native or non-invasive perennial grasses should be planted on downstream embankment slopes. See vegetation section above.

6.7.1.3.11 Fencing

1) Safety is provided either by fencing of the facility or by managing the contours of the basin to eliminate drop-offs and other hazards.

2) If fences are required, fences should be designed and constructed in accordance with relevant standards and should typically be located at or above the overflow water surface elevation. Shrubs (approved, California-adapted species) can be used to hide the fencing. See vegetation section above.

6.7.1.3.12 Right-of-Way

1) Dry extended detention basins and associated access roads to be maintained by a public agency should be dedicated in fee or in an easement to the public agency with appropriate access.

6.7.1.3.13 Maintenance Access

1) Ownership of the basin and maintenance thereof is the responsibility of the developer/applicant. A maintenance agreement with the Local permitting authority is required to ensure adequate performance and allow emergency access to the facilities.
2) Maintenance access road(s) should be provided to the control structure and other drainage structures associated with the basin (e.g., inlet, emergency overflow or bypass structures). Manhole and catch basin lids should be in or at the edge of the access road.
3) A ramp into the basin should be constructed near the basin outlet. An access ramp is required for removal of sediment with a backhoe or loader and truck. The ramp should extend to the basin bottom to avoid damage to vegetation planted on the basin slope.
4) All access ramps and roads should be provided in accordance with the current policies of the Ventura County Flood Control District or local approval authority.

6.7.1.3.14 Construction Considerations

The use of treated wood or galvanized metal anywhere inside the facility is prohibited.

6.7.1.4 Operations and Maintenance

Maintenance is of primary importance if extended detention basins are to continue to function as originally designed. A maintenance agreement must be developed with the local approval authority to ensure adequate performance and allow emergency access. Maintenance of the basin is the responsibility of the development, unless otherwise agreed upon.

A specific maintenance plan shall be formulated for each facility outlining the schedule and scope of maintenance operations, as well as the data handling and reporting requirements. The following are general maintenance requirements:

1) The basin should be inspected semiannually or more frequently, and inspections after major storm events are encouraged. Trash and debris should be removed as needed, but at least annually prior to the beginning of the wet season (see Appendix D for guidance on facility maintenance inspections).
2) Site vegetation should be maintained as follows:
    - Vegetation, such as large shrubs or trees, that limit access or interfere with basin operation should be pruned or removed.

- Slope areas that have become bare should be revegetated and eroded areas should be regraded prior to being revegetated.
- Grass should be mowed to 4 to 9 inch high and grass clippings should be removed.
- Fallen leaves and debris from deciduous plant foliage should be raked and removed.
- Invasive vegetation, such as Alligatorweed (Alternanthera philoxeroides), Halogeton (Halogeton glomeratus), Spotted Knapweed (Centaurea maculosa), Giant Reed (Arundo donax), Castor Bean (Ricinus communis), Perennial Pepperweed (Lepidium latifolium), and Yellow Starthistle (Centaurea solstitalis) should be removed and replaced with non-invasive species. Invasive species should never contribute more than 25% of the vegetated area. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.
- Dead vegetation should be removed if it exceeds 10% of area coverage. Vegetation should be replaced immediately to maintain cover density and control erosion where soils are exposed.
- No herbicides or other chemicals should be used to control vegetation.

3) Sediment buildup exceeding 50% of the forebay capacity should be removed. Sediment from the remainder of the basin should be removed when 6 inches of sediment accumulates. Sediments should be tested for toxic substance accumulation in compliance with current disposal requirements if land uses in the catchment include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed. If toxic substances are encountered at concentrations exceeding thresholds of Title 22, Section 66261 of the California Code of Regulations, the sediment must be disposed of in a hazardous waste landfill. It is recommended to clean the forebay frequently to reduce frequency of main basin cleaning.

4) Remove sediment from basin when accumulation reaches 25% of original design depth. Cleaning is recommended to occur in early spring to allow vegetation to reestablish.

5) Repair erosion to banks and bottom of basin as required.

6) Following sediment removal activities, replanting, and/or reseeding of vegetation may be required for reestablishment.

7) Control vectors as needed.

6.7.2 HM-2: Wet Detention Basin

Wet detention basins are constructed, naturalistic ponds with a permanent or seasonal pool of water (also called a “wet pool” or “dead storage”). Aquascape facilities, such as artificial lakes, are a special form of wet pool facility that can incorporate innovative design elements to allow them to function as a stormwater treatment facility in addition to an aesthetic water feature. Wet ponds require base flows to exceed or match losses through evaporation and/or infiltration and they must be designed with the outlet positioned and/or operated in such a way as to maintain a permanent pool. wet ponds can be designed to provide extended detention of incoming flows using the volume above the permanent pool surface.

Application

- Regional detention & treatment
- Roads, highways, parking lots, commercial, residential
- Parks, open spaces, and golf courses

Preventive Maintenance

- inspected at a minimum annually and inspections after major storm events
- Pruned or remove vegetation, large shrubs, or trees that limit access or interfere with basin operation
- Remove sediment buildup at inlets and outlets

Wet Detention Basin

Photo Credit: Geosyntec Consultants

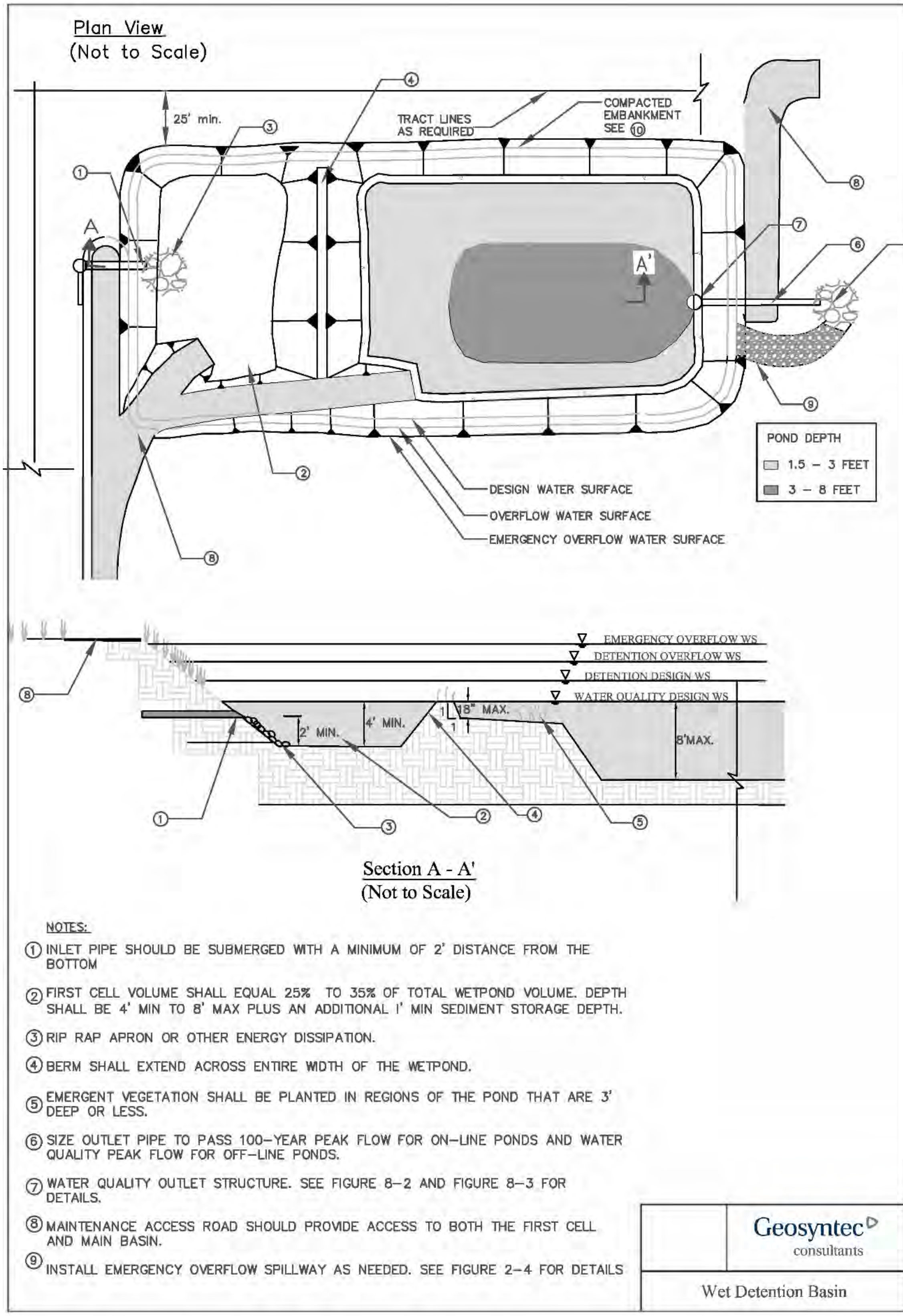


Figure 6-17: Wet Detention Basin Schematic

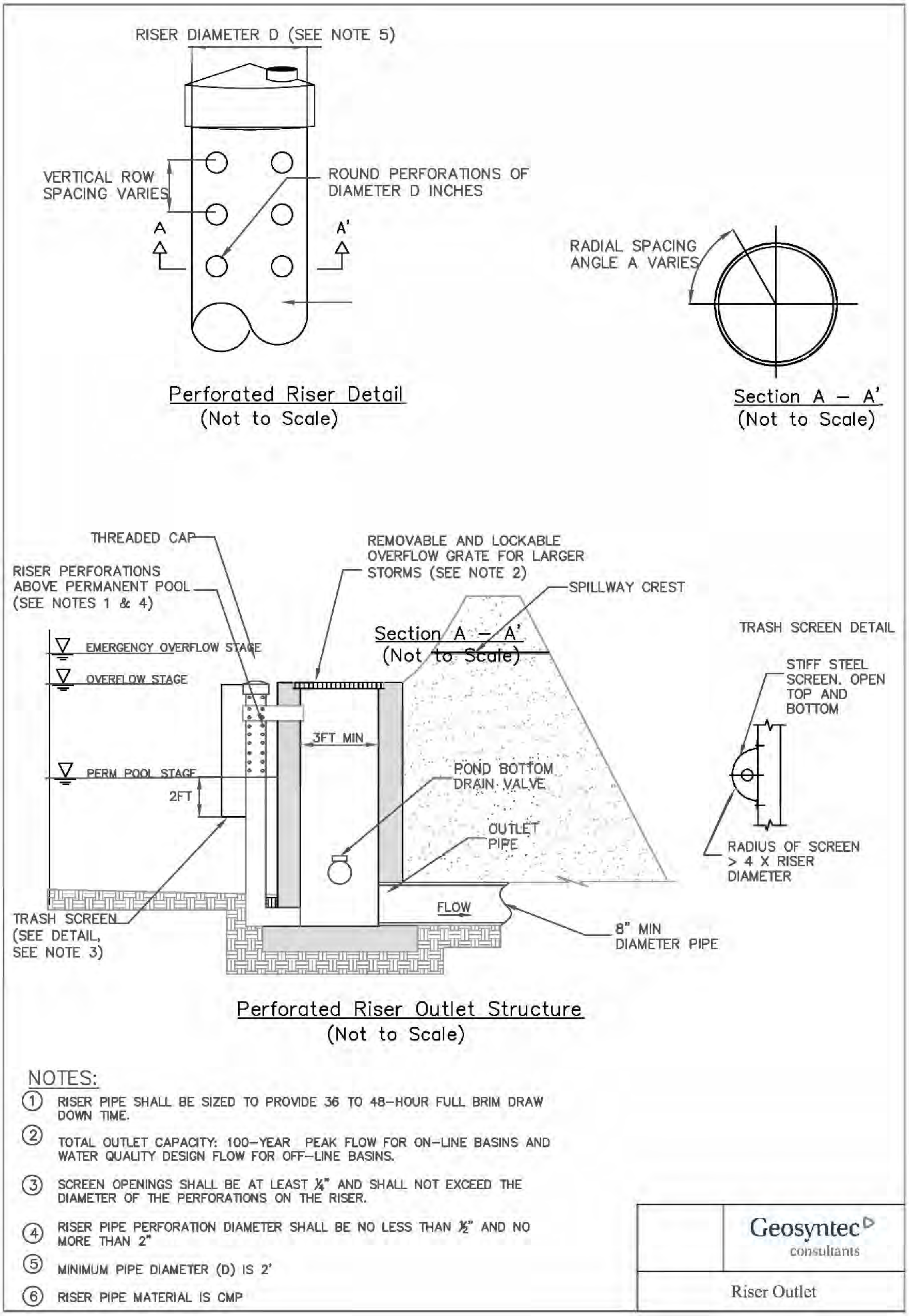
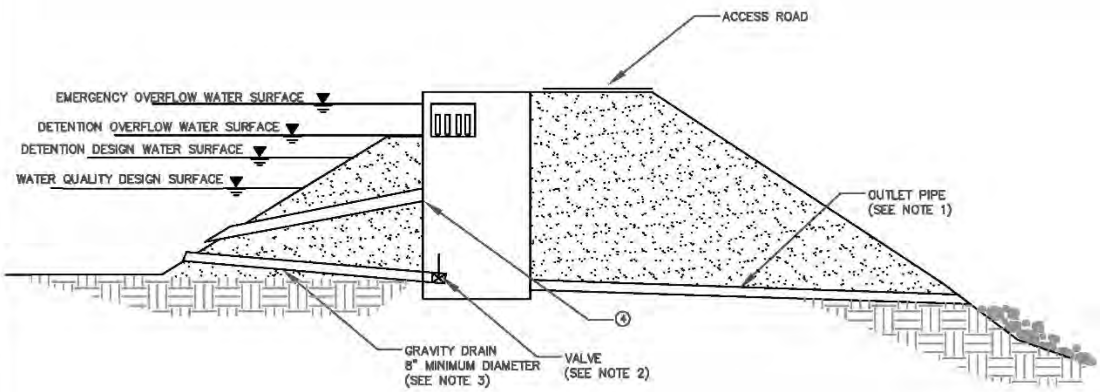


Figure 6-18: Riser Outlet



Inverted Pipe Outlet Structure
(Not to Scale)

NOTES:

1. SIZE OUTLET PIPE SYSTEM TO PASS 100–YEAR FLOW FOR ON–LINE PONDS AND WATER QUALITY PEAK FLOW FOR OFF–LINE PONDS.
2. VALVE MAY BE LOCATED INSIDE MANHOLE OR OUTSIDE WITH APPROVED OPERATIONAL ACCESS
3. INVERT OF DRAIN SHALL BE 6" MINIMUM BELOW TOP OF INTERNAL BERM. LOWER PLACEMENT IS DESIRABLE. INVERT SHALL BE 6" MINIMUM ABOVE BOTTOM OF POND.
4. OUTLET PIPE INVERT SHALL BE AT WETPOOL WATER SURFACE ELEVATION

Geosyntec consultants

Inverted Pipe Outlet

Figure 6-19: Inverted Pipe Outlet

6.7.2.1 Limitations

Limitations for wet detention basins include:

- Wet detention basins typically are used for treating areas larger than 10 acres and less than 10 square miles. They are especially applicable for regional water quality treatment and flow control.
- Off-line wet detention basins must not interfere with flood control functions of existing conveyance and detention structures.
- If wet detention basins are located in areas with site slopes greater than 15% or within 200 feet of a hazardous steep slope or mapped landslide area (on the uphill side), a geotechnical investigation and report must be provided to ensure that the basin does not compromise the stability of the site slope or surrounding slopes.
- Wet detention basins require a regular source of base flow if water levels are to be maintained. If base flow is insufficient during summer months, supplemental water may be necessary to maintain water levels.

6.7.2.2 Design Criteria

The main challenge associated with wet detention basins is maintaining desired water levels. A wet detention basin should be designed according to the requirements listed in Table 6-11 and outlined in the section below. BMP sizing worksheets are presented in Appendix C.

Table 6-11: Wet Detention Basin Design Criteria

Design Parameter	**Unit**	**Design Criteria**
Stormwater quality design volume, SQDV	acre-ft	See Section 2 and Appendix C for calculating SQDV.
Permanent Pool Volume		SQDV
Forebay Volume		5 to 10% of SQDV
Maximum Forebay Drain Time	min	45
Depth without sediment storage	feet	0.5-12 (littoral zone, 25-40% permanent pool) 4 (first cell minimum) 8 (any cell maximum) Deeper zone: 4-8 feet average; 12 feet maximum depth
Maximum residence time	Days	7 (dry weather)

Design Parameter	Unit	Design Criteria
Freeboard (minimum)	inches	12
Flow path length to width ratio	L:W	2:1 (larger preferred)
Side slope (maximum)	H:V	4:1 (H:V) Interior and 3:1 (H:V) Exterior
Longitudinal slope	percentage	1 (forebay) and 0-2 (main basin)
Vegetation Type	--	Varies see vegetation section below
Vegetation Height	--	Varies see vegetation section below
Buffer zone (minimum)	feet	25
Minimum outflow device diameter	inches	18

6.7.2.3 Sizing Criteria

Procedures for sizing wet detention basins are described in Appendix C. Section C.10. A sizing example is also provided.

6.7.2.3.1 Sizing and Geometry

1) If there is no extended detention provided, wet detention basins shall be sized to provide a minimum wet pool volume equal to the stormwater quality design volume plus an additional 5% for sediment accumulation. If extended detention is provided above the permanent pool and the basin is designed for water quality treatment only, then the permanent pool volume should be a minimum of 10 percent of the stormwater quality design volume and the surcharge volume (above the permanent pool) should make up the remaining 90 percent. If extended detention is provided above the permanent pool and the basin is designed for water quality treatment and peak flow attenuation, then the permanent pool volume shall be equal to the water quality treatment volume and the surcharge volume should be sized to attenuate peak flows to meet the peak runoff discharge requirements. The extended detention portion of the wet detention basin above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see HM-1: Dry Extended Detention Basin).

2) The wet detention basin should be divided into two cells separated by a berm or baffle. The first cell should contain between 25 to 35 percent of the total volume. The berm or baffle volume should not count as part of the total volume. Intent: The full-length berm or baffle reduces short-circuiting and promotes plug flow.

3) Wet detention basins with wet pool volumes less than or equal to 4,000 cubic feet may be single-celled (i.e., no baffle or berm is required).

4) Sediment storage should be provided in the first cell. The sediment storage should have a minimum depth of 1 foot. This volume should not be included as part of the required water quality volume.

5) The minimum depth of the first cell should be 4 feet, exclusive of sediment storage requirements. The depth of the first cell may be greater than the depth of the second cell. Average depth should be between 4 feet and 8 feet.

6) For wet detention basin depths in excess of 6 feet, some form of recirculation should be provided, such as a fountain or aerator, to prevent stratification, stagnation and low dissolved oxygen conditions.

7) The edge of the basin should slope from the surface of the permanent pool to a depth of 12 to 18 inches at a slope of 1:1 or greater. If soil conditions will not support a 1:1 (H:V) slope, then the steepest slope that can be supported should be used or a shallow retaining wall constructed (18 inch max). Beyond the edge of the basin, a bench sloped at 4:1 (H:V) maximum should extend into the basin to a depth of at least 3 feet. A steeper slope may be used beyond the 3 foot depth to a maximum of 8 feet. Intent: steep slopes at water’s edge will minimize very shallow areas that can support mosquitoes.

8) At least 25% of the basin area should be deeper than 3 feet to prevent the growth of emergent vegetation across the entire basin. If greater than 50% of the wet pool area is in excess of 6 feet deep, some form of recirculation should be provided, such as a fountain or aerator, to prevent stratification, stagnation and low dissolved oxygen conditions.

9) A wet detention basin should have a surface area of not less than 0.3 acres for each acre-foot of permanent pool volume. In addition, extra area needed to provide a design that meets all other provisions of this section should be provided. Additional surface area in excess of the minimum may be provided. There is no maximum surface area provided that all provisions of this section are met.

10) Inlets and outlets should be placed to maximize the flowpath through the facility. The flowpath length-to-width ratio should be a minimum of 1.5:1, but a flowpath length-to-width ratio of 2:1 or greater is preferred. The flowpath length is defined as the distance from the inlet to the outlet, as measured at mid-depth. The width at mid-depth can be found as follows: width = (average top width + average bottom width)/2. Intent: a long flowpath length will improve fine sediment removal.

11) All inlets should enter the first cell. If there are multiple inlets, the length-to-width ratio should be based on the average flowpath length for all inlets.

12) The minimum freeboard should be 1 foot above the maximum water surface elevation (2 feet preferred) for on-line basins and 1 foot above the maximum water surface elevation for on-line basins.

13) The maximum residence time for dry weather flows should be 7 days. Intent: Vector control.

6.7.2.3.2 Internal Berms and Baffles

1) A berm or baffle should extend across the full width of the wet detention basin and be keyed into the basin side slopes. If the berm embankments are greater than 4 feet in height, the berm should be constructed by excavating a key equal to 50% of the embankment cross-sectional height and width. This requirement may be waived if recommended by a licensed civil and/or geotechnical engineer for the specific site conditions. The geotechnical investigation must consider the situation in which one of the two cells is empty while the other remains full of water.

2) The top of the berm should extend to the permanent pool surface or be one foot below the permanent pool surface to discourage public access. If the top of the berm is at the water permanent pool surface, the side slopes should be 4H:1V. Berm side slopes may be steeper (up to 3:1) if the berm is submerged one foot.

3) If good vegetation cover is not established on the berm, erosion control measures should be used to prevent erosion of the berm back-slope when the basin is initially filled.

4) The interior berm or baffle may be a retaining wall provided that the design is prepared and stamped by a licensed civil and/or geotechnical engineer. If a baffle or retaining wall is used, it should be submerged one foot below the permanent pool surface to discourage access by pedestrians.

5) Internal earthen berms 6 feet high or less should have a minimum top width 6 feet or as recommended by a civil and/or geotechnical engineer.

6.7.2.3.3 Water Supply

1) Water balance calculations should be provided to demonstrate that adequate water supply will be present to maintain a pool of water during a drought year when precipitation is 50% of average for the site. Water balance calculations should include evapotranspiration, infiltration, precipitation, spillway discharge, and dry weather flow (where appropriate).

2) Where water balance indicates that losses will exceed inputs, a source of water should be provided to maintain the basin water surface elevation throughout the year. The water supply should be of sufficient quantity and quality to not have an adverse impact on the wet detention basin water quality. Water that meets drinking water standards should be assumed to be of sufficient quality.

3) Wet detention basin may be designed as seasonal ponds where the water balance and water supply conditions make it infeasible to sustain a permanent wet detention basin.

6.7.2.3.4 Soils Considerations

Wet detention basin implementation in areas with high permeability soils requires liners to increase the chances of maintaining a permanent pool in the basin. Liners can be either synthetic materials or imported lower permeability soils (i.e., clays). The water balance assessment should determine whether a liner is required.

If low permeability soils are used for the liner, a minimum of 18 inches of native soil amended with good topsoil or compost (one part compost mixed with 3 parts native soil) should be placed over the liner. If a synthetic material is used, a soil depth of 2 feet is recommended to prevent damage to the liner during planting.

6.7.2.3.5 Buffer Zone

A minimum of 25 feet buffer should be provided around the top perimeter of the wet detention basin. The portion of the access road outside of the maximum water level may be included as part of the buffer.

6.7.2.3.6 Stormwater Quality Design Features

1) Wet detention basins that are located in publicly-accessible or highly visible locations should include design features that will improve and maintain the quality of water within the BMP at a level suitable for the proposed location and uses of the surrounding area. Typical design features include aeration, pumped circulation, filters, biofilters, and other facilities that operate year-round to remove pollutants and nutrients. Stormwater quality design features will result in higher quality water in the BMP and lower discharges of pollutants downstream.
2) Wet detention basins in publicly-accessible or highly visible locations should have a maintenance plan that includes regular collection and removal of trash from the area within and surrounding the BMP.
3) If fencing is required for wet detention basins in publicly-accessible or highly visible locations, the fence can be designed to be aesthetically incorporated into the site and Shrubs (approved, California-adapted species) can be used to hide the fencing. See vegetation section below.

6.7.2.3.7 Energy Dissipation

1) The inlet to the wet detention basin should be submerged with the inlet pipe invert a minimum of two feet from the basin bottom (not including sediment storage). The top of the inlet pipe should be submerged at least 1 foot, if possible. Intent: The inlet is submerged to dissipate energy of the incoming flow. The distance from the bottom is set to minimize resuspension of settled sediments. Alternative inlet designs that accomplish these objectives are acceptable.

2) Energy dissipation controls should also be used at the outlet from the wet detention basin unless the basin discharges to a stormwater conveyance system or hardened channel.

6.7.2.3.8 Vegetation

A plan should be prepared that indicates how aquatic, temporarily submerged areas (extended detention wet detention basins) and terrestrial areas will be stabilized with vegetation.

1) If the second cell of the wet detention basin is 3 feet or shallower, the bottom area should be planted with emergent wetland vegetation.

2) Emergent aquatic vegetation should be planted to cover 25-75% of the area of the permanent pool.

3) Outside of the basin, native vegetation adapted for site conditions should be used in non-irrigated sites.

4) The area surrounding a wet detention basin should be landscaped to minimize erosion and should adhere to the following criteria so as not to hinder maintenance operations:

5) No trees or shrubs may be planted within 15 feet of inlet or outlet pipes or manmade drainage structures such as spillways, flow spreaders, or earthen embankments. Species with roots that seek water, such as willow or poplar, should not be used within 50 feet of pipes or manmade structures. Weeping willow (Salix babylonica) should not be planted in or near detention basins.

6) Prohibited non-native plant species will not be permitted. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website- or the California Invasive Plant Council website at www.cal-ipc.org.

7) A landscape professional should provide recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth.

6.7.2.3.9 Outlet Structure

1) An outlet pipe and outlet structure should be provided. The outlet pipe may be a perforated standpipe strapped to a manhole or placed in an embankment, suitable for extended detention, or may be back-sloped to a catch basin with a grated opening (jail house window) or manhole with a cone grate (birdcage). The grate or birdcage openings provide an overflow route should the basin outlet pipe become clogged.

2) For extended detention wet detention basin, outlet structures should be designed to provide 12 to 48 hour emptying time for the water quality volume above the permanent pool.

3) The basin outlet pipe should be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for off-line basins or flows greater than the peak runoff discharge rate for the 100-year, 24-hr design storm for on-line basins.

6.7.2.3.10 Emergency Spillway

An emergency overflow spillway in addition to the primary overflow outlet (as described above) is required. The emergency spillway should be sized for flows greater than the peak 100-year 24-hour storm if the basin is designed on-line or, if the basin is designed off-line, the spillway should be sized for flows greater than the basin design volume (e.g., stormwater quality design volume). The spillway provides for adequate energy dissipation downstream. The spillway should allow for at least 12 inches of freeboard above the emergency overflow water surface elevation if the basin is on-line. If the basin is -line, 2 feet of freeboard is preferable.

Spillways shall meet the California Department of Water Resources, Division of Safety of Dams Guidelines for the Design and Construction of Small Embankment Dams . *Intent: Emergency overflow spillways are intended to control the location of basin overtopping and safely direct overflows back into the downstream conveyance system or other acceptable discharge point.*

On-line Basins

1) On-line basins must have an emergency overflow spillway to prevent overtopping of walls or berms should blockage of the primary outlet occur based on a downstream risk assessment.

2) The overflow spillway must be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm.

3) The minimum freeboard should be 1 foot (but preferably at least 2 feet) above the maximum water surface elevation over the emergency spillway.

Off-line Basins

1) Off-line basins must have either an emergency overflow spillway or an emergency overflow riser. The emergency overflow must be designed to pass flows greater than the basin design volume (e.g., stormwater quality design volume) directly to the downstream conveyance system or another acceptable discharge point. Where an emergency overflow spillway would discharge to a steep slope, an emergency overflow riser, in addition to the spillway should be provided. See Appendix C for basin/pond outlet sizing worksheets.

2) The emergency overflow spillway should be armored to withstand the energy of the spillway flows. The spillway should be constructed of grouted rip-rap.

3) The minimum freeboard should be 1 foot above the maximum water surface elevation over the emergency spillway.

6.7.2.3.11 Side Slopes

1) Interior side slopes above the stormwater quality design depth and up to the emergency overflow water surface steeper than 4:1 (H:V) should be stabilized to prevent erosion with a method approved by the local permitting authority.

2) Exterior side slopes steeper than 2:1 (H:V) should be stabilized to prevent erosion with a method approved by the local permitting authority.

3) For any slope (interior or exterior) greater than 2:1 (H:V), a geotechnical investigation and report must be submitted and approved by the local permitting authority.

4) Landscaped slopes should be no steeper than 3:1 (H:V) to allow for maintenance.

5) Basin walls may be vertical retaining walls, provided: (a) they are constructed of reinforced concrete, (b) a fence is provided along the top of the wall (see fencing below) or further back, and (c) the design is stamped by a licensed civil and/or geotechnical engineer.

6.7.2.3.12 Embankments

1) Earthworks and berm embankments should be performed in accordance with the latest edition of the "Greenbook Standard Specifications for Public Works Construction".

2) Embankments are earthen slopes or berms used for detaining or redirecting the flow of water.

3) Top of berm should be 2 feet minimum below the stormwater quality design water surface and should be keyed into embankment a minimum of 1 foot on both sides.

4) Typically, the top width of berm embankments are at least 20 feet, but narrower embankments may be plausible if approved by the civil and/or geotechnical engineer and the local permitting authority.

5) Basin berm embankments should be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a licensed civil and/or geotechnical engineer) free of loose surface soil materials, roots, and other organic debris.

6) The berm embankment should be constructed of compacted soil (95% minimum dry density, modified proctor method per ASTM D1557), placed in 6-inch lifts.

7) Basin berm embankments greater than 4 feet in height should be constructed by excavating a key equal to 50% of the berm embankment cross-sectional height and width. This requirement may be waived if specifically recommended by a licensed civil and/or geotechnical engineer.

8) The berm embankment should be constructed of compacted soil (95% minimum dry density, modified proctor method per ASTM D1557), placed in 6-inch lifts.

9) Low growing native or non-invasive perennial grasses should be planted on downstream embankment slopes. See vegetation section above.

6.7.2.3.13 Fencing

Safety is provided either by fencing of the facility or by managing the contours of the basin to eliminate drop-offs and other hazards.

If fences are required, fences should be designed and constructed in accordance with current and relevant policies and typically are required to be located at or above the overflow water surface elevation. Shrubs (approved, California-adapted species) can be used to hide the fencing. See vegetation section above.

6.7.2.3.14 Right-of-Way

Wet detention basins and associated access roads to be maintained by a public agency should be dedicated in fee or in an easement to the public agency with appropriate access.

6.7.2.3.15 Maintenance Access

1) Ownership of the basin and maintenance thereof is the responsibility of the developer/applicant. A maintenance agreement is required to ensure adequate performance and allow emergency access to the facilities.

2) Maintenance access road(s) should be provided to the control structure and other drainage structures associated with the basin (e.g., inlet, emergency overflow or bypass structures). Manhole and catch basin lids should be in or at the edge of the access road.

3) A ramp into the basin should be constructed near the basin outlet. An access ramp is required for removal of sediment with a backhoe or loader and truck. The ramp should extend to the basin bottom to avoid damage to vegetation planted on the basin slope.

4) All access ramps and roads should be provided in accordance with the current policies of the Flood Control District.

6.7.2.4 Vector Control

A Mosquito Management Plan or Service Contract should be approved or waived by the local Vector Control District for any facility that maintains a pool of water for 72 hours or more.

6.7.2.5 Construction Considerations

The use of treated wood or galvanized metal anywhere inside the facility is prohibited. The use of galvanized fencing is permitted if in accordance with the Fencing requirement above

6.7.2.6 Operations and Maintenance

Maintenance is of primary importance if extended detention basins are to continue to function as originally designed. A maintenance agreement must be developed with the Flood Control District to ensure adequate performance and allow the County emergency access. Maintenance of the basin is the responsibility of the development, unless otherwise agreed upon.

A specific maintenance plan shall be formulated for each facility outlining the schedule and scope of maintenance operations, as well as the data handling and reporting requirements. The following are general maintenance requirements:

1) The basin should be inspected annually and inspections after major storm events are encouraged. Trash and debris should be removed as needed, but at least annually prior to the beginning of the wet season (see Appendix D for guidance on facility maintenance inspections).

2) Site vegetation should be maintained as follows:

3) Vegetation, large shrubs, or trees that limit access or interfere with basin operation should be pruned or removed.

4) Slope areas that have become bare should be revegetated and eroded areas should be regraded prior to being revegetated.

5) Grass should be mowed to 4”-9” high and grass clippings should be removed.

6) Fallen leaves and debris from deciduous plant foliage should be raked and removed.

7) Invasive vegetation, such as Alligatorweed (Alternanthera philoxeroides), Halogeton (Halogeton glomeratus), Spotted Knapweed (Centaurea maculosa), Giant Reed (Arundo donax), Castor Bean (Ricinus communis), Perennial Pepperweed (Lepidium latifolium), and Yellow Starthistle (Centaurea solstitalis) should be removed and replaced with non-invasive species. Invasive species should never contribute more than 25% of the vegetated area. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.

8) Dead vegetation should be removed if it exceeds 10% of area coverage. Vegetation should be replaced immediately to maintain cover density and control erosion where soils are exposed.

9) No herbicides or other chemicals should be used to control vegetation.

10) Sediment buildup exceeding 50% of the forebay capacity should be removed. Sediment from the remainder of the basin should be removed when 6 inches of sediment accumulates. Sediments should be tested for toxic substance accumulation in

compliance with current disposal requirements if land uses in the catchment include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed. If toxic substances are encountered at concentrations exceeding thresholds of Title 22, Section 66261 of the California Code of Regulations, the sediment must be disposed of in a hazardous waste landfill.

11) Following sediment removal activities, replanting, and/or reseeding of vegetation may be required for reestablishment. .

6.7.3 HM-3: Constructed Wetland

A constructed treatment wetland is a system consisting of a sediment forebay and one or more permanent micro-pools with aquatic vegetation covering a significant portion of the basin. Constructed treatment wetlands typically include components such as an inlet with energy dissipation, a sediment forebay for settling out coarse solids and to facilitate maintenance, a base with shallow sections (1 to 2 feet deep) planted with emergent vegetation, deeper areas or micro pools (3 to 5 feet deep), and a water quality outlet structure. The interactions between the incoming stormwater runoff, aquatic vegetation, wetland soils, and the associated physical, chemical, and biological unit processes are a fundamental part of constructed treatment wetlands.

Application

- Regional detention & treatment
- Roads, highways, parking lots, commercial, residential
- Parks, open spaces, and golf courses

Preventive Maintenance

- inspected at a minimum annually and inspections after major storm events
- Pruned or remove vegetation, large shrubs, or trees that limit access or interfere with basin operation
- Remove sediment buildup at inlets and outlets

Constructed Wetlands

Photo Credits: Geosyntec Consultants

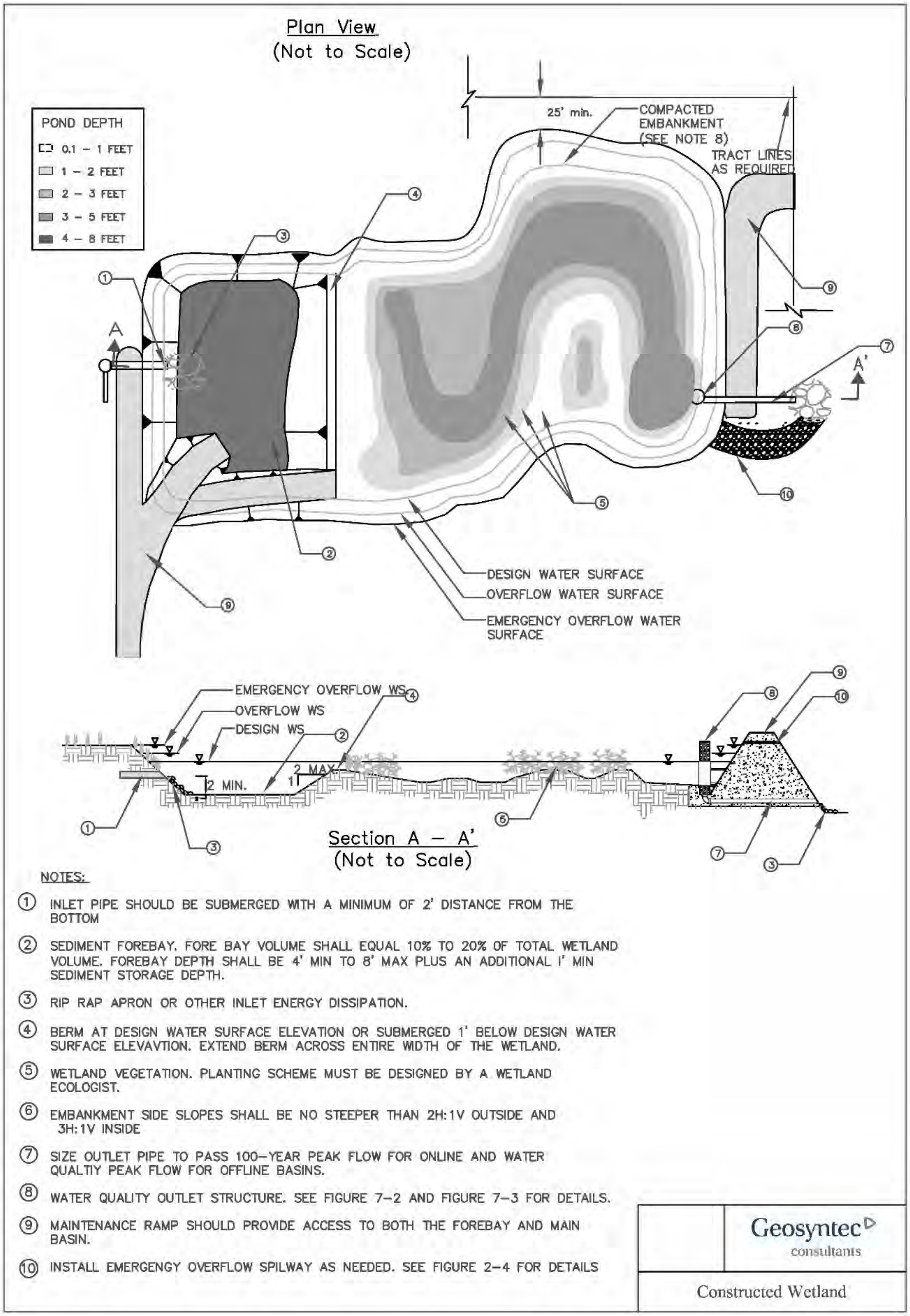


Figure 6-20: Constructed Wetland Schematic

6.7.3.1 Limitations

- In theory, there are no limitations on the tributary area size draining to a constructed treatment wetland; however, constructed treatment wetlands usually require considerable land area. Typically, treatment wetlands capture runoff from tributary areas larger than 10 acres and less than 10 square miles. Smaller “pocket” wetlands can be feasible in areas where space is restricted.
- If the constructed treatment wetland is not used for flow control, the wetland must not interfere with flood control functions of existing conveyance and detention structures.
- Constructed treatment wetlands should not be permitted in areas with site slopes greater than 7% or within 200 feet (on the uphill side) of a steep slope hazard area or a mapped landslide area unless a geotechnical investigation and report is completed by a licensed civil and/or geotechnical engineer.
- Constructed treatment wetlands require a regular source of water (base flow) to maintain wetland vegetation and associated treatment processes. If adequate base flow is not available year-round, supplemental water may be needed during the summer months to maintain adequate base flow.

6.7.3.2 Design Criteria

The main challenge associated with constructed treatment wetlands is maintaining base flow to support vegetation. Constructed wetlands should be designed according to the requirements listed in Table 6-12 and outlined in the section below. Constructed wetland BMP sizing worksheets are presented in Appendix C.

Table 6-12: Constructed Wetland Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume, SQDV	acre-feet	See Section 2 and Appendix C for calculating SQDV.
Permanent pool volume	%	75% of SQDV
Drawdown time for extended detention (over permanent pool)	hours	48 ; 12 for 50% SQDV (minimum)
Sediment forebay volume	%	30 to 50% of permanent pool surface area
Depth of sediment forebay	feet	2-4 (1 foot of sediment storage required)
Wetland zone volume	%	50-70% of permanent pool surface area
Depth of wetland basin	feet	0.5 to 1.0 (30 to 50% should be 0.5 feet deep)

Design Parameter	Unit	Design Criteria
Wetland (littoral zone) bottom slope	%	10 maximum
Maximum residence time	Days	7 (dry weather)
Freeboard (minimum)	inches	12
Flow path length to width ratio	L:W	2:1, larger preferred
Side slope (maximum)	H:V	4:1 Interior; 3:1 Exterior
Vegetation Type	--	Varies see vegetation section below
Vegetation Height	--	Varies see vegetation section below
Buffer zone (minimum)	feet	25
Minimum outflow device diameter	inches	18

6.7.3.3 Sizing

Procedures for sizing constructed wetlands are described in Appendix C. Section C.11. A sizing example is also provided.

6.7.3.3.1 Sizing and Geometry

In most cases, the constructed treatment wetland permanent pool should be sized to be greater than or equal to the stormwater quality design volume. If extended detention is provided above the permanent pool and the wetland is designed for water quality treatment only, then the permanent pool volume should be a minimum of 80 percent of the stormwater quality design volume and the surcharge volume (above the permanent pool) should make up the remaining 20 percent and provide at least 12 hours of detention. If extended detention is provided and the basin is designed for water quality treatment and peak flow attenuation, then the permanent pool volume should be equal to the water quality treatment volume and the surcharge volume should be sized to attenuate peak flows to meet the peak runoff discharge requirements. A constructed treatment wetland design worksheet is presented in Appendix C. The extended detention portion of the wetland above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see HM-1: Dry Extended Detention Basin).

1) Constructed treatment wetlands should consist of at least two cells including a sediment forebay and a wetland basin.

2) The sediment forebay must contain between 10 and 20 percent of the total basin volume.

3) The depth of the sediment forebay should be between 4 and 8 feet.

4) One foot of sediment storage should be provided in the sediment forebay.

5) The "berm" separating the two basins should be uniform in cross-section and shaped such that its downstream side gradually slopes to the main wetland basin.

6) The top of berm should be either at the stormwater quality design water surface or submerged 1 foot below the stormwater quality design water surface, as with wet retention basins. Correspondingly, the side slopes of the berm should meet the following criteria:

    a. If the type of the berm is at the stormwater quality design water surface, the berm side slopes should be no steeper than 4H:1V.

    b. If the top of berm is submerged 1 foot, the upstream side slope may be a max of 3H:1V.

7) The constructed treatment wetlands should be designed with a "naturalistic" shape and a range of depths intermixed throughout the wetland basin to a maximum of 5 feet.

Depth Range (feet)	Percent by Area
0.1 to 1	15
1 to 3	55
3 to 5	30

8) The flowpath length-to-width ratio should be a minimum of 2:1, but preferably at least 4:1 or greater. *Intent: a high flow path length to width ratio will maximize fine sediment removal.*

9) The minimum freeboard should be 1 foot above the maximum water surface elevation for on-line basins (2 feet preferable) and 1 foot above the maximum water surface elevation for on-line basins.

10) Wetland pools should be designed such that the residence time for dry weather flows is no greater than 7 days. *Intent: Minimize vector and stagnation issues.*

6.7.3.3.2 Water Supply

Water balance calculations should be provided to demonstrate that adequate water supply will be present to maintain a permanent pool of water during a drought year when precipitation is 50% of average for the site. Water balance calculations should include evapotranspiration, infiltration, precipitation, spillway discharge, and dry weather flow (where appropriate).

Where water balance indicates that losses will exceed inputs, a source of water should be provided to maintain the wetland water surface elevation throughout the year. The water supply should be of sufficient quantity and quality to not have an adverse impact on the wetland water quality. Water that meets drinking water standards should be assumed to be of sufficient quality.

6.7.3.3.3 Soils Considerations

1) Implementation of constructed treatment wetlands in areas with high permeability soils (>0.1 in/hr) requires liners to increase the chances of maintaining permanent pools and/or micro-pools in the basin. Liners can be either synthetic materials or imported lower permeability soils (i.e., clays). The water balance assessment should determine whether a liner is required. The following conditions can be used as a guideline.

2) The wetland basin should retain water for at least 10 months of the year.

3) The sediment forebay should retain at least 3 feet of water year-round.

4) Many wetland plants can adapt to periods of summer drought, so a limited drought period is allowed in the wetland basin. This may allow for a soil liner rather than a geosynthetic liner. The sediment forebay should retain water year-round for presettling to be effective.

5) If low permeability soils are used for the liner, a minimum of 18 inches of native soil amended with good topsoil or compost (one part compost mixed with 3 parts native soil) should be placed over the liner. If a synthetic material is used, a soil depth of 2 feet is recommended to prevent damage to the liner during planting.

6.7.3.3.4 Buffer Zone

A minimum of 25 feet buffer should be provided around the top perimeter of the constructed treatment wetlands.

6.7.3.3.5 Energy Dissipation

1) The inlet to the constructed treatment wetland should be submerged with the inlet pipe invert a minimum of two feet from the cell bottom (not including sediment storage). The top of the inlet pipe should be submerged at least 1 foot, if possible. *Intent: the inlet is submerged to dissipate energy of the incoming flow. The distance from the bottom is set to minimize resuspension of settled sediments. Alternative inlet designs that accomplish these objectives are acceptable.*

2) Energy dissipation controls must also be used at the outlet/spillway from the constructed treatment wetlands unless the wetland discharges to a stormwater conveyance system or hardened channel.

6.7.3.3.6 Vegetation

1) The wetland cell(s) should be planted with emergent wetland plants following the recommendations of a wetlands specialist.

2) Landscaping outside of the basin is required for all constructed wetlands and should adhere to the following criteria so as not to hinder maintenance operations:

    a. No trees or shrubs may be planted within 15 feet of inlet or outlet pipes or manmade drainage structures such as spillways, flow spreaders, or earthen embankments. Species with roots that seek water, such as willow or poplar, should not be used within 50 feet of pipes or manmade structures. Weeping willow (*Salix babylonica*) should not be planted in or near detention basins.

    b. Prohibited non-native plant species will not be permitted. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.

3) Project-specific planting recommendations should be provided by a wetland ecologist or a qualified landscape professional including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth.

6.7.3.3.7 Outlet Structure

An outlet pipe and outlet structure should be provided. The outlet pipe may be a perforated standpipe strapped to a manhole or placed in an embankment, suitable for extended detention, or may be back-sloped to a catch basin with a grated opening (jail house window) or manhole with a cone grate (birdcage). The grate or birdcage openings provide an overflow route should the basin outlet pipe become clogged. The outlet should be protected from clogging by a skimmer shield that starts at the bottom of the permanent pool and extends above the SQDV depth. A trash rack is also required.

For wetlands with detention, the outlet structures should be designed to provide 12 hours emptying time for the water quality volume or the required detention necessary for achieving the peak runoff discharge requirements if the extended detention is designed for flow attenuation.

The wetland outlet pipe should be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for on-line basins or flows greater than the peak runoff discharge rate for the 100-year, 24-hr design storm for on-line basins.

See the dry extended detention section (see HM-1: Dry Extended Detention Basin) and Appendix C for further detail on outlet sizing.

6.7.3.3.8 Emergency Spillway

An emergency overflow spillway in addition to the primary overflow outlet (as described above) is required. The emergency spillway should be sized for flows greater than the peak 100-year 24-hour storm if the basin is designed on-line or, if the basin is designed on-line, the spillway should be sized for flows greater than the basin design volume (e.g., stormwater quality design volume). The spillway shall provide for adequate energy dissipation downstream. The spillway should allow for at least 12 inches of freeboard above the emergency overflow water surface elevation if the basin is on-line. If the basin is on-line, 2 feet of freeboard is preferable.

Spillways shall meet the California Department of Water Resources, Division of Safety of Dams Guidelines for the Design and Construction of Small Embankment Dams. *Intent: Emergency overflow spillways are intended to control the location of basin overtopping and safely direct overflows back into the downstream conveyance system or other acceptable discharge point.*

On-line Basins

1) On-line basins must have an emergency overflow spillway to prevent overtopping of walls or berms should blockage of the primary outlet occur based on a downstream risk assessment.

2) The overflow spillway must be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm.

3) The minimum freeboard should be 1 foot (but preferably at least 2 feet) above the maximum water surface elevation over the emergency spillway.

Off-line Basins

1) Off-line basins must have either an emergency overflow spillway or an emergency overflow riser. The emergency overflow must be designed to pass the 100-yr 24-hr post-development peak stormwater runoff discharge rate (see Appendix C for further detail) directly to the downstream conveyance system or another acceptable discharge point. Where an emergency overflow spillway would discharge to a steep slope, an emergency overflow riser, *in addition* to the spillway should be provided.

2) The emergency overflow spillway should be armored to withstand the energy of the spillway flows. The spillway should be constructed of grouted rip-rap.

3) The minimum freeboard should be 1 foot above the maximum water surface elevation over the emergency spillway.

6.7.3.3.9 Side Slopes

1) Interior side slopes above the stormwater quality design depth and up to the emergency overflow water surface steeper than 4:1 (H:V) should be stabilized to prevent erosion with a method approved by the local permitting authority.
2) Exterior side slopes steeper than 2:1 (H:V) should be stabilized to prevent erosion with a method approved by the local permitting authority.
3) For any slope (interior or exterior) greater than 2:1 (H:V), a geotechnical investigation and report must be submitted and approved by the local permitting authority.
4) Landscaped slopes should be no steeper than 3:1 (H:V) to allow for maintenance.
5) Basin walls may be vertical retaining walls, provided: (a) they are constructed of reinforced concrete, (b) a fence is provided along the top of the wall (see fencing below) or further back, and (c) the design is stamped by a licensed civil and/or geotechnical engineer and approved by the local permitting authority.

6.7.3.3.10 Embankments

1) Earthworks and berm embankments should be performed in accordance with the latest edition of the “Greenbook Standard Specifications for Public Works Construction”.
2) Embankments are earthen slopes or berms used for detaining or redirecting the flow of water.
3) Top of berm should be 2 feet minimum below the stormwater quality design water surface and should be keyed into embankment a minimum of 1 foot on both sides.
4) Typically, the top width of berm embankments are at least 20 feet, but narrower embankments may be plausible if approved by the civil and/or geotechnical engineer and the local permitting authority.
5) Basin berm embankments should be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a licensed civil and/or geotechnical engineer) free of loose surface soil materials, roots, and other organic debris.
6) Basin berm embankments greater than 4 feet in height should be constructed by excavating a key equal to 50% of the berm embankment cross-sectional height and width. This requirement may be waived if specifically recommended by a licensed civil and/or geotechnical engineer.
7) The berm embankment should be constructed of compacted soil (95% minimum dry density, modified proctor method per ASTM D1557), placed in 6-inch lifts.

8) Low growing native or non-invasive perennial grasses should be planted on downstream embankment slopes. See vegetation section above.

6.7.3.3.11 Fencing

Safety is provided either by fencing of the facility or by managing the contours of the basin to eliminate drop-offs and other hazards.

1) Provide fencing in accordance with the local permitting agency's requirements Perimeter fencing (minimum height of 42 inches) should be required on all basins exceeding two feet in depth or where interior side slopes are steeper than 6:1 (H:V).

2) If fences are required, fences should be designed and constructed in accordance with current policies of the local permitting agency and should be located at or above the overflow water surface elevation. Shrubs (approved, California-adapted species) can be used to hide the fencing. See vegetation section above.

6.7.3.3.12 Right-of-Way

Constructed treatment wetlands and associated access roads to be maintained by a public agency should be dedicated in fee or in an easement to the public agency with appropriate access.

6.7.3.3.13 Maintenance Access

1) Ownership of the basin and maintenance thereof is the responsibility of the developer/applicant. A maintenance agreement is required to ensure adequate performance and allow emergency access to the facilities.

2) Maintenance access road(s) should be provided to the control structure and other drainage structures associated with the basin (e.g., inlet, emergency overflow or bypass structures). Manhole and catch basin lids should be in or at the edge of the access road.

3) An access ramp into the basin should be constructed near the basin outlet. An access ramp is required for removal of sediment with a backhoe or loader and truck. The ramp should extend to the basin bottom to avoid damage to vegetation planted on the basin slope.

4) All access ramps and roads should be provided in accordance with the current policies of the Flood Control District.

6.7.3.4 Vector Control

A Mosquito Management Plan or Service Contract should be approved or waived by the local Vector Control District for any facility that maintains a pool of water for 72 hours or more.

6.7.3.5 Construction Considerations

The use of treated wood or galvanized metal anywhere inside the facility is prohibited. The use of galvanized fencing is permitted if in accordance with the Fencing requirement above.

6.7.3.6 Operations and Maintenance

Maintenance is of primary importance if constructed treatment wetlands basins are to continue to function as originally designed. A specific maintenance plan shall be formulated for each facility outlining the schedule and scope of maintenance operations, as well as the data handling and reporting requirements. The following are general maintenance requirements:

1) The constructed treatment wetlands basin should be inspected twice annually or more frequently, and inspections after major storm events are encouraged (see Appendix D for a constructed treatment wetland inspection and maintenance checklist). Trash and debris should be removed as needed, but at least annually prior to the beginning of the wet season.

2) Site vegetation should be maintained as frequently as necessary to maintain the aesthetic appearance of the site and to prevent clogging of outlets, creation of dead volumes, and barriers to mosquito fish to access pooled areas, and as follows:

3) Vegetation, large shrubs, or trees that limit access or interfere with basin operation should be pruned or removed.

4) Slope areas that have become bare should be revegetated and eroded areas should be regraded prior to being revegetated.

5) Invasive vegetation, such as Alligatorweed (*Alternanthera philoxeroides*), Halogeton (*Halogeton* glomeratus), Spotted Knapweed (*Centaurea maculosa*), Giant Reed (*Arundo donax*), Castor Bean (*Ricinus communis*), Perennial Pepperweed (*Lepidium latifolium*), and Yellow Starthistle (*Centaurea solstitalis*) should be removed and replaced with non-invasive species. Invasive species should never contribute more than 25% of the vegetated area. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.

6) Dead vegetation should be removed if it exceeds 10% of area coverage. This does not include seasonal die-back where roots would grow back later in colder areas. Vegetation should be replaced immediately to maintain cover density and control erosion where soils are exposed.

7) Sediment buildup exceeding 6 inches over the storage capacity in the first cell should be removed. Sediments should be tested for toxic substance accumulation in

compliance with current disposal requirements if land uses in the catchment include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed. If toxic substances are encountered at concentrations exceeding thresholds of Title 22, Section 66261 of the California Code of Regulations, the sediment must be disposed of in a hazardous waste landfill. Clean forebay every two years at a minimum, to avoid accumulation in main wetland area. Environmental regulations and permits may be involved with the removal of wetland deposits. When the main wetland area needs to be cleaned, it is suggested that the main area be cleaned one half at a time with at least one growing season in between cleanings. This will help to preserve the vegetation and enable the wetland to recover more quickly from the cleaning.

8) Repair erosion to banks and bottom as required.

9) Inspect outlet for clogging a minimum of twice a year, before and after the rainy season, after large storms, and more frequently if needed. Correct observed problems as necessary.

10) Following sediment removal activities, replanting, and/or reseeding of vegetation may be required for reestablishment.

6.8 Pretreatment/Gross Solids Removal BMPs

All pretreatment/Gross Solids Removal BMPs, are not stand alone BMPs; they must be used in combination with other, non-pretreatment BMP(s).

6.8.1 PT-1: Hydrodynamic Separators

Hydrodynamic separators or hydrodynamic separation devices are devices that remove trash, debris, and coarse sediment from incoming flows using screening, gravity settling, and centrifugal forces generated by forcing the influent into a circular motion. By having the water move in a circular fashion, rather than a straight line, it is possible to obtain significant removal of suspended sediments and attached pollutants with less space as compared to wet vaults and other settling devices. Hydrodynamic separators were originally developed for combined sewer overflows (CSOs), where they were used primarily to remove coarse inorganic solids. Hydrodynamic separation has been adapted for stormwater treatment by several manufacturers and is currently used to remove trash, debris, and other coarse solids down to sand-sized particles. Several types of hydrodynamic separation devices are also designed to remove floating oils and grease using sorbent media.

Project applicants must choose hydrodynamic separator devices that are certified by the State Water Resources Control Board; the list of certified devices is updated regularly and it is published at https://www.waterboards.ca.gov/water_issues/programs/stormwater/trash_implementation.html.

Hydrodynamic separators, like all pretreatment BMPs, are not stand alone BMPs; they must be used in combination with other BMP(s).

Example Hydrodynamic Separator

Photo Credit: County of Ventura

Application:

- Parking lots
- Areas adjacent to parking lots
- Areas adjacent to buildings
- Road medians and shoulders

Preventive Maintenance:

- Sediment, trash and debris removal
- Vector control

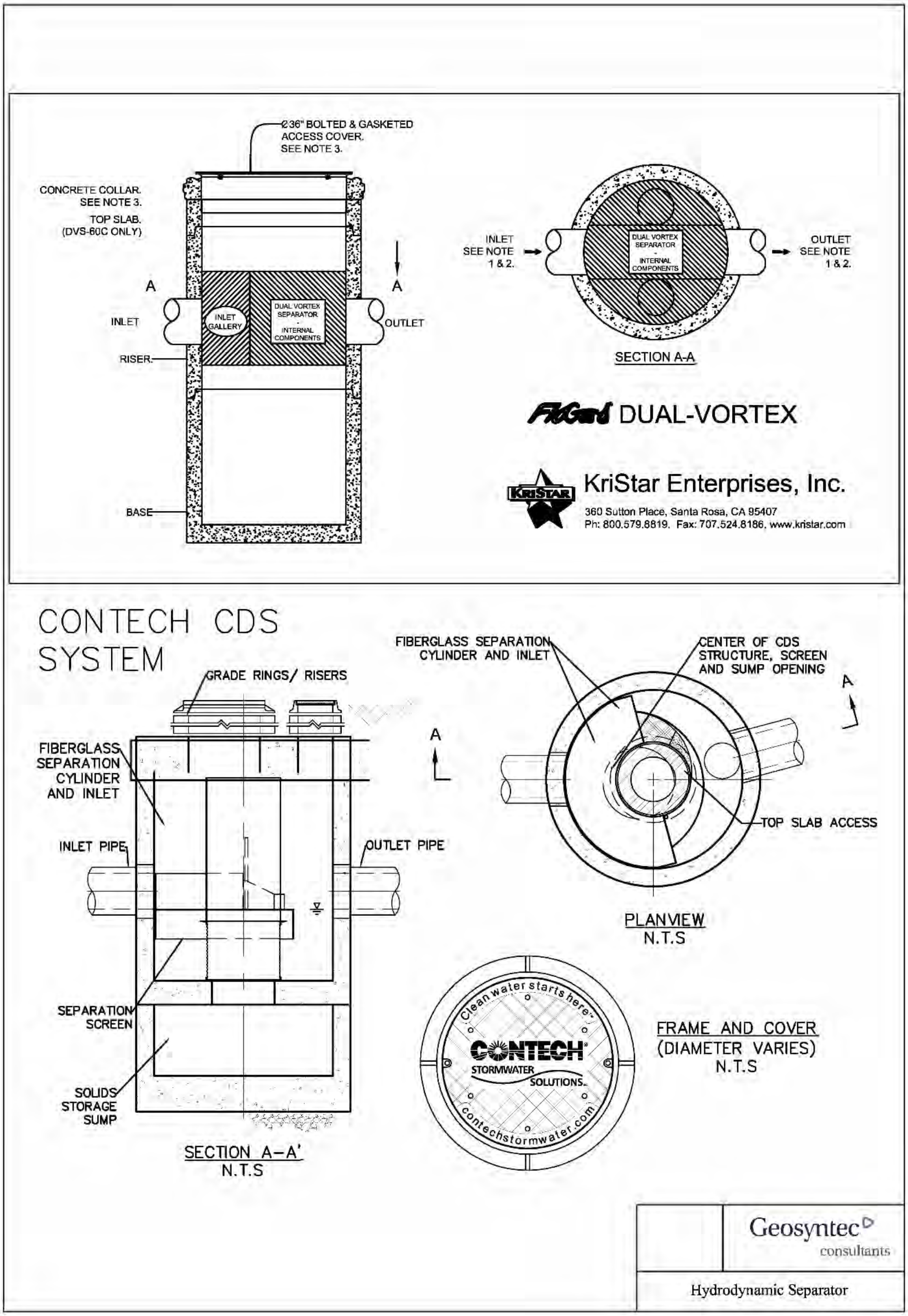


Figure 6-21: Example Hydrodynamic Separator Design Schematic

6.8.1.1 Limitations

Hydrodynamic separation devices are effective for the removal of course sediment, trash, and debris, and are useful as pretreatment in combination with other BMP types that target smaller particle sizes.

Hydrodynamic separators represent a wide range of device types that have different unit processes and design elements (e.g., storage versus flow-through designs, inclusion of media filtration, etc.) that vary significantly within the category. These design features likely have significant effects on BMP performance; therefore, generalized performance data for hydrodynamic devices is not practical.

6.8.1.2 Design Criteria

Proprietary hydrodynamic separator vendors are constantly updating and expanding their product lines. Please refer to the latest design guidance from each of the vendors. General guidelines on the performance, sizing, operations and maintenance of proprietary devices are provided by the vendors.

6.8.1.2.1 Sizing

Hydrodynamic separators shall be sized to capture and treat the stormwater quality design flow rate and to completely drain within 72 hours.

Sizing of proprietary devices is reduced to a simple process whereby a model can simply be selected from a table or a chart based on a few known quantities (tributary area, location, design flow rate, design volume, etc.). A few of the manufacturers either size the devices for potential clients or offer calculators on their websites that simplify the design process even further and lessens the possibility of using obsolete design information. For the latest sizing guidelines, refer to the manufacturer's website.

Hydrodynamic separators are designed to have a permanent pool of water stored within the system. Various methods of vector control are available to prevent mosquito breeding including manhole cover screens and the use of mosquito dunks. In many designs, oil and grease is stored at the water surface and provides a deterrent to mosquito breeding.

6.8.1.3 Operations and Maintenance

Hydrodynamic separators should be inspected every 6 months during the first year of operation. Inspection should also occur immediately following a storm event to assess the function of the device. Once the device is performing as designed, the frequency of inspection may be reduced to once per year.

6.8.2 PT-2: Catch Basin Insert

Catch basin inserts are manufactured filters or fabric placed in a drop inlet to remove sediment and debris and may include sorbent media (oil absorbent pouches) to remove floating oils and grease. Catch basin inserts are selected specifically based upon the orientation of the inlet.

Project applicants must choose catch basin inserts that are certified by the State Water Resources Control Board; the list of certified devices is updated regularly and it is published at https://www.waterboards.ca.gov/water_issues/programs/stormwater/trash_implementation.html.

Catch basin inserts, like all pretreatment BMPs, are not stand alone BMPs; they must be used in combination with other, non-pretreatment BMP(s).

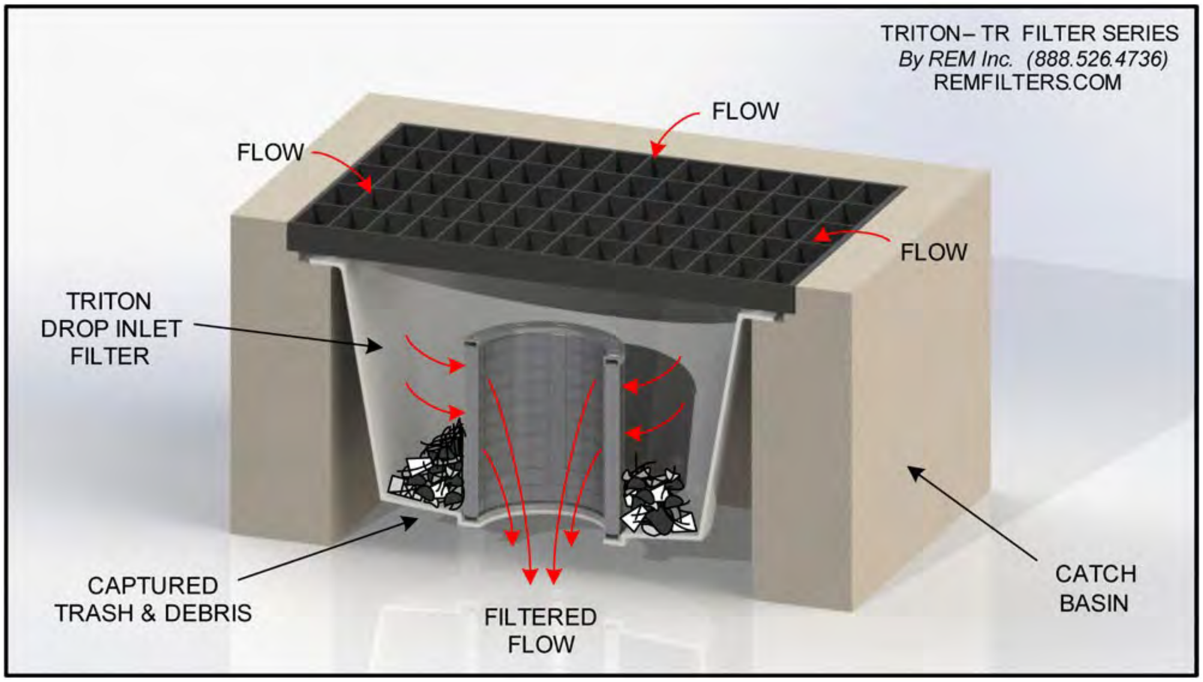
- **Application**
- Parking lots
- Roads
- Athletic courts
- Outdoor food areas

Preventive Maintenance

- After storm inspection
- Sediment removal
- Trash removal
- Filter/sorbent media replacement

Catch Basin Inserts

Photo Credits: Left – KriStar; Right – County of Ventura



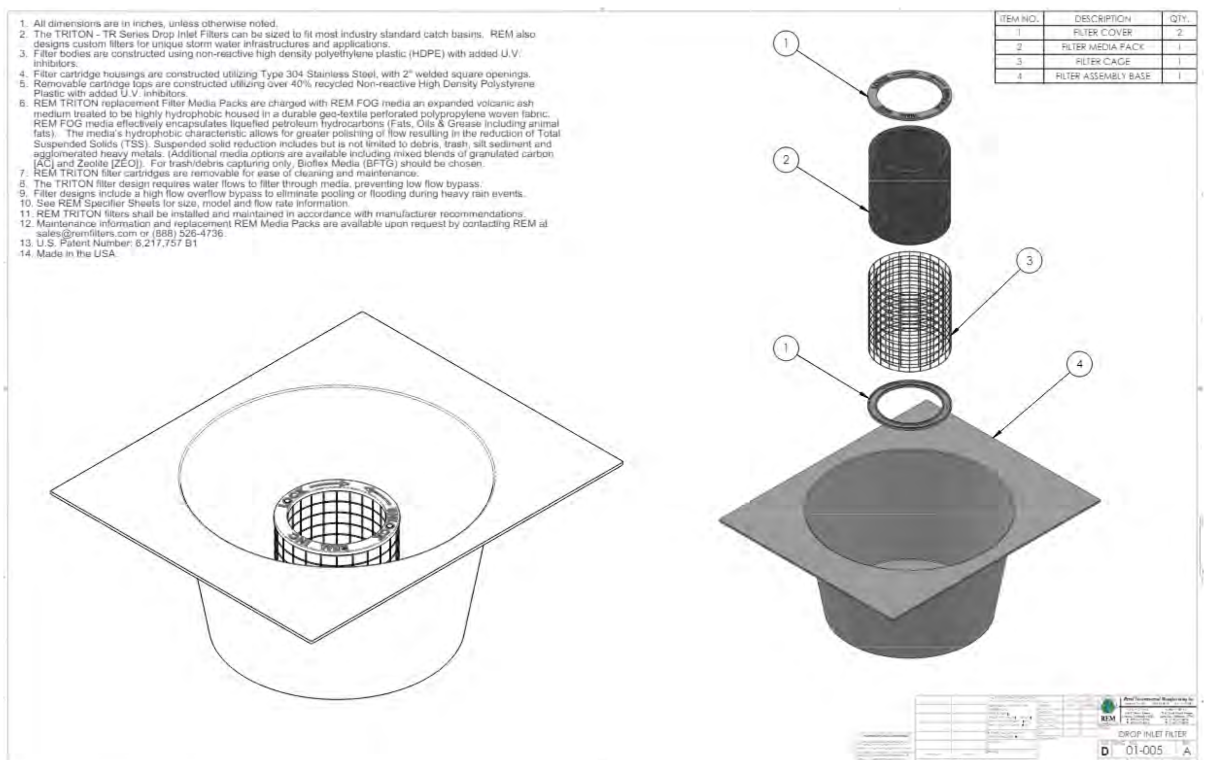


Figure 6-22: Example of Catch Basin Insert Design Schematic

6.8.2.1 Limitations

Catch basin inserts come in such a wide range of configurations that it is practically impossible to generalize the expected performance. Inserts should mainly be used for catching coarse sediments and floatable trash, and are effective as pretreatment in combination with other types of structures that are recognized as water quality treatment BMPs. Trash and large objects can greatly reduce the effectiveness of catch basin inserts with respect to sediment and hydrocarbon capture. Frequent maintenance and the use of screens and grates to keep trash out may decrease the likelihood of clogging and prevent obstruction and bypass of incoming flows.

6.8.2.2 Design Criteria

Catch basin inserts shall be sized to capture and treat the stormwater quality design flow rate (refer to Section Appendix C-1 and Equation C-3).

6.8.2.3 Operations and Maintenance

1) Trash, debris, and sediment around insert grate and inside chamber requiring trash to be cleared.

2) Repair filter media if damaged or severely clogged.

3) Inspection of catch basin insert after each storm greater than 0.2 inches is recommended.

6.8.3 PT-3: Vegetated Swale

NOTE: The vegetated swale design discussed in this section is not the same as the TAPE-certified vegetated swale design which is part of Section 6.6.3 FLO-3: Other TAPE-Certified Enhanced Treatment BMPs. The design discussed herein is a simpler type of facility, intended as a pretreatment-only option and not as a standalone BMP.

Vegetated swales are open, shallow channels with low-lying vegetation covering the side slopes and bottom that collect and slowly convey runoff to downstream discharge points. Vegetated swales provide pollutant removal through settling and filtration in the vegetation (usually grasses) lining the channels, provide the opportunity for stormwater volume reduction through infiltration and evapotranspiration, reduce the flow velocity, and conveying stormwater runoff. An effective vegetated swale achieves uniform sheet flow through a densely vegetated area for a period of several minutes. The vegetation in the swale can vary depending on its location and is the choice of the designer, depending on the design criteria outlined in this section. Please consult with local decision making body for swale requirements.

Vegetated swales, like all pretreatment BMPs, are not stand alone BMPs; they must be used in combination with other, non-pretreatment BMP(s).

Application

- Open areas adjacent to parking lots
- Open spaces adjacent to athletic fields
- Roadway medians and shoulders

Preventive Maintenance

- Remove excess sediment, trash, and debris
- Clean and reset flow spreaders
- Mow regularly
- Remove sediment and debris build-up near inlets and outlets
- Repair minor erosion and scouring

Vegetated Swale

Photo Credit: County of Ventura

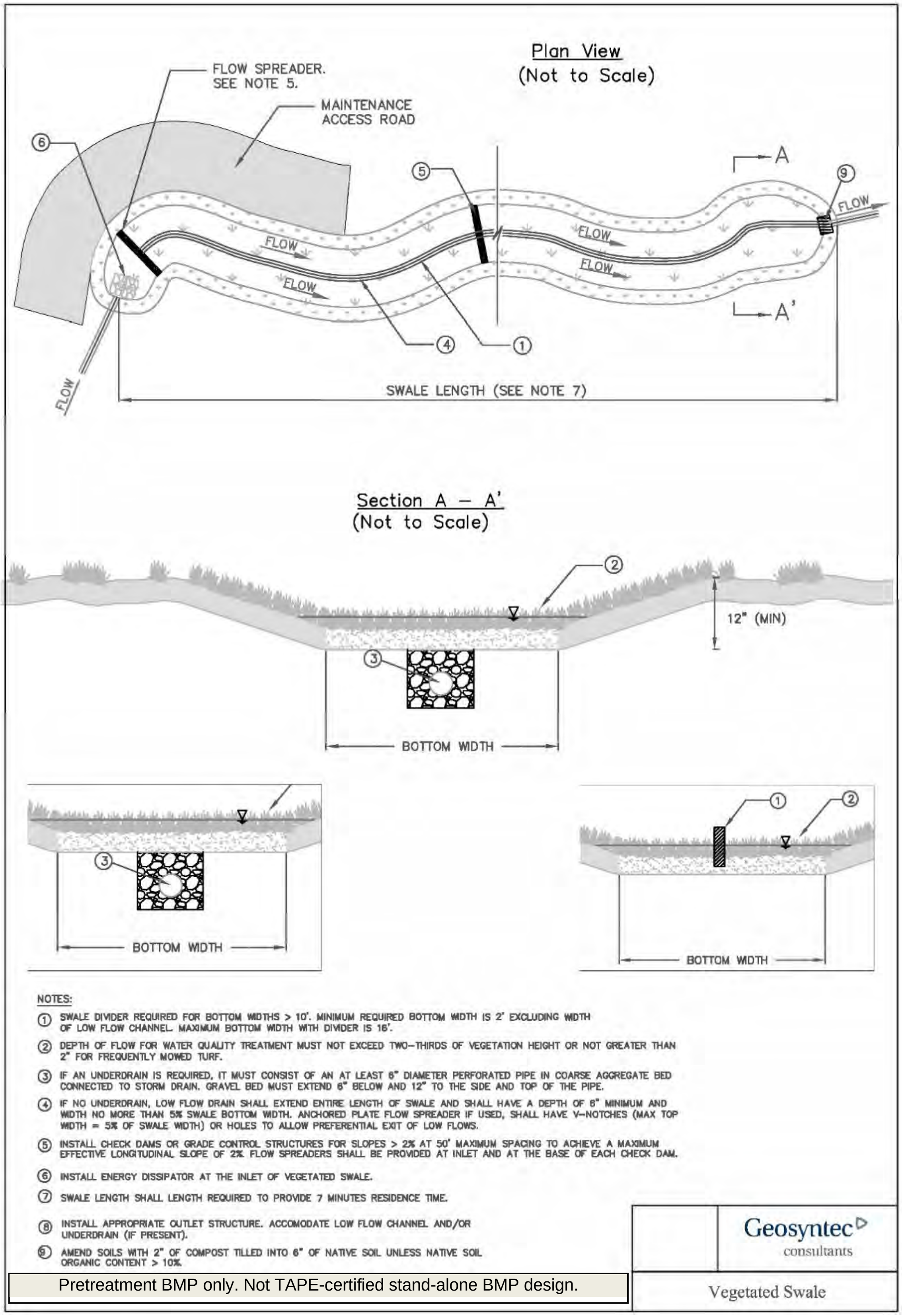


Figure 6-23: Vegetated Swale Design Schematic

6.8.3.1 Limitations

1) Compatibility with flood control - swales should not interfere with flood control functions of existing conveyance and detention structures.

2) Vegetation - select vegetation appropriately based on irrigation requirements and exposure (shady versus sunny areas). A thick vegetative cover is needed for vegetated swales to function properly. Native and drought tolerant plants are recommended.

3) Drainage area - each vegetated swale can treat a relatively small drainage area. Large areas should be divided and treated using multiple swales.

6.8.3.2 Design Criteria

Vegetated swales should be designed according to the requirements listed in Table 6-13 and outlined in the section below. BMP sizing worksheets are presented in Appendix C.

Table 6-13: Vegetated Swale Filter Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design flow rate (SQDF)	cfs	See Section 2 and Appendix C for calculating SQDF.
Swale Geometry	-	Trapezoidal
Minimum bottom width	feet	2
Maximum bottom width	feet	10; if greater than 10 must use swale dividers; with dividers, max is 16
Minimum length	feet	sufficient length to provide minimum contact time
Minimum slope in flow direction	%	0.2 (provide underdrains for slopes less < 0.5%)
Maximum slope in flow direction	%	2.0 (provide grade-control checks for slopes > 2.0)
Maximum flow velocity	ft/sec	1.0 (water quality treatment); 3.0 (flood conveyance)
Maximum depth of flow for water quality treatment	inches	3 to 5 (1 inch below top of grass)
Minimum residence (contact) time	minutes	7 (provide sufficient length to yield minimum residence time)
Vegetation type	--	Varies (see vegetation section below); Native and drought tolerant plants are recommended
Vegetation height	inches	4 to 6 (trim or mow to maintain height)

6.8.3.3 Sizing Criteria

Procedures for sizing vegetated swales are described in Appendix C, Section C.12. A vegetated swale sizing worksheet and example are also provided.

6.8.3.3.1 Geometry and Size

1) In general, a trapezoidal channel shape should be assumed for sizing calculations above, but a more naturalistic channel cross-section is preferred.

2) Swales designed for water quality treatment purposes only are usually fairly shallow, generally less than 1 ft. Therefore, a side slope of 2:1 (H:V) can be used and is acceptable.

3) Swales shall be greater than 100 feet in length. The vegetated swale can be shorter than 100 feet if it is used for pretreatment only (i.e., prior to infiltration). Length can be increased by meandering the swale.

4) The minimum swale bottom width shall be 2 feet to allow for ease of mowing.

5) The maximum swale bottom width shall be limited to 10 feet, unless a swale divider is provided, then the maximum bottom width can be a maximum of 16 feet wide. The swale width is calculated without the swale diving berm. *The intention is that experience shows that when the width exceeds about 10 feet, it is difficult to keep the water from concentrating in low flow channels. It is also difficult to construct the bottom level without sloping to one side. Vegetated swales are best constructed by leveling the bottom after excavating. A single-width pass with a front-end loader produces a better result than a multiple-width pass.*

6) Swales that are required to convey flood flow as well as the SQDF should be sized to convey the flood control design storm and include a provision of freeboard as required by the local approval authority.

7) Gradual meandering bends in the swale are desirable for aesthetic purposes and to promote slower flow.

6.8.3.3.2 Bottom Slope

1) The longitudinal slope (along the direction of flow) should be between 1% and 6%.

2) If longitudinal slopes are less than 1.5% and the soils are poorly drained (e.g., silts and clays), then underdrains should be provided. A soils report to verify soils properties should be provided for swales less than 1.5%.

3) If longitudinal slope exceeds 2%, check dams with vertical drops of 12 inches or less should be provided to achieve a bottom slope of 2% or less between the drop structures.

4) The lateral (horizontal) slope at the bottom of the swale should be zero (flat) to discourage channeling.

6.8.3.3.3 Water Depth and Dry Weather Flow Drain

1) Water depth should not exceed 4 inches (or 2/3 of the expected vegetation height), except for frequently mowed turf swales, in which the depth should not exceed 2 inches.

2) The swale length must provide a minimum hydraulic residence time of 7 minutes.

3) A low flow drain should be provided if the potential for dry weather flows exists. The low flow drain should extend the entire length of the swale. The drain should have a minimum depth of 6 inches, and a width no more than 5% of the calculated swale bottom width. The width of the drain should be in addition to the required bottom width. The flow spreader at the swale inlet should have v-notches (maximum top width = 5% of swale width) or holes to allow preferential exit of low flows into the drain, if applicable. If an underdrain or gravel drainage layer is installed as discussed below, the low flow drain should be omitted.

6.8.3.3.4 Swale Inflow and Design Capacity

1) Whenever possible, inflow should be directed towards the upstream end of the swale and should, at a minimum, occur evenly over the length of the swale. Swale inflow design should provide for positive drainage into the swale to function on the long-term with minimal maintenance.

2) On-line vegetated swales should be designed to convey flow rates up to the post-development peak stormwater runoff discharge rate (flow rate) for the 100-yr 24-hour storm event, with appropriate freeboard (see Ventura County Hydrology Manual (2017)).

3) Off-line vegetated swales should be designed to convey the flow-based SQDF by using a flow diversion structure (e.g., flow splitter) which diverts the SQDF to the off-line vegetated swale designed to handle SQDF. Freeboard for off-line swales is not required but should be provided if space is available.

6.8.3.3.5 Energy Dissipation

1) Vegetated swales may be designed either on-line or off-line. If the facility is on-line, velocities should be maintained below the maximum design flow velocity of 3 feet per second to prevent scour and resuspension of deposited sediments.

2) The maximum flow velocity under the stormwater quality design flow rate should not exceed 1.0 foot per second. *The intention is that this maximum SQDV promotes settling and keeps vegetation upright.*

3) This velocity limitation combined with a maximum depth of 4 inches and bottom width of 10 feet results in a recommended maximum flow capacity of about 3.3 cfs, after accounting for the side slopes. The contributory drainage area to each swale is limited so as not to exceed this recommended maximum flow capacity.

4) The maximum flow velocity during the 100-yr 24-hr storm event should not exceed 3.0 foot per second. This can be accomplished by:

   a. Splitting roadside swales near high points in the road so that flows drain in opposite directions, mimicking flow patterns on the road surface.

   b. Limiting tributary areas to long swales by diverting flows throughout the length of the swale at regular intervals, to the downstream stormwater conveyance system.

5) A flow spreader (see "Flow Spreaders" below) should be used at the inlet so that the entrance velocity is quickly dissipated, and the flow is uniformly distributed across the whole swale. Energy dissipation controls should be constructed of sound materials such as stones, concrete, or proprietary devices that are rated to withstand the energy of the influent flows.

6) If check dams are used to reduce the longitudinal slope, a flow spreader should be provided at the toe of each vertical drop, with specifications described below.

7) If flow is to be introduced through curb cuts, place pavement approximately one inch above the elevation of the vegetated areas. Curb cuts should be at least 12 inches wide to prevent clogging.

6.8.3.3.6 Flow Spreaders

1) An anchored plate flow spreader or similar device should be provided at the inlet to the swale. Equivalent methods for spreading flows evenly throughout the width of the swale are acceptable.

2) The top surface of the flow spreader plate should be level, projecting a minimum of 2 inches above the ground surface of the water quality facility, or v-notched with notches 6 to 10 inches on center and 1 to 4 inches deep (use shallower notches with closer spacing).

3) A flow spreader plate should extend horizontally beyond the bottom width of the facility to prevent water from eroding the side slope. The plate should have a row of horizontal perforations at its base to prevent ponding for long durations. The horizontal extent should be such that the bank is protected for all flows up to the 100-yr 24-hr storm event (on-line swales) or the maximum flow that will enter the water quality facility (off-line swales).

4) Flow spreader plates should be securely fixed in place.

5) Flow spreader plates may be made of either concrete, stainless steel, or other durable material.

6) Anchor posts should be 4-inch square concrete, tubular stainless steel, or other material resistant to decay.

6.8.3.3.7 Check Dams

If check dams are required, they can be designed using a number of different materials, including riprap, earthen berms, or removal stop logs. Where vegetated swales parallel urban streets, the check dam can double as a crossing walk so that pedestrians have a pathway from the parked car to the building.

Check dams must be placed to achieve the desired slope (1 to 6%) at a maximum of 50 feet apart. Check dams should be no higher than 12 inches. If riprap is used, the material should consist of well-graded stone consisting of a mixture of rock sizes. The following is an example of an acceptable gradation:

Particle Size	% Passing
24 inches	100
15 inches	75
9 inches	50
4 inches	10

6.8.3.3.8 Underdrains

If underdrains (not to be confused with a dry weather flow drain) are required, then they should meet the following criteria:

1) Underdrains should be made of slotted, polyvinyl chloride (PVC) pipe (PVC SDR 35 or approved equivalent). *The intention is that in comparison to round-hole perforated pipe, slotted underdrains provide greater intake capacity, clog resistant drainage, and reduced entrance velocity into the pipe, thereby reducing the chances of solids migration.*

2) Slotted pipe should have 2 to 4 rows of slots cut perpendicular to the axis of the pipe or at right angles to the pitch of corrugations. Slots should be 0.04 to 0.1 inch and should have a length of 1 to 1.25 inches. Slots should be longitudinally spaced such that the pipe has a minimum of one square inch of opening per linear foot of pipe.

3) Underdrains should be sloped at a minimum of 0.5%.

4) The underdrain pipe should be 6 inches or greater in diameter, so it can be cleaned without damage to the pipe. Clean-out risers with diameters equal to the underdrain pipe should be placed at the terminal ends of the underdrain and can be incorporated into the flow spreader and outlet structure to minimize maintenance obstacles in the swale. Intermediate clean-out risers may also be placed in the check dams or grade control structures. The cleanout risers should be capped with a lockable screw cap.

5) The underdrain should be placed parallel to the swale bottom and back filled with six inches of drain rock. The following coarse aggregate should be used to provide a gravel

blanket and bedding for the underdrain pipe to provide a 1-foot minimum depth around the top and sides of the slotted pipe.

Sieve size	Percent Passing
¾ inch	100
¼ inch	30-60
US No. 8	20-50
US No. 50	3-12
US No. 200	0-1

6) At the option of the designer/geotechnical engineer, the drain rock may be wrapped in a geotextile fabric meeting the following minimum materials requirements. If a geotextile fabric is used, it should pass 75 gal/min/ft^2, should not impede the infiltration rate of the soil medium, and should meet the following minimum materials requirements.

Geotextile Property	Value	Test Method
Trapezoidal Tear (lbs)	40 (min)	ASTM D4533
Permeability (cm/sec)	0.2 (min)	ASTM D4491
AOS (sieve size)	#60 - #70 (min)	ASTM D4751
Ultraviolet resistance	70% or greater	ASTM D4355

Preferably, aggregate should be used in place of geotextile fabric to reduce the potential for clogging. This aggregate layer should consist of 2 to 4 inches of washed sand underlain with 2 inches of choking stone (Typically #8 or #89 washed).

7) The underdrain should drain freely to an acceptable discharge point. The underdrain can be connected to a downstream open conveyance (vegetated swale), to another bioretention cell as part of a connected treatment system, daylight to a vegetated dispersion area using an effective flow dispersion device, stored for rainwater harvesting, or to a storm drain.

6.8.3.3.9 Gravel Drainage Layer

To increase volume reduction and if soil conditions allow (infiltration rate > 0.5 in/hr), omit the low flow drain or underdrain and install an appropriately sized gravel drainage layer (typically a washed 57 stone) beneath the swale to achieve desired volume reduction goals. Where slopes are greater than 1%, the gravel drainage layer should be installed in combination with check dams (e.g., drop structures) to slow the flow in the swale and allow for infiltration into the gravel drainage layer and then into the subsurface. The base of the drainage layer should have zero slope. The drawdown time in the gravel drainage layer should not exceed 72 hours. The soil and gravel layers should be separated with a geotextile filter fabric or a thin, 2 to 4-inch layer of pure sand and a thin layer (nominally two inches) of choking stone (such as #8). Sizing of the gravel drainage layer is based on volume reduction requirements.

6.8.3.3.10 Swale Divider

1) If a swale divider is used, the divider should be constructed of a firm material that will resist weathering and not erode, such as concrete, plastic, or compacted soil seeded with grass. Treated timber should not be used. Selection of divider material should consider maintenance activities, such as mowing.

2) The divider should have a minimum height of 1 inch greater than the stormwater quality design water depth.

3) Earthen berms should be no steeper than 2H:1V.

4) Material other than earth should be embedded to a depth sufficient to be stable.

6.8.3.3.11 Soils

Swale soils should be amended with 2 inches of compost, unless the organic content is already greater than 10%. The compost should be mixed into the native soils to a depth of 6 inches to prevent soil layering and washout of compost. The compost will contain no sawdust, green or under-composted material, or any other toxic or harmful substance. It should contain no un-sterilized manure, which can lead to high levels of pathogen indictors (coliform bacteria) in the runoff.

6.8.3.3.12 Vegetation

Swales must be vegetated in order to provide adequate treatment of runoff via filtration. Vegetation, when chosen and maintained appropriately, also improves the aesthetics of a site. It is important to maximize water contact with vegetation and the soil surface.

1) The swale area should be appropriately vegetated with a mix of erosion-resistant plant species that effectively bind the soil. A diverse selection of low growing plants that thrive under the specific site, climatic, and watering conditions should be specified. A mixture of dry-area and wet-area grass species that can continue to grow through silt deposits is most effective. Native or adapted grasses are preferred because they generally require less fertilizer, limited maintenance, and are more drought-resistant than exotic plants. When appropriate, swales that are integrated within a project may use turf or other more intensive landscaping, while swales that are located on the project perimeter, within a park, or close to an open space area are encouraged to be planted with a more naturalistic plant palette.

2) Trees or shrubs may be used in the landscape as long as they do not over-shade the turf.

3) Above the design treatment elevation, a typical lawn mix or landscape plants can be used provided they do not shade the swale vegetation.

4) Irrigation is required if the seed is planted in the spring or summer. Use of a permanent irrigation system may help provide maximal water quality performance. Drought-tolerant grasses should be specified to minimize irrigation requirements.

5) Vegetative cover should be at least 4 inches in height, ideally 6 inches. Swale water depth should ideally be 2/3 of the height of the shortest plant species.

6) Locate the swale in an area without excessive shade to avoid poor vegetative growth. For moderately shaded areas, shade tolerant plants should be used.

7) Locate the swale away from large trees that may drop excessive leaves or needles, which may smother the grass or impede the flow through the swale. Landscape planter beds should be designed and located so that soil does not erode from the beds and enter a nearby swale.

6.8.3.3.13 Maintenance Access

1) Access to the swale inlet and outlet should be safely provided, with ample room for maintenance and operational activities.

6.8.3.4 Operations and Maintenance

1) Inspect vegetated swales for erosion or damage to vegetation after every storm greater than 0.75 inches for on-line swales and at least twice annually for off-line swales, preferably at the end of the wet season to schedule summer maintenance and in the fall to ensure readiness for winter. Additional inspection after periods of heavy runoff is recommended. Each swale should be checked for debris and litter and areas of sediment accumulation (see Appendix D for a vegetated swale inspection and maintenance checklist).

2) Swale inlets (curb cuts or pipes) should maintain a calm flow of water entering the swale. Remove sediment as needed at the inlet, if vegetation growth is inhibited in greater than 10% of the swale or if the sediment is blocking even distribution and entry of the water. Following sediment removal activities, replanting and/or reseeding of vegetation may be required for reestablishment.

3) Flow spreaders should provide even dispersion of flows across the swale. Sediments and debris should be removed from the flow spreader if blocking flows. Splash pads should be repaired if needed to prevent erosion. Spreader level should be checked and releveled if necessary.

4) Side slopes should be maintained to prevent erosion that introduces sediment into the swale. Slopes should be stabilized and planted using appropriate erosion control measures when native soil is exposed, or erosion channels are formed.

5) Swales should drain within 48 hours of the end of a storm. Till the swale if compaction or clogging occurs and revegetate. If a perforated underdrain pipe is present, it should be cleaned if necessary.

6) Vegetation should be healthy and dense enough to provide filtering, while protecting underlying soils from erosion:

- Mulch should be replenished as needed to ensure survival of vegetation.
- Vegetation, such as large shrubs or trees, that interfere with landscape swale operation should be pruned.
- Fallen leaves and debris from deciduous plant foliage should be removed.
- Grassy swales should be mowed to 4 to 6 inches height. Grass clippings should be removed.
- Invasive vegetation, such as Alligatorweed (*Alternanthera philoxeroides*), Halogeton (*Halogeton glomeratus*), Spotted Knapweed (*Centaurea maculosa*), Giant Reed (*Arundo donax*), Castor Bean (*Ricinus communis*), Perennial Pepperweed (*Lepidium latifolium*), and Yellow Starthistle (*Centaurea solstitalis*) should be removed and replaced with non-invasive species. Invasive species should never contribute more than 10% of the vegetated area. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.
- Dead vegetation should be removed if coverage is greater than 10% of the area or when swale function is impaired. Vegetation should be replaced and established before the wet season to maintain cover density and control erosion where soils are exposed.

7) Check dams (if present) should control and distribute flow across the swale. Causes for altered water flow and/or channelization should be identified and obstructions cleared. Check dams and swales should be repaired if damaged.

8) The vegetated swale should be well maintained. Trash and debris, sediment, visual contamination (e.g., oils), noxious or nuisance weeds should all be removed.

6.8.4 PT-4: Vegetated Filter Strip

NOTE: The vegetated filter strip design discussed in this section is not the same as the TAPE-certified vegetated filter strip design which is part of Section 6.6.3 FLO-3: Other TAPE-Certified Enhanced Treatment BMPs. The design discussed herein is a simpler type of facility, intended as a pretreatment-only option and not as a standalone BMP.

Filter strips are vegetated areas designed to treat sheet flow runoff from adjacent impervious surfaces or intensive landscaped areas such as golf courses. Filter strips decrease runoff velocity, filter out total suspended solids and associated pollutants, and provide some infiltration into underlying soils. While some assimilation of dissolved constituents may occur, filter strips are generally more effective in trapping sediment and particulate-bound metals, nutrients, and pesticides. Filter strips are more effective when the runoff passes through the vegetation and thatch layer in the form of shallow, uniform flow. Biological and chemical processes may help break down pesticides, uptake metals, and use nutrients that are trapped in the filter.

Vegetated filter strips, like all pretreatment BMPs, are not stand alone BMPs; they must be used in combination with other, non-pretreatment BMP(s).

Applications

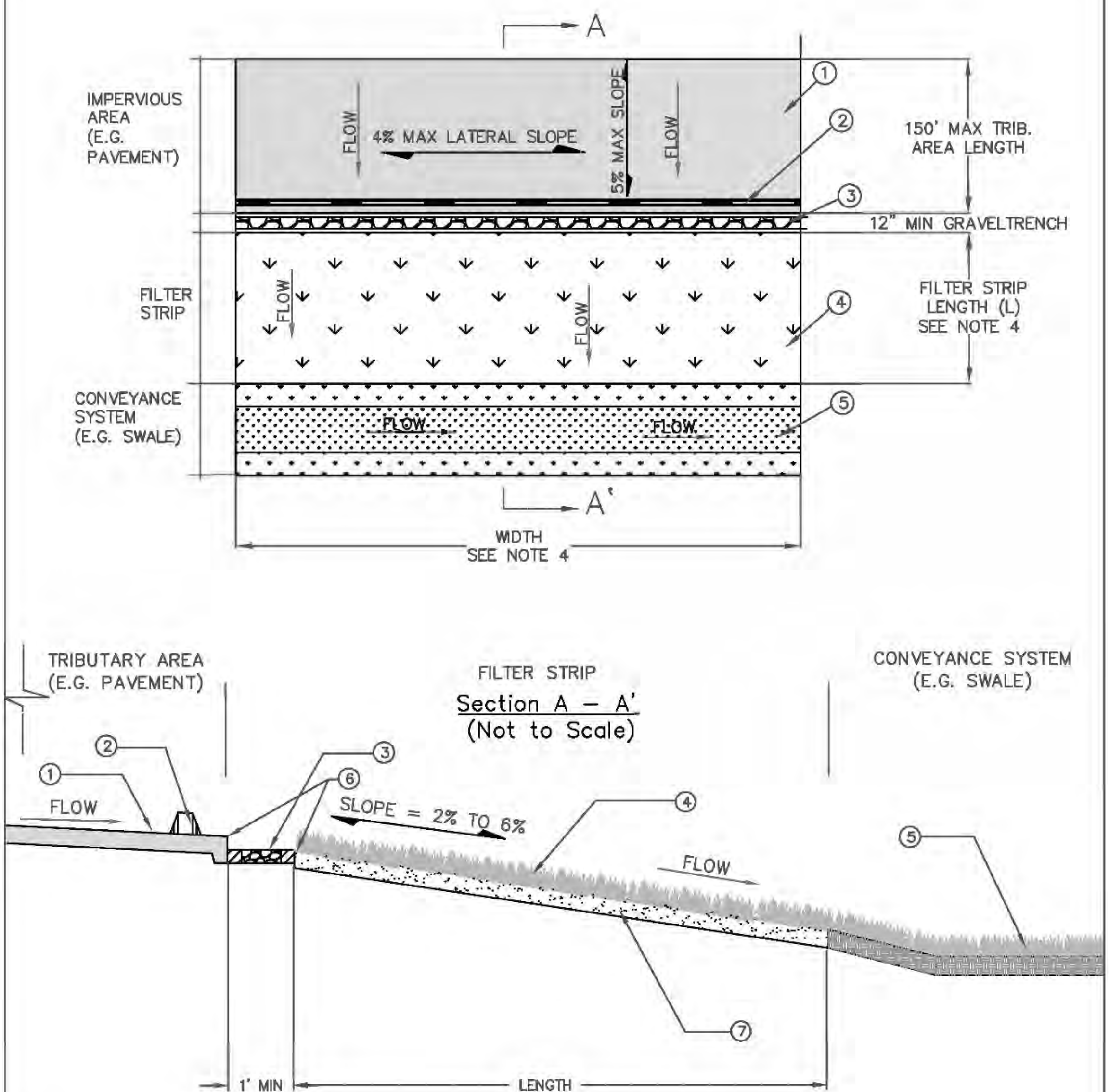
- Areas adjacent to parking lots and driveways
- Road medians and shoulders

Preventive Maintenance

- Remove excess sediment
- Stabilize/repair minor erosion and scouring
- Remove trash and debris
- Mow regularly

Vegetated Filter Strip Captures Runoff from Freeway

Photo Credit: County of Ventura



NOTES:

1. MAXIMUM LENGTH OF IMPERVIOUS TRIBUTARY AREA (PER UNIT WIDTH OF FILTER STRIP) SHALL BE 150'.
2. OPTIONAL NOTCHED CURB SPREADERS MAY BE USED IN CONJUNCTION WITH GRAVEL FLOW SPREADER.
3. GRAVEL FLOW SPREADER 6" DEEP BY 12" WIDE MIN SHALL BE PROVIDED.
4. VEGETATED FILTER STRIP SURFACE. SLOPE SHALL BE BETWEEN 2–4%. LENGTH OF STRIP MUST BE BETWEEN 15' AND 150'. WIDTH MUST BE EQUAL OR GREATER THAN THE WIDTH OF THE TRIBUTARY AREA.
5. INSTALL SWALE OR OTHER CONVEYANCE SYSTEM DOWNSTREAM OF FILTER STRIP.
6. TOP OF FILTER STRIP SHALL BE >1" BELOW TOP OF ADJACENT PAVEMENT.
7. AMEND SOILS WITH 2" OF COMPOST TILLED INTO 6" OF NATIVE SOIL UNLESS NATIVE SOIL ORGANIC CONTENT > 10%.

Geosyntec consultants

Pretreatment BMP only. Not TAPE-certified stand-alone BMP design.

Vegetated Filter Strip

Figure 6-24: Vegetated Filter Strip Design Schematic

6.8.4.1 Limitations

The following describes limitations for vegetated filter strips:

- High flow velocity - steep terrain and/or large tributary area may cause concentrated, erosive flows.
- Sheet flow - shallow, evenly-distributed flow across the entire width of the filter strip is required. Filter strips are designed to treat small areas. The maximum flow path from a contributing impervious surface should not exceed 150 feet. Flows should enter as sheet flow and not exceed a depth of 1 inch.
- Shallow grades – a limited site slope may cause ponding.
- Availability of pervious area adjacent to impervious area - filter strips require sheet flow from impervious areas.

6.8.4.2 Design Criteria

The main challenge associated with filter strips is maintaining sheet flow, which is critical to the performance of this BMP. If flows are concentrated, then little or no treatment of stormwater runoff is achieved and erosive rilling is likely. The use of a flow spreading device (e.g., gravel trench or level spreader) to deliver shallow, evenly-distributed sheet flow to the strip is required. Vegetated filter strips should be designed according to the requirements listed in Table 6-14 and outlined in the section below. BMP sizing worksheets are presented in Appendix C.

Table 6-14: Vegetated Filter Strip Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design flow (SQDF)	cfs	See Section 2 and Appendix C for calculating SQDF.
Maximum design flow depth	inches	1
Design residence time	minutes	7
Design flow velocity	ft/sec	< 1 ft/sec
Minimum length in flow direction	feet	15 (25 preferred); If sized for pretreatment only, filter strip can be a minimum of 4.
Maximum length (parallel to flow) of tributary area per unit width (perpendicular to flow) of filter strip	feet	150
Minimum slope in flow direction	%	2

Design Parameter	Unit	Design Criteria
Maximum slope in flow direction	%	4
Maximum lateral slope	%	4
Vegetation	-	Turf grass (irrigated) or approved equal
Minimum grass height	inches	2
Maximum grass height	inches	4 (typical) or as required to prevent shading
Elevation of flow spreader	inches	> 1 inch below the pavement surface

6.8.4.3 Sizing Criteria

Procedures for sizing filter strips are described in Appendix C, Section C.13. A filter strip sizing example is also provided.

6.8.4.3.1 Geometry and Size

1) The width of the filter strip shall extend across the full width of the tributary area. The upstream boundary of the filter should be located contiguous to the developed tributary area.

2) The length (in direction of flow) should be between 15 and 150 feet. A minimum length of 25 feet is preferred. Filter strips used for pretreatment shall be at least 4 feet long (in direction of flow).

3) Filter strips shall be designed on slopes (parallel to the direction of flow) between 2% and 4%; steeper slopes tend to result in concentrated flow. Slopes less than 2% could pond runoff, and in poorly permeable soils, create a mosquito breeding habitat.

4) The lateral slope of strip (parallel to the edge of the pavement, perpendicular to the direction of flow) should be 4% or less.

5) Grading should be even: a filter strip with uneven grading perpendicular to the flow path will develop flow channels over time.

6) The top of the strip should be installed 2 to 5 inches below the adjacent pavement to allow for vegetation and sediment accumulation at the edge of the strip. A beveled transition is acceptable and may be required per roadside design specifications.

7) Both the top and toe of the slope should be as flat as possible to encourage sheet flow and prevent channeling and erosion. For engineered filter strips, the facility surface should be graded flat prior to placement of vegetation.

6.8.4.3.2 Energy Dissipation / Level Spreading

Runoff entering a filter strip must not be concentrated. A flow spreader should be installed at the edge of the pavement to uniformly distribute the flow along the entire width of the filter strip.

1) At a minimum, a gravel flow spreader (gravel-filled trench) should be placed between the impervious area contributing flows and the filter strip, and meet the following requirements:

    a. The gravel flow spreader should be a minimum of 6 inches deep and should be 12 inches wide.

    b. The gravel should be a minimum of 1 inch below the pavement surface. *The intention is that this allows sediment from the paved surface to be accommodated without blocking drainage onto the strip.*

2) The gravel flow spreader should be a minimum of 6 inches deep and should be 12 inches wide.

    a. Where the ground surface is not level, the gravel spreader must be installed so that the bottom of the gravel trench and the outlet lip are level.

    b. Along roadways, gravel flow spreaders must be placed and designed in accordance with County road design specifications for compacted road shoulders.

3) Curb ports and interrupted curbs may only be used in conjunction with a gravel spreader to better ensure that water sheet flows onto the strip, provided:

    a. Curb ports use fabricated openings that allow concrete curbing to be poured or extruded while still providing an opening through the curb to admit water to the filter strip. Interrupted curbs are sections of curb placed to have gaps spaced at regular intervals along the total width of the treatment area. Openings or gaps in the curb should be at regular intervals but at least every 6 feet. The width of each opening should be a minimum of 11 inches.

    b. At a minimum, gaps should be every 6 feet to allow distribution of flows into the treatment facility before they become too concentrated. The opening should be a minimum of 11 inches. Approximately 15 percent or more of the curb section length should be in open ports, and as a general rule, no opening should discharge more than 10 percent of the overall flow entering the facility.

4) Energy dissipaters are needed in a filter strip if sudden slope drops occur, such as locations where flows in a filter strip pass over a rockery or retaining wall aligned

perpendicular to the direction of flow. Adequate energy dissipation at the base of a drop section can be provided by a riprap pad.

6.8.4.3.3 Access

1) Access should be provided at the upper edge of a filter strip to enable maintenance of the inflow spreader throughout the strip width and allow access for mowing equipment.

6.8.4.3.4 Water Depth and Velocity

2) The design water depth shall not exceed 1 inch.

3) Runoff flow velocities should not exceed approximately 1 foot per second across the filter strip surface.

6.8.4.3.5 Soils

Filter strip soils should be amended with 2 inches of compost, unless the organic content is already greater than 10%. The compost should be mixed into the native soils to a depth of 6 inches to prevent soil layering and washout of compost. The compost will contain no sawdust, green or under-composted material, or any other toxic or harmful substance. It should contain no un-sterilized manure which can lead to high levels of potentially pathogenic bacteria in the runoff.

6.8.4.3.6 Vegetation

Filter strips must be uniformly graded and densely vegetated with erosion-resistant grasses that effectively bind the soil. Native or adapted grasses are preferred because they generally require less fertilizer and are more drought-resistant than exotic plants. The following vegetation guidelines should be followed for filter strips:

1) Sod (turf) can be used instead of grass seed, as long as there is complete coverage.

2) Irrigation should be provided to establish the grasses.

3) Grasses or turf should be maintained at a height of 2 to 4 inches. Regular mowing is often required to maintain the turf grass cover.

4) Trees or shrubs should not be used in abundance because they shade the turf and impede sheet flow.

6.8.4.4 Operations and Maintenance

Filter strips mainly require vegetation management. Therefore, minimal special training is needed for maintenance crews. Typical maintenance activities and frequencies include:

5) Inspect strips at least twice annually for erosion or damage to vegetation, preferably at the end of the wet season to schedule summer maintenance and in the fall to ensure the strip is ready for winter. However, additional inspection after periods of heavy runoff is most desirable. The strip should be checked for debris and litter and areas of sediment accumulation (see Appendix D for a vegetated filter strip inspection and maintenance checklist).

6) Mow as frequently as necessary (at least twice a year) for safety and aesthetics or to suppress weeds and woody vegetation.

7) Trash tends to accumulate in strip areas, particularly along roadways. The need for litter removal should be determined through periodic inspection. Litter should always be removed prior to mowing.

8) Regularly inspect vegetated buffer strips for pools of standing water. Vegetated filter strips can become a nuisance due to mosquito breeding in level spreaders (unless designed to dewater completely in less than 72 hours), in pools of standing water if obstructions develop (e.g. debris accumulation, invasive vegetation), and/or if proper drainage slopes are not implemented and maintained.

9) Activities that lead to ruts or depressions on the surface of the filter strip should be prevented or the integrity of the strip should be restored by leveling and reseeding. Examples are vehicle tracks, utility maintenance, and pedestrian (short-cut) tracks.

10) Vegetation should be healthy and dense enough to provide filtering, while protecting underlying soils from erosion:

    - Mulch should be replenished as needed to ensure survival of vegetation.
    - Vegetation, such as large shrubs or trees, that interfere with landscape swale operation should be pruned.
    - Fallen leaves and debris from deciduous plant foliage should be removed.
    - Filter strips should be mowed to 4 to 6 inches height. Grass clippings should be removed.
    - Invasive vegetation, such as Alligatorweed (*Alternanthera philoxeroides*), Halogeton (*Halogeton glomeratus*), Spotted Knapweed (*Centaurea maculosa*), Giant Reed (*Arundo donax*), Castor Bean (*Ricinus communis*), Perennial Pepperweed (*Lepidium latifolium*), and Yellow Starthistle (*Centaurea solstitalis*) should be removed and replaced with non-invasive species. Invasive species should never contribute more than 10% of the vegetated area. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California

Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.

- Dead vegetation should be removed if coverage is greater than 10% of the area or when filter strip function is impaired. Vegetation should be replaced and established before the wet season to maintain cover density and control erosion where soils are exposed.

7 MAINTENANCE PLAN

This chapter identifies the basic information that should be included in a maintenance plan. Refer to Fact Sheets for individual control measures in Chapter 6 regarding device-specific maintenance requirements.

7.1 Site Map

1) Provide a site map showing boundaries of the site, acreage, and drainage patterns/contour lines. Show each discharge location from the site and any drainage flowing onto the site. Distinguish between soft and hard surfaces on the map.

2) Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems and grade-breaks for purposes of pollution prevention.

3) With legend, show locations of expected sources of pollution generation (outdoor work and storage areas, heavy traffic areas, delivery areas, trash enclosures, fueling areas, industrial clarifiers, wash-racks, etc.). Identify any areas that have contaminated soil or where toxins are stored or have been stored/disposed of in the past.

4) With legend, indicate types and locations of stormwater management control measures which will be built to permanently control stormwater pollution. Distinguish between pollution prevention, treatment, sewer diversion, and containment devices.

7.2 Baseline Descriptions

1) List the property owners and persons responsible for operation and maintenance of the stormwater management control measures onsite. Include phone numbers and addresses.

2) Identify the intended method of providing financing for operation, inspection, routine maintenance, and upkeep of stormwater control measures.

3) List all permanent stormwater control measures. Provide a brief description of stormwater management control measures selected and if appropriate, facts sheets or additional information.

4) As appropriate for each stormwater control measure, provide:

    a. A written description and check list of all maintenance and waste disposal activities that will be performed. Distinguish between the maintenance appropriate for a 2-year establishment period and expected long-term maintenance. For example, maintenance requirements for vegetation in a constructed wetland may be more intensive during the first few years until the vegetation is established. The post-establishment maintenance plan should address maintenance needs (e.g., pruning, irrigation, weeding) for a larger, more stable system. Include maintenance performance procedures for facility components that require relatively unique maintenance knowledge, such as specific plant removal / replacement, landscape features, or constructed wetland maintenance. These procedures should provide enough detail for a person unfamiliar with maintenance to perform the activity or identify the specific skills or knowledge necessary to perform and document the maintenance.

b. A description of site inspection procedures and documentation system, including record-keeping and retention requirements.

c. An inspection and maintenance schedule, preferably in the form of a table or matrix, for each activity for all facility components. The schedule should demonstrate how it will satisfy the specified level of performance, and how the maintenance/inspection activities relate to storm events and seasonal issues.

d. Identification of the equipment and materials required to perform the maintenance.

5) As appropriate, list all housekeeping procedures for prohibiting illicit discharges or potential illicit discharges to the storm drain. Identify housekeeping BMPs that reduce maintenance of Treatment Control Measures. These procedures are listed based on facility operations and can be found in the Ventura County Industrial/Commercial Clean Business Program document.

7.3 Spill Plan

1) Provide emergency notification procedures (phone and agency/persons to contact).

2) As appropriate for the site, provide emergency containment and cleaning procedures.

3) Note downstream receiving water bodies or wetlands which may be affected by spills or chronic untreated discharges.

4) As appropriate, create an emergency sampling procedure for spills. (Note: Emergency sampling can protect the property owner from erroneous liability for down-stream receiving water area clean-ups).

7.4 Facility Changes

Operational or facility changes which significantly affect the character or quantity of pollutants discharging into the stormwater management control measures will require modifications to the Maintenance Plan and/or additional stormwater control measures.

7.5 Training

1) Identify appropriate persons to be trained and assure proper training.

2) Training to include:

    a. Good housekeeping procedures defined in the plan.

    b. Proper maintenance of all pollution mitigation devices.

    c. Identification and cleanup procedures for spills and overflows.

    d. Large-scale spill or hazardous material response.

    e. Safety concerns when maintaining devices and cleaning spills.

7.6 Basic Inspection and Maintenance Activities

1) Create and maintain onsite, a log for inspector names, dates and stormwater control measure devices to be inspected and maintained. Provide a checklist for each inspection and maintenance category.

2) Once annually, perform testing of any mechanical or electrical devices prior to wet weather.

3) Report any significant changes in stormwater management control measures to the site management. As appropriate, assure mechanical devices are working properly and/or landscaped BMP plantings are irrigated and nurtured to promote thick growth.

4) Note any significant maintenance requirements due to spills or unexpected discharges.

5) As appropriate, perform maintenance and replacement as scheduled and as needed in a timely manner to assure stormwater management control measures are performing as designed and approved.

6) Assure unauthorized low-flow discharges from the property do not bypass stormwater control measures.

7) Perform an annual assessment of each pollution generation operation and its associated stormwater management control measures to determine if any part of the pollution reduction train can be improved.

7.7 Revisions of Pollution Mitigation Measures

If future correction or modification of past stormwater management control measures or procedures is required, the owner shall obtain approval from the governing stormwater agency prior to commencing any work. Corrective measures or modifications shall not cause discharges to bypass or otherwise impede existing stormwater control measures.

7.8 Monitoring & Reporting Program

1) The governing stormwater agency may require a Monitoring & Reporting Program to assure the stormwater management control measures approved for the site are performing according to design.

2) If required by the local permitting agency, the Maintenance Plan shall include performance testing and reporting protocols.

APPENDIX A: GLOSSARY OF TERMS

A.1 Acronyms and Abbreviations

303(d)	List of Impaired Water Bodies
API	American Petroleum Institute (oil/water separator type)
BMP	Best Management Practice
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act
CP	Coalescing Plate (oil/water separator type)
CTR	California Toxics Rule
CWA	Clean Water Act
EMC	Event Mean Concentration
ESA	Environmentally Sensitive Area
LID	Low Impact Development
MCM	Minimum Control Measures
MEP	Maximum Extent Practicable
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
SIC	Standard Industrial Classification
SQDF	Stormwater Quality Design Flow
SQDV	Stormwater Quality Design Volume
TAPE	Washington State of Ecology's Technology Assessment Protocol - Ecology Program
TGM	Technical Guidance Manual
TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
U.S. EPA	United States Environmental Protection Agency
WERF	Water Environment Research Foundation

A.2 Definitions

Artificial Turf: Synthetic fibers that look and feel like natural grass. Synthetic turf has a permeable backing that allows liquids to permeate the material and drain to the base underneath. The base layer and drainage system ensure stormwater can infiltrate.

Automotive Repair Shop: A facility that is categorized in any one of the following Standard Industrial Classification (SIC) codes: 5013, 5014, 5541, 7532-7534, or 7536-7539.

Backfill: Earth or engineered material used to refill a trench or an excavation.

Berm: An earthen mound used to direct the flow of runoff around or through a structure.

Best Management Practice (BMP): Any program, technology, process, siting criteria, operational methods or measures, or engineered systems, which when implemented prevent, control, remove, or reduce pollution.

Best Management Practices (BMPs): Includes schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the United States. BMPs also include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

Biofiltration: The simultaneous process of filtration, infiltration, adsorption, and biological uptake of pollutants in stormwater that takes place when runoff flows over and through vegetated areas. Biofiltration BMPs are designed based on the stormwater quality design volume.

Bioretention Facility: A facility that utilizes soil infiltration and both woody and herbaceous plants to remove pollutants from stormwater runoff. Runoff is typically captured and infiltrated or released over a period of 24 to 48 hours.

Blue Roof: A roof that is designed to store rainwater, typically in a cistern-type device.

Brown Roof: A type of green roof which focuses on biodiversity and locally sourced material.

Buffer Strip or Zone: Strip of erosion-resistant vegetation over which stormwater runoff is directed.

Capacity: The capacity of a stormwater drainage facility is the flow volume or rate that the facility (e.g., pipe, basin, vault, swale, ditch, drywell, etc.) is designed to safely contain, receive, convey, reduce pollutants from, or infiltrate stormwater to meet a specific performance standard. There are different performance standards for pollution reduction, flow control, conveyance, and destination/ disposal, depending on location.

Catch Basin: Box-like underground concrete structure with openings in curbs and gutters designed to collect runoff from streets and pavements.

Check Dam: Small temporary barrier, grade control structure, or dam constructed across a swale, drainage ditch, or area of concentrated flow with the intent to slow or stop runoff.

Clean Water Act (CWA): (33 U.S.C. 1251 et seq.) requirements of the National Pollutant Discharge Elimination System (NPDES) program are defined under Sections 307, 402, 318 and 405 of the CWA.

Commercial Development: Any development on private land that is not heavy industrial or residential. The category includes, but is not limited to hospitals, laboratories and other medical facilities, educational institutions, recreational facilities, plant nurseries, multi-apartment buildings, car wash facilities, mini-malls and other business complexes, shopping malls, hotels, office buildings, public warehouses and other light industrial complexes.

Conduit: Any channel or pipe for directing the flow of water.

Construction General Permit: A NPDES permit issued by the State Water Resources Control Board (SWRCB) for the discharge of stormwater associated with construction activity from soil disturbance of one or more acres.

Control Device: A device used to hold back or direct a calculated amount of stormwater to or from a stormwater management facility. Typical control structures include vaults or manholes fitted with baffles, weirs, or orifices.

Conveyance System: Any channel or pipe for collecting and directing the stormwater.

Culvert: A covered channel or a large diameter pipe that crosses under a road, sidewalk, etc.

Dead-end Sump:A below surface collection chamber for small drainage areas that is not connected to the public storm drainage system. Accumulated water in the chamber must be pumped and disposed of in accordance with all applicable laws.

Designated Public Access Points: Any pedestrian, bicycle, equestrian, or vehicular point of access to jurisdictional channels in the area of Ventura County subject to permit requirements.

Detention: The temporary storage of stormwater runoff to allow treatment by sedimentation and metered discharge of runoff at reduced peak flow rates.

Detention Facility: A facility designed to receive and hold stormwater and release it at a slower rate, usually over a number of hours. The full volume of stormwater that enters the facility is eventually released.

Detention Tank, Vault, or Oversized Pipe: A structural subsurface facility used to provide flow control for a particular drainage basin.

Development: any construction, rehabilitation, redevelopment or reconstruction of any public or private residential project (whether single-family, multi-unit or planned unit development); industrial, commercial, retail and any other non-residential projects, including public agency projects; or mass grading for future construction. It does not include routine maintenance to maintain original line and grade, hydraulic capacity, or original purpose of facility, nor does it include emergency construction activities required to immediately protect public health and safety.

Directly Adjacent: Situated within 200 feet of the contiguous zone required for the continued maintenance, function, and structural stability of the environmentally sensitive area.

Directly Connected Impervious Area (DCIA): The area covered by a building, impermeable pavement, and/or other impervious surfaces, which drains directly into the storm drain without first flowing across permeable land area (e.g. turf buffers).

Directly Discharging: Outflow from a drainage conveyance system that is composed entirely or predominantly of flows from the subject, property, development, subdivision, or industrial facility, and not commingled with the flows from adjacent lands.

Discharge: A release or flow of Stormwater or other substance from a conveyance system or storage container.

Disturbed Area: Any area that is altered as a result of land disturbance, such as: clearing, grading, grubbing, stockpiling and excavation.

Drainage Basin: A specific area that contributes stormwater runoff to a particular point of interest, such as a stormwater management facility, drainageway, wetland, river, or pipe.

Environmentally Sensitive Area (ESA): An area “in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which would be easily disturbed or degraded by human activities and developments” (California Public Resources Code § 30107.5). Areas subject to stormwater mitigation requirements are: 303(d) listed water bodies in all reaches that are unimproved, all California Coastal Commission’s *Environmentally Sensitive Habitat Areas* as delineated on maps in Local Coastal Plans, and Regional Water Quality Control Board’s Basin Plan Rare, Threatened or Endangered Species

(RARE) and Preservation of Biological Habitats (BIOL) designated waterbodies. The California Department of Fish and Game's (CDFG) *Significant Natural Areas* map will be considered for inclusion as the department field-verifies the designated locations. Watershed restoration projects will be considered for inclusion as the department field verifies the designated locations.

Erosion: The gradual destruction of land surface by wind or water. Erosion occurs naturally from weather or runoff, but can be intensified by land-clearing practices relating to farming; residential, commercial, or industrial development; road building; or timber cutting.

Excavation: The process of removing earth, stone, or other materials, usually by digging.

Existing Urban Area: Existing urban areas and corresponding maps in Appendix B are based on the cities' City Urban Restriction Boundaries (CURB) lines and the Existing Community designation in the unincorporated County. These boundaries are a growth management tool intended to channel growth and protect agricultural and open-space land. The TGM utilizes existing urban areas (as defined in Appendix B) to provide parameters around eligibility for alternative compliance in two areas: 1) Smart Growth and 2) low-income housing projects.

Extended Detention Basin: A surface vegetated basin used to provide flow control for a particular drainage basin. Stormwater temporarily fills the extended detention basin during large storm events and is slowly released over a number of hours, reducing peak flow rates.

Facility: A collection of industrial processes discharging stormwater associated with industrial activity within the property boundary or operational unit.

Filter Fabric: Geotextile of relatively small mesh or pore size that is used to: (a) allow water to pass through while keeping sediment out (permeable); or (b) prevent both runoff and sediment from passing through (impermeable).

Filter Strip: A gently sloping, densely grassed area used to filter, slow, and infiltrate stormwater.

Flow Control Facility: Any structure or drainage device that is designed, constructed, and maintained to collect, retain, infiltrate, or detain surface water runoff during and after a storm event for the purpose of controlling post-development quantity leaving the site.

Flow-Based BMPs: Flow-based BMPs must be sized and designed to: (a) filter or treat either: 1.) the maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or 2.) the maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity (for each hour of a storm event), as determined from the local historical rainfall record, multiplied by a factor of two; and (b) be certified for “Enhanced Treatment” under the Washington State Department of Ecology’s TAPE Program; or an appropriate future BMP certification developed by the State of California.

Flow Control: The practice of limiting the release of peak flow rates, flow durations, and volumes from a site. Flow control is intended to protect downstream properties, infrastructure, and natural resources from the increased stormwater runoff flow rates and volumes resulting from development.

Grading: The cutting and/or filling of the land surface to a desired shape or elevation.

Green Roof: A roofing system that layers a soil/vegetative cover over a waterproofing membrane. Green roofs rely on highly porous media and moisture retention layers to store intercepted precipitation and to support vegetation that can reduce the volume of stormwater runoff via evapotranspiration

Hazardous Substance: (1) Any material that poses a threat to human health and/or the environment. Typical hazardous substances are toxic, corrosive, ignitable, explosive, or chemically reactive; (2) any substance named by EPA to be reported if a designated quantity of the substance is spilled in the waters of the United States or if otherwise emitted into the environment.

Hazardous Waste: By-products of society that can pose a substantial or potential hazard to human health or the environment when improperly managed. Possesses at least one of four characteristics (flammable, corrosivity, reactivity, or toxicity), or appears on special EPA lists.

Hillside: Property located in an area with known erosive soil conditions, where the development contemplates grading on any natural slope that is 25 percent or greater.

Hydrodynamic Separation: Flow-through structures with a settling or separation unit to remove sediments and other pollutants in which no outside power source is required, because the energy of the flowing water allows the sediments to efficiently separate. Depending on the type of unit, this separation may be by means of swirl action or indirect filtration.

Illegal Discharges: Any discharge to a municipal separate storm sewer that is not composed entirely of stormwater except discharges authorized by an NPDES permit (other than the NPDES permit for discharges from the municipal separate storm sewer) and discharges resulting from firefighting activities.

Impervious Surface/Area: A hard surface area which either prevents or retards the entry of water into the predevelopment soil mantle. A hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under predevelopment conditions. Common impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, parking lots or storage areas, (impermeable) concrete or asphalt paving, gravel roads, packed earthen materials, and oiled macadam or other surfaces which similarly impede the natural infiltration of storm water.

Industrial General Permit: A NPDES permit issued by the State Water Resources Control Board for the discharge of Stormwater associated with industrial activity.

Infiltration: The downward entry of water into the surface of the soil.

Integrated Pest Management Plan (IPMP): A balanced approach to pest management which incorporates many aspects of plant health care in ways that mitigate harmful environmental impacts and protect human health.

Inlet: An entrance into a ditch, storm sewer, or other waterway.

Legacy Pollutants: Pollutants that are no longer in production but remain in site soils and groundwater and still have the potential to cause ecological and water quality impacts.

Material Storage Areas: On-site locations where raw materials, products, final products, by-products, or waste materials are stored.

Maximum Extent Practicable (MEP): The technology-based permit requirement established by Congress in CWA section 402(p)(3)(B)(iii) that municipal dischargers of stormwater must meet. Technology-based requirements, including MEP, establish a level of pollutant control that is derived from available technology or other controls. MEP requires municipal dischargers to perform at maximum level that is practicable. Compliance with MEP may be achieved by emphasizing pollution prevention and source control BMPs in combination with structural and treatment methods where appropriate. The MEP approach is an ever evolving and advancing concept, which considers technical and economic feasibility.

Municipal Separate Storm Sewer System (MS4) Permit: A NPDES permit issued by the Regional Water Quality Control Board for the discharge of stormwater from Municipal Separate Storm Sewer Systems.

New Development: Land disturbing activities; structural development, including construction or installation of a building or structure, creation and replacement of impervious surfaces; and land subdivision.

Non-Stormwater Discharge: Any discharge to a municipal separate storm drain that is not composed entirely of stormwater. Discharges containing process wastewater, non-contact cooling water, or sanitary wastewater are non-stormwater discharges.

Non-Structural Source Control Measure: Low technology, low-cost activities, procedures or management practices designed to prevent pollutants associated with site functions and activities from being discharged with Stormwater runoff.

Examples include good housekeeping practices, employee training, standard operating practices, inventory control measures, etc.

Notice of Intent (NOI): A formal notice to State Water Resources Control Board submitted by the owner/developer that a construction project is about to begin. The NOI provides information on the owner, location, type of project, and certifies that the permittee will comply with the conditions of the construction general permit.

NPDES Permit: An authorization, license, or equivalent control document issued by EPA or an approved State agency to implement the requirements of the NPDES program.

Operations and Maintenance (O&M): The continuing activities required to keep storm water management facilities and their components functioning in accordance with design objectives. An O&M Plan consists of a site map, property description (i.e., owner and persons responsible for maintenance), spill plan, facility changes, training, inspection and maintenance activities, pollution mitigation measures, and monitoring and reporting requirements.

Outfall: The point where stormwater discharges from a pipe, channel, ditch, or other conveyance to a waterway.

Parking Lot: Land area or facility for the temporary parking or storage of motor vehicles used for businesses, commerce, industry, or personal use.

Permeability: A property of soil that enables water or air to move through it. Usually expressed in inches/hour or inches/day.

Permeable Pavement: A type of pavement that contains small voids which allow water to pass through to a stone base. While conventional pavements result in increased rates and volumes of surface runoff, porous pavements when properly constructed and maintained, allow some of the stormwater to percolate through the pavement and enter the soil below. When designed per standards in the TGM, permeable pavement is a type of infiltration BMP (see Section 6.3.5 and INF-5 Fact Sheet in Appendix C.5)

Pervious Surface/Area: A surface or area with a surface (i.e., soil, loose rock, permeable pavement, etc.) that allows water to infiltrate (soak) into the ground.

Planter Box: A structural facility filled with topsoil and gravel and planted with vegetation. The planter is completely sealed, and a perforated collection pipe is placed under the soil and gravel, along with an overflow provision, and directed to an acceptable destination point. The storm water planter receives runoff from impervious surfaces, which is filtered and retained for a period of time.

Pollutant: An elemental or physical material that can be mobilized or dissolved by water or air and creates a negative impact on human health and/ or the environment. Pollutants include suspended solids (sediment), heavy metals (such as lead, copper, zinc, and cadmium), nutrients (such as nitrogen and phosphorus), bacteria and viruses, organics (such as oil, grease, hydrocarbons, pesticides, and fertilizers), floatable debris, and increased temperature.

Pollutants of Concern: Constituents that have exceeded Basin Plan Objectives, and California Toxics Rule chronic or acute objectives during monitoring at mass emission, receiving water, and land use stations.

Pollution Reduction: The practice of filtering, retaining, or detaining surface water runoff during and after a storm event for the purpose of maintaining or improving surface and/or groundwater quality.

Precipitation: Any form of rain or snow.

Predevelopment: The existing land use condition prior to the proposed development activity.

Practicable: Available and capable of being done, after taking into consideration existing technology, legal issues, and logistics in light of overall project purpose.

Pre-developed Condition: The native vegetation and soils that existed at a site prior to first development. The pre-developed condition may be assumed to be the typical vegetation, soil, and stormwater runoff characteristics of open space areas in coastal Southern California unless reasonable historic information is provided that the area was atypical.

Pre-project Condition: The condition of the site at the time of the proposed project.

Pretreatment: Treatment of wastewater before it is discharged to a wastewater collection system.

Priority Development Projects: Land development projects that fall under a local permitting agency's planning and building authority which must implement LID practices that achieve flow reduction and water quality performance requirements specified in Provision VIII.F.4 of the 2021 MS4 Permit.

Process Wastewater: Wastewater that has been used in one or more industrial processes.

Project: Development, redevelopment, and land disturbing activities. The term is not limited to "project" as defined under CEQA (Reference: California Public Resources Code § 21065).

Project Area: Project area for new development and redevelopment projects is the disturbed, developed portion of a property along with the undisturbed portion(s) that drain to the disturbed portion.

Public Facility: A street, right-of-way, park, sewer, drainage, stormwater management, or other facility that is either currently owned by the City/County or will be conveyed to the City/County for maintenance responsibility after construction.

Receiving Stream: (*For purposes of this Manual only*) any natural or man-made surface water body that receives and conveys stormwater runoff.

Redevelopment: Land-disturbing activity that results in the creation, addition, or replacement of 5,000 square feet or more of impervious surface area on an already developed site. Redevelopment includes, but is not limited to: the expansion of a building footprint; addition or replacement of a structure; replacement of impervious surface area that is not part of a routine maintenance activity; and land disturbing activities related to structural or impervious surfaces. It does not include routine maintenance to maintain original line and grade, hydraulic capacity, or original purpose of facility, nor does it include emergency construction activities required to immediately protect public health and safety. Note: redevelopment as defined here is not the same as a “Redevelopment Project” as defined by California redevelopment law.

Restaurant: A stand-alone facility that sells prepared foods and/or drinks for consumption, including stationary lunch counters and refreshment stands selling prepared foods and/or drinks for immediate consumption (SIC code 5812).

Retail Gasoline Outlet: Any facility engaged in selling gasoline and lubricating oils.

Retention Facility: A facility designed to receive and hold stormwater runoff. Rather than storing and releasing the entire runoff volume, retention facilities permanently retain a portion of the water on-site, where it infiltrates, evaporates, or is absorbed by surrounding vegetation. In this way, the full volume of storm water that enters the facility is not released off-site.

Retrofit: Retrofit projects implement structural treatment BMPs as a stand-alone project, without other site improvements. The BMP sizing requirements of this Technical Guidance Manual do not apply to retrofit projects.

Runoff: Water originating from rainfall and other precipitations (e.g., sprinkler irrigation) that is found in drainage facilities, rivers, streams, springs, seeps, ponds, lakes, wetlands, and shallow groundwater.

Runon: Stormwater surface flow or other surface flow which enters property other than that where it originated.

Secondary Containment: Structures, usually dikes or berms, surrounding tanks or other storage containers and designed to catch spilled material from the storage containers.

Sedimentation: The process of depositing soil particles, clays, sands, or other sediments that were picked up by runoff.

Sediments: Soil, sand, and minerals washed from land into water usually after rain, that accumulate in reservoirs, rivers, and harbors, destroying aquatic animal habitat and clouding the water so that adequate sunlight might not reach aquatic plants.

Site: Land or water area where any "facility" or "activity" is physically located or conducted including adjacent land used in connection with the facility or activity.

Source Control BMP or Measure: Any schedules of activities, structural devices, prohibitions of practices, maintenance procedures, managerial practices or operational practices that aim to prevent stormwater pollution by reducing the potential for contamination at the source of pollution.

Source Control BMPs: Operational practices or design features that prevent pollution by reducing potential pollutants at the source.

Spill Guard: A device used to prevent spills of liquid materials from storage containers.

Spill Prevention Control and Countermeasures Plan (SPCC): Plan consisting of structures, such as curbing, and action plans to prevent and respond to spills of hazardous substances as defined in the Clean Water Act.

Storm Drains: Above and below ground structures for transporting stormwater to streams or outfalls for flood control purposes.

Storm Drain System: Network of above and below-ground structures for transporting stormwater to streams or outfalls.

Storm Event: A rainfall event that produces more than 0.1 inch of precipitation and is separated from the previous storm event by at least 72 hours of dry weather.

Stormwater Discharge Associated with Industrial Activity: Discharge from any conveyance which is used for collecting and conveying stormwater which is related to manufacturing processing or raw materials storage areas at an industrial plant [see 40 CFR 122.26(b)(14)].

Stormwater: Stormwater runoff, snow-melt runoff, surface runoff, and drainage, excluding infiltration and irrigation tailwater.

Structural BMP or Control Measure: Any structural facility designed and constructed to mitigate the adverse impacts of stormwater and urban runoff pollution (e.g. canopy, structural enclosure). The category may include both Treatment Control BMPs and Source Control BMPs.

Subsurface Infiltration: Subsurface infiltration facilities are facilities with the majority of runoff is stored in the void space within the gravel or subsurface drainage structure and infiltrated through the sides and the bottom of the facility.

Total Suspended Solids (TSS): Matter suspended in stormwater excluding litter, debris, and other gross solids exceeding 1 millimeter in diameter.

Treatment: The application of engineered systems that use physical, chemical, or biological processes to remove pollutants. Such processes include, but are not limited to, filtration, gravity settling, media adsorption, biodegradation, biological uptake, chemical oxidation, and UV radiation.

Tributary Area: The area from which all runoff produced flows to the same specific discharge point.

Vegetated Facilities: Stormwater management facilities that rely on plantings to enhance their performance. Plantings can provide wildlife habitat and enhance many facility functions, including infiltration, pollutant removal, water cooling, flow calming, and prevention of erosion.

Vegetated Swale: A long and narrow, trapezoidal or semicircular channel, planted with a variety of trees, shrubs, and grasses or with a dense mix of grasses. Stormwater runoff from impervious surfaces is directed through the swale, where it is slowed and, in some cases, infiltrated, allowing pollutants to settle out. Check dams are often used to create small ponded areas to facilitate infiltration.

APPENDIX B: MAPS

General Mapping Information

Interactive versions of the map layers listed below are available on the Ventura County Public Works Agency map viewer located at the following link: https://maps.ventura.org/pwagisviewer/. Select the 'Map' tab along the top ribbon. Use the ‘Filter Layer’ at the top of the layers list to search for applicable layers. For example, searching for "Rainfall 85th Percentile" will provide the 85th percentile, 24-hour rain event. Map/layer names may vary slightly on map viewer.

Images of the first two maps listed, the 85th *Percentile, 24-Hour Design Storm Depth* and the *Ventura County Soils Classification* are included herein as quick references for illustration purposes only. Project applicants shall refer to the online maps for information specific to a project site.

- Ventura County 85th Percentile, 24-Hour Storm Depths (Figure B-1)
- Ventura County Soils (Figure B-2)
- Basemap information (City Boundaries, Streets, Rivers, Streams)
- County Unincorporated Urban Infill Areas
- Environmentally Sensitive Habitat Areas (ESHA)
- HUC10 – Hydrologic Boundaries
- 303(d) Listed Waterbodies

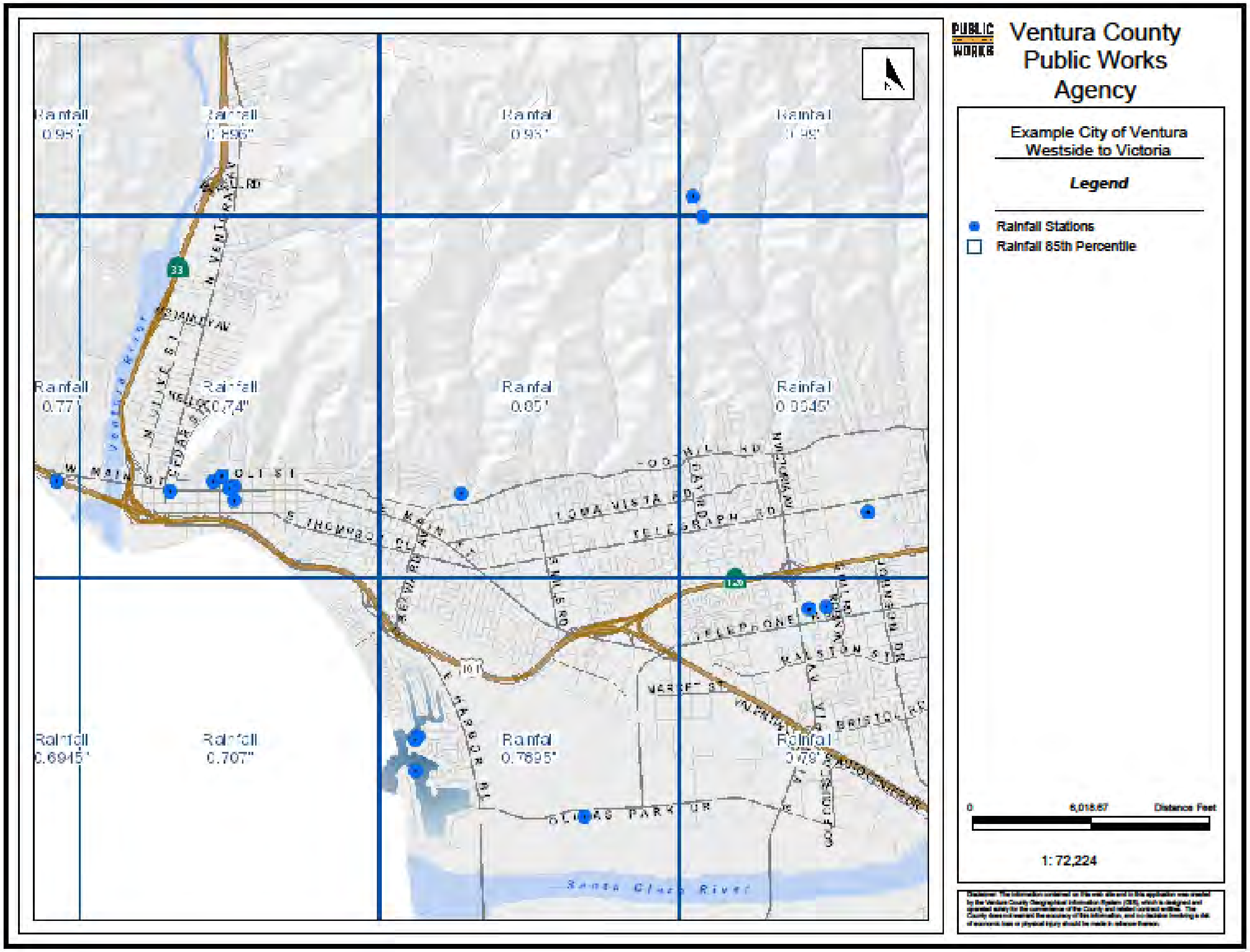


Figure B-1 Example portion City of Ventura - Ventura County 85th Percentile 24-Hour Storm Depths

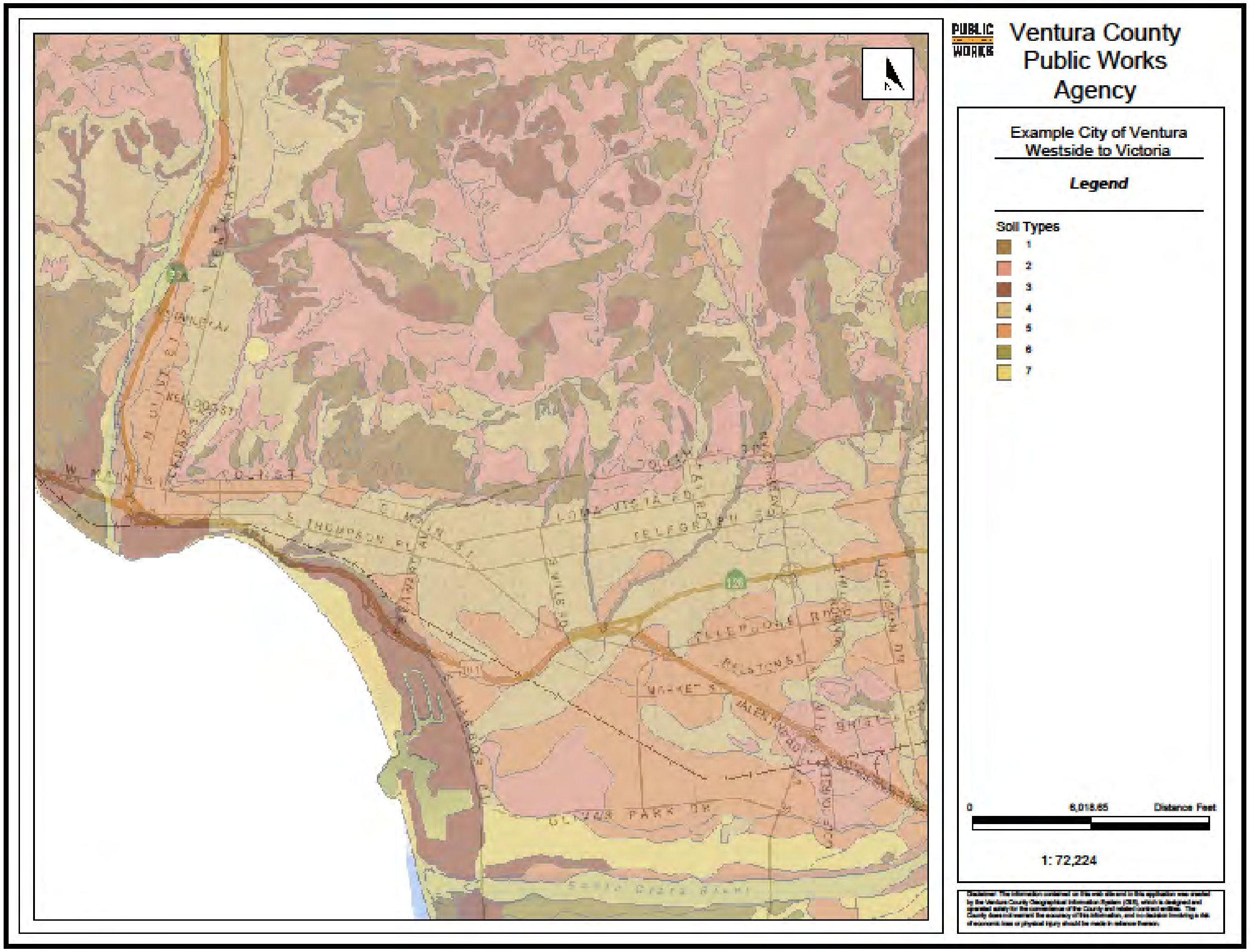


Figure B-2 Example portion City of Ventura - Ventura County Soil Types

APPENDIX C: BMP SIZING WORKSHEETS

C.1 Structural Treatment BMP Sizing Criteria

The BMP sizing criteria for determining the design volume or design flow for a proposed BMP are discussed in this appendix. These criteria must be used for all stormwater BMPs installed in new and re-development projects in Ventura County. This section outlines the rainfall analyses, Ventura County MS4 Permit sizing criteria, and recommended sizing methods for both volumetric and flow-based analysis.

Sizing Criteria

The type of rainfall analysis required depends on whether the BMP is a volume-based or flow-based BMP. This distinction between volume-based and flow-based controls is not always clear, especially in a sequence of BMPs or a treatment train. The following are general guidelines for each type of control.

- Volume-based BMPs are designed to treat a volume of runoff, which is detained for a certain period of time to allow for the settling of solids and associated pollutants. Volume-based BMPs included in this manual are bioretention, planter boxes, infiltration systems, and retention/detention BMPs.
- Flow-based BMPs treat water on a continuous flow basis. Flow-based BMPs included in this manual are vegetated swales, filter strips, filtration systems, and hydrodynamic devices.

The water quality design volume (SQDV) for volume-based BMPs must be determined using the following options, *whichever is greater*:

1) The runoff from the 0.75-inch, 24-hour rain event; or

2) The runoff from the 85th percentile, 24-hour rain event.

If approved for use, flow-based BMPs must be designed to filter or treat the water quality design flow rate (SQDF) generated from one of the following criterion:

1) The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or

2) The maximum flow rate of runoff produced by the 85^{th} percentile hourly rainfall intensity (for each hour of a storm event), as determined from the local historical rainfall record, *multiplied by a factor of two*.

Determining the Water Quality Design Volume (SQDV)

Equation C-2 can be used to determine the water quality design volume.

Calculation Procedure

1) Determine the composite runoff coefficient ("runoff coefficient") per the following method:

$$C = 0.95*imp + C_p (1-imp) \quad \text{(Equation C-1)}$$

Where:

C	=	runoff coefficient
imp	=	impervious fraction of project area
C_p	=	pervious runoff coefficient, determined using table below

Table C-1: Pervious Runoff Coefficient

Land Use	Cp value or range(1)
Unimproved Areas, based on the Ventura Soil Type	
Soil Number 1	0.15
Soil Number 2-3	0.10
Soil Number 4-5	0.05
Soil Number 6-7	0
Lawns	
Sandy soil, flat, 2%	0.05 – 0.10
Sandy soil, avg., 2-7%	0.10 – 0.15
Sandy soil, steep, 7%	0.15 - 0.20
Heavy soil, flat, 2%	0.13 – 0.17
Heavy soil, avg., 2-7%	0.18 – 0.22
Heavy soil, steep, 7%	0.25 – 0.35
Agricultural Land	
Bare packed soil	
Smooth	0.30 - 0.60
Rough	0.20 - 0.50
Cultivated Rows	
Heavy soil, no crop	0.30 - 0.60
Heavy soil, with crop	0.20 - 0.50
Sandy soil, no crop	0.20 – 0.40

Sandy soil, with crop	0.10 – 0.25
Pasture	
Heavy soil	0.15 – 0.45
Sandy soil	0.05 – 0.25
Woodlands	0.05 – 0.25
Miscellaneous	
Parks & cemeteries	0.10 – 0.25
Playgrounds	0.20 – 0.35
Railroad yard areas	0.20 – 0.40

(1) The designer must use judgment to select the appropriate "C" value within the range. Generally, larger areas with permeable soils, flat slopes and dense vegetation should have the lowest "C" values. Smaller areas with dense soils, moderate to steep slopes, and sparse vegetation should assign the highest "C" values.

3) The volume can be calculated using Equation C-2 below:

$$SQDV = C*(P/12)*A_{project} \quad \text{(Equation C-2)}$$

Where:

SQDV	=	the water quality design volume (acre-feet)
C	=	runoff coefficient, calculated as C = 0.95*imp + C_p (1-imp) (Equation C-1 (unitless)
P	=	the design rainfall depth (in), either the 0.75-inch or the 85th percentile 24-hour rain event, whichever is greater for the project location. Refer to the *Ventura County 85th Percentile Rain Depths Map* in Appendix B-2.
$A_{project}$	=	the total project area (acres)

Methods for Determining the Water Quality Design Flow

Each of the flow-based sizing alternatives is described in detail below.

<u>Method 1: Runoff Produced by 0.2 Inches per Hour Rainfall Intensity</u>

The rainfall analysis for flow-based controls focuses on estimating the design rainfall intensity, which is then converted to a design flow rate using the rational method shown in Equation C-3.

$$SQDF = CiA_{project} \quad \text{(Equation C-3)}$$

Where:

SQDF	=	design flow rate (cfs)
C	=	runoff coefficient, calculated using Equation C-1 (unitless)
i	=	rainfall intensity (in/hr) (0.2 in/hr)
$A_{project}$	=	total project area (acres)

Note that 1 acre-in/hr = 1.0083 cfs; this conversion factor can be used with Equation C-3, but is not necessary as the uncertainty for the other parameters is generally well above 0.8%.

Method 2: Runoff Produced by Twice the 85th Percentile Rainfall Intensity

This method is analogous to the rational method used in Method 1, except that twice the historical 85th percentile rainfall intensity for the site location is used for the design rainfall intensity. This method is expected to result in a higher design rainfall intensity and design flow rate compared to Method 1 for most of the rain gages in the District.

References

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Schueler, T., 1987. "Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs," Publication No. 87703, Metropolitan Washington Council of Governments, Washington, DC.

WEF Manual of Practice No. 23/ASCE Manual and Report on Engineering Practice No. 87, 1998: Urban Runoff Quality Management.

C.2 Design Percolation Rate Safety Factors for Infiltration BMPs

When designing infiltration BMPs (INF-1 through INF-7) it is important to account for the fact that the percolation rate of underlying soils will not be reliably consistent across an infiltration BMP due to variability in site soil conditions. In addition, percolation rates will decline between maintenance cycles as the surface becomes occluded and particulates accumulate in the infiltrative layer. Monitoring actual facility performance has shown that the full-scale infiltration rate is often far lower than the rate measured by small-scale testing; therefore, it is important that adequate conservatism is incorporated in the selection of design percolation rates. The design percolation rate discussed here is the percolation rate of the soils underlying the facility and not the percolation rate of the treatment media bed (refer to the "Geometry and Sizing" section of the facility Fact Sheets in Section 6.3 for the recommended composition of the media layers for each type of facility).

Considerations for Design Percolation Rate Corrections

Suitability assessment related considerations include:

- **Soil assessment methods** – the site assessment extent (e.g., number of borings, test pits, etc.) and the measurement method used to estimate the short-term infiltration rate.
- **Predominant soil texture/percent fines** – soil texture and the percent fines can greatly influence the potential for clogging.
- **Site soil variability** – sites with spatially heterogeneous soils (vertically or horizontally), as determined from site investigations, are more difficult to estimate average properties resulting in a higher level of uncertainty associated with initial estimates.
- **Depth to seasonal high groundwater/impervious layer** – groundwater mounding may become an issue during excessively wet conditions where shallow aquifers or shallow clay lenses are present.

Table C-2: Suitability Assessment Related Considerations for Infiltration Facility Safety Factors

Consideration	High Concern	Medium Concern	Low Concern
Assessment methods	Use of soil survey maps or simple texture analysis to estimate short-term infiltration rates. *Factor Value (v)= 3*	Direct measurement of ≥ 20 percent of infiltration area with localized infiltration measurement methods (e.g., infiltrometer) *Factor Value (v)= 2*	Direct measurement of ≥ 50 percent of infiltration area with localized infiltration measurement methods or Use of extensive test pit infiltration measurement methods *Factor Value (v)= 1*
Ventura Hydrology Manual soil number (measured infiltration rate)	3 (f = 0.5 – 0.64) *Factor Value (v) = 3*	4 or 5 (f = 0.65 –0.91) *Factor Value (v)= 2*	6 or 7 (f = 0.92 or higher) *Factor Value (v)= 1*
Site soil variability	Highly variable soils indicated from site assessment or limited soil borings collected during site assessment. *Factor Value (v) = 3* *Example Guidance:* Three or more soil units/layers with substantially different infiltration properties (i.e., different texture class) are present in the locations/strata where the BMP will infiltrate. or Limited soil borings are collected during site assessment (2 or less) near the BMP, resulting in uncertainty about soil variability.	Soil borings/test pits indicate moderately homogeneous soils *Factor Value (v)= 2* *Example Guidance:* 2 to 3 soil units/layers with substantially different infiltration properties are present in the locations/strata where the BMP will infiltrate and 2 to 3 more borings are collected near the BMP to assess variability and define extents of units/layers.	Multiple soil borings/test pits indicate relatively homogeneous soils *Factor Value (v)= 1* *Example Guidance:* Soils units/layers near the BMP have similar properties and 3 or more borings are collected near BMPs to confirm homogeneity
Depth to groundwater/ impervious layer	<10 ft below facility bottom *Factor Value (v)=3*	10-30 ft below facility bottom *Factor Value (v)= 2*	>30 below facility bottom *Factor Value (v)= 1*

Localized infiltration testing refers to methods such as the double ring infiltrometer test (ASTM D3385-88), which measure infiltration rates over an area less than 10 sq-ft and do not attempt to account for soil heterogeneity. Extensive infiltration testing refers to methods that include excavating a significant portion of the proposed infiltration area, filling the excavation with water, and monitoring drawdown. In all cases, testing should be conducted in the area of the proposed BMP where, based on geotechnical data, soils appear least likely to support infiltration. Refer to the Los Angeles County Public Works Guidelines for Geotechnical Investigation and Reporting Low Impact Development Stormwater Infiltration (June 30, 2021, and subsequent versions) for specifics on the different infiltration testing methods.

Design related considerations include (Table C-3):

- Size of area tributary to facility – both physical and economic risk factors related to infiltration facilities increase with an increase in the tributary area served. Therefore, facilities serving larger tributary areas should use more restrictive adjustment factors.

- Level of pretreatment/expected influent sediment loads – credit should be given for good pretreatment by allowing less restrictive factors to account for the reduced probability of clogging from high sediment loading. Also, facilities designed to capture runoff from relatively clean surfaces such as rooftops are likely to see low sediment loads and therefore should be allowed to apply less restrictive safety factors.

- Redundancy – facilities that consist of multiple subsystems operating in parallel such that parts of the system remains functional when other parts fail and/or bypass, should be rewarded for the built-in redundancy with less restrictive correction and safety factors. For example, if bypass flows are at least partially treated by another BMP, the risk of discharging untreated runoff in the event of clogging the primary facility is reduced. A bioretention facility that overflows to a landscaped area is another example. Compaction during construction – proper construction oversight is needed during construction to ensure that the bottoms of infiltration facility are not overly compacted. Facilities that do not commit to proper construction practices and oversight should have to use more restrictive correction and safety factors.

Table C-3: Design Related Considerations for Infiltration Facility Safety Factors

Consideration	High Concern	Medium Concern	Low Concern
Tributary area size	Greater than 10 acres. *Factor Value (v)= 3*	Greater than 2 acres but less than 10 acres. *Factor Value (v)= 2*	2 acres or less. *Factor Value (v)= 1*
Level of pre-treatment/ expected influent sediment loads	Pre-treatment from gross solids removal devices only, such as hydrodynamic separators, racks and screens, AND tributary area includes landscaped areas, steep slopes, high traffic areas, or any other areas expected to produce high sediment, trash, or debris loads. *Factor Value (v)= 3*	Good pre-treatment with BMPs that mitigate coarse sediments such as vegetated swales AND influent sediment loads from the tributary area are expected to be relatively low (e.g., low traffic, mild slopes, disconnected impervious areas, etc.). *Factor Value (v)= 2*	Excellent pre-treatment with BMPs that mitigate fine sediments such as bioretention or media filtration OR sedimentation or facility only treats runoff from relatively clean surfaces, such as rooftops. *Factor Value (v)= 1*
Redundancy of treatment	No redundancy in BMP treatment train. *Factor Value (v)= 3*	Medium redundancy, other BMPs available in treatment train to maintain at least 50% of function of facility in event of failure. *Factor Value(v)= 2*	High redundancy, multiple components capable of operating independently and in parallel, maintaining at least 90% of facility functionality in the event of failure. *Factor Value (v)= 1*
Compaction during construction	Construction of facility on a compacted site or elevated probability of unintended/ indirect compaction. *Factor Value (v)= 3*	Medium probability of unintended/ indirect compaction. *Factor Value (v)= 2*	Heavy equipment actively prohibited from infiltration areas during construction and low probability of unintended/ indirect compaction. *Factor Value (v)= 1*

Adjust the measured short-term infiltration rate using a weighted average of several safety factors using the worksheet shown below in **Table C-4**. The design percolation rate would be determined as follows:

- For each consideration shown in Table C-2 and Table C-3 above, determine whether the consideration is a high, medium, or low concern.
- For all high concerns, assign a factor value of 3, for medium concerns, assign a factor value of 2, and for low concerns assign a factor value of 1.

- Multiply each of the factors by the corresponding weight to get a product.
- Sum the products within each factor category to obtain a safety factor for each.
- Multiply the two safety factors together to get the final combined safety factor. If the combined safety factor is less than 2, then use 2 as the safety factor.
- Divide the measured short-term infiltration rate by the combined safety factor to obtain the adjusted design percolation rate for use in sizing the infiltration facility.

Table C-4: Infiltration Facility Safety Factor Determination Worksheet

Factor Category		Factor Description	Assigned Weight (w)	Factor Value (v)	Product (p) $p = w \times v$
A	Suitability Assessment	Soil assessment methods	0.25		
		Predominant soil texture	0.25		
		Site soil variability	0.25		
		Depth to groundwater / impervious layer	0.25		
		Suitability Assessment Safety Factor, $S_A = \Sigma p$			
B	Design	Tributary area size	0.25		
		Level of pre-treatment/ expected sediment loads	0.25		
		Redundancy	0.25		
		Compaction during construction	0.25		
		Design Safety Factor, $S_B = \Sigma p$			
Combined Safety Factor = $S_A \times S_B$					

Note: The minimum combined adjustment factor shall not be less than 2.0 and the maximum combined adjustment factor shall not exceed 9.

C.3 INF-1 Infiltration Basin/ INF-2 Subsurface Infiltration / INF-4 Drywell

This worksheet can be used for sizing INF-1 infiltration basins, INF-2 subsurface infiltration, or INF-4 drywells. An infiltration basin is an earthen basin constructed into naturally pervious soils which retains the SQDV and allows the retained runoff to percolate into the underlying native soils over a specified period of time. Subsurface infiltration facilities are facilities with the majority of runoff is stored in the void space within the gravel or subsurface drainage structure and infiltrated through the sides and the bottom of the facility. Drywells are similar to subsurface infiltration, but the geometry and materials are slightly different. A drywell may be either a small, excavated pit filled with aggregate or a prefabricated storage chamber or pipe segment, with the depth of the drywell greater than the width.

Sizing Methodology

The sizing procedures provided below can be used for all three types of facilities.

Step 1: Calculate the design volume

Infiltration facilities shall be sized to capture and infiltrate the SQDV volume (see Section 2) with a 12 - 72 hour drawdown time (see Appendix C.1).

Step 2: Determine the BMP Design Percolation Rate

The percolation rate will decline between maintenance cycles as particulates accumulate in the infiltrative layer and the surface becomes occluded. Additionally, monitoring of actual facility performance has shown that the full-scale infiltration rate is far lower than the rate measured by small-scale testing. It is important that adequate conservatism is incorporated in the selection of design percolation rates. For infiltration BMPs, the design percolation rate discussed here is the percolation rate of the underlying soils, which will ultimately drive infiltration through the BMP, and not the percolation rate of the filter media bed (refer to the "Geometry and Sizing" section of INF-2 for the recommended composition of the filter media bed for subsurface infiltration). See Section C.2 for guidance in developing design percolation rate correction factors.

Step 3: Calculate Surface Area

Determine the size of the required infiltrating surface by assuming the SQDV will fill the available ponding depth plus (for subsurface infiltration/ drywells with aggregate) the void spaces within the filter media based on the computed porosity of the media (normally about 32%).

1) Determine the maximum depth of runoff that can be infiltrated within the required drain time as follows:

$$d_{\max} = \frac{P_{design}}{12} t \quad \text{(Equation C-4)}$$

Where:

d_{max} = the maximum depth of water that can be infiltrated within the required drain time (ft)

P_{design} = design percolation rate of underlying soils (in/hr)

t = required drain time (hrs)

2) Choose the ponding depth (d_p) and/or trench depth (d_t) such that:

$d_{\max} \geq d_p$ For Infiltration Basins (Equation C-5)

$d_{\max} \geq n_t d_t + d_p$ For Subsurface infiltration or aggregate-filled drywells (Equation C-6)

Where:

d_{max} = the maximum depth of water that can be infiltrated within the required drain time (ft)

d_p = ponding depth (ft)

n_t = subsurface infiltration/drywell fill aggregate porosity (unitless)

d_t = depth of trench/drywell filter media (ft)

3) Calculate infiltrating surface area (filter bottom area) required:

$$A = \frac{SQDV}{((TP_{design}/12) + d_p)}$$ For infiltration basins (Equation C-7)

$$A = \frac{SQDV}{((TP_{design}/12) + n_t d_t + d_p)}$$ For subsurface infiltration or aggregate-filled drywells (Equation C-8)

Where:

$SQDV$ = stormwater quality design volume (ft^3)

n_t = trench fill aggregate porosity (unitless)

P_{design} = design percolation rate (in/hr)

d_p = ponding depth (ft)

d_t = depth of trench filter media (ft)

T = fill time (time to fill to max ponding depth with water) (hrs) [use 2 hours for most designs]

Step 4: Size the forebay (applies to infiltration basins and trenches)

Infiltration facilities require pre-treatment to reduce sediment load into the basin. If a separate pre-treatment unit is not used, a forebay should be constructed for the facility. If a forebay is used, all inlets must enter the sediment forebay. The sediment forebay must be sized to 25% of the basin volume. The forebay must have interior slopes no steeper than 4:1.

1) Calculate the volume of the sediment forebay:

$$V_{forebay} = 0.25 \times SQDV \qquad \text{(Equation C-9)}$$

Where:

$V_{forebay}$ = Volume of sediment forebay

SQDV = Stormwater Quality Design Volume of Infiltration Basin

2) Select the depth of forebay, $d_{forebay}$.

3) Determine bottom surface area of forebay:

$$A_{forebay} = \frac{V_{forebay}}{d_{forebay}} \qquad \text{(Equation C-10)}$$

Where:

$A_{forebay}$ = Bottom surface area of forebay

$V_{forebay}$ = Volume of forebay

$d_{forebay}$ = Depth of forebay

4) Size forebay outlet pipe. Pipe must be 8 inches in diameter, minimum, and must be sized such that the forebay drains completely within 10 minutes.

Step 5: Provide conveyance capacity for filter clogging

The infiltration facility should be placed off-line, but an emergency overflow must still be provided in the event the filter becomes clogged. Spillway and overflow structures should be designed in accordance with applicable standards of the Ventura County Flood Control District or local jurisdiction.

Sizing Worksheet - INF-1 Infiltration Basin/ INF-2 Subsurface Infiltration / INF-4 Drywell

Designer: Project Proponent: Date: Project: Location:		
Type of Vegetation: (Check type used or describe “Other”)	___ Native Grasses ___ Irrigated Turf Grass ___ Other	
Pretreatment Feature:		
Outflow Collection:		
Step 1: Determine water quality design volume		
1-1. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ =	acres
1-2. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =	
1-5. Enter design rainfall depth of the storm (in), P_i	P_i =	in
1-6. Calculate rainfall depth (ft), $P = P_i/12$	P =	ft
1-7. Calculate water quality design volume (ft^3), $SQDV=43560 \times C*P*A_{project}$	SQDV=	ft^3
Step 2: Determine the design percolation rate		
2-1. Enter measured soil infiltration rate (in/hr, 0.3 in/hr min.), $P_{measured}$	$P_{measured}$ =	in/hr
2-2. Determine percolation rate correction factor, S_A based on suitability assessment (see Appendix C.2)	S_A =	
2-3. Determine percolation rate correction factor, S_B based on design (see Appendix C.2)	S_b =	
2-4. Calculate combined safety factor, $S = S_A \times S_b$	S =	

2-5. Calculate the design percolation rate (in/hr), $P_{design} = P_{measured}/S$	P_{design} =	in/hr
Step 3: Calculate the surface area		
3-1. Enter required drain time (hours,72 hrs max.), t	t =	hrs
3-2. Calculate max. depth of runoff that can be infiltrated within the t (ft), $d_{max} = P_{design}\ t/12$	d_{max} =	ft
3-3. For basins, select ponding depth (ft), d_p, such that $d_p \leq d_{max}$	d_p =	ft
3-4. For trenches, enter trench fill aggregate porosity, n_t	n_t =	
3-5. For trenches, enter depth of trench fill (ft), d_t	d_t =	ft
3-5. For trenches, select ponding depth d_p such that $d_p \leq d_{max} - n_t d_t$	d_p=	ft
3-6. Enter the time to fill infiltration basin or trench with water (Use 2 hours for most designs), T	T =	hrs
3-7. Calculate infiltrating surface area for infiltration basin (ft^2): $A_b = SQDV/((T\ P_{design}/12)+d_p)$ OR Calculate infiltrating surface area for subsurface infiltration facilities or aggregate- filled drywells (ft^2): $A_t = SQDV/((T\ P_{design}/12)+n_t d_t+dp)$	A_b = A_t =	ft^2 ft^2
Step 4: Size the forebay (infiltration basins or trenches)		
If a separate pre-treatment unit is designed for the infiltration facility, skip to Step 5. If not, continue through 4-1 through 4-4.		
4-1. Calculate the volume of the forebay (ft^3), $V_{forebay}$=0.25*SQDV	$V_{forebay}$= =	ft^3
4-2. Determine forebay depth (ft), $d_{forebay}$	$d_{forebay}$=	ft
4-3. Calculate forebay bottom surface area (ft^2), $A_{forebay}=V_{forebay}/d_{forebay}$	$A_{forebay}$=	ft^2
4-4. Provide outlet pipe such that the forebay drains to the infiltration facility within 10 minutes.		
Step 5: Provide conveyance capacity for filter clogging		
5-1.The infiltration facility should be placed off-line, but an emergency overflow must still be provided in the event the filter becomes clogged. Design emergency overflow in accordance with applicable standards of the Ventura County Flood Control District or local jurisdiction.		

Design Example

Step 1: Determine water quality design volume

For this design example, a 10-acre residential development with a 60% total impervious area is considered to drain to an infiltration basin. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine Water Quality Design Volume			
1-1. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	A =	10	acres
1-2. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	0.6	
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	0.05	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p (1\text{-}imp)$	C =	0.59	
1-5. Enter design rainfall depth of the storm (in), P_i	P_i =	0.75	in
1-6. Calculate rainfall depth (ft), $P = P_i/12$	P =	0.06	ft
1-7. Calculate water quality design volume (ft^3), $SQDV=43560 \times C*P*A_{project}$	SQDV =	15,420.2	ft^3

Step 2: Calculate Design Percolation Rate

Infiltration facilities require a minimum soil infiltration rate of 0.3 in/hr. If the rate exceeds 2.4 in/hr as in this example, then the runoff should be fully treated in an upstream BMP prior to infiltration to protect the groundwater quality.

Step 2: Determine the Design Percolation Rate			
2-1. Enter measured soil infiltration rate (0.3 in/hr min.), $P_{measured}$	$P_{measured}$ =	4.0	in/hr
2-2. Determine percolation rate correction factor, S_A, based on suitability assessment (see Appendix C.2)	S_A =	3	
2-3. Determine percolation rate correction factor, S_B, based on design (see Appendix C.2)	S_b =	3	
2-4. Calculate combined safety factor, $S = S_A \times S_b$	S =	9	
2-5. Calculate the design percolation rate, $P_{design} = P_{measured}/S$	P_{design} =	0.44	in/hr

Step 3: Determine Facility Size

The size of the infiltrating surface is determined by assuming the SQDV will fill the available ponding depth (plus the void spaces of the computed porosity (usually about 32%) of the gravel in the trench).

Step 3: Calculate the Surface Area			
3-1. Enter drawdown time (72 hrs max.), t_d	t =	72	hrs
3-2. Calculate max. depth of runoff that can be infiltrated within the *drawdown time*, $d_{max} = P_{design}\ t/12$	d_{max}=	2.64	ft
3-3. Enter trench fill aggregate porosity, n_t	n_t=	0.32	
3-4. Enter depth of trench fill, d_t	d_t =	4	ft
3-5. Select trench ponding depth d_p such that $d_p \leq d_{max} - n_t d_t$	d_p=	1.1	ft
3-6. Enter the time to fill infiltration basin or trench with water (Use 2 hours for most designs), *T*	T =	2	hrs
3-7. Calculate infiltrating surface area for infiltration basin: $A_b = SQDV/((T\ P_{design}\ /12)+d_p)$	A_b =	13,142.2	ft^2

Step 4: Size the Forebay

A sediment forebay will be provided for this example as there is no separate pre-treatment unit provided.

Step 4: Size the forebay			
4-1. Calculate the volume of the forebay, $V_{forebay}$=0.25*SQDV	$V_{forebay}$=	3,855.1	ft^3
4-2. Determine forebay depth, $d_{forebay}$	$d_{forebay}$=	3	ft
4-3. Calculate forebay bottom surface area, $A_{forebay}=V_{forebay}/d_{forebay}$	$A_{forebay}$=	1,285	ft^2
4-4. Provide outlet pipe such that the forebay drains to the infiltration facility within 10 minutes.			

Step 5: Provide Conveyance Capacity for Flows Higher than Qwq

The infiltration facility should be placed off-line, but an emergency overflow for flows greater than the peak design storm must still be provided in the event the filter becomes clogged. Design emergency overflow in accordance with applicable standards of the Ventura County Flood Control District or local jurisdiction.

C.4 INF-3 Bioretention

Sizing Methodology

A bioretention sizing worksheet and example are provided in this appendix. The runoff entering the facility must completely drain the ponding area within 48 hours, and runoff must be completely infiltrated within 72 hours. Bioretention is to be sized, with or without underdrains, such that the SQDV will fill the available ponding depth, the void spaces in the planting soil, and the optional gravel layer below the media.

Step 1: Determine the stormwater quality design volume (SQDV)

Bioretention areas should be sized to capture and treat the water quality design volume (see Appendix C.1).

Step 2: Determine the design percolation rate

The percolation rate will decline between maintenance cycles as particulates accumulate in the infiltrative layer and the surface becomes occluded. Additionally, monitoring of actual facility performance has shown that the full-scale infiltration rate is far lower than the rate measured by small-scale testing. It is important that adequate conservatism is incorporated in the selection of design percolation rates. For infiltrating bioretention facilities, the design percolation rate discussed here is the percolation rate of the underlying soils, which will drive infiltration through the facility. See Section C.2 for guidance in developing design percolation rate correction factors.

Step 3: Calculate the bioretention surface area

1) Determine the maximum depth of surface ponding that can be infiltrated within the required surface drain time:

$$d_{\max} = \frac{P_{design} \times t_{ponding}}{12\frac{in}{ft}} \qquad \text{(Equation C-11)}$$

Where:

$t_{ponding}$	=	required drain time of surface ponding (48 hrs)
P_{design}	=	design percolation rate of underlying soils (in/hr) (see Step 2, above)
d_{max}	=	the maximum depth of surface ponding water that can be infiltrated within the required drain time (ft)

2) Choose surface ponding depth (dp) such that:

$$d_p \le d_{\max} \quad \text{(Equation C-12)}$$

Where:

d_p = selected surface ponding depth (ft)

d_{max} = the maximum depth of water that can be infiltrated within the required drain time (ft)

3) Choose thickness(es) of amended media and aggregate layer(s) and calculate total effective storage depth of the bioretention area as follows:

$$d_{effective} \le d_p + n^*_{media} l_{media} + n_{gravel} l_{gravel} \quad \text{(Equation C-13)}$$

Where:

$d_{effective}$ = total equivalent depth of water stored in bioretention area (ft)

d_p = surface ponding depth (ft)

n^*_{media} = available porosity of amended soil media (ft/ft), approximately 0.25 ft/ft accounting for antecedent moisture conditions

l_{media} = thickness of amended soil media layer (ft)

n_{gravel} = porosity of optional gravel layer (ft/ft), approximately 0.30 ft/ft

l_{gravel} = thickness of optional gravel layer (ft)

4) Check that entire effective depth (surface plus subsurface storage) infiltrates in no greater than 72 hours as follows:

$$t_{total} = \frac{d_{effective}}{P_{design}} \times 12 \frac{in}{ft} \le 72\ hr \quad \text{(Equation C-14)}$$

Where:

$d_{effective}$ = total equivalent depth of water stored in bioretention area (ft)

P_{design} = design percolation rate of underlying soils (in/hr) (see Step 2, above)

If t_{total} > 72 hrs, then reduce surface ponding depth and/or amended media thickness and/or gravel thickness and return to Step [A].

If $t_{total} \le$ 72 hrs, then proceed to Step [E].

5) Calculate required infiltrating surface area (filter bottom area):

$$A_{req} = \frac{SQDV}{d_{effective}} \quad \text{(Equation C-15)}$$

Where:

SQDV = stormwater quality design volume (ft3)

Step 4: Calculate the bioretention total footprint

Calculate total footprint required by including a buffer for side slopes and freeboard; A_{req} is measured at the as the filter bottom area (toe of side slopes).

Step 5: Provide conveyance capacity for filter clogging

The infiltration facility should be placed off-line, but an emergency overflow must still be provided in the event the filter becomes clogged. Spillway and overflow structures should be designed in accordance with applicable standards of the Ventura County Flood Control District or local jurisdiction.

Sizing Worksheet - INF-3 Bioretention

Designer: Project Proponent: Date: Project: Location:	
Type of Vegetation:	
Pretreatment Feature:	
Outflow Collection:	
Step 1: Determine water quality design volume	
1-1. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ = acres
1-2. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =
1-5. Enter design rainfall depth of the storm (in), P_i	P_i = in
1-6. Calculate rainfall depth (ft), $P = P_i/12$	P = ft
1-7. Calculate water quality design volume (ft^3), $SQDV=43560×C*P*A_{project}$	SQDV= ft^3
Step 2: Determine the design percolation rate	
2-1. Enter measured soil infiltration rate (in/hr) (0.3 in/hr minimum), $P_{measured}$	$P_{measured}$ = in/hr
2-2. Determine percolation rate correction factor, S_A based on suitability assessment (see Section 6 INF-3)	S_A =
2-3. Determine percolation rate correction factor, S_B based on design (see Section 6 INF-3)	S_B =
2-4. Calculate combined safety factor, $S = S_A \times S_b$	S =
2-5. Calculate the design percolation rate (in/hr), $P_{design} = P_{measured}/S$	P_{design} = in/hr

Step 3: Calculate Bioretention Infiltrating surface area		
3-1. Enter water quality design volume (ft^3), *SQDV*	SQDV =	ft^3
3-2. Enter design percolation rate (in/hr), P_{design}	P_{design} =	in/hr
3.3 Enter the required drain time (48 hours), $t_{ponding}$	$t_{ponding}$ =	hours
3-3. Calculate the maximum depth of surface ponding that can be infiltrated within the required drain time (ft): $d_{max} = (P_{design} \times t_{ponding})/12$	d_{max} =	ft
3-4. Select surface ponding depth (ft), d_p, such that $d_p \leq d_{max}$	d_p =	ft
3-5. Select thickness of amended media (ft,2 feet minimum, 3 preferred), l_{media}	l_{media} =	ft
3-6. Enter porosity of amended media (roughly 25% or 0.25 ft/ft), n_{media}	n_{media}=	ft/ft
3-7. Select thickness of optional gravel layer (ft), l_{gravel}	l_{gravel} =	ft
3-8. Enter porosity of gravel (roughly 30% or 0.3 ft/ft), n_{gravel}	n_{gravel}=	ft/ft
3-9. Calculate the total effective storage depth of bioretention facility (ft): $d_{effective} \leq (d_p + n_{media} l_{media} + n_{gravel} l_{gravel})$	$d_{effective}$=	ft
3-10. Check that the entire effective depth infiltrates in required drainage time, 72 hours: $t_{total} = (d_{effective}/P_{design}) \times 12$ If t_{total} > 72 hours, reduce surface ponding depth and/or amended media thickness and/or gravel thickness and return to 3-4. If $t_{total} \leq$ 72 hours, proceed to 3-11.	t_{total} =	hours
3-11. Calculate the required infiltrating surface area (ft^2): $A_{req} = SQDV/d_{effective}$	A_{req} =	ft^2
Step 4: Calculate Bioretention Area Total Footprint		
4-1. Calculate total footprint required by including a buffer for side slopes and freeboard (ft^2) [A_{req} is measured at the as the filter bottom area (toe of side slopes)], A_{tot}	A_{tot} =	ft^2
Step 5: Provide conveyance capacity for filter clogging		
5-1.The infiltration facility should be placed off-line, but an emergency overflow must still be provided in the event the filter becomes clogged. Design emergency overflow in accordance with applicable standards of the Ventura County Flood Control District or local jurisdiction.		

Design Example

Bioretention areas have several components that allow the pretreatment, spreading, filtration, collection and discharge of the incoming flows.

Step 1: Determine water quality design volume

For this design example, a 10-acre site with soil type 4 and 60% total impervious area is considered. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine water quality design volume			
1-1. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ =	10	acres
1-2. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	0.6	
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	0.05	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =	0.59	
1-5. Enter design rainfall depth of the storm (in), P_i	P_i =	0.75	in
1-6. Calculate rainfall depth (ft), $P = P_i/12$	P =	0.06	ft
1-8. Calculate water quality design volume (ft^3), $SQDV=43560 \times C*P*A_{project}$	SQDV=	15,420.2	ft^3

Step 2: Determine the design percolation rate

For this design example, a native soil infiltration rate of 4.0 in/hr is assumed.

Step 2: Determine the design percolation rate			
2-1. Enter measured soil infiltration rate (in/hr, 0.3 in/hr minimum), $P_{measured}$	$P_{measured}$ =	4.0	in/hr
2-2. Determine percolation rate correction factor, S_A, based on suitability assessment (see Appendix C.2)	S_A =	3	
2-3. Determine percolation rate correction factor, S_B, based on design (see Appendix C.2)	S_b =	3	
2-4. Calculate combined safety factor, $S = S_A \times S_b$	S =	9	
2-5. Calculate the design percolation rate (in/hr), $P_{design} = P_{measured}/S$	P_{design} =	0.44	in/hr

Step 3: Determine bioretention/ planter box area footprint

A bioretention area is designed with two components: (1) temporary storage reservoir to store runoff, and (2) a plant mix filter bed (planting soil mixed with sand content = 70%) through which the stored runoff must percolate to obtain treatment.

Step 3: Calculate bioretention/planter box surface area			
3-1. Enter water quality design volume (ft^3), *SQDV*	SQDV =	15,420.2	ft^3
3-2. Enter design percolation rate (in/hr), P_{design}	P_{design} =	0.44	in/hr
3.3 Enter the required drain time (48 hours), $t_{ponding}$	$t_{ponding}$ =	48	hours
3-3. Calculate the maximum depth of surface ponding (ft) that can be infiltrated within the required drain time (48 hours): $d_{max} = (P_{design} \times t_{ponding})/12$	d_{max} =	1.76	ft
3-4. Select surface ponding depth d_p such that $d_p \leq d_{max}$	d_p =	1.5	ft
3-5. Select thickness of amended media (2 feet minimum), l_{media}	l_{media} =	3	ft
3-6. Enter porosity of amended media (roughly 25% or 0.25 ft/ft), n_{media}	n_{media}=	0.25	ft/ft
3-7. Select thickness of optional gravel layer (ft), l_{gravel}	l_{gravel} =	1	ft
3-8. Enter porosity of gravel (roughly 30% or 0.3 ft/ft), n_{gravel}	n_{gravel}=	0.3	ft/ft
3-9. Calculate the total effective storage depth of bioretention facility (ft): $d_{effective} \leq (d_p + n_{media} l_{media} + n_{gravel} l_{gravel})$	$d_{effective}$=	2.05	ft
3-10. Check that the entire effective depth infiltrates in required drainage time, 72 hours: $t_{total} = (d_{effective}/P_{design}) \times 12$ If t_{total} > 72 hours, reduce surface ponding depth and/or amended media thickness and/or gravel thickness and return to 3-4. If $t_{total} \leq$ 72 hours, proceed to 3-11.	t_{total} =	55.9	hours
3-11. Calculate the required infiltrating surface area (ft^2), $A_{req} = SQDV/d_{effective}$	A_{req} =	7,522.0	ft^2

Step 4: Calculate Bioretention Area Total Footprint

For this design example, a natural-shaped bioretention area is assumed, with 3:1 side slopes. To calculate the total footprint, the side slopes would be added to the design geometry.

<u>Step 5: Provide Conveyance Capacity for Flows Higher than Qwq</u>

The infiltration facility should be placed off-line, but an emergency overflow for flows greater than the peak design storm must still be provided in the event the filter becomes clogged. Design emergency overflow in accordance with applicable standards of the Ventura County Flood Control District or local jurisdiction.

C.5 INF-5 Permeable Pavement

Sizing Methodology

Permeable pavement (including the base layers) shall be designed to drain in less than 72 hours. The basis for this is that soils must be allowed to dry out periodically in order to restore hydraulic capacity; this is essential in order to receive flows from subsequent storms, maintain infiltration rates, maintain adequate sub soil oxygen levels for healthy soil biota, and to provide proper soil conditions for biodegradation and retention of pollutants.

Another important consideration for sizing permeable pavement is that the maximum impervious area tributary to the permeable pavement should not exceed three times (3x) the permeable pavement area itself in order to minimize sediment loading.

Permeable pavement must be built and designed by a licensed civil engineer in accordance with Ventura County roadway and pavement specifications.

Step 1: Calculate the design volume

Permeable pavement shall be sized to capture and treat the stormwater quality design volume, SQDV (see Section 2).

Step 2: Determine the Design Percolation Rate

The percolation rate will decline between maintenance cycles as particulates accumulate in the infiltrative layer and the surface becomes occluded. Additionally, monitoring of actual facility performance has shown that the full-scale infiltration rate is far lower than the rate measured by small-scale testing. It is important that adequate conservatism is incorporated in the selection of design percolation rates. For infiltrating bioretention facilities, the design percolation rate discussed here is the percolation rate of the underlying soils, which will drive infiltration through the facility. See Section C.2 for guidance in developing design percolation rate correction factors.

Step 3: Determine gravel drainage layer depth

Permeable pavement (including the base layers) shall be designed to drain in less than 72 hours. The basis for this is that soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive flows from subsequent storms, maintain infiltration rates, maintain adequate sub soil oxygen levels for healthy soil biota, and to provide proper soil conditions for biodegradation and retention of pollutants.

1) Calculate the maximum depth of runoff, d_{max}, that can be infiltrated within the drawdown time:

$$d_{\max} = \frac{P_{design} \bullet t}{12} \quad \text{(Equation C-16)}$$

Where:

d_{max} = maximum depth that can be infiltrated (ft)

P_{design} = design percolation rate of underlying soils (in/hr) (see Step 2, above)

t = drawdown time (72 hrs maximum) (hr)

1) Select the gravel drainage layer depth, l, such that:

$$d_{\max} \geq n \times l \quad \text{(Equation C-17)}$$

Where:

d_{max} = maximum depth that can be infiltrated (ft) (see 1) above)

n = gravel drainage layer porosity(unitless) (generally about 32% or 0.32 for gravel)

l = gravel drainage layer depth (ft)

<u>Step 4: Determine infiltrating surface area</u>

1) Calculate infiltrating surface area for permeable pavement, A:

$$A = \frac{SQDV}{\frac{TP_{design}}{12} + nl} \quad \text{(Equation C-18)}$$

Where:

P_{design} = design percolation rate of underlying soils (in/hr) (see Step 2, above)

n = gravel drainage layer porosity(unitless)[about 32% or 0.32 for gravel]

l = depth of gravel drainage layer (ft)

T = time to fill the gravel drainage layer with water (use 2 hours for most designs) (hr)

The maximum ratio of impervious area (tributary to the permeable pavement) to the permeable pavement area should be no greater than 2:1 to minimize sediment loading. Additional pretreatment should be implemented when the ratio exceeds 2:1 to reduce excessive sediment loading and ensure the long-term surface permeability performance of the permeable pavement. The design of the permeable pavement shall not receive runoff from landscape areas. Incidental landscape areas, such as an island planter, shall be designed so that the soils and sediments are contained inside the planter.

Step 5: Provide conveyance capacity for clogging

The permeable pavement must have an emergency overflow for storm events greater than the design and in the event the permeable pavement becomes clogged. See INF-5 Permeable Pavement for overflow details.

Sizing Worksheet

The design of the permeable pavement shall not receive runoff from landscape areas. Incidental landscape areas, such as an island planter, shall be designed so that the soils and sediments are contained inside the planter.

Sizing Worksheet - INF-5 Permeable Pavers

Designer: Project Proponent: Date: Project: Location: *The design of the permeable pavement shall not receive runoff from landscape areas. Incidental landscape areas, such as an island planter, shall be designed so that the soils are contained inside the planter.*	
Pretreatment Feature (if applicable):	
Outflow Collection:	
Step 1: Determine water quality design volume	
1-1. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ = acres
1-2. Enter Project impervious fraction, *Imp* (for the permeable pavement BMP, this fraction is 100% as no pervious areas should drain to it and risk clogging)	Imp=
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =
1-5. Enter design rainfall depth of the storm (in), P_i	P_i = in
1-6. Calculate rainfall depth (ft), $P = P_i/12$	P = ft
1-7. Calculate water quality design volume (ft^3), $SQDV=43560 \times C*P*A_{project}$	SQDV= ft^3
Step 2: Determine the design percolation rate	
2-1. Enter measured soil infiltration rate (0.3 in/hr minimum), $P_{measured}$	$P_{measured}$ = in/hr
2-2. Determine percolation rate correction factor, S_A based on suitability assessment (see Section 6 INF-5)	S_A =
2-3. Determine percolation rate correction factor, S_B based on design (see Section 6 INF-5)	S_B =
2-4. Calculate combined safety factor, $S = S_A \times S_b$	S =
2-5. Calculate the design percolation rate (in/hr), $P_{design} = P_{measured}/S$	P_{design} = in/hr
Step 3: Determine the Gravel Drainage Layer Depth	

3-1. Enter drawdown time (hours, 72 hrs max.), *t*	t =	hours
3-2. Calculate max. depth of runoff (ft) that can be infiltrated within the t, $d_{max}=P_{design}t/12$	d_{max} =	ft
3-3. Enter the gravel drainage layer porosity, *n* (typically 32% or 0.32 for gravel)	n =	
3-4. Select the gravel drainage layer depth (ft) such that $d_{max} \geq n \times l$	l =	ft
Step 4: Determine infiltrating surface area		
4-1. Enter gravel drainage layer porosity, *n*	n =	
4-2. Enter depth of gravel drainage layer (ft), *l*	l =	ft
4-3. Enter the time to fill the gravel drainage layer with water (Use 2 hours for most designs), *T*	T =	hrs
4-4. Calculate infiltrating surface area (ft^3): $A=SQDV/((TP_{design}/12)+nl)$	A =	ft^2
Check that the maximum ratio of impervious area (Aproject impervious) to permeable pavement (A) is no greater than 2:1 to minimize sediment loading.		
Step 5: Provide conveyance capacity for clogging		
5-1. The permeable pavement must have an emergency overflow for storm events greater than the design and in the event the permeable pavement becomes clogged.		

Design Example

Step 1: Determine Water Quality Design Volume

For this design example, a 1-acre commercial development with a 100% total impervious area is considered. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine Water Quality Design Volume			
1-1. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	A =	1	acres
1-2. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	1	
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	0.05	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p\,(1\text{-}imp)$	C =	0.95	
1-5. Enter design rainfall depth of the storm (in), P_i	P_i =	0.75	in
1-6. Calculate rainfall depth (ft), $P = P_i/12$	P =	0.06	ft
1-7. Calculate water quality design volume (ft^3), $SQDV=43560\times C*P*A_{project}$	SQDV =	2,482.9	ft^3

Step 2: Calculate Design Percolation Rate

Permeable pavement with no underdrain requires a minimum soil infiltration rate of 0.3 in/hr. For this design example, a native soil infiltration rate of 4.0 in/hr is assumed.

Step 2: Determine the design percolation rate			
2-1. Enter measured soil infiltration rate (0.3 in/hr min.), $P_{measured}$	$P_{measured}$ =	4.0	in/hr
2-2. Determine percolation rate correction factor, S_A, based on suitability assessment (see Appendix C.2)	S_A =	3	
2-3. Determine percolation rate correction factor, S_B, based on design (see Appendix C.2)	S_b =	3	
2-4. Calculate combined safety factor, $S = S_A \times S_b$	S =	9	
2-5. Calculate the design percolation rate (in/hr), $P_{design} = P_{measured}/S$	P_{design} =	0.44	in/hr

Step 3: Determine maximum depth that can be infiltrated

Based on the design infiltration rate and the max drawdown, determine the maximum depth that can be infiltrated within the time constraints.

Step 3: Determine maximum depth that can be infiltrated			
3-1. Enter drawdown time (72 hrs max.), *t*	t =	72	hrs
3-2. Calculate max. depth of runoff (ft) that can be infiltrated within the t, $d_{max}=P_{design}t/12$	d_{max} =	2.6	ft
3-3. Enter the gravel drainage layer porosity, *n* (typically 32% or 0.32 for gravel)	n =	0.32	
3-4. Select the gravel drainage layer depth (ft) such that $d_{max} \geq n \times l$	l =	4	ft

Step 4: Determine the infiltrating surface area (pavement area)

Using the depth calculated in Step 3, the required infiltrating surface area of the pavement can be calculated.

Step 4: Determine the infiltrating surface area			
4-1. Enter gravel drainage layer porosity, *n*	n =	0.32	
4-2. Enter depth of gravel drainage layer (ft), *l*	l =	4	ft
4-3. Enter the time to fill the gravel drainage layer with water (Use 2 hours for most designs), *T*	T =	2	hrs
4-4. Calculate infiltrating surface area (ft^3): $A=SQDV/(TP_{design}/12)+n*l))$	A =	1,835.1	ft^2

Step 5: Provide conveyance capacity for clogging

The permeable pavement must have an emergency overflow for storm events greater than the design and in the event the permeable pavement becomes clogged.

C.6 INF-7 Bioinfiltration

Sizing Methodology

Bioinfiltration shall be designed to drawdown in 48-hours, equivalent to 72-hours from surface ponding plus subsurface pore; with a ponding depth of 18-inches; with a minimum thickness of amended soils of 2 to 3-feet; with an underdrain; with a minimum thickness of 2-feet; and with an underdrain.

Step 1: Calculate the Design Volume

Bioinfiltration facilities shall be sized to capture and partially infiltrate and partially biotreat the SQDV volume (see Appendix C.1).

Step 2: Determine the Design Percolation Rate

The percolation rate will decline between maintenance cycles as particulates accumulate in the infiltrative layer and the surface becomes occluded. Additionally, monitoring of actual facility performance has shown that the full-scale infiltration rate is far lower than the rate measured by small-scale testing. It is important that adequate conservatism is incorporated in the selection of design percolation rates. For infiltration BMPs, the design percolation rate discussed here is the percolation rate of the underlying soils, which will ultimately drive infiltration through the BMP, and not the percolation rate of the filter media bed (refer to the "Geometry and Sizing" section of INF-2 for the recommended composition of the filter media bed for subsurface infiltration). See Section C.2 for guidance in developing design percolation rate correction factors.

Step 3: Calculate the Surface Area

Determine the size of the required infiltrating surface by assuming the SQDV will fill the available ponding depth plus the void spaces in the media, based on the computed porosity of the filter media and optional aggregate layer.

1) Determine the maximum depth of surface ponding that can be infiltrated within the required surface drain time (48 hr), (d_{max}), as follows:

$$d_{\max} = \frac{P_{design} \times t_{ponding}}{12 \frac{in}{ft}} \qquad \text{(Equation C-19)}$$

Where:

$t_{ponding}$	=	required drain time of surface ponding (48 hrs)
P_{design}	=	design percolation rate of underlying soils (in/hr) (see Step 2, above)

d_{max} = the maximum depth of surface ponding water that can be infiltrated within the required drain time (ft)

2) Choose surface ponding depth (d_p) such that:

$$d_p \leq d_{\max} \quad \text{(Equation C-20)}$$

Where:

d_p = selected surface ponding depth (ft)

d_{max} = the maximum depth of water that can be infiltrated within the required drain time (ft)

3) Choose thickness(es) of amended media and aggregate layer(s) and calculate total effective storage depth of the bioinfiltration area ($d_{effective}$), as follows:

$$d_{effective} \leq (d_p + n^*_{media} l_{media} + n_{gravel} l_{gravel}) \quad \text{(Equation C-21)}$$

Where:

$d_{effective}$ = total equivalent depth of water stored in bioinfiltration area (ft), including surface ponding and volume available in pore spaces of media and gravel layers

d_p = surface ponding depth (ft), chosen using Equation C-20

n^*_{media} = available porosity of amended soil media (ft/ft), approximately 0.25 ft/ft accounting for antecedent moisture conditions. This represents the volume of available pore space as a fraction of the total soil volume; sometimes has units of (ft^3/ft^3) or described as a percentage.

l_{media} = thickness of amended soil media layer (ft), minimum 2 ft

n_{gravel} = porosity of gravel layer (ft/ft), approximately 0.40 ft/ft

l_{gravel} = thickness of gravel layer (ft), minimum 2 ft

4) Check that entire effective depth (surface plus subsurface storage), $d_{effective}$, infiltrates in no greater than 72 hours as follows:

$$t_{total} = \frac{d_{effective}}{P_{design}} \times 12 \frac{in}{ft} \leq 72\ hr \quad \text{(Equation C-22)}$$

Where:

$d_{effective}$	=	total equivalent depth of water stored in bioinfiltration area (ft), calculated using Equation C-21
P_{design}	=	design percolation rate of underlying soils (in/hr) (see Step 2, above)

If $t_{total} > 72$ hrs, then reduce surface ponding depth and/or amended media thickness and/or gravel thickness and return to 1).

If $t_{total} \leq 72$ hrs, then proceed to 5).

5) Calculate required infiltrating surface area, (A_{req}):

$$A_{req} = \frac{SQDV}{d_{effective}} \quad \text{(Equation C-23)}$$

Where:

A_{req}	=	required infiltrating area (ft^2). Should be calculated at the contour corresponding to the mid ponding depth (i.e., $0.5 \times d_p$ from the bottom of the facility).
$SQDV$	=	stormwater quality design volume (ft^3)
$d_{effective}$	=	total equivalent depth of water stored in bioinfiltration area (ft), calculated using Equation C-21

Step 4: Calculate Bioinfiltration Area Total Footprint

Calculate total footprint required by including a buffer for side slopes and freeboard; A_{req} is calculated at the contour corresponding to the mid ponding depth (i.e., $0.5 \times d_p$ from the bottom of the facility).

Step 5: Provide Conveyance Capacity for Clogging

An overflow device is required at the 18-inch ponding depth. The following, or equivalent should be provided:

1) A vertical PVC pipe (SDR 35) to act as an overflow riser.
2) The overflow riser(s) should be 6 inches or greater in diameter, so it can be cleaned without damage to the pipe.

The inlet to the riser should be at the ponding depth (18 inches for fenced bioinfiltration areas and 6 inches for areas that are not fenced), and be capped with a spider cap to exclude floating mulch and debris. Spider caps should be screwed in or glued, i.e., not removable.

Sizing Worksheet - INF-7 Bioinfiltration

Designer: Project Proponent: Date: Project: Location:	
Type of Vegetation:	
Pretreatment Feature:	
Outflow Collection:	
Step 1: Calculate Design Volume	
1-1. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ = acres
1-2. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =
1-5. Enter design rainfall depth of the storm (in), P_i	P_i = in
1-6. Calculate rainfall depth (ft), $P = P_i/12$	P = ft
1-7. Calculate water quality design volume (ft^3), $SQDV=43560 \times C*P*A_{project}$	SQDV= ft^3
Step 2: Determine the design percolation rate	
2-1. Enter measured soil infiltration rate (in/hr, 0.3 in/hr min.), $P_{measured}$	$P_{measured}$ = in/hr
2-2. Determine percolation rate correction factor, S_A based on suitability assessment (see Appendix C.2)	S_A =
2-3. Determine percolation rate correction factor, S_B based on design (see Appendix C.2)	S_b =
2-4. Calculate combined safety factor, $S = S_A \times S_b$	S =
2-5. Calculate the design percolation rate (in/hr), $P_{design} = P_{measured}/S$	P_{design} = in/hr
Step 3: Calculate the Surface Area	

3-1. Determine the maximum depth of surface ponding water $d_{max} = \frac{P_{design} \times t_{ponding}}{12\frac{in}{ft}}$ The required drain time of surface ponding $t_{ponding}$ is 72 hours.	d_{max}	ft
3-2. Choose surface ponding depth (d_p) such that: $d_p \leq d_{max}$	d_p	ft
3-3. Choose thickness(es) of amended media and aggregate layer(s) and calculate total effective storage depth of bioinfiltration area Thickness(es) of amended media Available porosity of amended soil media (approximately 0.25 ft/ft) Choose thickness(es) of aggregate layer(s) Available porosity of gravel layer (approximately 0.40 ft/ft) $d_{effective} \leq (d_p + n^*_{media} l_{media} + n_{gravel} l_{gravel})$	l_{media} n^*_{media} l_{gravel} n_{gravel} $d_{effective}$	ft ft/ft ft ft/ft ft
3-4. Check entire effective depth infiltrates in less than 72 hrs $t_{total} = \frac{d_{effective}}{P_{design}} \times 12\frac{in}{ft}$ ≤ 72 hrs	t_{total}	hrs
3-5. Calculate required infiltration surface area $A_{req} = \frac{SQDV}{d_{effective}}$	A_{req}	ft^2
Step 4: Calculate Bioinfiltration Area Total Footprint		
4-1. Calculate the total footprint by including the buffer for side slopes	A_{total}	ft^2
Step 5: Provide conveyance capacity for clogging		
5-1.The infiltration facility should be placed off-line, but an emergency overflow must still be provided in the event it becomes clogged. Design emergency overflow in accordance with applicable standards of the Ventura County Flood Control District or local jurisdiction.		

Design Example

Step 1: Calculate Design Volume

For this design example, a 10-acre site with soil type 4 and 60% total impervious area is considered. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine water quality design volume			
1-1. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ =	10	acres
1-4. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	0.6	
1-2. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	0.05	
1-3. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =	0.59	
1-4. Enter design rainfall depth of the storm (in), P_i	P_i =	0.75	in
1-5. Calculate rainfall depth (ft), $P = P_i/12$	P =	0.06	ft
1-6. Calculate water quality design volume (ft^3), $SQDV=43560\times C*P*A_{project}$	SQDV=	15,420	ft^3

Step 2: Determine the Design Percolation Rate

For this design example, a native soil infiltration rate of 4.0 in/hr is assumed.

Step 2: Determine the design percolation rate			
2-1. Enter measured soil infiltration rate (in/hr, 0.3 in/hr minimum), $P_{measured}$	$P_{measured}$ =	4.0	in/hr
2-2. Determine percolation rate correction factor, S_A, based on suitability assessment (see Appendix C.2)	S_A =	3	
2-3. Determine percolation rate correction factor, S_B, based on design (see Appendix C.2)	S_b =	3	
2-4. Calculate combined safety factor, $S = S_A \times S_b$	S =	9	
2-5. Calculate the design percolation rate (in/hr), $P_{design} = P_{measured}/S$	P_{design} =	0.44	in/hr

Step 3: Determine the Bioinfiltration Surface Area

A bioinfiltration area is designed with two components: (1) temporary storage reservoir to store runoff, and (2) a plant mix filter bed (planting soil mixed with sand content = 70%) through which the stored runoff must percolate to obtain treatment.

Step 3: Calculate the Surface Area			
3-1. Determine the maximum depth of surface ponding water $d_{\max} = \frac{P_{design} \times t_{ponding}}{12\frac{in}{ft}}$ The required drain time of surface ponding $t_{ponding}$ is 48 hours.	d_{max}	1.76	ft
3-2. Choose surface ponding depth (d_p) such that: $d_p \le d_{\max}$	d_p	1.5	ft
3-3. Choose thickness(es) of amended media and aggregate layer(s) and calculate total effective storage depth of bioinfiltration area			
Thickness(es) of amended media	l_{media}	3	ft
Available porosity of amended soil media (approximately 0.25 ft/ft)	n^*_{media}	0.25	ft/ft
Choose thickness(es) of aggregate layer(s)	l_{gravel}	1	ft
Available porosity of gravel layer (approximately 0.40 ft/ft)	n_{gravel}	0.3	ft/ft
$d_{effective} \le (d_p + n^*_{media} l_{media} + n_{gravel} l_{gravel})$	$d_{effective}$	≤ 2.55	ft
3-4. Check entire effective depth infiltrates in less than 72 hrs $t_{total} = \frac{d_{effective}}{P_{design}} \times 12\frac{in}{ft} \le 72\ hrs$	t_{total}	69.5	hrs
3-5. Calculate required infiltration surface area $A_{req} = \frac{SQDV}{d_{effective}}$	A_{req}	6,047	ft^2

Step 4: Calculate Bioinfiltration Area Total Footprint

For this design example, a natural-shaped bioretention area is assumed, with 3:1 side slopes. To calculate the total footprint, the side slopes would be added to the design geometry.

Step 5: Provide Conveyance Capacity for Flows Higher than Qwq

The infiltration facility should be placed off-line, but an emergency overflow for flows greater than the peak design storm must still be provided in the event the filter becomes clogged. Design emergency overflow in accordance with applicable standards of the Ventura County Flood Control District or local jurisdiction.

C.7 RWH-1 Rainwater Harvesting

Sizing Criteria

The effectiveness of rainwater harvesting (RWH) systems is a function of tributary area, storage volume, demand patterns and magnitudes, and operational regime. If either of the latter two factors are too complex, simple design criteria metrics are not possible. The rainwater harvesting design criteria provided in this Fact Sheet are intended for the evaluation of systems that have relatively simple demand regimes and passive operation. If the answer to any of the following complexity screening questions is yes, a site-specific evaluation of rainwater harvesting effectiveness should be completed using a continuous simulation model with a long-term precipitation record.

Complexity Screening Questions:

1) Does the proposed system have seasonally varying demand other than irrigation?
2) Will the system be operated by advanced control systems or otherwise actively controlled?
3) Does the operational regime call for the system be shut down at any time during the rainy season?

Effectiveness of a harvesting system for retaining the SQDV depends on the cistern's effective storage capacity (i.e., the volume available for storage at the beginning of each event). Therefore, the required storage volume varies based on precipitation and demand. Using the following sizing charts, cisterns should be sized to achieve 80 percent capture efficiency, when used as the sole on-site retention BMP at a project site. These nomographs are based on continuous simulation performed in EPA SWMM using precipitation and ET records representative of lowland regions (Oxnard Airport Precipitation Gauge, El Rio Spreading Grounds ET station) and mountainous regions (Ojai-Stewart Canyon Precipitation Gauge, Matilja ET Station) of the County.

Instructions for determining required cistern volume and demand are provided below:

Step 1: Determine Rainwater Harvesting Design Volume (RWHDV) required for full capture

When used as the sole on-site retention BMP, the rainwater harvesting system must be sized for 80% capture runoff (as determined by continuous modeling), which can draw down in 72 hours. Partial capture of runoff through rainwater harvesting is allowable, with the remaining SQDV being captured by other onsite retention BMPs. Sizing instructions for partial capture are included in Step 3.

1) Determine the design storm required for 80% capture with a 72-hour drawdown time by selecting the project region (lowland or mountainous), then determining where the 72-hour drawdown curve intersects the 80% capture line. Pivot down from this intersection to the x axis to read the design storm, d_{design}.

2) Determine the required rainwater harvesting system volume using the following equation:

$$RWHDV = C*(d_{design}/12)*A_{project} \quad \text{(Equation C-24)}$$

Where:

RWHDV	=	rainwater harvesting design volume (acre-ft)
C	=	runoff coefficient
d_{design}	=	design storm required for 80% capture with a 72 hour drawdown time, estimated as described in 1) (inches)
$A_{project}$	=	the project area (acres)

Step 2: Determine the Required Daily Demand to Achieve 80% Capture

1) The required daily demand to achieve 80% capture of runoff can be calculated as follows:

$$Demand = [RWHDV/(72/24)] * (325{,}851) \quad \text{(Equation C-25)}$$

Where:

Demand	=	required project daily demand to draw down rainwater harvesting system sized for 80% capture in 72 hours (gallons)
RWHDV	=	rainwater harvesting design volume (acre-ft), from Step 1 above

If the project daily demand is less than the Demand calculated, rainwater harvesting cannot be used as the sole onsite retention BMP at a project site. In this case, rainwater harvesting can be used for partial capture and may prove to be a valuable tool towards meeting the SQDV capture requirement.

Step 3: Determine RWHDV for Partial Retention

1) Calculate RWHDV for selected combination of % capture and drawdown time using nomographs and the following equation:

$$RWHDV = C^*(d_{design}/12)^*A_{project} \qquad \text{(Equation C-26)}$$

Where:

RWHDV	=	rainwater harvesting design volume (acre-ft)
C	=	runoff coefficient
d_{design}	=	design storm required for selected % capture and drawdown time (inches)
$A_{project}$	=	the project area (acres)

2) Determine the required daily demand for the selected capture efficiency and/or drawdown time:

$$Demand = [RWHDV/(t_{drawdown}/24)] * (325{,}851) \qquad \text{(Equation C-27)}$$

Where:

Demand	=	required project daily demand to draw down rainwater harvesting system sized for the selected capture efficiency and/or drawdown time (gallons)
RWHDV	=	rainwater harvesting design volume (acre-ft), from 1) above
$t_{drawdown}$	=	selected drawdown time (hours), up to 72 hours

Step 4: Determine RWHDV for a Predetermined Daily Demand

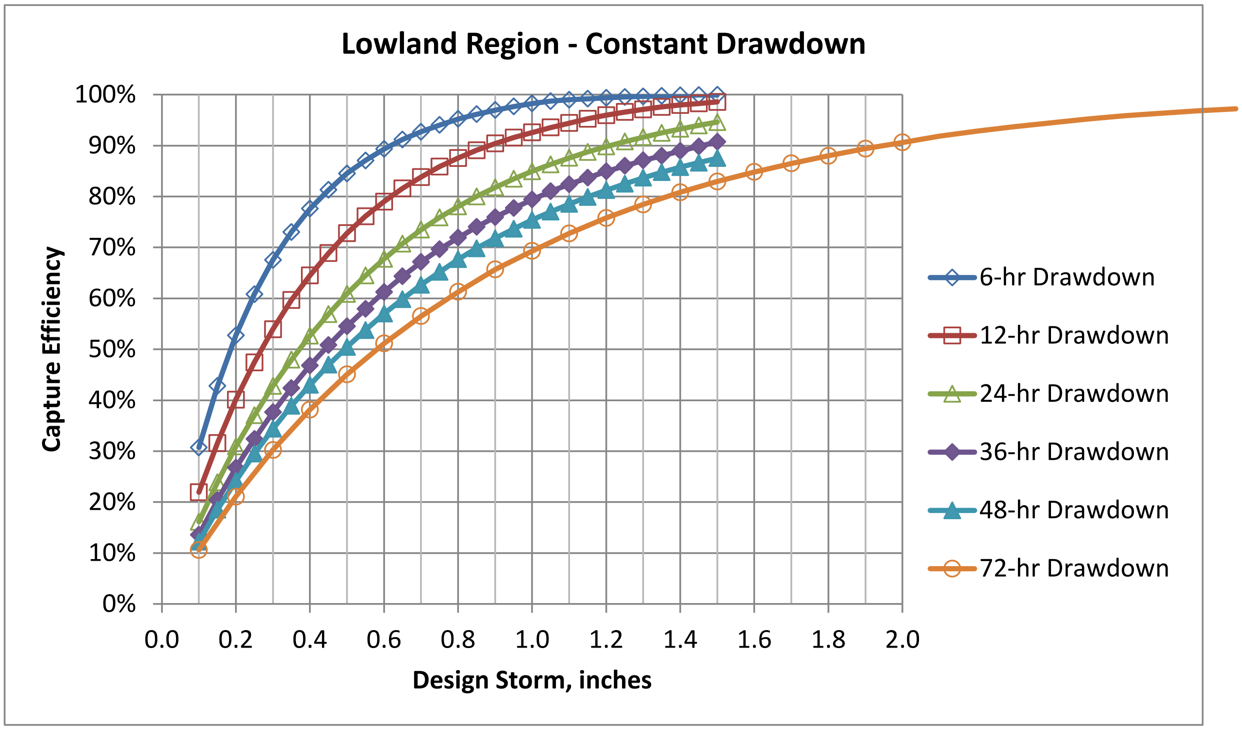
1) Determine the daily demand requirement in acre-feet (1 acre-foot = 325,851 gallons).

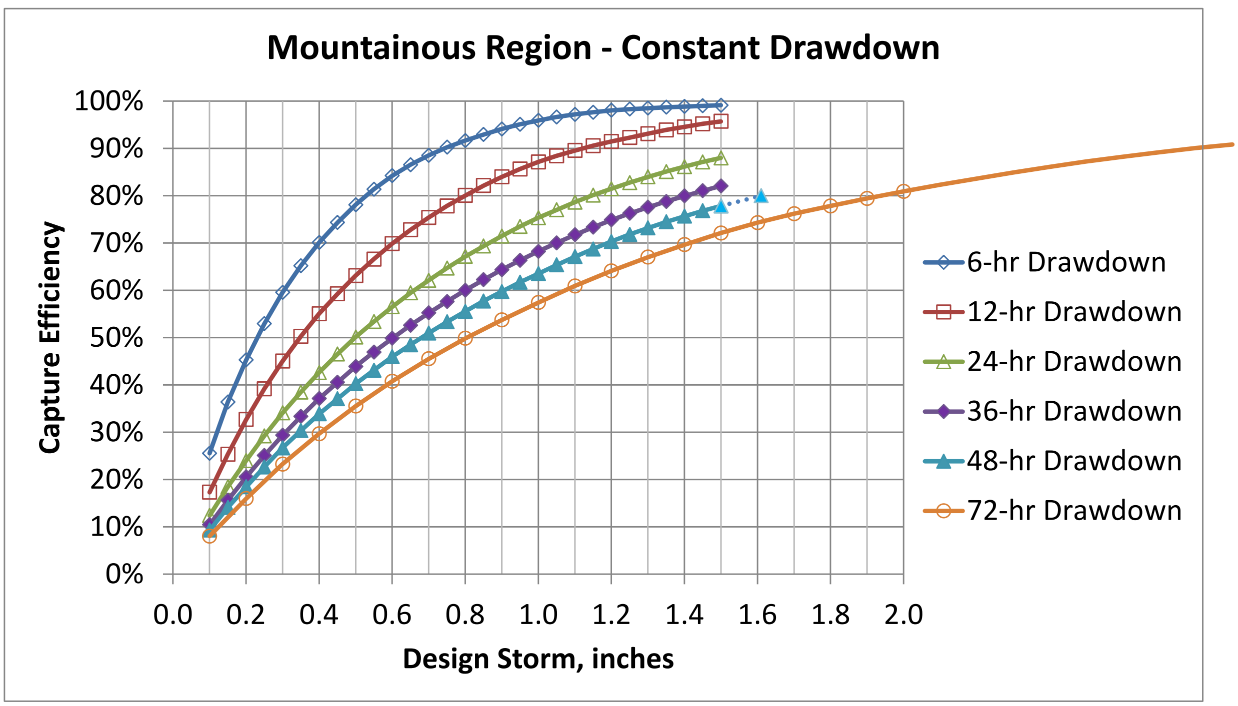
2) Calculate the required RWHDV for the desired drawdown time using the following equation:

$$RWHDV = Demand *(t_{drawdown}/24) \qquad \text{(Equation C-28)}$$

Where:

Demand	=	required project daily demand (acre-feet)
RWHDV	=	rainwater harvesting design volume (acre-ft)
$t_{drawdown}$	=	selected drawdown time (hours), up to 72 hours


Lowland Region - Constant Drawdown
Capture Efficiency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Design Storm, inches
6-hr Drawdown
12-hr Drawdown
24-hr Drawdown
36-hr Drawdown
48-hr Drawdown
72-hr Drawdown


Mountainous Region - Constant Drawdown
Capture Efficiency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Design Storm, inches
6-hr Drawdown
12-hr Drawdown
24-hr Drawdown
36-hr Drawdown
48-hr Drawdown
72-hr Drawdown

Sizing Worksheet - RWH-1 Rainwater Harvesting

Designer: Project Proponent: Date: Project: Location:		
Outflow Collection:		
Step 1: Determine Rainwater Harvesting Design Volume (RWHDV) required for full capture		
1-1. Determine the design storm required for 80% capture with a 72-hour drawdown time, d_{design}.	d_{design} =	in
1-2. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ =	acres
1-3. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	
1-4. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	
1-5. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =	
1-6. Determine the rainwater harvesting system volume, $RWHDV = C*(d_{design}/12)*A_{project}$	*RWHDV =*	ac-ft
Step 2: Determine the required daily demand		
2-1. Determine the required daily demand to achieve 80% capture of runoff, Demand = [RWHDV/(72/24)] * (325,851)	*Demand =*	gallons
2-2. Enter the project daily demand	*Project daily demand =*	gallons
If the project daily demand is less than the Demand calculated, the project cannot utilize rainwater harvesting as the sole onsite retention BMP. If rainwater harvesting is desired for use for partial retention or if a predetermined daily demand is to be used, refer to Step 3 and Step 4, respectively.		

Step 3: Determine RWHDV required for partial capture (Optional)		
3-1. Enter desired % capture		
3-2. Enter the desired drawdown time (72 hours max), $t_{drawdown}$	$t_{drawdown}$ =	hours
3-3. Determine the design storm required for selected % capture and drawdown time	d_{design} =	in
3-4. Enter Project area (acres), $A_{project}$	$A_{project}$ =	acres

If this BMP captures runoff from a portion of the project area, enter the tributary area	
3-5. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=
3-6. Determine pervious runoff coefficient using Table C-1, C_p	C_p =
3-7. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =
3-8. Determine the RWHDV for selected combination of % capture and drawdown time, $RWHDV = C*(d_{design}/12)*A_{project}$	*RWHDV* = ac-ft
3-9. Determine the required daily demand for the selected capture efficiency and/or drawdown time, Demand = [RWHDV/($t_{drawdown}$/24)] * (325,851)	*Demand* = gallons

Step 4: Determine RWHDV for a predetermined daily demand (Optional)	
4-1. Enter the daily demand requirement	*Demand* gallons
4-2. Determine the daily demand requirement in acre-feet (1 acre-foot = 325,851 gallons)	*Demand* ac-ft
4-3. Enter the desired drawdown time (72 hours max), $t_{drawdown}$	$t_{drawdown}$ = hours
4-4. Calculate the required RWHDV for the desired drawdown time, RWHDV = Demand *($t_{drawdown}$/24)	*RWHDV* = ac-ft

Design Example

Step 1: Determine Rainwater Harvesting Design Volume (RWHDV) required for full capture

For this design example, a 1-acre site in a low-lying area of Ventura County is considered. The site is 60% impervious and the impervious area is flat, with sandy soils covered with a lawn.

Step 1: Determine Rainwater Harvesting Design Volume (RWHDV) required for full capture			
1-1. Determine the design storm required for 80% capture with a 72-hour drawdown time, d_{design}.	d_{design} =	1.35	in
1-2. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ =	1	acre
1-3. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	0.6	
1-4. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	0.05	
1-5. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =	0.59	
1-6. Determine the rainwater harvesting system volume, $RWHDV = C*(d_{design}/12)*A_{project}$	*RWHDV* =	0.067	ac

Step 2: Determine the required daily demand to utilize the full RWHDV

For this design example, a project daily demand of 4,000 gallons for turf irrigation is assumed.

Step 2: Determine the required daily demand			
2-1. Determine the required daily demand to achieve 80% capture of runoff, Demand = [RWHDV/(72/24)] * (325,851)	*Demand =*	7,277.3	gallons
2-2. Enter the project daily demand	*Project daily demand =*	4,000	gallons
Because the project daily demand is less than the Demand calculated, the project cannot utilize rainwater harvesting as the sole onsite retention BMP. If rainwater harvesting is desired for partial retention or if a predetermined daily demand is to be used, refer to Step 3 and Step 4, respectively.			

Step 3: Determine Rainwater Harvesting Design Volume (RWHDV) required for full capture (Optional)

For this design example, rainwater harvesting is desired for 10% of the project runoff. The system will be designed for a drawdown time of 72 hours.

Step 3:Determine RWHDV required for partial capture (Optional)			
3-1. Enter desired % capture		10%	
3-2. Enter the desired drawdown time (72 hours max), $t_{drawdown}$	$t_{drawdown}$ =	72	hours
3-3. Determine the design storm required for selected % capture and drawdown time	d_{design} =	0.1	in
3-4. Enter Project area (acres), $A_{project}$	$A_{project}$ =	1	acre
3-5. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	0.6	
3-6. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	0.05	
3-7. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =	0.59	
3-8. Determine the RWHDV for selected combination of % capture and drawdown time, $RWHDV = C*(d_{design}/12)*A_{project}$	*RWHDV =*	0.005	ac-ft
3-9. Determine the required daily demand for the selected capture efficiency and/or drawdown time, Demand = [RWHDV/($t_{drawdown}$/24)] * (325,851)	*Demand =*	543.1	gallons

Step 4: Determine RWHDV required for a predetermined daily demand (Optional)

For this design example, a project daily demand of 4,000 gallons for turf irrigation is assumed. The system will be designed for a drawdown time of 72 hours.

Step 4: Determine RWHDV for a predetermined daily demand (Optional)			
4-1. Enter the daily demand requirement	*Demand*	4,000	gallons
4-2. Determine the daily demand requirement in acre-feet (1 acre-foot = 325,851 gallons)	*Demand*	0.012	ac-ft
4-3. Enter the desired drawdown time (72 hours max), $t_{drawdown}$	$t_{drawdown}$ =	72	hours
4-4. Calculate the required RWHDV for the desired drawdown time, RWHDV = Demand *($t_{drawdown}$/24)	RWHDV =	0.036	ac-ft

C.8 BIO-1 Biofiltration/BIO-2 Planter Box with Underdrain

Sizing Methodology

Biofiltration and planter boxes are sized the same as bioretention areas with underdrains using parameters appropriate for these BMPs as discussed below. However, as these are alternative compliance BMPs, per Section 2.6 of the TGM, onsite biofiltration BMPs must be sized to treat 1.5 times the portion of SQDV that is not reliably retained on site.

The runoff entering the facility must completely drain the ponding area within 48 hours, and runoff must be completely infiltrated within 72 hours. Biofiltration and planter boxes are to be sized such that the SQDV will fill the available ponding depth, the void spaces in the planting soil, and the optional aggregate layer.

Step 1: Determine the stormwater quality design volume (SQDV)

BIO-1 and BIO-2 BMPs should be sized to capture and treat 1.5 times the water quality design volume that is not reliably retained on site (see Appendix C.1 for SQDV calculations).

Step 2: Determine the Design Percolation Rate

Sizing is based on the design saturated hydraulic conductivity (K_{sat}) of the amended soil layer. A target K_{sat} of 5 inches per hour is recommended for newly installed non-proprietary amended soil media. The media K_{sat} will decline between maintenance cycles as the surface becomes occluded and particulates accumulate in the amended soil layer. A factor of safety of 2.0 should be applied such that the resulting recommended design percolation rate is 2.5 inches per hour. This value should be used for sizing unless sufficient rationale is provided to justify a higher design percolation rate.

Step 3: Calculate the biofiltration or planter box surface area

Determine the size of the required infiltrating surface by assuming the SQDV will fill the available ponding depth plus the void spaces in the media, based on the computed porosity of the filter media and optional aggregate layer.

1) Select a surface ponding depth (d_p) that satisfies geometric criteria and congruent with the constraints of the site. Selecting a deeper ponding depth (18 inches maximum) generally yields a smaller footprint, however, requires greater consideration for public safety and energy dissipation.

2) Compute time for selected ponding depth to filter through media:

$$t_{ponding} = \frac{d_p}{K_{design}} 12 \frac{in}{ft} \leq 48 \text{ hours} \qquad \text{(Equation C-29)}$$

Where:

$t_{ponding}$	=	required drain time of surface ponding (48 hrs)
d_p	=	selected surface ponding water depth (ft)
K_{design}	=	design saturated hydraulic conductivity (in/hr) (see Step 2, above)

If $t_{ponding}$ exceeds 48 hours, return to (1) and reduce surface ponding depth or increase media K_{design}. Otherwise, proceed to next step.

Note: In nearly all cases, $t_{ponding}$ will not approach 48 hours unless a low Kdesign is specified.

3) Calculate required infiltrating surface area (filter bottom area):

$$A_{req} = \frac{SQDV}{d_p + d_{filtered}} \quad \text{(Equation C-30)}$$

Where:

A_{req}	=	required area at bottom of filter area (ft^2); does not account for side slopes and freeboard
$SQDV$	=	stormwater quality design volume (ft^3)
d_p	=	selected surface ponding water depth (ft)
$d_{filtered}$	=	depth of water that can be considered to be filtered during the design storm event (ft); this value should not exceed surface ponding depth (d_p)

Step 4: Calculate the biofiltration/planer box total footprint

Calculate total footprint required by including a buffer for side slopes and freeboard; A_{req} is measured at the filter bottom area (toe of side slopes).

Step 5: Calculate underdrain system capacity

Underdrains are required for planter boxes and biofiltration BMPs. For guidance on sizing, refer to step 5 of the worksheet below. Alternatively, the Ventura County Hydrology Manual can be used for pipe sizing guidance.

Sizing Worksheet - BIO-1 Biofiltration/BIO-2 Planter Box with Underdrain

Designer: Project Proponent: Date: Project: Location:		
Type of Vegetation:		
Pretreatment Feature:		
Outflow Collection:		
Step 1: Determine water quality design volume		
1-1. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ =	acres
1-2. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	
1-3. Determine pervious runoff coefficient using <u>Table C-1</u>, C_p	C_p =	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p (1\text{-}imp)$	C =	
1-5. Enter design rainfall depth of the storm (in), P_i	P_i =	in
1-6. Calculate rainfall depth (ft), $P = P_i/12$	P =	ft
1-7. Calculate water quality design volume (ft^3) $SQDV=43560 \bullet C*P*A_{project)}$	SQDV=	ft^3
Step 2: Determine the design percolation rate		
2-1. Enter the design saturated hydraulic conductivity of the amended filter media (2.5 in/hr recommended rate), K_{design}	K_{design} =	in/hr
Step 3: Calculate Bioretention/Planter Box surface area		
3-1. Enter water quality design volume (ft^3), *SQDV*	SQDV =	ft^3
3-2. Enter design saturated hydraulic conductivity (in/hr), K_{design}	K_{design} =	in/hr
3-3. Enter ponding depth (max 1.5 ft for Bioretention, 1 ft for Planter Box) above area, d_p	d_p =	ft
3-4. Calculate the drawdown time for the ponded water to filter through media (hours), $t_{ponding}^{*} = (d_p/K_{design}) \times 12$ **If tponding exceeds 48 hours, reduce surface ponding depth or increase media Kdesign.*	$t_{ponding}$=	hrs

3-5. Calculate the depth of water (ft) filtered, $$d_{filtered} = Minimum\left[\frac{K_{design} \times T_{routing}}{12\ in/ft}, d_p\right]$$ where $T_{routing}$= storm duration that may be assumed for routing calculations; this should be assumed to be 3 hours unless rationale for an alternative assumption is provided	$d_{filtered}$ =	ft
3-6. Calculate the infiltrating surface area as follows (ft^2); account for infiltrating 1.5 times SQDV value. A_{req} =1.5 X SQDV/(d_p + $d_{filtered}$)	A_{req} =	ft^2
Step 4: Calculate Bioretention Area Total Footprint		
4-1. Calculate total footprint required by including a buffer for side slopes and freeboard (ft^2) [A_{req} is measured at the as the filter bottom area (toe of side slopes)], A_{tot}	A_{tot} =	ft^2
Step 5: Calculate Underdrain System Capacity		
To calculate the underdrain system capacity, continue through steps 5-1 to 5-7.		
5-1. Calculated filtered flow rate to be conveyed by the longitudinal drainpipe, $Q_f = K_{design} \times A_{req}/43,200$	Q_f =	cfs
5-2. Enter minimum slope for energy gradient, S_e	S_e =	
5-3. Enter Hazen-Williams coefficient for plastic, C_{HW}	C_{HW} =	
5-4. Enter pipe diameter (min 4 inches), D	D =	in
5-5. Calculate pipe hydraulic radius (ft), $R_h = D/48$	R_h =	ft
5-6. Calculate velocity at the outlet of the pipe (ft/s), $V_p = 1.318 C_{HW} R_h^{0.63} S_e^{0.54}$	V_p =	ft/s
5-7. Calculate pipe capacity (cfs), $Q_{cap} = 0.25\pi(D/12)^2 V_p$	Q_{cap} =	cfs

Design Example

Bioretention areas have several components that allow the pretreatment, spreading, filtration, collection and discharge of the incoming flows.

Step 1: Determine water quality design volume

For this design example, a 10-acre residential development with a 60% total impervious area is considered. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine Water Quality Design Volume			
1-1. Enter project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ =	10	acres
1-2. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	0.6	
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	0.05	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	0.59	
1-5. Enter design rainfall depth of the storm, P_i (in)	P_i =	0.75	in
1-6. Calculate rainfall depth, $P = P_i/12$	P =	0.06	ft
1-7. Calculate water quality design volume, $SQDV = 43560 \bullet P * A_{project} * C$	SQDV =	15,420.2	ft^3

Step 2: Determine the design percolation rate

For this design example, the recommended amended filter hydraulic conductivity is used, 2.5 in/hr.

Step 2: Determine the design percolation rate			
2-1. Enter the design saturated hydraulic conductivity of the amended filter media (2.5 in/hr recommended rate), K_{design}	K_{design} =	2.5	in/hr

Step 3: Determine bioretention/ planter box area footprint

A bioretention area is designed with two components: (1) temporary storage reservoir to store runoff, and (2) a plant mix filter bed (planting soil mixed with sand content = 70%) through which the stored runoff must percolate to obtain treatment.

Step 3: Calculate Bioretention/Planter Box surface area			
3-1. Enter water quality design volume (ft^3), *SQDV*	SQDV =	15,420.2	ac-ft
3-2. Enter design saturated hydraulic conductivity (in/hr), K_{design}	K_{design} =	2.5	in/hr

3-3. Enter ponding depth (max 1.5 ft for Biofiltration, 1 ft for Planter Box) above area, d_p	d_p =	1.5	ft
3-4. Calculate the drawdown time for the ponded water to filter through media (hours), $t_{ponding}^* = (d_p/K_{design}) \times 12$ **If tponding exceeds 48 hours, reduce surface ponding depth or increase media Kdesign.*	$t_{ponding}$=	7.2	hrs
3-5. Calculate the depth of water (ft) filtered, $d_{filtered} = Minimum\left[\frac{K_{design} \times T_{routing}}{12\ in/ft}, d_p\right]$ where $T_{routing}$= 3 hours	$d_{filtered}$ =	0.625	ft
3-8. Calculate the infiltrating surface area as follows (ft^2): $A_{req} = 1.5\ X\ SQDV/(d_p + d_{filtered})$	A_{req} =	10,884.8	ft^2

Step 4: Calculate Bioretention Area Total Footprint

For this design example, a natural-shaped bioretention area is assumed, with 3:1 side slopes. To calculate the total footprint, the side slopes would be added to the design geometry.

Step 5: Calculate filter longitudinal underdrain collection pipe

All underdrain pipes must be 6 inches or greater in diameter to facilitate cleaning.

Step 5: Calculate underdrain system (required for planter box)			
To calculate the underdrain system capacity, continue through steps 5-1 to 5-7. If you don't need to calculate the underdrain capacity, skip this step.			
5-1. Calculated filtered flow rate to be conveyed by the longitudinal drainpipe (cfs), $Q_f = K_{design} \times A_{req}/43,200$	Q_f =	0.63	cfs
5-2. Enter minimum slope for energy gradient, S_e	S_e =	0.005	
5-3. Enter Hazen-Williams coefficient for plastic, C_{HW}	C_{HW} =	140	
5-4. Enter pipe diameter (min 6 in), D	D =	8	in
5-5. Calculate pipe hydraulic radius (ft), $R_h = D/48$	R_h =	0.167	ft
5-6. Calculate velocity at the outlet of the pipe (ft/s), $V_p = 1.318 C_{HW} R_h^{0.63} S_e^{0.54}$	V_p =	3.42	ft/s
5-7. Calculate pipe capacity (cfs), $Q_{cap} = 0.25\pi(D/12)^2 V_p$	Q_{cap} =	1.19	cfs

C.9 HM-1 Dry Extended Detention Basin

Sizing Methodology

Dry extended detention (ED) basins are basins designed such that the stormwater quality design volume, SQDV, is detained for 36 to 48 hours. This allows sediment particles and associated pollutants to settle and be removed from stormwater. Procedures for sizing extended detention basins are summarized below. A sizing example is also provided.

Step 1: Calculate the design volume

Dry extended detention facilities shall be sized to capture and treat the water quality design volume (see Appendix C.1).

Step 2: Calculate the volume of the active basin

The total basin volume shall be increased an additional 20% of the stormwater quality design volume to account for sediment accumulation, at a minimum. If the basin is designed only for water quality treatment, then the basin volume would be 120% of the stormwater quality design volume, SQDV. Freeboard is in addition to the total basin volume. Calculate the volume of the active basin, V_a:

$$V_a = 1.20*SQDV \qquad \text{(Equation C-31)}$$

Step 3: Determine detention basin location and preliminary geometry based on site constraints

Based on site constraints, determine the basin geometry and the storage available by developing an elevation-storage relationship for the basin. The cross-sectional geometry across the width of the basin shall be approximately trapezoidal with a maximum side slope of 4:1 (H:V) on interior slopes and 3:1 (H:V) on exterior slopes unless specifically permitted by Ventura County (see Side Slopes below). Shallower side slopes are necessary if the basin is designed to have recreational uses during dry weather conditions.

1) Calculate the width of the basin footprint, W_{tot}, as follows:

$$W_{tot} = \frac{A_{tot}}{L_{tot}} \qquad \text{(Equation C-32)}$$

Where:

A_{tot} = total surface area of the basin footprint (ft^2)

L_{tot} = total length of the basin footprint (ft)

2) Calculate the length of the active volume surface area including the internal berm but excluding the freeboard, $L_{av\text{-}tot}$:

$$L_{av-tot} = L_{tot} - 2Zd_{fb} \quad \text{(Equation C-33)}$$

Where:

Z = interior side slope as length per unit height

d_{fb} = freeboard depth

3) Calculate the width of the active volume surface area including the internal berm but excluding freeboard, $W_{av\text{-}tot}$:

$$W_{av-tot} = W_{tot} - 2Zd_{fb} \quad \text{(Equation C-34)}$$

4) Calculate the total active volume surface area including the internal berm and excluding freeboard, $A_{av\text{-}tot}$:

$$A_{av-tot} = L_{av-tot} \times W_{av-tot} \quad \text{(Equation C-35)}$$

5) Calculate the area of the berm, A_{berm}:

$$A_{berm} = W_{berm} \times L_{berm} \quad \text{(Equation C-36)}$$

Where:

W_{berm} = width of the internal berm

L_{berm} = length of the internal berm

6) Calculate the surface area excluding the internal berm and freeboard, A_{av}:

$$A_{av} = A_{av=tot} - A_{berm} \quad \text{(Equation C-37)}$$

Step 4: Determine Dimensions of Forebay

5-15% of the basin active volume, V_a, is required to be within the active volume of the forebay.

1) Calculate the active volume of forebay, V_1:

$$V_1 = Va \times \%V_1 \quad \text{(Equation C-38)}$$

Where:

$\%V_1$ = percent of V_a in forebay (%)

V_a = active volume (ft^3)

2) Calculate the surface area for the active volume of forebay, A_1:

$$A_1 = \frac{V_1}{d_1} \quad \text{(Equation C-39)}$$

Where:

d_1 = average depth for the active volume of forebay (ft)

3) Calculate the length of forebay, L_1:

$$L_1 = \frac{A_1}{W_1} \quad \text{(Equation C-40)}$$

Where:

W_1 = width of forebay (ft)

Step 5: Determine Dimensions of Cell 2

Cell 2 will consist of the remainder of the basin's active volume.

1) Calculate the active volume of Cell 2, V_2:

$$V_2 = V_a - V_1 \quad \text{(Equation C-41)}$$

Where:

V_a = total basin active volume (ft^3)

V_1 = volume of forebay (ft^3)

2) Calculate the surface area, A_2, for the active volume of Cell 2:

$$A_2 = A_{av} - A_1 \quad \text{(Equation C-42)}$$

Where:

A_{av} = basin surface area excluding berm and freeboard (ft^2)

A_1 = surface area of forebay (ft^2)

3) Calculate the average depth, d_2, for the active volume of Cell 2:

$$d_2 = \frac{V_2}{A_2} \quad \text{(Equation C-43)}$$

4) Calculate the length of Cell 2, L_2:

$$L_2 = \frac{A_2}{W_2} \text{(Equation C-44)}$$

Where:

W_2 = width of Cell 2 (ft)

5) Verify that the length-to-width ratio of Cell 2 at half of d_2 is at least 1.5:1 with ≥2:1 preferred. If the length-to width ratio is less than 1.5:1, modify input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the basin should be chosen. Calculate the length-to width, LW_{mid2}, ratio of Cell 2 at half of d_2 follows:

$$LW_{mid2} = \frac{L_{mid2}}{W_{mid2}} \text{(Equation C-45)}$$

Where:

$W_{mid2} = W_2 - Zd_2$ and (Equation C-46)

$L_{mid2} = L_2 - Zd_2$ (Equation C-47)

W_{mid2} = width of Cell 2 at half of d_2 (ft)

L_{mid2} = length of Cell 2 at half of d_2 (ft)

Z = interior side slope as length per unit height (H:V)

Step 6: Ensure Design Requirements and Site Constraints are achieved

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location or alternative treatment BMP.

Step 7: Size Outlet Structure

The total drawdown time for the basin should be 36-48 hours. The outlet structure shall be designed to release the bottom 50% of the detention volume (half-full to empty) over 24-32 hours, and the top half (full to half-full) in 12-16 hours. A primary overflow should be sized to pass the peak flow rate from the developed capital design storm.

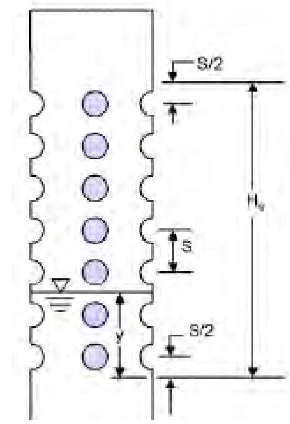
There are two options that can be used for the outlet structure:

- Uniformly perforated riser structures.

- Multiple orifice structures (orifice plate).

Perforated Risers Outlet Sizing Methodology

The following attributes influence the perforated riser outlet sizing calculations**:**



Perforated Riser Outlet

Geosyntec Consultants

1) Shape of the basin (e.g., trapezoidal)
2) Depth and volume of the basin
3) Elevation / depth of first row of holes
4) Elevation / depth of last row of holes
5) Size of perforations
6) Number of rows or perforations and number of perforations per row
7) Desired drawdown time (e.g., 16 hours and 32 hours draw down for top half and bottom half respectively, 48 hours total drawdown time for the stormwater quality design volume)

The governing rate of discharge from a perforated riser structure can be calculated using the equation below:

$$Q = C_p \frac{2A_p}{3H_s}\sqrt{2g}H^{3/2}$$

(Equation C-48)

Where:

Q	=	riser flow discharge (cfs)
C_p	=	discharge coefficient for perforations (use 0.61)
A_p	=	cross-sectional area of all the holes (ft^2)
s	=	center to center vertical spacing between perforations (ft)
H_s	=	distance from s/2 below the lowest row of holes to s/2 above the top row of holes (McEnroe 1988).
H	=	effective head on the orifice (measured from center of orifice to water surface)

For the iterative computations needed to size the perforations in the riser and determine the riser height, a simplified version of Equation C-48 may be used as shown below:

$$Q = kH^{3/2}$$ (Equation C-49)

Where:

H	=	effective head on the orifice (measured from center of orifice to water surface)

$$k = C_p \frac{2A_p}{3H_s}\sqrt{2g}$$ (Equation C-50)

Where:

C_p	=	discharge coefficient for perforations (use 0.61)
A_p	=	cross-sectional area of all the holes (ft^2)
s	=	center to center vertical spacing between perforations (ft)
H_s	=	distance from s/2 below the lowest row of holes to s/2 above the top row of holes.
g	=	32.17 ft/sec^2

Uniformly perforated riser designs are defined by the depth or elevation of the first row of perforations, the length of the perforated section of pipe, and the size or diameter of each perforation.

Multiple Orifice Outlet Sizing Methodology

The following attributes influence multiple orifice outlet sizing calculations**:**

1) Shape of the basin (e.g., trapezoidal)
2) Depth and volume of the basin
3) Elevation of each orifice
4) Desired draw-down time (e.g., 16 hours and 32 hours draw down times for top half and bottom half respectively, 48 hour drawdown time for stormwater quality design volume)

The rate of discharge from a single orifice can be calculated using the equation below.

$$Q = CA(2gH)^{0.5}$$ (Equation C-51)

Where:

Q	=	orifice flow discharge
C	=	discharge coefficient
A	=	cross-sectional area of orifice or pipe (ft2)
g	=	acceleration due to gravity (32.2 ft/s2)
H	=	effective head on the orifice (measured from center of orifice to water surface)

Multiple orifice designs are defined by the depth (or elevation) and the size (or diameter) of each orifice. Multiple orifices may be provided and sized using a similar approach.

Step 8: Determine Emergency Spillway Requirements

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm in order to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the 100-yr, 24-hr post-development peak storm water runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

Sizing Worksheet - HM-1 Dry Extended Detention Basin

Designer: Project Proponent: Date: Project: Location:	
Type of Vegetation:	Native Grasses _____ Irrigated Turf _____ Other ________________________
Outflow Collection: Outlet Type (check one	Single Orifice _____ Multi-orifice Plate _____ Perforated Pipe _____ Other ________________________
Depth of water above bottom orifice	Depth = _____ feet
Single Orifice Outlet 1)Total Area 2) Diameter or W x L	A = _____ square inches D = _____ inches
Multiple Orifice Outlet 1) Area per row of perforations 2) Perforation Diameter (2 inches max.) 3) No. of Perforations (columns) per Row 4) No. of Rows (4 inch spacing) 5) Total Orifice Area (Area per row) x (Number of Rows)	A = _____ square inches D = _____ Perforations = _____ Rows = _____ Area = _____ square inches
Step 1: Determine water quality design volume	
1-1. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ = acres
1-2. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =

1-4. Calculate runoff coefficient, *$C = 0.95*imp + C_p (1-imp)$*	C =	
1-5. Enter design rainfall depth of the storm (in), P_i	P_i =	in
1-6. Calculate rainfall depth (ft), $P = P_i/12$	P =	ft
1-7. Calculate water quality design volume (ft^3), $SQDV=43560 \bullet C*P*A_{project}$	SQDV =	ft^3
Step 2: Calculate the volume of the active basin		
2-1. Calculate basin active volume (includes water quality design volume + sediment storage volume) (ft^3), $V_a = 1.20 \times SQDV$	V_a =	ft^3
Step 3: Determine Detention Basin Location and Preliminary Geometry Based on Site Constraints		
3-1. Based on site constraints, determine the basin geometry and the storage available by developing an elevation-storage relationship for the basin. For this simple example, assume a trapezoidal geometry for cell 1 (forebay) and cell 2.		
3-2. Enter the total surface area of the basin footprint based on site constraints (ft^2), A_{tot}	A_{tot} =	ft^2
3-3. Enter the length of the basin footprint based on site constraints (ft), L_{tot}	L_{tot} =	ft
3-4. Calculate the width of the basin footprint (L:W = 1.5:1 min) (ft), $W_{tot} = A_{tot} / L_{tot}$	W_{tot} =	ft
3-5. Enter interior side slope as length per unit height (H:V, min = 3), Z	Z =	
3-6. Enter desired freeboard depth (ft), d_{fb} (min: 2 ft on-line; 1 ft offline)	d_{fb} =	ft
3-7. Calculate the length of the active volume surface area including the internal berm but excluding freeboard, $L_{av\text{-}tot} = L_{tot} - 2Zd_{fb}$	$L_{av\text{-}tot}$ =	ft
3-8. Calculate the width of the active volume surface area including the internal berm but excluding freeboard, $W_{av\text{-}tot} = W_{tot} - 2Zd_{fb}$	$W_{av\text{-}tot}$ =	ft
3-9. Calculate the total active volume surface area including the internal berm and excluding freeboard, $A_{av\text{-}tot} = L_{av\text{-}tot} \times W_{av\text{-}tot}$	$A_{av\text{-}tot}$ =	ft^2
3-10. Enter the width of the internal berm (6 ft min), W_{berm}	W_{berm} =	ft
3-11. Enter the length of the internal berm (ft), $L_{berm} = W_{av\text{-}tot}$	L_{berm} =	ft

3-12. Calculate the area of the berm (ft^2), $A_{berm} = W_{berm} \times L_{berm}$	A_{berm} =	ft^2
3-13. Calculate the surface area excluding the internal berm and freeboard (ft^2), $A_{av} = A_{av\text{-}tot} - A_{berm}$	A_{av} =	ft^2
Step 4: Determine Dimensions of forebay		
4-1. Enter the percentage of V_a in forebay (5-15% required), $\%V_1$	$\%V_1$ =	%
4-2. Calculate the active volume of forebay, $V_1 = V_a \bullet \%V_1$	V_1 =	ft^3
4-3. Enter a desired average depth for the active volume of forebay, d_1	d_1 =	ft
4-4. Calculate the surface area for the active volume of forebay, $A_1 = V_1 / d_1$	A_1 =	ft^2
4-5. Enter the width of forebay, $W_1 = W_{av\text{-}tot} = L_{berm}$	W_1 =	ft
4-6. Calculate the length of forebay (<u>Note:</u> inlet and outlet should be configured to maximize the residence time), $L_1 = A_1 / W1$	L_1 =	ft
Step 5: Determine Dimensions of Cell 2		
5-1. Calculate the active volume of Cell 2, $V_2 = V_a - V_1$	V_2 =	ft^3
5-2. Calculate the surface area of the active volume of Cell 2, $A_2 = A_{av} - A_1$	A_2 =	ft^2
5-3. Calculate the average depth for the active volume of Cell 2, $d_2 = V_2 / A_2$	d_2 =	ft
5-4. Enter the width of Cell 2, $W_2 = W_1 = W_{av\text{-}tot} = L_{berm}$	W_2 =	ft
5-5. Calculate the length of Cell 2, $L_2 = A_2 / W_2$	L_2 =	ft
5-6. Calculate the width of Cell 2 at half of d_2, $W_{mid2} = W_2 - Zd_2$	W_{mid2} =	ft
5-7. Calculate the length of Cell 2 at half of $d_{2,}$ $L_{mid2} = L_2 - Zd_2$	L_{mid2} =	ft
5-8. Verify that the length-to-width ratio of Cell 2 at half of d_2 is at least 1.5:1 with ≥ 2:1 preferred. If the length-to-width ratio is less than 1.5:1, modify input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the basin should be chosen, $LW_{mid2} = L_{mid2} / W_{mid2}$	LW_{mid2} =	

Step 6: Ensure Design Requirements and Site Constraints are Achieved
6-1. Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location or alternative treatment BMP.
Step 7: Size Outlet Structure
7-1. The total drawdown time for the basin should be 36-48 hours. The outlet structure shall be designed to release the bottom 50% of the detention volume (half-full to empty) over 24-32 hours, and the top half (full to half-full) in 12-16 hours. A primary overflow should be sized to pass the peak flow rate from the developed capital design storm.
Step 8: Determine Emergency Spillway Requirements
8-1. For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm in order to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the 100-yr, 24-hr post-development peak storm water runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

Design Example

Step 1: Determine water quality design volume

For this design example, a 10-acre residential development with a 60% total impervious area is considered. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine water quality design volume			
1-1. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	A =	10	acres
1-2. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	0.6	
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	0.05	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =	0.59	
1-5. Enter design rainfall depth of the storm (in), P_i	P_i =	0.75	in
1-6. Calculate rainfall depth (ft), $P = P_i/12$	P =	0.06	ft
1-7. Calculate water quality design volume (ft^3), $SQDV=43560•C*P*A_{project}$	SQDV =	15,420.2	ft^3

Step 2: Calculate Volume of the Active Basin and the Forebay Basin

Step 2: Calculate the design volume of the active basin			
2-1. Calculate basin active design volume (includes water quality design volume + sediment storage volume), $V_a = 1.20*SQDV$	V_a =	18,504.2	ft^3

Step 3: Determine Detention Basin Location and Preliminary Geometry Based on Site Constraints

The detention basin in this example has an internal berm separating the forebay (Cell 1) and the main basin (Cell 2). The internal berm elevation is 2 ft below the elevation of the SUSMP volume within the entire basin. The berm length is equal to the width of the basin when filled to the active design volume.

Step 3: Determine Detention Basin Location and Preliminary Geometry Based on Site Constraints
3-1. Based on site constraints, determine the basin geometry and the storage available by developing an elevation-storage relationship for the basin. For this simple example, assume a trapezoidal geometry for cell 1 (forebay) and cell 2.

Step 3: Determine Detention Basin Location and Preliminary Geometry Based on Site Constraints			
3-2. Enter the total surface area of the basin footprint based on site constraints, A_{tot}	A_{tot} =	8,000	ft^2
3-3. Enter the length of the basin footprint based on site constraints, L_{tot} (L:W = 1.5:1 min)	L_{tot} =	200	ft
3-4. Calculate the width of the basin footprint, $W_{tot} = A_{tot} / L_{tot}$	W_{tot} =	40	ft
3-5. Enter interior side slope as length per unit height (min = 3), Z	Z =	3	
3-6. Enter desired freeboard depth, d_{fb} (min: 2 ft on-line; 1 ft offline)	d_{fb} =	2	ft
3-7. Calculate the length of the active volume surface area including the internal berm but excluding freeboard, $L_{av\text{-}tot} = L_{tot} - 2Zd_{fb}$	$L_{av\text{-}tot}$ =	188	ft
3-8. Calculate the width of the active volume surface area including the internal berm but excluding freeboard, $W_{av\text{-}tot} = W_{tot} - 2Zd_{fb}$	$W_{av\text{-}tot}$ =	28	ft
3-9. Calculate the total active volume surface area including the internal berm and excluding freeboard, $A_{av\text{-}tot} = L_{av\text{-}tot} \bullet W_{av\text{-}tot}$	$A_{av\text{-}tot}$ =	5,264	ft^2
3-10. Enter the width of the internal berm (6 ft min), W_{berm}	W_{berm} =	6	ft
3-11. Enter the length of the internal berm, $L_{berm} = W_{av\text{-}tot}$	L_{berm} =	28	ft
3-12. Calculate the area of the berm, $A_{berm} = W_{berm} \bullet L_{berm}$	A_{berm} =	168	ft^2
3-13. Calculate the surface area excluding the internal berm and freeboard, $A_{av} = A_{av\text{-}tot} - A_{berm}$	A_{av} =	5,096	ft^2

Step 4: Calculate Dimensions of Cell 1

Calculate the dimensions of the forebay (Cell 1) based on the active design volume for Cell 1 (5-15% of V_a) and a desired average depth, d_1. The width of the forebay, W_1, is equivalent to the length of the berm, L_{berm}, and the width of Cell 2, W_2.

Step 4: Determine Dimensions of forebay			
4-1. Enter the percentage of V_a in forebay (5-15% required), $\%V_1$	$\%V_1$ =	15	%
4-2. Calculate the active volume of forebay (including sediment storage), $V_1 = V_a \bullet \%V_1$)	V_1 =	2,775.6	ft^3

4-3. Enter a desired average depth for the active volume of forebay, d_1	d_1 =	5	ft
4-4. Calculate the surface area for the active volume of forebay, $A_1 = V_1 / d_1$	A_1 =	555.1	ft^2
4-5. Enter the width of forebay, $W_1 = W_{wq\text{-}tot} = L_{berm}$	W_1 =	28	ft
4-6. Calculate the length of forebay (<u>Note:</u> inlet and outlet should be configured to maximize the residence time), $L_1 = A_1 / W1$	L_1 =	19.8	ft

<u>Step 5: Calculate the Dimensions of Cell 2</u>

Calculate the dimensions of the main basin (Cell 2) based on the active design volume for Cell 2 and a desired average depth, d_2. A calculation of the length, L_{mid2}, and width, W_{mid2}, at half basin depth, d_2, is conducted in order to verify that the length-to-width ratio at half d_2 is greater than 1.5:1.

Step 5: Calculate the dimensions of Cell 2			
5-1. Calculate the active volume of Cell 2, $V_2 = V_a - V_1$	V_2 =	15,728.6	ft^3
5-2. Calculate the surface area of the active volume of Cell 2, $A_2 = A_{av} - A_1$	A_2 =	4,708.9	ft^2
5-3. Calculate the average depth of the active volume of Cell 2, $d_2 = V_2 / A_2$	d_2 =	3.34	ft
5-4. Enter the width of Cell 2, $W_2 = W_1 = W_{av\text{-}tot} = L_{berm}$	W_2 =	28	ft
5-5. Calculate the length of Cell 2, $L_2 = A_2 / W_2$	L_2 =	168.2	ft
5-6. Calculate the width of Cell 2 at half of d_2, $W_{mid2} = W_2 - Zd_2$	W_{mid2} =	18	ft
5-7. Calculate the length of Cell 2 at half of d_2, $L_{mid2} = L_2 - Zd_2$	L_{mid2} =	158.2	ft
5-8. Verify that the length-to-width ratio of Cell 2 at half of d_2 is at least 1.5:1 with ≥ 2:1 preferred. If the length-to-width ratio is less than 1.5:1, modify input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the basin should be chosen, $LW_{mid2} = L_{mid2} / W_{mid2}$	LW_{mid2} =	8.8	

<u>Step 6: Ensure Design Requirements and Site Constraints are Achieved</u>

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location or an alternative treatment BMP.

<u>Step 7: Size Outlet Structure</u>

The total drawdown time for the basin should be 36-48 hours. The outlet structure shall be designed to release the bottom 50% of the detention volume (half-full to empty) over 24-32 hours, and the top half (full to half-full) in 12-16 hours. A primary overflow should be sized to pass the peak flow rate from the developed capital design storm.

Step 8: Determine Emergency Spillway Requirements

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm in order to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the 100-yr, 24-hr post-development peak storm water runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

C.10 HM-2 Wet Detention Basin

Sizing Methodology

Wet Detention basins may be designed with or without extended detention above the permanent pool. The extended detention portion of the wet detention basin above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see HM-1: Dry Extended Detention Basin). If there is no extended detention provided, wet detention basins shall be sized to provide a minimum wet pool volume equal to the stormwater quality design volume plus an additional 5% for sediment accumulation. If extended detention is provided above the permanent pool, the sizing is dependent of the functionality of the basin; the basin may function as water quality treatment only or water quality plus peak flow attenuation.

If the basin is designed for water quality treatment only, then the permanent pool volume shall be a minimum of 10 percent of the stormwater quality design volume and the surcharge volume (above the permanent pool) shall make up the remaining 90 percent. If extended detention is provided above the permanent pool and the basin is designed for water quality treatment and peak flow attenuation, then the permanent pool volume shall be equal to the water quality treatment volume, and the surcharge volume shall be sized to attenuate peak flows in order to meet the peak runoff discharge requirements. The extended detention portion of the wet detention basin above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see HM-1: Dry Extended Detention Basin).

Step 1: Calculate the design volume

Wet detention basins shall be sized with a permanent pool volume equal to the SQDV volume (see Section 2).

Step 2: Determine the active design volume for the wet detention basin without extended detention

The active volume of the wet detention basin, V_a, shall be equal to the SQFV plus an additional 5% for sediment accumulation.

$V_a = 1.05 \times SQDV$ (Equation C-52)

Step 3: Determine pond location and preliminary geometry based on site constraints

Based on site constraints, determine the pond geometry and the storage available by developing an elevation-storage relationship for the pond. Note that a more natural geometry may be used and is in many cases recommended; the preliminary basin geometry calculations should be used for sizing purposes only.

1) Calculate the width of the pond footprint, W_{tot}, as follows:

$$W_{tot} = \frac{A_{tot}}{L_{tot}} \quad \text{(Equation C-53)}$$

Where:

A_{tot} = total surface area of the pond footprint (ft^2)

L_{tot} = total length of the pond footprint (ft)

7) Calculate the length of the active volume surface area including the internal berm but excluding the freeboard, $L_{av\text{-}tot}$:

$$L_{av-tot} = L_{tot} - 2Zd_{fb} \quad \text{(Equation C-54)}$$

Where:

Z = interior side slope as length per unit height

d_{fb} = freeboard depth

8) Calculate the width of the active volume surface area including the internal berm but excluding freeboard, $W_{av\text{-}tot}$:

$$W_{av-tot} = W_{tot} - 2Zd_{fb} \quad \text{(Equation C-55)}$$

9) Calculate the total active volume surface area including the internal berm and excluding freeboard, $A_{av\text{-}tot}$:

$$A_{av-tot} = L_{av-tot} \times W_{av-tot} \quad \text{(Equation C-56)}$$

10) Calculate the area of the berm, A_{berm}:

$$A_{berm} = W_{berm} \times L_{berm} \quad \text{(Equation C-57)}$$

Where:

W_{berm} = width of the internal berm

L_{berm} = length of the internal berm

11) Calculate the active volume surface area excluding the internal berm and freeboard, A_{wq}:

$$A_{wq} = A_{tot} - A_{berm} \quad \text{(Equation C-58)}$$

Step 4: Determine Dimensions of Forebay

The wet detention basin shall be divided into two cells separated by a berm or baffle. The forebay shall contain between 5 and 10 percent of the total volume. The berm or baffle volume shall not count as part of the total volume. Calculate the active volume of forebay, V_1:

$$V_1 = Va \times \%V_1 \quad \text{(Equation C-59)}$$

Where:

$\%V_1$ = percent of SQDV in forebay (%)

1) Calculate the surface area for the active volume of forebay, A_1:

$$A_1 = \frac{V_1}{d_1} \quad \text{(Equation C-60)}$$

Where:

d_1 = average depth fo rhte active volume of forebay (ft)

2) Calculate the length of forebay, L_1. Note, inlet and outlet should be configured to maximize the residence time.

$$L_1 = \frac{A_1}{W_1} \quad \text{(Equation C-61)}$$

Where:

W_1 = width of forebay (ft), $W_1 = W_{av\text{-}tot} = L_{berm}$

Step 5: Determine Dimensions of Cell 2

Cell 2 will consist of the remainder of the basin's active volume.

3) Calculate the active volume of Cell 2, V_2:

$$V_2 = V_a - V_1 \quad \text{(Equation C-62)}$$

4) The minimum wetpool surface area includes 0.3 acres of wetpool per acre-foot of permanent wetpool volume. Calculate A_{min2}:

$$A_{min2} = (V_2 \times 0.3 \ \frac{acres}{acre-feet}) \quad \text{(Equation C-63)}$$

5) Calculate the actual wetpool surface area, A_2:

$$A_2 = A_{av} - A_1 \quad \text{(Equation C-64)}$$

Verify that A_2 is greater than A_{min2}. If A_2 is less than A_{min2}, then modify input parameters to increase A_2 until it is greater than A_{min2}. If site constraints limit this criterion, then another site for the pond should be chosen.

6) Calculate the top length of Cell 2, L_2:

$$L_2 = \frac{A_2}{W_2} \text{(Equation C-65)}$$

Where:

W_2= width of Cell 2 (ft), $W_2 = W_1 = W_{wq\text{-}tot} = L_{berm}$

7) Verify that the length-to-width ratio of Cell 2 is at least 1.5:1 with ≥ 2:1 preferred. If the length-to-width ratio is less than 1.5:1, modify input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the pond should be chosen.

$$LW_2 = \frac{L_2}{W_2} \text{(Equation C-66)}$$

8) Calculate the emergent vegetation surface area, A_{ev}:

$$Aev = A2 \bullet \%Aev \text{(Equation C-67)}$$

Where:

$\%A_{ev}$= percent of surface area that will be planted with emergent vegetation

9) Calculate the volume of the emergent vegetation shallow zone (1.5 – 3 ft), V_{ev}:

$$V_{ev} = A_{ev} \times d_{ev} \text{(Equation C-68)}$$

Where:

d_{ev}= average depth of the emergent vegetation shallow zone (1.5 – 3 ft)

10) Calculate the length of the emergent vegetation shallow zone, L_{ev}:

$$L_{ev} = \frac{A_{ev}}{W_{ev}} \text{(Equation C-69)}$$

Where:

W_{ev} = width of the emergent vegetation shallow zone (ft), $W_{ev} = W_2$

11) Calculate the volume of the deep zone, V_{deep}:

$$V_{deep} = V_2 - V_{ev} \text{(Equation C-70)}$$

12) Calculate the surface area of the deep (>3 ft) zone, A_{deep}:

$$A_{deep} = A_2 - A_{ev} \text{(Equation C-71)}$$

13) Calculate the average depth of the deep zone (4-8 ft), d_{deep}:

$$d_{deep} = \frac{V_{deep}}{A_{deep}} \text{(Equation C-72)}$$

14) Calculate length of the deep zone, L_{deep}:

$$L_{deep} = \frac{A_{deep}}{W_{deep}} \text{(Equation C-73)}$$

Where:

W_{deep}= width of the deep zone (ft), $W_{deep} = W_2$

<u>Step 6: Ensure design requirements and site constraints are achieved</u>

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location for the BMP.

<u>Step 7: Size Outlet Structure</u>

For extended detention wet detention basin, outlet structures shall be designed to provide 12 to 48 hour emptying time for the water quality volume above the permanent pool.

The basin outlet pipe shall be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for off-line basins or flows greater than the peak runoff discharge rate for the 100-year, 24-hr design storm for on-line basins.

<u>Step 8: Determine Emergency Spillway Requirements</u>

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the water quality design storm. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

Sizing Worksheet - HM-2 Wet Detention Basin

Designer: Project Proponent: Date: Project: Location:	
Type of Vegetation: (Check type used or describe "Other")	___ Native Grasses ___ Irrigated Turf Grass ___ Emergent Aquatic Plants (specify type / density) ___ Other_____________________ ____________________________
Outflow Collection:	
Outlet Type (check one)	Single Orifice _____ Multi-orifice Plate _____ Perforated Pipe _____ Other ________________________
Depth of water above bottom orifice	Depth = _____ feet
Single Orifice Outlet	
1)Diameter	D = _____ feet
2) Area	A = _____ square feet
Multiple Orifice Outlet	
1) Area per row of perforations	A = _____ square feet
2) Perforation Diameter (2 inches max.)	D = _____ inches
3) No. of Perforations (columns) per Row	Perforations = _____
4) No. of Rows (4 inch spacing)	Rows = _____
5) Total Orifice Area (Area per row) x (Number of Rows)	Area = _____ square feet
Step 1: Determine water quality design volume	
1-1. Enter project area, $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ = acres
1-2. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =

1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =
1-5. Enter design rainfall depth of the storm, P_i (in)	P_i = in
1-6. Calculate rainfall depth, $P = P_i/12$	P = ft
1-7. Calculate water quality design volume, $SQDV = 43560 \bullet P*A_{project}*C$	SQDV = ft^3
Step 2: Determine active design volume for the wet pond without extended detention	
2-1. Calculate the active design volume (without extended detention), $V_a = 1.05*SQDV$	V_a = ft^3
Step 3: Determine Pond Location and Preliminary Geometry Based on Site Constraints	
3-1. Based on site constraints, determine the pond geometry and the storage available by developing an elevation-storage relationship for the pond. For this simple example, assume a trapezoidal geometry for cell 1 (forebay) and cell 2.	
3-2. Enter the total surface area of the pond footprint based on site constraints, A_{tot}	A_{tot} = ft^2
3-3. Enter the length of the pond footprint based on site constraints, L_{tot}	L_{tot} = ft
3-4. Calculate the width of the pond footprint, $W_{tot} = A_{tot} / L_{tot}$	W_{tot} = ft
3-5. Enter interior side slope as length per unit height (min = 3), Z	Z =
3-6. Enter desired freeboard depth, d_{fb} (1 ft min)	d_{fb} = ft
3-7. Calculate the length of the water quality volume surface area including the internal berm but excluding freeboard, $L_{av\text{-}tot} = L_{tot} - 2Zd_{fb}$	$L_{av\text{-}tot}$ = ft
3-8. Calculate the width of the water quality volume surface area including the internal berm but excluding freeboard, $W_{av\text{-}tot} = W_{tot} - 2Zd_{fb}$	$W_{av\text{-}tot}$ = ft
3-9. Calculate the total water quality volume surface area including the internal berm and excluding freeboard, $A_{av\text{-}tot} = L_{av\text{-}tot} \bullet W_{av\text{-}tot}$	$A_{av\text{-}tot}$ = ft^2
3-10. Enter the width of the internal berm (6 ft min), W_{berm}	W_{berm} = ft
3-11. Enter the length of the internal berm, $L_{berm} = W_{av\text{-}tot}$	L_{berm} = ft
3-12. Calculate the area of the berm, $A_{berm} = W_{berm} \bullet L_{berm}$	A_{berm} = ft^2
3-13. Calculate the water quality volume surface area excluding the internal berm and freeboard, $A_{av} = A_{av\text{-}tot} - A_{berm}$	A_{av} = ft^2

Step 4: Determine Dimensions of forebay		
4-1. Enter the percent of V_a in forebay (5-10% required), $\%V_1$	$\%V_1$ =	%
4-2. Calculate the active volume of forebay (includes sediment storage volume), $V_1 = V_a \bullet \%V_1$	V_1 =	ft^3
4-3. Enter desired average depth of forebay (5-9 ft including sediment storage of 1 ft), d_1	d_1 =	ft
4-4. Calculate the surface area for the active volume of forebay, $A_1 = V_1 / d_1$	A_1 =	ft^2
4-5. Enter the width of forebay, $W_1 = W_{av\text{-}tot} = L_{berm}$	W_1 =	ft
4-6. Calculate the length of forebay (<u>Note:</u> inlet and outlet should be configured to maximize the residence time), $L_1 = A_1 / W1$	L_1 =	ft
Step 5: Determine Dimensions of Cell 2		
5-1. Calculate the active volume of Cell 2, $V_2 = V_a - V_1$	V_2 =	ft^3
5-2. Determine minimum wetpool surface area, $A_{min2} = V_2 \bullet 0.3$	A_{min2} =	ft^2
5-3. Determine actual wetpool surface area, $A_2 = A_{av} - A_1$	A_2 =	ft^2
5-4. If A_2 is greater than A_{min2} then move on to step 5-5. If A_2 is less than A_{min2}, then modify input parameters to increase A_2 until it is greater than A_{min2}. If site constraints limit this criterion, then another site for the pond should be chosen.		
5-5. Enter width of Cell 2, $W_2 = W_1 = W_{av\text{-}tot} = L_{berm}$	W_2 =	ft
5-6. Calculate top length of Cell 2, $L_2 = A_2 / W_2$	L_2 =	ft
5-7. Verify that the length-to-width ratio of Cell 2 is at least 1.5:1 with ≥ 2:1 preferred. If the length-to-width ratio is less than 1.5:1, modify input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the pond should be chosen, $LW_2 = L_2 / W_2$	LW_2 =	
5-8. Enter percent of surface area that will be planted with emergent vegetation (25-75%), $\%A_{ev}$	$\%A_{ev}$ =	%
5-9. Calculate emergent vegetation surface area, $A_{ev} = A_2 \bullet \%A_{ev}$	A_{ev} =	ft^2
5-10. Enter average depth of emergent vegetation shallow zone (1.5 – 3 ft), d_{ev}	d_{ev} =	ft

5-11. Calculate volume of emergent vegetation shallow zone (1.5 – 3 ft), $V_{ev} = A_{ev} \bullet d_{ev}$	V_{ev} =	ft^3
5-12. Enter width of emergent vegetation shallow zone, $W_{ev} = W_2$	W_{ev}=	ft
5-13. Calculate length of emergent vegetation shallow zone, $L_{ev} = A_{ev} / W_{ev}$	L_{ev} =	ft
5-14. Calculate volume of deep zone, $V_{deep} = V_2 – V_{ev}$	V_{deep} =	ft^3
5-15. Calculate surface area of deep (>3 ft) zone, $A_{deep} = A_2 – A_{ev}$	A_{deep} =	ft^2
5-16. Calculate average depth of deep zone (4 - 8 ft), $d_{deep} = V_{deep} / A_{deep}$	d_{deep} =	ft
5-17. Enter width of deep zone, $W_{deep} = W_2$	W_{deep} =	ft
5-18. Calculate length of deep zone, $L_{deep} = A_{deep} / W_{deeo}$	L_{deep} =	ft
Step 6: Ensure Design Requirements and Site Constraints are Achieved		
6-1. Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location for the BMP.		
Step 7: Size Outlet Structure		
7-1. The basin outlet pipe shall be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for off-line basins or flows greater than the peak runoff discharge rate for the 100-year, 24-hr design storm for on-line basins.		
Step 8: Determine Emergency Spillway Requirements		
8-1. For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the water quality design storm. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.		

Design Example

Wet detention basin siting requires the following considerations prior to construction: (1) availability of base flow – wet detention basins require a regular source of water if water level is to be maintained, (2) surface space availability – large footprint area is required, and (3) compatibility with flood control – basins must not interfere with flood control functions of existing conveyance and detention structures.

The wet detention basin in this example does not have extended detention. An internal berm separates the forebay (Cell 1) and the main basin (Cell 2). The berm is at the elevation of the active volume design surface which is also the permanent wetpool elevation.

Step 1: Determine Water Quality Design Volume

For this design example, a 20-acre residential development with a 60% total impervious area is considered. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine water quality design volume			
1-1. Enter project drainage area, $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ =	20	acres
1-2. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	0.6	
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	0.05	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	0.59	
1-5. Enter design rainfall depth of the storm, P_i (in)	P_i =	0.75	in
1-6. Calculate rainfall depth, $P = P_i/12$	P =	0.06	ft
1-7. Calculate water quality design volume, $SQDV = 43560 \bullet P * A_{project} * C$	SQDV =	30,840.5	ft^3

Step 2: Determine Active Design Volume for a Wet Detention Basin without Extended Detention

If there is no extended detention provided, wet detention basins shall be sized to provide a minimum wet pool volume equal to the water quality design volume plus an additional 5% for sediment accumulation.

Step 2: Determine Active Design Volume for a Wet Detention Basin without Extended Detention			
2-1. Calculate the active design volume (without extended detention), $V_a = 1.05*SQDV$	V_a =	32,382.5	ft^3

Step 3: Determine Pond Location and Preliminary Geometry Based on Site Constraints

A total footprint area and total length available for the basin is provided. This step calculates the total active volume surface area which is equivalent to the permanent wetpool surface area. This step also calculates the dimensions of the internal berm.

Step 3: Determine Pond Location and Preliminary Geometry Based on Site Constraints			
3-1. Based on site constraints, determine the pond geometry and the storage available by developing an elevation-storage relationship for the pond. For this simple example, assume a trapezoidal geometry for cell 1 (forebay) and cell 2.			
3-2. Enter the total surface area of the pond footprint based on site constraints, A_{tot}	A_{tot} =	7,500	ft^2
3-3. Enter the length of the pond footprint based on site constraints, L_{tot}	L_{tot} =	150	ft
3-4. Calculate the width of the pond footprint, $W_{tot} = A_{tot} / L_{tot}$	W_{tot} =	50	ft
3-5. Enter interior side slope as length per unit height (min = 3), Z	Z =	3	
3-6. Enter desired freeboard depth, d_{fb} (1 ft min)	d_{fb} =	2	ft
3-7. Calculate the length of the water quality volume surface area including the internal berm but excluding freeboard, $L_{av\text{-}tot} = L_{tot} - 2Zd_{fb}$	$L_{av\text{-}tot}$ =	138	ft
3-8. Calculate the width of the water quality volume surface area including the internal berm but excluding freeboard, $W_{av\text{-}tot} = W_{tot} - 2Zd_{fb}$	$W_{av\text{-}tot}$ =	38	ft
3-9. Calculate the total water quality volume surface area including the internal berm and excluding freeboard, $A_{av\text{-}tot} = L_{av\text{-}tot} \bullet W_{av\text{-}tot}$	$A_{av\text{-}tot}$ =	5,244	ft^2
3-10. Enter the width of the internal berm (6 ft min), W_{berm}	W_{berm} =	6	ft
3-11. Enter the length of the internal berm, $L_{berm} = W_{av\text{-}tot}$	L_{berm} =	38	ft
3-12. Calculate the area of the berm, $A_{berm} = W_{berm} \bullet L_{berm}$	A_{berm} =	228	ft^2
3-13. Calculate the water quality volume surface area excluding the internal berm and freeboard, $A_{av} = A_{av\text{-}tot} - A_{berm}$	A_{av} =	5,016	ft^2

Step 4: Determine Dimensions of forebay

It should be assumed that the forebay should be 5-10% of the total active design volume, V_a.

Step 4: Determine Dimensions of Cell 1			
4-1. Enter the percent of V_a in forebay (5-10% required), $\%V_1$	$\%V_1$ =	10	%
4-2. Calculate the active volume of forebay (includes sediment storage volume), $V_1 = V_a \bullet \%V_1$	V_1 =	3,238.3	ft^3
4-3. Enter desired average depth of forebay (5-9 ft including sediment storage of 1 ft), d_1	d_1 =	8	ft
4-4. Calculate the surface area for the active volume of forebay, $A_1 = V_1 / d_1$	A_1 =	404.8	ft^2
4-5. Enter the width of forebay, $W_1 = W_{av\text{-}tot} = L_{berm}$	W_1 =	38	ft
4-6. Calculate the length of forebay (Note: inlet and outlet should be configured to maximize the residence time), $L_1 = A_1 / W1$	L_1 =	10.7	ft

Step 5: Determine Dimensions of Cell 2

Verify that the surface area and length-to-width ratio of Cell 2 meet the design criteria. Calculate volumes, depths and surface areas for the emergent vegetation shallow zone and the deep zone.

Step 5: Determine Dimensions of Cell 2			
5-1. Calculate the active volume of Cell 2, $V_2 = V_a - V_1$	V_2 =	29,144.2	ft^3
5-2. Determine minimum wetpool surface area, $A_{min2} = V_2 \bullet 0.3$	A_{min2} =	8,743.3	ft^2
5-3. Determine actual wetpool surface area, $A_2 = A_{av} - A_1$	A_2 =	4,610.2	ft^2
5-4. If A_2 is greater than A_{min2} then move on to step 5-5. If A_2 is less than A_{min2}, then modify input parameters to increase A_2 until it is greater than A_{min2}. If site constraints limit this criterion, then another site for the pond should be chosen.			
5-5. Enter width of Cell 2, $W_2 = W_1 = W_{av\text{-}tot} = L_{berm}$	W_2 =	38	ft
5-6. Calculate top length of Cell 2, $L_2 = A_2 / W_2$	L_2 =	121.3	ft
5-7. Verify that the length-to-width ratio of Cell 2 is at least 1.5:1 with ≥ 2:1 preferred. If the length-to-width ratio is less than 1.5:1, modify input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the pond should be chosen, $LW_2 = L_2 / W_2$	LW_2 =	3.2	

Step 5: Determine Dimensions of Cell 2			
5-8. Enter percent of surface area that will be planted with emergent vegetation (25-75%), $\%A_{ev}$	$\%A_{ev}$ =	25	%
5-9. Calculate emergent vegetation surface area, $A_{ev} = A_2 \bullet \%A_{ev}$	A_{ev} =	1,152.6	ft^2
5-10. Enter average depth of emergent vegetation shallow zone (1.5 – 3 ft), d_{ev}	d_{ev} =	2	ft
5-11. Calculate volume of emergent vegetation shallow zone (1.5 – 3 ft), $V_{ev} = A_{ev} \bullet d_{ev}$	V_{ev} =	1,950	ft^3
5-12. Enter width of emergent vegetation shallow zone, $W_{ev} = W_2$	W_{ev}=	38	ft
5-13. Calculate length of emergent vegetation shallow zone, $L_{ev} = A_{ev} / W_{ev}$	L_{ev} =	30.33	ft
5-14. Calculate volume of deep zone, $V_{deep} = V_2 – V_{ev}$	V_{deep} =	27,194	ft^3
5-15. Calculate surface area of deep (>3 ft) zone, $A_{deep} = A_2 – A_{ev}$	A_{deep} =	3,457.6	ft^2
5-16. Calculate average depth of deep zone (4 - 8 ft), $d_{deep} = V_{deep} / A_{deep}$	d_{deep} =	7.9	ft
5-17. Enter width of deep zone, $W_{deep} = W_2$	W_{deep} =	38	ft
5-18. Calculate length of deep zone, $L_{deep} = A_{deep} / W_{deeo}$	L_{deep} =	91.0	ft

Step 6: Ensure Design Requirements and Site Conditions are Achieved

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location for the BMP.

Step 7: Size Outlet Structure

The basin outlet pipe shall be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for off-line basins or flows greater than the peak runoff discharge rate for the 100-year, 24-hr design storm for on-line basins.

Step 8: Determine Emergency Spillway Requirements

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the water quality design storm. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

C.11 HM-3 Constructed Wetland

Sizing Methodology

In most cases, the constructed treatment wetland permanent pool shall be sized to be greater than or equal to the stormwater quality design volume. If extended detention is provided above the permanent pool and the wetland is designed for water quality treatment only, then the permanent pool volume shall be a minimum of 80 percent of the stormwater quality design volume and the surcharge volume (above the permanent pool) shall make up the remaining 20 percent and provide at least 12 hours of detention. If extended detention is provided and the basin is designed for water quality treatment and peak flow attenuation, then the permanent pool volume shall be equal to the water quality treatment volume and the surcharge volume shall be sized to attenuate peak flows to meet the peak runoff discharge requirements. The extended detention portion of the wetland above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see HM-1: Dry Extended Detention Basin).

Step 1: Calculate the design volume

Constructed wetlands shall be sized to be greater than or equal to the SQDV volume (see Section 2).

Step 2: Determine the Wetland Location, Wetland Type and Preliminary Geometry Based on Site Constraints

Based on site constraints, determine the wetland geometry and the storage available by developing an elevation-storage relationship for the wetland. The equations provided below assume a trapezoidal geometry for cell 1 (Forebay) and cell 2, and assumes that the wetland does not have extended detention.

1) Calculate the width of the wetland footprint, W_{tot}, as follows:

$$W_{tot} = \frac{A_{tot}}{L_{tot}} \qquad \text{(Equation C-74)}$$

Where:

A_{tot} = total surface area of the wetland footprint (ft^2)

L_{tot} = total length of the wetland footprint (ft)

2) Calculate the length of the water quality volume surface area including the internal berm but excluding the freeboard, $L_{wq\text{-}tot}$:

$$L_{wq-tot} = L_{tot} - 2Zd_{fb} \qquad \text{(Equation C-75)}$$

Where:

Z = interior side slope as length per unit height

d_{fb} = freeboard depth

3) Calculate the width of the water quality volume surface area including the internal berm but excluding freeboard, $W_{wq\text{-}tot}$:

$$W_{wq-tot} = W_{tot} - 2Zd_{fb}$$ (Equation C-76)

4) Calculate the total water quality volume surface area including the internal berm and excluding freeboard, $A_{wq\text{-}tot}$:

$$A_{wq-tot} = L_{wq-tot} \times W_{wq-tot}$$ (Equation C-77)

5) Calculate the area of the berm, A_{berm}:

$$A_{berm} = W_{berm} \times L_{berm}$$ (Equation C-78)

Where:

W_{berm} = width of the internal berm

L_{berm} = length of the internal berm

6) Calculate the water quality surface area excluding the internal berm and freeboard, A_{wq}:

$$A_{wq} = A_{tot} - A_{berm}$$ (Equation C-79)

Step 3: Determine Dimensions of Forebay

30-50% of the SQDV is required to be within the active volume of forebay.

1) Calculate the active volume of forebay, V_1:

$$V_1 = SQDV \times \%V_1$$ (Equation C-80)

Where:

$\%V_1$ = percent of SQDV in forebay (%)

2) Calculate the surface area for the active volume of forebay, A_1:

$$A_1 = \frac{V_1}{d_1}$$ (Equation C-81)

Where:

d_1 = average depth fo rhte active volume of forebay (2 -4 ft) (ft)

3) Calculate the length of forebay, L_1. Note, inlet and outlet should be configured to maximize the residence time.

$$L_1 = \frac{A_1}{W_1} \text{ (Equation C-82)}$$

Where:

W_1 = width of forebay (ft), $W_1 = W_{av\text{-}tot} = L_{berm}$

Step 4: Determine Dimensions of Cell 2

Cell 2 will consist of the remainder of the basin's active volume.

1) Calculate the active volume of Cell 2, V_2:

$$V_2 = SQDV - V_1 \quad \text{(Equation C-83)}$$

2) Calculate the surface area of Cell 2, A_2:

$$A_2 = A_{av} - A_1 \quad \text{(Equation C-84)}$$

3) Calculate the top length of Cell 2, L_2:

$$L_2 = \frac{A_2}{W_2} \text{ (Equation C-85)}$$

Where:

W_2= width of Cell 2 (ft), $W_2 = W_1 = W_{wq\text{-}tot} = L_{berm}$

4) Verify that the length-to-width ratio of Cell 2, LW_2, is at least 3:1 with ≥ 4:1 preferred. If the length-to-width ratio is less than 3:1, modify input parameters until a ratio of at least 3:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the pond should be chosen.

$$LW_2 = \frac{L_2}{W_2} \text{ (Equation C-86)}$$

5) Calculate the very shallow zone surface area, A_{vs}:

$$Avs = A2 \bullet \%Avs \text{(Equation C-87)}$$

Where:

$\%A_{vs}$= percent of surface area of very shallow zone

6) Calculate the volume of the shallow zone, V_{vs}:

$$V_{vs} = A_{vs} \times d_{ds} \text{(Equation C-88)}$$

Where:

d_{vs}= average depth of the very shallow zone (0.1 – 1 ft)

7) Calculate the length of the very shallow zone, L_{vs}:

$$L_{vs} = \frac{A_{vs}}{W_{vs}} \text{ (Equation C-89)}$$

Where:

W_{vs} = width of the very shallow zone (ft), $W_{vs} = W_2$

8) Calculate the surface area of the shallow zone, A_s:

$$As = A2 \bullet \%As \text{(Equation C-90)}$$

Where:

$\%A_s$ = percent of surface area of shallow zone

9) Calculate the volume of the shallow zone, V_s:

$$V_s = A_s \times d_s \text{(Equation C-91)}$$

Where:

d_s= average depth of shallow zone (1 - 3 ft)

10) Calculate length of the shallow zone, L_s:

$$L_s = \frac{A_s}{W_s} \text{ (Equation C-92)}$$

Where:

W_s= width of the shallow zone (ft), $W_s = W_2$

11) Calculate the surface area of the deep zone, A_{deep}:

$$A_{deep} = A_2 - A_{vs} - A_s \text{(Equation C-93)}$$

12) Calculate the volume of the deep zone, V_{deep}:

$$V_{deep} = V_2 - V_{vs} - V_s \text{(Equation C-94)}$$

13) Calculate the average depth of the deep zone (3-5 ft), d_{deep}:

$$d_{deep} = \frac{V_{deep}}{A_{deep}} \text{ (Equation C-95)}$$

14) Calculate length of the deep zone, L_{deep}:

$$L_{deep} = \frac{A_{deep}}{W_{deep}} \text{ (Equation C-96)}$$

Where:

W_{deep} = width of the deep zone (ft), $W_{deep} = W_2$

Step 5: Ensure design requirements and site constraints are achieved

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location or alternative treatment BMP.

Step 6: Size Outlet Structure

For wetlands with detention, the outlet structures shall be designed to provide 12 hours emptying time for the water quality volume or the required detention necessary for achieving the peak runoff discharge requirements if the extended detention is designed for flow attenuation.

The wetland outlet pipe shall be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for on-line basins or flows greater than the peak runoff discharge rate for the 100-year, 24-hr design storm for on-line basins.

Step 7: Determine Emergency Spillway Requirements

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm in order to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the 100-yr, 24-hr post-development peak storm water runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

Sizing Worksheet - HM-3 Constructed Wetland

Designer: Project Proponent: Date: Project: Location:	
Type of Vegetation: (Check type used or describe "Other")	___ Native Grasses ___ Irrigated Turf Grass ___ Emergent Aquatic Plants (specify type / density)* ___ Other ____________________ *Describe Species Density and Mix:_______________________________________ ____ ____ __________________
Outflow Collection:	
Outlet Type (check one)	Single Orifice _____ Multi-orifice Plate _____ Perforated Pipe _____ Other ________________________
Depth of water above bottom orifice	Depth = _____ feet
Single Orifice Outlet	
1)Diameter	D = _____ feet
2) Area	A = _____ square feet
Multiple Orifice Outlet	
1) Area per row of perforations	A = _____ square inches
2) Perforation Diameter (2 inches max.)	D = _____
3) No. of Perforations (columns) per Row	Perforations = _____
4) No. of Rows (4 inch spacing)	Rows = _____
5) Total Orifice Area (Area per row) x (Number of Rows)	Area = _____ square inches

Step 1: Determine water quality design volume		
1-1. Enter project drainage area, A If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ =	acres
1-2. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =	
1-5. Enter design rainfall depth of the storm, P_i (in)	P_i =	in
1-6. Calculate rainfall depth, $P = P_i/12$	P =	ft
1-7. Calculate water quality design volume, $SQDV = 43560 \bullet P * A_{project} * C$	SQDV =	ft^3
Step 2: Determine Wetland Location, Wetland Type and Preliminary Geometry Based on Site Constraints		
2-1. Based on site constraints, determine the wetland geometry and the storage available by developing an elevation-storage relationship for the wetland. For this simple example, assume a trapezoidal geometry for cell 1 (forebay) and cell 2. The wetland does not have extended detention.		
2-2. Enter the total surface area of the wetland footprint based on site constraints, A_{tot}	A_{tot} =	ft^2
2-3. Enter the length of the wetland footprint based on site constraints, L_{tot}	L_{tot} =	ft
2-4. Calculate the width of the wetland footprint, $W_{tot} = A_{tot} / L_{tot}$	W_{tot} =	ft
2-5. Enter interior side slope as length per unit height (min = 3), Z	Z =	
2-6. Enter desired freeboard depth, d_{fb}	d_{fb} =	ft
2-7. Calculate the length of the water quality volume surface area including the internal berm but excluding freeboard, $L_{wq-tot} = L_{tot} - 2Zd_{fb}$	L_{wq-tot} =	ft
2-8. Calculate the width of the water quality volume surface area including the internal berm but excluding freeboard, $W_{wq-tot} = W_{tot} - 2Zd_{fb}$	W_{wq-tot} =	ft
2-9. Calculate the total water quality volume surface area including the internal berm and excluding freeboard, $A_{wq-tot} = L_{wq-tot} \bullet W_{wq-tot}$	A_{wq-tot} =	ft^2
2-10. Enter the width of the internal berm (6 ft min), W_{berm}	W_{berm} =	ft
2-11. Enter the length of the internal berm, $L_{berm} = W_{wq-tot}$	L_{berm} =	ft

2-12. Calculate the area of the berm, $A_{berm} = W_{berm} \bullet L_{berm}$	A_{berm} =	ft^2
2-13. Calculate the water quality volume surface area excluding the internal berm and freeboard, $A_{wq} = A_{wq\text{-}tot} - A_{berm}$	A_{wq} =	ft^2
Step 3: Determine Dimensions of forebay		
3-1. Enter the percentage of SQDV in forebay (30-50% required), $\%V_1$	$\%V_1$ =	%
3-2. Calculate the active volume of forebay (includes water quality volume + sediment storage volume), $V_1 = SQDV \bullet \%V_1$	V_1 =	ft^3
3-3. Enter desired average depth of forebay1 (2-4 ft including sediment storage of 1 ft), d_1	d_1 =	ft
3-4. Calculate the surface area for the water quality volume of forebay, $A_1 = V_1 / d_1$	A_1 =	ft^2
3-5. Enter the width of forebay, $W_1 = W_{av\text{-}tot} = L_{berm}$	W_1 =	ft
3-6. Calculate the length of forebay (<u>Note:</u> inlet and outlet should be configured to maximize the residence time), $L_1 = A_1 / W1$	L_1 =	ft
Step 4: Determine Dimensions of Cell 2		
4-1. Calculate the active volume of Cell 2, $V_2 = SQDV - V_1$	V_2 =	ft^3
4-2. Calculate surface area of Cell 2, $A_2 = A_{wq} - A_1$	A_2 =	ft^2
4-3. Enter width of Cell 2, $W_2 = W_1 = W_{wq\text{-}tot} = L_{berm}$	W_2 =	ft
4-4. Calculate top length of Cell 2, $L_2 = A_2 / W_2$	L_2 =	ft
4-5. Verify that the length-to-width ratio of Cell 2 is at least 3:1 with ≥ 4:1 preferred. If the length-to-width ratio is less than 3:1, modify input parameters until a ratio of at least 3:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the pond should be chosen, $LW_2 = L_2 / W_2$	LW_2 =	
4-6. Enter percent of surface area of very shallow zone, $\%A_{vs}$	$\%A_{vs}$ =	%
4-7. Calculate very shallow zone surface area, $A_{vs} = A_2 \bullet \%A_{vs}$	A_{vs} =	ft^2
4-8. Enter average depth of very shallow zone (0.1 - 1 ft), d_{vs}	d_{vs} =	ft
4-9. Calculate volume of very shallow zone, $V_{vs} = A_{vs} \bullet d_{vs}$	V_{vs} =	ft^3
4-10. Enter width of very shallow zone, $W_{vs} = W_2$	W_{vs} =	ft
4-11. Calculate length of very shallow zone, $L_{vs} = A_{vs} / W_{vs}$	L_{vs} =	ft

4-12. Enter percent of surface area of shallow zone, $\%A_s$	$\%A_s$ =	%
4-13. Calculate surface area of shallow zone, $A_s = A_2 \bullet \%A_s$	A_s =	ft^2
4-14. Enter average depth of shallow zone (1 - 3 ft), d_s	d_s =	ft
4-15. Calculate volume of shallow zone, $V_s = A_s \bullet d_s$	V_s =	ft^3
4-16. Enter width of shallow zone, $W_s = W_2$	W_s =	ft
4-17. Calculate length of shallow zone, $L_s = A_s / W_s$	L_s =	ft
4-18. Calculate surface area of deep zone, $A_{deep} = A_2 - A_{vs} - A_s$	A_{deep} =	ft^2
4-19. Calculate volume of deep zone, $V_{deep} = V_2 - V_{vs} - V_s$	V_{deep} =	ft^3
4-20. Calculate average depth of deep zone (3 - 5 ft), $d_{deep} = V_{deep} / A_{deep}$	d_{deep} =	ft
4-21. Enter width of deep zone, $W_{deep} = W_2$	W_{deep} =	ft
4-22. Calculate length of deep zone, $L_{deep} = A_{deep} / W_{deeo}$	L_{deep} =	ft
Step 5: Ensure Design Requirements and Site Constraints are Achieved		
5-1. Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the wetland is inadequate to meet the design requirements, choose a new location for the wetland or select an alternative treatment BMP.		
Step 6: Size Outlet Structure		
6-1. The wetland outlet pipe shall be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for off-line basins or flow from the capital storm for on-line basins.		
Step 7: Determine Emergency Spillway Requirements		
7-1. For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm in order to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the 100-yr, 24-hr post-development peak storm water runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point.		

Design Example

Wetland siting requires the following considerations prior to construction: (1) availability of base flow – stormwater wetlands require a regular source of water to support wetland biota, (2) slope stability – stormwater wetlands are not permitted near steep slope hazard areas, (3) surface space availability – large footprint area is required, and (4) compatibility with flood control – basins must not interfere with flood control functions of existing conveyance and detention structures.

The wetland in this example does not have extended detention. An internal berm separates the forebay (Cell 1) and the main basin (Cell 2). The berm is at the elevation of the active volume (SQDV plus sediment storage volume) design surface which is also the permanent wetpool elevation.

Step 1: Determine Water Quality Design Volume

For this design example, a 20-acre residential development with a 60% total impervious area is considered. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine water quality design volume			
1-1. Enter project drainage area, A If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ =	20	acres
1-2. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	0.6	
1-4. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	0.05	
1-5. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =	0.59	
1-6. Enter design rainfall depth of the storm, P_i (in)	P_i =	0.75	in
1-7. Calculate rainfall depth, $P = P_i/12$	P =	0.06	ft
1-8. Calculate water quality design volume, $SQDV = 43560 \bullet P*A_{project}*C$	SQDV =	30,840	ft^3

Step 2: Determine Pond Location and Preliminary Geometry Based on Site Constraints

A total footprint area and total length available for the wetland is provided. This step calculates the total active volume surface area which is equivalent to the permanent wetpool surface area. This step also calculates the dimensions of the internal berm.

Step 2: Determine Wetland Location, Wetland Type and Preliminary Geometry Based on Site Constraints
2-1. Based on site constraints, determine the wetland geometry and the storage available by developing an elevation-storage relationship for the wetland. For this simple example, assume a trapezoidal geometry for cell 1 (forebay) and cell 2. The wetland does not have extended detention.

Step 2: Determine Wetland Location, Wetland Type and Preliminary Geometry Based on Site Constraints			
2-2. Enter the total surface area of the wetland footprint based on site constraints, A_{tot}	A_{tot} =	14,000	ft^2
2-3. Enter the length of the wetland footprint based on site constraints, L_{tot}	L_{tot} =	250	ft
2-4. Calculate the width of the wetland footprint, $W_{tot} = A_{tot} / L_{tot}$	W_{tot} =	56	ft
2-5. Enter interior side slope as length per unit height (min = 3), *Z*	Z =	3	
2-6. Enter desired freeboard depth, d_{fb}	d_{fb} =	2	ft
2-7. Calculate the length of the water quality volume surface area including the internal berm but excluding freeboard, $L_{wq\text{-}tot} = L_{tot} - 2Zd_{fb}$	$L_{wq\text{-}tot}$ =	238	ft
2-8. Calculate the width of the water quality volume surface area including the internal berm but excluding freeboard, $W_{wq\text{-}tot} = W_{tot} - 2Zd_{fb}$	$W_{wq\text{-}tot}$ =	44	ft
2-9. Calculate the total water quality volume surface area including the internal berm and excluding freeboard, $A_{wq\text{-}tot} = L_{wq\text{-}tot} \bullet W_{wq\text{-}tot}$	$A_{wq\text{-}tot}$ =	10,472	ft^2
2-10. Enter the width of the internal berm (6 ft min), W_{berm}	W_{berm} =	6	ft
2-11. Enter the length of the internal berm, $L_{berm} = W_{wq\text{-}tot}$	L_{berm} =	44	ft
2-12. Calculate the area of the berm, $A_{berm} = W_{berm} \bullet L_{berm}$	A_{berm} =	264	ft^2
2-13. Calculate the active volume surface area excluding the internal berm and freeboard, $A_{wq} = A_{wq\text{-}tot} - A_{berm}$	A_{wq} =	10,206	ft^2

Step 3: Determine Dimensions of Forebay

It should be assumed that the forebay should be 30-50% of the SQDV.

Step 3: Determine Dimensions of forebay			
3-1. Enter the percentage of SQDV in forebay (30-50% required), $\%V_1$	$\%V_1$ =	30	%
3-2. Calculate the active volume of forebay (including sediment storage), $V_1 = (SQDV \bullet \%V_1)/100$	V_1 =	9,250	ft^3
3-3. Enter desired average depth of forebay (2-4 ft including sediment storage of 1 ft), d_1	d_1 =	4	ft

3-4. Calculate the surface area for the water quality volume of forebay, $A_1 = V_1 / d_1$	A_1 =	2,312.5	ft^2
3-5. Enter the width of forebay, $W_1 = W_{av\text{-}tot} = L_{berm}$	W_1 =	44	ft
3-6. Calculate the length of forebay (<u>Note:</u> inlet and outlet should be configured to maximize the residence time), $L_1 = A_1 / W1$	L_1 =	52.6	ft

Step 4: Determine Dimensions of Cell 2

Verify that the surface area and length-to-width ratio of Cell 2 meet the design criteria. Calculate volumes, depths and surface areas for the very shallow, shallow and deep zones.

Step 4: Determine Dimensions of Cell 2			
4-1. Calculate the active volume of Cell 2, V_2 = SQDV - V_1	V_2 =	21,590	ft^3
4-2. Calculate surface area of Cell 2, $A_2 = A_{wq} - A_1$	A_2 =	7,893.5	ft^2
4-3. Enter width of Cell 2, $W_2 = W_1 = W_{wq\text{-}tot} = L_{berm}$	W_2 =	44	ft
4-4. Calculate top length of Cell 2, $L_2 = A_2 / W_2$	L_2 =	179.4	ft
4-5. Verify that the length-to-width ratio of Cell 2 is at least 3:1 with ≥ 4:1 preferred. If the length-to-width ratio is less than 3:1, modify input parameters until a ratio of at least 3:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the pond should be chosen, $LW_2 = L_2 / W_2$	LW_2 =	4.1	
4-6. Enter percent of surface area of very shallow zone, $\%A_{vs}$	$\%A_{vs}$ =	15	ft^2
4-7. Calculate very shallow zone surface area, $A_{vs} = A_2 \bullet \%A_{vs}$	A_{vs} =	1,184	ft^2
4-8. Enter average depth of very shallow zone (0.1 - 1 ft), d_{vs}	d_{vs} =	1	ft
4-9. Calculate volume of very shallow zone, $V_{vs} = A_{vs} \bullet d_{vs}$	V_{vs} =	1,184	ft^3
4-10. Enter width of very shallow zone, $W_{vs} = W_2$	W_{vs} =	44	ft
4-11. Calculate length of very shallow zone, $L_{vs} = A_{vs} / W_{vs}$	L_{vs} =	26.9	ft
4-12. Enter percent of surface area of shallow zone, $\%A_s$	$\%A_s$ =	55	
4-13. Calculate surface area of shallow zone, $A_s = A_2 \bullet \%A_s$	A_s =	4,341.4	ft^2
4-14. Enter average depth of shallow zone (1 - 3 ft), d_s	d_s =	3	ft
4-15. Calculate volume of shallow zone, $V_s = A_s \bullet d_s$	V_s =	13,024.3	ft^3
4-16. Enter width of shallow zone, $W_s = W_2$	W_s =	44	ft
4-17. Calculate length of shallow zone, $L_s = A_s / W_s$	L_s =	98.1	ft
4-18. Calculate surface area of deep zone, $A_{deep} = A_2 - A_{vs} - A_s$	A_{deep} =	2,368.1	ft^2

Step 4: Determine Dimensions of Cell 2			
4-19. Calculate volume of deep zone, $V_{deep} = V_2 - V_{vs} - V_s$	V_{deep} =	7,351.7	ft^3
4-20. Calculate average depth of deep zone (3 - 5 ft), $d_{deep} = V_{deep} / A_{deep}$	d_{deep} =	3.1	ft
4-21. Enter width of deep zone, $W_{deep} = W_2$	W_{deep} =	44	ft
4-22. Calculate length of deep zone, $L_{deep} = A_{deep} / W_{deeo}$	L_{deep} =	53.8	ft

Step 5: Ensure Design Requirements and Site Conditions are Achieved

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the wetland is inadequate to meet the design requirements, choose a new location for the wetland or select an alternative treatment BMP.

Step 6: Size Outlet Structure

6-1. The wetland outlet pipe shall be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for off-line basins or flow from the capital storm for on-line basins.

Step 7: Determine Emergency Spillway Requirements

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm in order to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the 100-yr, 24-hr post-development peak storm water runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point.

C.12 PT-3 Vegetated Swale

Sizing Methodology

The flow capacity of a vegetated swale is a function of the longitudinal slope (parallel to flow), the resistance to flow (i.e. Manning's roughness), and the cross-sectional area. The cross section is normally approximately trapezoidal, and the area is a function of the bottom width and side slopes. The flow capacity of vegetated swales should be such that the design water quality flow rate will not exceed a flow depth of 2/3 the height of the vegetation within the swale or 4 inches at the water quality design flow rate. Once design criteria have been selected, the resulting flow depth for the design water quality design flow rate is checked. If the depth restriction is exceeded, swale parameters (e.g. longitudinal slope, width) are adjusted to reduce the flow depth.

Procedures for sizing vegetated swales are summarized below. A vegetated swale sizing worksheet and example are also provided.

Step 1: Select design flows

The swale size is based on the stormwater quality design flow SQDF (see Appendix C.1).

Step 2: Calculate swale bottom width

The swale bottom width is calculated based on Manning's equation for open-channel flow. This equation can be used to calculate discharges as follows:

$$Q = \frac{1.49AR^{0.67}S^{0.5}}{n}$$

(Equation C-97)

Where:

Q	=	flow rate (cfs)
n	=	Manning's roughness coefficient (unitless)
A	=	cross-sectional area of flow (ft^2)
R	=	hydraulic radius (ft) = area divided by wetted perimeter
S	=	longitudinal slope (ft/ft)

For shallow flow depths in swales, channel side slopes are ignored in the calculation of bottom width. Use the following equation (a simplified form of Manning's formula) to estimate the swale bottom width:

$$b = \frac{SQDF * n_{wq}}{1.49\, y^{1.67} S^{0.5}} \qquad \text{(Equation C-98)}$$

Where:

b	=	bottom width of swale (ft)
$SQDF$	=	stormwater quality design flow (cfs)
n_{wq}	=	Manning's roughness coefficient for shallow flow conditions = 0.2 (unitless)
y	=	design flow depth (ft)
s	=	longitudinal slope (along direction of flow) (ft/ft)

Proceed to Step 3 if the bottom width is calculated to be between 2 and 10 feet. A minimum 2-foot bottom width is required. Therefore, if the calculated bottom width is less than 2 feet, increase the width to 2 feet and recalculate the design flow depth y using the Equation C-13, where Q_{wq}, n_{wq}, and s are the same values as used above, but b = 2 feet.

The maximum allowable bottom width is 10 feet; therefore, if the calculated bottom width exceeds 10 feet, then one of the following steps is necessary to reduce the design bottom width:

1) Increase the longitudinal slope (s) to a maximum of 6 feet in 100 feet (0.06 feet per foot).
2) Increase the design flow depth (y) to a maximum of 4 inches.
3) Place a divider lengthwise along the swale bottom (Figure 3-1) at least three-quarters of the swale length (beginning at the inlet), without compromising the design flow depth and swale lateral slope requirements. Swale width can be increased to an absolute maximum of 16 feet if a divider is provided.

Step 3: Determine design flow velocity

To calculate the design flow velocity through the swale, use the flow continuity equation:

$$V_{wq} = SQDF/A_{wq} \qquad \text{(Equation C-99)}$$

Where:

V_{wq}	=	design flow velocity (fps)
$SQDF$	=	stormwater quality design flow (cfs)

A_{wq} = $by + Zy^2$ = cross-sectional area (ft^2) of flow at design depth, where Z = side slope length per unit height (e.g., Z = 3 if side slopes are 3H:1V)

If the design flow velocity exceeds 1 foot per second, go back to Step 2 and modify one or more of the design parameters (longitudinal slope, bottom width, or flow depth) to reduce the design flow velocity to 1 foot per second or less. If the design flow velocity is calculated to be less than 1 foot per second, proceed to Step 4. *Note: It is desirable to have the design velocity as low as possible, both to improve treatment effectiveness and to reduce swale length requirements.*

Step 4: Calculate swale length

Use the following equation to determine the necessary swale length to achieve a hydraulic residence time of at least 7 minutes:

$$L = 60 t_{hr} V_{wq} \qquad \text{(Equation C-100)}$$

Where:

L = minimum allowable swale length (ft)

t_{hr} = hydraulic residence time (min)

V_{wq} = design flow velocity (fps)

The minimum swale length is 100 feet; therefore, if the swale length is calculated to be less than 100 feet, increase the length to a minimum of 100 feet, leaving the bottom width unchanged. If a larger swale can be fitted on the site, consider using a greater length to increase the hydraulic residence time and improve the swale's pollutant removal capability. If the calculated length is too long for the site, or if it would cause layout problems, such as encroachment into shaded areas, proceed to Step 5 to further modify the layout. If the swale length can be accommodated on the site (meandering may help), proceed to Step 6.

Step 5: Adjust swale layout to fit on site

If the swale length calculated in Step 4 is too long for the site, the length can be reduced (to a minimum of 100 feet) by increasing the bottom width up to a maximum of 16 feet, as long as the 10-minute retention time is retained. However, the length cannot be increased in order to reduce the bottom width because Manning's depth-velocity-flow rate relationships would not be preserved. If the bottom width is increased to greater than 10 feet, a low flow dividing berm is needed to split the swale cross section in half to prevent channelization.

Length can be adjusted by calculating the top area of the swale and providing an equivalent top area with the adjusted dimensions.

1) Calculate the swale treatment top area based on the swale length calculated in Step 4:

$$A_{top} = (b_i + b_{slope})L_i \qquad \text{(Equation C-101)}$$

Where:

A_{top} = top area (ft^2) at the design treatment depth

b_i = bottom width (ft) calculated in Step 2

b_{slope} = the additional top width (ft) above the side slope for the design water depth (for 3:1 side slopes and a 4-inch water depth, b_{slope} = 2 feet)

L_i = initial length (ft) calculated in Step 4

2) Use the swale top area and a reduced swale length L_f to increase the bottom width, using the following equation:

$$L_f = A_{top} / (b_f + b_{slope}) \qquad \text{(Equation C-102)}$$

Where:

L_f = reduced swale length (ft)

b_f = increased bottom width (ft).

3) Recalculate V_{wq} according to Step 3 using the revised cross-sectional area A_{wq} based on the increased bottom width b_f. Revise the design as necessary if the design flow velocity exceeds 1 foot per second.

4) Recalculate to assure that the 10-minute retention time is retained.

Step 6: Provide conveyance capacity for flows higher than SQDF

Vegetated swales may be designed as flow-through channels that convey flows higher than the water quality design flow rate, or they may be designed to incorporate a high-flow bypass upstream of the swale inlet. A high-flow bypass usually results in a smaller swale size. If a high-flow bypass is provided, this step is not needed. If no high-flow bypass is provided, proceed with the procedure below.

1) Check the swale size to determine whether the swale can convey the flood control design storm peak flows (Refer to the Ventura County Hydrology Manual, 2006).

2) The peak flow velocity of the flood control design storm (e.g., flood control design storm – see Ventura County Hydrology Manual, 2006) must be less than 3.0 feet per second. If this velocity exceeds 3.0 feet per second, return to Step 2 and increase the bottom width or flatten the longitudinal slope as necessary to reduce

the flood control design storm peak flow velocity to 3.0 feet per second or less. If the longitudinal slope is flattened, the swale bottom width must be recalculated (Step 2) and must meet all design criteria.

Sizing Worksheet - PT-3 Vegetated Swale

Designer: Project Proponent: Date: Project: Location:		
Type of Vegetation: (describe)	____________________________________	
Outflow Collection: (Check type used or describe "Other")	___ Grated Inlet ___ Subsurface infiltration ___ Underdrain Used ___ Other ___________________________________	
Step 1: Determine water quality design flow		
1-1. Enter project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ =	acres
1-2. Enter impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp =	
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =	
1-5. Enter design rainfall intensity (in/hr), *i*	i =	in/hr
1-6. Calculate water quality design flow (cfs), $SQDF= CiA_{project}$	SQDF =	cfs
Step 2: Calculate swale bottom width		
2-1. Enter water quality design flow (cfs), *SQDF*	SQDF =	cfs
2-2. Enter Manning's roughness coefficient for shallow flow conditions, $n_{wq} = 0.2$	n_{wq} =	
2-3. Calculate design flow depth (ft), *y*	y =	ft
2-4. Enter longitudinal slope (ft/ft) (along direction of flow), *s*	s =	ft/ft
2-5. Calculate bottom width of swale (ft), $b = (SQDF*n_{wq})/(1.49y^{1.67}s^{0.5})$	b =	ft
2-6. If *b* is between 2 and 10 feet, go to Step 3		
2-7. If b is less than 2 ft, assume b = 2 ft and recalculate flow depth, $y = ((SQDF*n_{wq})/(2.98 s^{0.5}))^{1.49}$	y =	ft

2-8. If b is greater than 10 ft, one of the following design adjustments must be made (recalculate variables as necessary): Increase the longitudinal slope to a maximum of 0.06 ft/ft. Increase the design flow depth to a maximum of 4 in (0.33 ft). Place a divider lengthwise along the swale bottom (Figure 3-1) at least three-quarters of the swale length (beginning at the inlet). Swale width can be increased to an absolute maximum of 16 feet if a divider is provided.		
Step 3: Determine design flow velocity		
3-1. Enter side slope length per unit height (H:V) (e.g. 3 if side slopes are 3H :1V), *Z*	Z =	
3-2. Enter bottom width of swale (ft), *b*	b =	ft
3-3. Enter design flow depth (ft), *y*	y =	ft
3-4. Calculate the cross-sectional area of flow at design depth (ft^2), $A_{wq} = by + Zy^2$	A_{wq} =	ft^2
3-5. Calculate design flow velocity (ft/s), $V_{wq} = SQDF/ A_{wq}$	V_{wq} =	ft/s
3-6. If the design flow velocity exceeds 1 ft/s, go back to Step 2 and change one or more of the design parameters to reduce the design flow velocity. If design flow velocity is less than 1 ft/s, proceed to Step 4.		
Step 4: Calculate swale length		
4-1. Enter hydraulic residence time (minutes, minimum 7 min), t_{hr}	t_{hr} =	min
4-2. Calculate swale length (ft), $L = 60t_{hr}V_{wq}$	L =	ft
4-3. If *L* is too long for the site, proceed to Step 5 to adjust the swale layout If *L* is greater than 100 ft and will fit within the constraints of the site, skip to Step 6 If *L* is less than 100 ft, increase the length to a minimum of 100 ft, leaving the bottom width unchanged, and skip to Step 6		
Step 5: Adjust swale layout to fit within site constraints		
5-1. Enter the bottom width calculated in Step 2 (ft), $b_i = b$	b_i =	ft
5-2. Enter design flow depth (ft), *y*	y=	ft
5-3. Enter the swale side slope ratio (H:V), *Z*	Z =	ft:ft
5-4. Enter the additional top width above the side slope for the design water depth (ft), $b_{slope} = 2Zy$	b_{slope} =	ft
5-5. Enter the initial length calculated in Step 4 (ft), $Li = L$	L_i =	ft
5-6. Calculate the top area at the design treatment depth (ft^2), $A_{top} = (b_i + b_{slope}) \times L_i$	A_{top} =	ft^2

5-7. Choose a reduced swale length based on site constraints (ft), L_f	L_f = ft
5-8. Calculate the increased bottom width (ft), $b_f = (A_{top}/L_f) - b_{slope}$	b_f = ft
5-9. Recalculate the cross-sectional area of flow at design depth (ft2), $A_{wq,f} = b_f y + Zy^2$	$A_{wq,f}$ = ft^2
5-10. Recalculate design flow velocity (ft/s), $V_{wq} = SQDF/ A_{wq}$ Revise design as necessary if design flow velocity exceeds 1 ft/s.	V_{wq} = ft/s
5-11. Recalculate the hydraulic residence time (min), $t_{hr} = L_f/(60V_{wq})$ Ensure that t_{hr} is greater or equal to 10 minutes.	t_{hr} = min
5-12. When V_{wq} and t_{hr} are recalculated to meet requirements, proceed to Step 6.	
Step 6: Provide conveyance capacity for flows higher than SQDF (if swale is on-line)	
6-1. If the swale already includes a high-flow bypass to convey flows higher than the water quality design flow rate, skip this step and verify that all parameters meet design requirements to complete sizing	
6-2. If swale does not include a high-flow bypass, determine that the swale can convey flood control design storm peak flows. Calculate the capital peak flow velocity per Ventura County requirements (ft/s), V_p	V_p = ft/s
6-3. If V_p > 3.0 feet per second, return to Step 2 and increase the bottom width or flatten the longitudinal slope as necessary to reduce the flood control design storm peak flow velocity to 3.0 feet per second or less. If the longitudinal slope is flattened, the swale bottom width must be recalculated (Step 2) and must meet all design criteria.	

Design Example

Step 1: Determine water quality design Flow

For this design example, a 10-acre site with Type 4 soil and 60% total imperviousness is considered. Flow-based sizing Method 1 is assumed. Therefore, the design intensity is 0.2 in/hr.

Step 1: Determine water quality design flow			
1-1. Enter project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ =	10	acres
1-2. Enter impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp =	0.60	
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	0.05	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1\text{-}imp)$	C =	0.59	
1-5. Enter design rainfall intensity (in/hr), *i*	i =	0.2	in/hr
1-6. Calculate water quality design flow (cfs), $SQDF = CiA_{project}$	*SQDF*=	1.18	cfs

Step 2: Calculate Swale Bottom Width

The swale bottom width is calculated based on Manning's equation. The grass height in the swale will be maintained at 6-inches. The design flow depth is assumed to be 2/3 of the grass height, or 4 inches (0.33 ft). The default Manning's roughness coefficient is assumed appropriate for expected vegetation density and design depth. The slope was assumed to be 0.04.

Step 2: Calculate swale bottom width			
2-1. Enter water quality design flow (cfs), *SQDF*	SQDF =	1.18	cfs
2-2. Enter Manning's roughness coefficient for shallow flow conditions, n_{wq} = 0.2	n_{wq} =	0.2	
2-3. Calculate design flow depth (ft), *y*	*y* =	0.33	ft
2-4. Enter longitudinal slope (along direction of flow) (ft/ft), *s*	s =	0.04	ft/ft
2-5. Calculate bottom width of swale (ft), $b = SQDF*n_{wq} / 1.49y^{1.67}s^{0.5}$	b =	5.0	ft
2-6. If *b* is between 2 and 10 feet, go to Step 3			
2-7. If *b* is less than 2 ft, assume *b* = 2 ft and recalculate flow depth, $y = (Q_{wq}n_{wq} / 2.98s^{0.5})^{1.49}$	Not applicable		

Step 2: Calculate swale bottom width	
2-8. If *b* is greater than 10 ft, one of the following design adjustments must be made (and recalculate as necessary): Increase the longitudinal slope to a maximum of 0.06 ft/ft. Increase the design flow depth to a maximum of 4 in (0.33 ft). Place a divider lengthwise along the swale bottom (Figure 3-1) at least three-quarters of the swale length (beginning at the inlet). Swale width can be increased to an absolute maximum of 16 feet if a divider is provided.	Not applicable

Step 3: Determine Design Flow Velocity

For this example, it is assumed the side slopes will be designed as 3H: 1V, so Z = 3.

Step 3: Determine design flow velocity			
3-1. Enter side slope length per unit height (H:V) (e.g. 3 if side slopes are 3H :1V), *Z*	Z =	3	
3-2. Enter bottom width of swale (ft), *b*	b =	5.0	ft
3-3. Enter design flow depth (ft), *y*	y =	0.33	ft
3-4. Calculate the cross-sectional area of flow at design depth (ft^2), $A_{wq} = by + Zy^2$	A_{wq} =	2.0	ft^2
3-5. Calculate design flow velocity (ft/s), $V_{wq} = SQDF/ A_{wq}$	V_{wq} =	0.59	ft/s
3-6. If the design flow exceeds 1 ft/s, go back to Step 2 and change one or more of the design parameters to reduce the design flow velocity. If design flow velocity is less than 1 ft/s, proceed to Step 4.			

Step 4: Calculate Swale Length

Using the design flow velocity and a minimum residence time of 7 minutes, the length of the swale is calculated as follows. The swale length must be a minimum of 100 ft.

Step 4: Calculate swale length			
4-1. Enter hydraulic residence time (min 7 min), t_{hr} (min)	t_{hr} =	10	min
4-2. Calculate swale length, $L = 60t_{hr}V_{wq}$	L =	354	ft
4-3. If *L* is too long for the site, proceed to Step 5 to adjust the swale layout If *L* is greater than 100 ft and will fit within the constraints of the site, skip to Step 6. If *L* is less than 100 ft, increase the length to a minimum of 100 ft, leaving the bottom width unchanged, and skip to Step 6	Not Applicable		

Site constraints only allow a swale length of 300 feet. Therefore, proceed to Step 5 to adjust the swale length.

Step 5: Adjust Swale Layout to Fit Within Site Constraints

To adjust swale length to 300 feet, the bottom width needs to be increased (up to a maximum of 16 ft if a divider is provided).

Step 5: Adjust swale layout to fit within site constraints			
5-1. Enter the bottom width calculated in Step 2 (ft), $b_i = b$	b_i =	5.0	ft
5-2. Enter design flow depth (ft), y	y=	0.33	ft
5-3. Enter the swale side slope ratio (H:V), Z	Z =	3	ft:ft
5-4. Enter the additional top width above the side slope for the design water depth (ft), $b_{slope} = 2Zy$	b_{slope} =	2	ft
5-5. Enter the initial length calculated in Step 4 (ft), $Li = L$	L_i =	354	ft
5-6. Calculate the top area at the design treatment depth (ft^2), $A_{top}= (b_i + b_{slope})\times L_i$	A_{top} =	2,478	ft^2
5-7. Choose a reduced swale length based on site constraints (ft), L_f	L_f =	300	ft
5-8. Calculate the increased bottom width (ft), $b_f = (A_{top}/L_f) – b_{slope}$	b_f =	6.3	ft
5-9. Recalculate the cross-sectional area of flow at design depth (ft2), $A_{wq,f} = b_f y + Zy^2$	$A_{wq,f}$ =	2.4	ft^2
5-10. Recalculate design flow velocity (ft/s), $V_{wq} = SQDF/ A_{wq}$ Revise design as necessary if design flow velocity exceeds 1 ft/s.	V_{wq} =	0.49	ft/s
5-11. Recalculate the hydraulic residence time (min), $t_{hr} = L_f/(60V_{wq})$ Ensure that t_{hr} is greater or equal to 10 minutes.	t_{hr} =	10.2	min
5-12. When V_{wq} and t_{hr} are recalculated to meet requirements, proceed to Step 6.			

Since the new length and width yields V_{wq} and t_{hr} which meet requirements, continue to Step 6.

Step 6: Provide Conveyance Capacity for Flows Higher than SQDF

The swale will be offline such that all flows greater than SQDF will be bypassed.

C.13 PT-4 Vegetated Filter Strip

Sizing Methodology

The flow capacity of vegetated filter strips (filter strips) is a function of the longitudinal slope (parallel to flow), the resistance to flow (e.g., Manning's roughness), and the width and length of the filter strip. The slope shall be small enough to ensure that the depth of water will not exceed 1 inch over the filter strip. Similarly, the flow velocity shall be less than 1 ft/sec. Procedures for sizing filter strips are summarized below. A filter strip sizing example is also provided.

<u>Step 1: Calculate the design flow rate</u>

The design flow is calculated based on the stormwater quality design flow rate, SQDF, as described in Appendix C.1.

<u>Step 2: Calculate the minimum width</u>

Determine the minimum width (i.e. perpendicular to flow) allowable for the filter strip and design for that width or larger.

$$W_{min} = (SQDF) / (q_{a,min}) \qquad \text{(Equation C-103)}$$

Where

W_{min}	=	minimum width of filter strip
$SQDF$	=	stormwater quality design flow (cfs)
$q_{a,min}$	=	minimum linear unit application rate, 0.005 cfs/ft

<u>Step 3: Calculate the design flow depth</u>

The design flow depth (d_f) is calculated based on the width and the slope (parallel to the flow path) using a modified Manning's equation as follows:

$$d_f = 12 * [SQDF * n_{wq} / 1.49 W_{trib} s^{0.5}]^{0.6} \qquad \text{(Equation C-104)}$$

Where:

d_f	=	design flow depth (inches)
$SQDF$	=	stormwater quality design flow (cfs)
W_{trib}	=	width (perpendicular to flow = width of impervious surface contributing area (ft))
s	=	slope (ft/ft) of strip parallel to flow, average over the whole width

n_{wq} = Manning's roughness coefficient (0.25-0.30)

If d_f is greater than 1 inch (0.083 ft), then a shallower slope is required, or a filter strip cannot be used.

Step 4: Calculate the design velocity

The design flow velocity is based on the design flow, design flow depth, and width of the strip:

$$V_{wq} = SQDF / (d_f \, W_{trib}) \quad \text{(Equation C-105)}$$

Where:

$d_{f,ft}$ = design flow depth (ft) (d_f/12)

$SQDF$ = stormwater quality design flow (cfs)

W_{trib} = width (perpendicular to flow = width of impervious surface contributing area (ft))

Step 5: Calculate the desired length of the filter strip

Determine the required length (L) to achieve a desired minimum residence time of 7 minutes using:

$$L = 60 t_{hr} V_{wq} \quad \text{(Equation C-106)}$$

Where:

L = minimum allowable strip length (ft)

t_{hr} = hydraulic residence time (s)

V_{wq} = design flow velocity (fps)

Sizing Worksheet - PT-4 Vegetated Filter Strip

Designer: Project Proponent: Date: Project: Location:	
Type of Vegetation: (describe)	______________________________________
Outflow Collection: (Check type used or describe "Other")	___ Grass Channel / Swale ___ Street Gutter ___ Storm Drain ___ Underdrain Used ___ Other ______________________________ ______________________________________

Step 1: Calculate the design flow		
1-1. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ =	acres
1-2. Enter impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp =	
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p\,(1-imp)$	C =	
1-5. Enter design rainfall intensity (in/hr), *i*	i =	in/hr
1-6. Calculate water quality design flow (cfs), $SQDF = CiA_{project}$	SQDF =	cfs
Step 2: Calculate the minimum width		
2-1. Enter the stormwater quality design flow (cfs), *SQDF*	SQDF =	cfs
2-2. Enter the minimum linear unit application rate (0.005 cfs/ft), $q_{a,min}$	$q_{a,min}$=	cfs/ft
2-3. Calculate the minimum width of filter strip (ft), W_{min}	W_{min}=	ft
Step 3: Calculate the design flow depth		
3-1. Enter filter strip longitudinal slope, *s* (ft/ft)	*s* =	ft/ft
3-2. Enter Manning roughness coefficient (0.25-0.30), n_{wq}	n_{wq} =	

3-3. Enter width of impervious surface contributing area (perpendicular to flow), *W* (ft)	W =	ft
Step 3: Calculate the design flow depth		
3-4. Calculate average depth of water using Manning equation (inches), $d_f = 12 * [SQDF * n_{wq} / 1.49 W_{trib}\, s^{0.5}]^{0.6}$	d_f =	inches
3-5. If d_f > 1" (0.083 ft), go back step 3-1 and decrease the slope		
3-6. If the slope cannot be changed due to construction constraints, go to step 3-3 and increase the width perpendicular to flow.		
Step 4: Calculate the design velocity		
4-1. Enter depth of water (ft), $d_{f,ft} = d_f / 12$	d_f =	ft
4-2. Enter width of strip (ft), *W*	W =	ft
4-3. Calculate design flow velocity (ft/s), $V_{wq} = SQDF/(d_{f,ft} W)$	V_{wq}=	ft/s
4-4. If the V_{wq} >1 ft/s, go back to step 3-1 and decrease the slope.		
Step 5: Calculate the length of the filter strip		
5-1. Enter desired residence time (minimum 7 minutes), *t*	t =	min
5-2. Enter design flow velocity (ft/s), V_{wq}	V_{wq}=	ft/s
5-3. Calculate length of the filter strip (ft), $L = 60tV_{wq}$	L =	ft
5-4. If *L* < 4 ft, go to step 3-1 and increase the slope		

Design Example

Step 1: Determine water quality design flow

For this design example, a 10-acre site with Type 4 soil and 60% total imperviousness is considered. Flow-based sizing Method 1 is used, as described in Appendix C.1.

Step 1: Calculate the design flow			
1-1. Enter Project area (acres), $A_{project}$ If this BMP captures runoff from a portion of the project area, enter the tributary area	$A_{project}$ =	10	acres
1-2. Enter impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp =	0.60	
1-3. Determine pervious runoff coefficient using Table C-1, C_p	C_p =	0.05	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p(1-imp)$	C =	0.59	
1-5. Enter design rainfall intensity (in/hr), *i*	i =	0.2	in/hr
1-6. Calculate water quality design flow (cfs), $SQDF= CiA_{project}$	SQDF =	1.18	cfs

Step 2: Calculate the minimum width of filter strip

Determine the minimum width (i.e. perpendicular to flow) allowable for the filter strip and design for that width or larger.

Step 2: Calculate the minimum width			
2-1. Enter the stormwater quality design flow (cfs), *SQDF*	SQDF =	1.18	cfs
2-2. Enter the minimum linear unit application rate (0.005 cfs/ft), $q_{a,min}$	$q_{a,min}$=	0.005	cfs/ft
2-3. Calculate the minimum width of filter strip (ft), $W_{min}=SQDF/q_{a,min}$	W_{min}=	236	ft

Step 3: Calculate the Design Flow Depth

A slope of 3% was assumed for the filter strip (2-4% recommended). The design water depth should not exceed 1 inch. For this design example a manning's coefficient of 0.27 was used.

Step 3: Calculate the design flow depth			
3-1. Enter filter strip longitudinal slope, *s* (ft/ft)	s =	0.03	ft/ft
3-2. Enter Manning roughness coefficient (0.25-0.30), n_{wq}	n_{wq} =	0.27	
3-3. Enter width of strip (=impervious surface contributing area perpendicular to flow), at least W_{min} (ft), *W*	W =	240	ft

3-4. Calculate average depth of water using Manning equation (inches), $d_f = 12 * [SQDF*n_{wq}/1.49Ws^{0.5}]^{0.6}$	d_f =	0.51	in
3-5. If d_f > 1" (0.083 ft), go back step 3-1 and decrease the slope			
3-6. If the slope cannot be changed due to construction constraints, go to step 3-3 and increase the width perpendicular to flow.			

Step 4: Calculate the Design Velocity

The designed flow velocity should not exceed 1 foot/second across the filter strip.

Step 4: Calculate the design velocity			
4-1. Enter depth of water (ft), $d_{f,ft} = d_f/12$	d_f =	0.043	ft
4-2. Enter width of strip (ft), W	W=	240	ft
4-3. Calculate design flow velocity (ft/s), $V_{wq} = SQDF/(d_{f,ft}W)$	V_{wq} =	0.11	ft/s
4-4. If the V_{wq} >1 ft/s, go back to step 3-1 and decrease the slope.			

Step 5: Calculate the Length of the Filter Strip

The filter strip should be at least 4 feet long (in the direction of flow) and accommodate a minimum residence time of 7 minutes to provide adequate water quality treatment.

Step 5: Calculate the length of the filter strip			
5-1. Enter desired residence time (minimum 10 minutes), t	t =	10	min
5-2. Enter design flow velocity (ft/s), V_{wq}	V_{wq}=	0.11	ft/s
5-3. Calculate length of the filter strip (ft), $L = 60tV_{wq}$	L =	66	ft
5-4. If L < 4 ft, go to step 3-1 and increase the slope			

APPENDIX D: STORMWATER CONTROL MEASURE MAINTENANCE PLAN GUIDELINES AND CHECKLISTS

Included in this appendix are a series of checklists that can be used by both inspectors and maintenance personnel to ensure that observed deficiencies in BMPs are maintained appropriately. The BMP Inspection/Maintenance Checklists are presented in the following order:

1) Bioretention/Planter Box with Underdrain
2) Vegetated Swale Filter
3) Vegetated Filter Strip
4) Infiltration BMPs
5) Permeable Pavement
6) Constructed Treatment Wetland
7) Wet Retention Basin
8) Dry Extended Detention Basin
9) Proprietary Devices

D.1 Bioretention/Planter Box with Underdrain Inspection and Maintenance Checklist

Date:_____________ Work Order #__________________

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: ____________________ Inspector(s): ________________________

Defect	Conditions When Maintenance Is Needed	Inspection Result (0, 1, or 2)†	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Appearance	Untidy			
Trash and debris accumulation	Trash, plant litter and dead leaves accumulated on surface.			
Vegetation	Unhealthy plants and appearance.			
Irrigation	Functioning incorrectly (if applicable).			
Inlet	Inlet pipe blocked or impeded.			
Splash blocks	Blocks or pads are correctly positioned to prevent erosion.			
Overflow	Overflow pipe blocked or broken.			
Filter media	Infiltration design rate is met (e.g., drains 36-48 hours after moderate - large storm event).			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

D.2 Vegetated Swale Inspection and Maintenance Checklist

Date:_____________ Work Order #__________________

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: _____________________ Inspector(s): ________________________

Defect	Conditions When Maintenance Is Needed	Inspection Result (0, 1, or 2)†	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Appearance	Untidy			
Trash and debris accumulation	Trash and debris accumulated in the swale.			
Vegetation	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation start to take over.			
Excessive shading	Vegetation growth is poor because sunlight does not reach swale. Evaluate vegetation suitability.			
Poor vegetation coverage	When vegetation is sparse, bare or eroded patches occur in more than 10% of the swale bottom. Evaluate vegetation suitability.			
Sediment accumulation	Sediment depth exceeds 2 inches or covers more than 10% of design area.			
Standing water	When water stands in the swale between storms and does not drain freely.			
Flow spreader or check dams	Flow spreader or check dams uneven or clogged so that flows are not uniformly distributed through entire swale width.			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0, 1, or 2)†	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Constant baseflow	When small quantities of water continually flow through the swale, even when it has been dry for weeks and an eroded, muddy channel has formed in the swale bottom.			
Inlet/outlet	Inlet/outlet areas clogged with sediment and/or debris.			
Erosion/ scouring	Eroded or scoured swale bottom due to flow channelization, or higher flows. Eroded or rilled side slopes.			
	Eroded or undercut inlet/outlet structures			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

D.3 Vegetated Filter Strip Inspection and Maintenance Checklist

Date:____________ Work Order #_________________

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: ____________________ Inspector(s): _______________________

Defect	Conditions When Maintenance Is Needed	Inspection Result (0, 1 or 2)†	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Appearance	Untidy			
Trash and debris accumulation	Trash and debris accumulated on the filter strip.			
Vegetation	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.			
Excessive shading	Grass growth is poor because sunlight does not reach swale. Evaluate grass species suitability.			
Poor vegetation coverage	When grass is sparse or bare or eroded patches occur in more than 10% of the swale bottom. Evaluate grass species suitability.			
Erosion/ scouring	Eroded or scoured areas due to flow channelization, or higher flows.			
Sediment accumulation on grass	Sediment depth exceeds 2 inches.			
Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire filter width.			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

D.4 Infiltration BMP Inspection and Maintenance Checklist

Date:____________ Work Order #_________________

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: ____________________ Inspector(s): _______________________

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Appearance, vegetative health	Mowing and trimming vegetation is needed to prevent establishment of woody vegetation, and for aesthetic and vector reasons.			
Vegetation	Poisonous or nuisance vegetation or noxious weeds.			
	Excessive loss of turf or ground cover (if applicable).			
Trash & debris	Trash and debris > 5 cf/1,000 sf (one standard size garbage can).			
Contaminants and pollution	Any evidence of oil, gasoline, contaminants or other pollutants.			
Erosion	Undercut or eroded areas at inlet or outlet structures.			
Sediment and debris	Accumulation of sediment, debris, and oil/grease on surface, inflow, outlet or overflow structures.			
Sediment and debris	Accumulation of sediment and debris, in sediment forebay and pretreatment devices.			
Water drainage rate	Standing water, or by visual inspection of wells (if available), indicates design drain times are not being achieved (i.e., within 72 hours).			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Media clogging surface layer	Lift surface layer (and filter fabric if installed) and check for media clogging with sediment (function may be able to be restored by replacing surface aggregate/filter cloth).			
Media clogging	Lift surface layer (and filter fabric if installed) and check for media clogging with sediment (partial or complete clogging which may require full replacement).			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

D.5 Permeable Pavement Inspection and Maintenance Checklist

Date:____________ Work Order #_________________

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: ___________________ Inspector(s): ______________________

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Sediment accumulation	Sediment is visible			
Missing gravel/sand fill	There are noticeable gaps in between pavers			
Weeds/ mosses filling voids	Vegetation is growing in/on permeable pavement			
Trash and Debris Accumulation	Trash and debris accumulated on the permeable pavement.			
Dead or dying vegetation in adjacent landscaping	Vegetation is dead or dying leaving bare soil prone to erosion			
Surface clog	Clogging is evidenced by ponding on the surface			
Overflow clog	Excessive buildup of water accompanied by observation of low flow in observation well (connected to underdrain system) If a surface overflow system is used, observation of an obvious clog			
Visual contaminants and pollution	Any visual evidence of oil, gasoline, contaminants or other pollutants.			
Erosion	Tributary area Exhibits signs of erosion Noticeably not completely stabilized			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Deterioration/roughening	Integrity of pavement is compromised (i.e., cracks, depressions, crumbling, etc.)			
Subsurface clog	Clogging is evidenced by ponding on the surface and is not remedied by addressing surface clogging.			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

D.6 Constructed Wetland Inspection and Maintenance Checklist

Date:_____________ Work Order #__________________

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: ____________________ Inspector(s): ________________________

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Trash & Debris	Any trash and debris which exceed 5 cubic feet per 1,000 sf of basin area (one standard garbage can). In general, there shall be no visual evidence of dumping. If less than threshold all trash and debris will be removed as part of next scheduled maintenance. If trash and debris is observed blocking or partially blocking an outlet structure or inhibiting flows between cells, it shall be removed quickly			
Sediment Accumulation	Sediment accumulation in basin bottom that exceeds the depth of sediment zone plus 6 inches in the sediment forebay. If sediment is blocking an inlet or outlet, it shall be removed.			
Erosion	Erosion of basin's side slopes and/or scouring of basin bottom.			
Oil Sheen on Water	Prevalent and visible oil sheen.			
Noxious Pests	Visual observations or receipt of complaints of numbers of pests that would not be naturally occurring and could pose a threat to human or aquatic health.			
Water Level	First cell is empty, doesn't hold water.			
Aesthetics	Minor vegetation removal and thinning. Mowing berms and surroundings			
Noxious Weeds	Any evidence of noxious weeds.			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Tree Growth	Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, vactoring, or equipment movements). If trees are not interfering, do not remove. Dead, diseased, or dying trees shall be removed.			
Settling of Berm	If settlement is apparent. Settling can be an indication of more severe problems with the berm or outlet works. A geotechnical engineer shall be consulted to determine the source of the settlement if the dike/berm is serving as a dam.			
Piping through Berm	Discernable water flow through basin berm. Ongoing erosion with potential for erosion to continue. A licensed geotechnical engineer shall be called in to inspect and evaluate condition and recommend repair of condition.			
Tree and Large Shrub Growth on Downstream Slope of Embankments	Tree and large shrub growth on downstream slopes of embankments may prevent inspection and provide habitat for burrowing rodents.			
Erosion on Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.			
Gate/Fence Damage	Damage to gate/fence, including missing locks and hinges			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

D.7 Wet Detention Basin Inspection and Maintenance Checklist

Date:____________ Work Order #_________________

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: ___________________ Inspector(s): ______________________

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Trash & Debris	Any trash and debris which exceed 5 cubic feet per 1,000 sf of basin area (one standard garbage can) or if trash and debris is excessively clogging the outlet structure. If less than threshold all trash and debris will be removed as part of next scheduled maintenance.			
Sediment Accumulation	Sediment accumulation in basin bottom that exceeds the depth of the design sediment zone plus 6 inches, usually in the first cell.			
Erosion	Erosion of basin's side slopes and/or scouring of basin bottom.			
Oil Sheen on Water	Prevalent and visible oil sheen.			
Noxious Pests	Visual observations or receipt of complaints of numbers of pests that would not be naturally occurring and could pose a threat to human or aquatic health.			
Water Level	First cell is empty, doesn't hold water.			
Algae Mats	Algae mats over more than 20% of the water surface.			
Aesthetics	Minor vegetation removal and thinning. Mowing berms and surroundings			
Noxious Weeds	Any evidence of noxious weeds.			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Tree Growth	Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, vactoring, or equipment movements). If trees are not interfering, do not remove. Dead, diseased, or dying trees shall be removed.			
Settling of Berm	If settlement is apparent. Settling can be an indication of more severe problems with the berm or outlet works. A geotechnical engineer shall be consulted to determine the source of the settlement if the dike/berm is serving as a dam.			
Piping through Berm	Discernable water flow through basin berm. Ongoing erosion with potential for erosion to continue. A licensed geotechnical engineer shall be called in to inspect and evaluate condition and recommend repair of condition.			
Tree and Large shrub growth on downstream slope of embankments	Tree and large shrub growth on downstream slopes of embankments may prevent inspection and provide habitat for burrowing rodents.			
Erosion on Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.			
Gate/Fence Damage	Damage to gate/fence, including missing locks and hinges			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

D.8 Dry Extended Detention Basin Inspection and Maintenance Checklist

Date:____________ Work Order #_________________

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: ____________________ Inspector(s): _______________________

Defect	Conditions When Maintenance Is Needed	Inspection Result (0, 1 or 2)†	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
General				
Appearance	Untidy, un-mown (if applicable)			
Vegetation	Access problems or hazards; dead or dying trees			
	Poisonous or nuisance vegetation or noxious weeds			
Insects	Insects such as wasps and hornets interfere with maintenance activities.			
Rodent Holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes			
Trash and Debris	Trash and debris > 5 cf/1,000 sf (one standard size garbage can).			
Pollutants	Any evidence of oil, gasoline, contaminants or other pollutants			
Inlet/Outlet Pipe	Inlet/Outlet pipe clogged with sediment and/or debris. Basin not draining.			
Erosion	Erosion of the basin's side slopes and/or scouring of the basin bottom that exceeds 2-inches, or where continued erosion is prevalent.			
Piping	Evidence of or visible water flow through basin berm.			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0, 1 or 2)†	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Settlement of Basin Dike/Berm	Any part of these components that has settled 4-inches or lower than the design elevation, or inspector determines dike/berm is unsound.			
Overflow Spillway	Rock is missing and/or soil is exposed at top of spillway or outside slope.			
Sediment Accumulation in Basin Bottom	Sediment accumulations in basin bottom that exceeds the depth of sediment zone plus 6-inches.			
Tree or shrub growth	Trees > 4 ft in height with potential blockage of inlet, outlet or spillway; or potential future bank stability problems			
Debris Barriers (e.g., Trash Racks)				
Trash and Debris	Trash or debris that is plugging more than 20% of the openings in the barrier.			
Damaged/ Missing Bars	Bars are bent out of shape more than 3 inches.			
	Bars are missing or entire barrier missing.			
	Bars are loose and rust is causing 50% deterioration to any part of barrier.			
Inlet/Outlet Pipe	Debris barrier missing or not attached to pipe.			
Fencing				
Missing or broken parts	Any defect in the fence that permits easy entry to a facility.			
Erosion	Erosion is more than 4 inches high and 12-18 inches wide, creating an opening under the fence.			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0, 1 or 2)†	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Damaged Parts	Damage to gate/fence, posts out of plumb, or rails bent more than 6 inches.			
Deteriorating Paint or Protective Coating	Part or parts that have a rusting or scaling condition that has affected structural adequacy.			
Gates				
Damaged or missing member	Missing gate or locking devices, broken or missing hinges, out of plum more than 6 inches and more than 1 foot out of design alignment, or missing stretcher bar, stretcher bands, and ties.			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

D.9 Proprietary Device Inspection and Maintenance Checklist

Date:____________ Work Order #_________________

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: ____________________ Inspector(s): _______________________

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Refer to the manufacturer's instructions for maintenance/inspection requirements, below are generic guidelines to supplement manufacturer's recommendations.				
Underground Vault				
Sediment Accumulation on Media	Sediment depth exceeds 0.25-inches.			
Sediment Accumulation in Vault	Sediment depth exceeds 6-inches in first chamber.			
Trash/ Debris Accumulation	Trash and debris accumulated on compost filter bed.			
Sediment in Drainpipes or Cleanouts	When drainpipes or clean-outs become full of sediment and/or debris.			
Damaged Pipes	Any part of the pipes that are crushed or damaged due to corrosion and/or settlement.			
Access Cover Damaged/Not Working	Cover cannot be opened; one person cannot open the cover using normal lifting pressure, corrosion/deformation of cover.			
Vault Structure Includes Cracks in Wall, Bottom, Damage to	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Frame and/or Top Slab	Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.			
Baffles	Baffles corroding, cracking warping, and/or showing signs of failure as determined by maintenance/inspection person.			
Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, or misaligned.			
Below Ground Cartridge Type				
Filter Media	Drawdown of water through the media takes longer than 1 hour and/or overflow occurs frequently.			
Short Circuiting	Flows do not properly enter filter cartridges.			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.