6 STORM WATER RUNOFF BMP OPTIONS

6.1 General Considerations

The storm water runoff BMP options provided in this chapter are intended to assist Tier 3 new development and redevelopment projects in meeting the storm water runoff requirements of the City of Santa Barbara's Post-Construction Storm Water Management Program. Tier 3 projects are defined in the project thresholds table (Table 1-1) and requirements for project approval are outlined in Section 1.3.3. The *storm water runoff requirements* are outlined below in Section 6.2 and in Appendix C.

Tier 3 project applicants must demonstrate an integrated approach to meeting the storm water runoff requirements by implementing a combination of site design BMPs (Chapter 4), basic BMPs (Chapter 5), and storm water runoff BMPs (this Chapter) that utilize a site's inherent natural hydrologic features to reduce the generation of runoff and to de-centralize runoff BMPs to handle the runoff generated. The site design BMPs described in Chapter 4 assist by reducing the volume of site runoff and maintaining pre-development time of concentration (T_c) to the maximum extent practicable by using natural, non-structural methods. The basic BMPs in Chapter 5 provide basic options for continuing to reduce the volume of site runoff and maintaining pre-development T_c. Some of the basic BMPs in Chapter 5 are intended specifically for single-family residential use, specifically rain gardens and rain barrels. The other BMPs in Chapter 5 are applicable to larger Tier 3 sites although explicit credit towards meeting the storm water runoff requirements is not provided for these BMPs (see Table 5-1 for more detail). By reducing the site's volume of runoff and T_c to the maximum extent practicable using site design and basic BMPs, there is an implicit reduction in the storm water runoff requirements by reducing a site's generation of runoff volume, flow rate, and pollutants of concern.

Tier 3 projects must use the storm water runoff BMPs in this Chapter to meet the storm water runoff requirements of the City. Tier 3 projects must also select BMPs that target identified pollutants of concern based on the project site's land use and must also select BMPs that target pollutants identified in the 2006 Clean Water Act 303(d) List of Water Quality Limited Segments if the project contributes to one or more of the impaired receiving waters within the City. Section 6.3 discusses the BMP selection process for Tier 3 projects. The City encourages applicants to integrate and distribute several storm water runoff BMP options across the site and to maximize vegetative cover and infiltration to the maximum extent practicable. For some Tier 3 single-family residential projects, an architect or other design professional may produce the analysis, dependent on City staff approval.

6.2 Storm Water Runoff Requirements for BMP Sizing

The City of Santa Barbara developed storm water runoff requirements for Tier 3 ("large") projects in order to meet or exceed the requirements of the NPDES Phase II State General Permit for the Discharge of Storm water from small MS4s (CAS000004). These requirements were incorporated into the City's Storm Water Management Plan (SWMP), approved by the Water Board in 2009, and include; (1) a peak runoff discharge requirement, (2) a volume reduction requirement, (3) and a water quality treatment requirement.

The City of Santa Barbara has implemented a peak runoff discharge rate requirement, a volume reduction requirement, and a treatment requirement. The following sections describe the requirements for which storm water runoff BMPs shall be sized. Methods for calculating the site-specific storm water runoff requirements are provided in Appendix C. Methods for sizing each of the storm water runoff BMPs are provided in the individual BMP sections of this chapter. An equivalent sizing approach to those provided in the individual BMP sections is acceptable as long as the applicant can demonstrate equal or greater runoff capture. For redevelopment projects, the net change in peak flow rates and volumes are to be compared with the predeveloped condition. Also for redevelopment projects, if a reduction in impervious surfaces (footprint) is proposed, then the Peak Runoff Discharge Rate and Volume Reduction Requirements do not apply.

6.2.1 Peak Runoff Discharge Rate Requirement

As required by the State General Permit, Santa Barbara County Flood Control District for the South Coast Region, and the City of Santa Barbara's SWMP, storm water runoff BMPs shall provide detention such that the post-development peak storm water runoff discharge rate shall not exceed the pre-development rate for the 2-, 5-, 10-, and 25-year 24-hour storm events. The method for calculating the peak storm water runoff discharge rate is described in Appendix C. For redevelopment projects, the net change in peak flow rates are to be compared with the predevelopment condition. If a project is subject to maintaining or reducing peak runoff discharge rates, the entire project site will be used to determine both the pre-development and post-development runoff discharge rate.

6.2.2 Volume Reduction Requirement

Retain on-site the larger of the following two volumes from the entire project site:

- The volume difference between the pre- and post-conditions for the 25-year, 24-hour design storm (for redevelopment, the pre-condition is the predevelopment condition).
- The volume difference between the pre- and post-conditions generated from a one-inch, 24-hr storm event

Methods for calculating volume reduction for both options are provided in Appendix C.

6.2.3 Water Quality Treatment Requirements

Water quality treatment requirements are differentiated based on whether the BMP is volume-based or flow-based. The criteria for both are as follows:

- Volume-based storm water runoff BMPs (e.g., bioretention areas) shall be sized for the one-inch 24-hr design storm from the entire project site (not just the new or redeveloped area).
- Flow-based storm water runoff BMPs (e.g., vegetated swale filters) shall be sized based on a constant rainfall intensity of 0.25 in/hr for 4 hours from the entire project site (not just the new or redeveloped area).

Methods for calculating the volume- and flow-based water quality treatment requirements are provided in Appendix C. The City's Storm Water Permit and this Manual demonstrate a preference for using infiltration designs to capture and treat storm water. However, infiltration is not the only solution for meeting the City's storm water requirements; the alternatives where infiltration is not recommended include flow-through treatment designs (such as planter boxes and/or vegetated swales with under drains) as well as rain barrels, cisterns, and tanks for containment and later use for landscaping irrigation. For sites where soil conditions limit feasibility of complying with requirements, flow-based BMPs will likely be more practical than for sites with infiltrative soils. Volume-based BMPs will require underdrains for most of these sites.

6.2.4 Meeting Storm Water Runoff Requirements Simultaneously

It shall be noted that the volume reduction requirement and water quality treatment requirement are not additive and may be met simultaneously in many cases. Meeting the volume reduction requirement also meets the water quality treatment requirement if the volume reduction requirement is larger than the water quality treatment requirement. If the water quality treatment requirement is larger than the volume reduction requirement, only the difference in the volumes is required to be treated beyond that already treated by meeting the volume reduction requirement. Storm water runoff BMPs that allow for infiltration shall be sized using a design volume, V_{design}, which is the larger of the volume reduction and water quality treatment requirements. Storm water runoff BMPs that do not allow for infiltration will only receive credit towards meeting the water quality treatment requirement and, when applicable, the peak discharge requirement. In these cases, other storm water runoff BMPs would then be needed for meeting the volume reduction requirements. See Section 6.5 for suggested strategies for meeting the storm water runoff requirements.

6.3 BMP Selection Process

1. To select a storm water runoff BMP, each Tier 3 project shall compare the list of pollutants anticipated to be generated by the project land use (as identified in Table 2-2) with the pollutants for which the downstream receiving waters are impaired, if any (as defined in Table 2-3).

   Any pollutants identified by Table 2-2, which are also causing a Clean Water Act section 303(d) impairment of receiving waters of the project as identified in Table 2-3, shall be considered *primary* pollutants of concern. Tier 3 projects shall select a single or combination of storm water runoff BMPs, which address the particular *primary* pollutant(s) of concern and suitability based on site conditions. The BMP selection matrices (Table 6-1 and Table 6-2) shall be used as a guide to assist in the selection of BMPs. **BMPs shall be selected that have high or very high treatment effectiveness for the primary pollutants of concern.** The selected storm water runoff BMPs will address other pollutants in addition to the primary pollutant(s) as shown in Table 6-1.

2. Tier 3 projects that are not anticipated to generate *primary* pollutants of concern, shall select a single or combination of storm water runoff BMPs based on pollutants of concern anticipated to be generated by the project land use (as identified in Table 2-2) as well as the BMP selection matrices (Table 6-1 and Table 6-2). The selected BMP(s) shall be suitable for the site conditions and be designed to be effective in reducing pollutants of concern as outlined in Section 1.2.1.

3. Alternative storm water runoff BMPs not identified in the BMP selection matrices (Table 6-1 and Table 6-2) may be approved at the discretion of the City, provided the alternative storm water runoff BMP meets the storm water runoff requirements and can prove through documented BMP performance data that it is as or more effective in removal of applicable pollutants of concern as other feasible BMPs listed in the BMP selection matrices.

6.4 Waivers for Storm Water Runoff BMP Requirements

The City may allow for one or more of the storm water runoff requirements to be waived for a Tier 3 project if technical or legal infeasibility can be established by the project applicant. The City shall only grant a waiver of infeasibility when all available storm water runoff BMPs have been considered and rejected as infeasible. The burden of proof is on the project applicant to demonstrate that all available measures are infeasible. Where strict compliance with the City's storm water runoff requirements is found to be infeasible, the project applicant must utilize all feasible measures to achieve the greatest compliance possible.

Table 6-1: BMP Selection Matrix - Pollutants of Concern

Important Note to Users: Treatment effectiveness for pollutants of concern can vary widely for individual BMPs.This table should be used to provide general BMP comparisons only and should not replace the evaluation performed by a water quality professional. For greater accuracy, only compare treatment effectiveness within each of the Stormwater Runoff BMP Categories. BMPs shall be selected that have high or very high treatment effectiveness for the primary pollutants of concern as defined in Section 6.3.

Manual Section	Stormwater Runoff BMP Category	Stormwater Runoff BMP	Volume Mitigation (% of inflow)	Treatment Effectiveness for Pollutants of Concern[1]					
				Trash	Nutrients	Bacteria	Metals (particulate and dissolved fractions)	Sediment	Organics (hydrocarbons, oil, and grease)
6.6	**Biofiltration and Filtration BMPs**	Bioretention	High	Very High	High	High	High	Very High	High
		Vegetated Swale Filter	Moderate	Moderate	Low	Very Low	Moderate	Moderate	Moderate
		Vegetated Filter Strip	Moderate	Moderate	Low	Very Low	Moderate	High	Moderate
		Sand Filter	Very Low	Very High	Moderate	High	High	Very High	High
6.7	**Infiltration BMPs**	Includes infiltration trenches, infiltration basins, and dry wells	Very High	Very High	Very High	Very High	Very High	Very High	Very High
6.8	**Permeable Pavement BMPs**	Includes pervious concrete, porous asphalt, permeable pavers, grass-pave, and gravel-pave	High	Very Low	Moderate	High	High	Very High	High
6.9	**Building BMPs**	Cistern/Rain Barrel	High	Building BMPs are generally intended for achieving volume reduction of roof drainage. Treatment effectiveness of building BMPs are not comparable to other BMPs in this table that treat runoff from a wide range of impervious surfaces that generally have higher pollutant concentrations.					
		Planter Box	Moderate						
		Green Roof	Moderate						
6.10	**Retention and Detention BMPs**	Constructed Treatment Wetland	Low	Very High	High	Moderate	High	Very High	High
		Wet Retention Basin	Low	Very High	High	Moderate	High	Very High	High
		Dry Extended Detention Basin	Moderate	High	Low	Low	Moderate	Moderate	Low
6.11	**Proprietary Devices**	Includes hydrodyamic devices, catch basins, media filters, and biotreatment devices	*The treatment effectiveness of specific proprietary devices must be provided by the manufacturer and should be verified by independent third-party sources and data or assessed by a professional consultant.*						

Very High	High	Moderate	Low	Very Low
● (solid circle)	◓ (top half filled)	⦿ (circle with dot)	◒ (bottom half filled)	○ (empty circle)

[1] Effectiveness may change based on design variations; standard BMP designs have been assumed.

Table 6-2: BMP Selection Matrix - Site Suitability

Important Note to Users: Site suitability can vary widely for individual BMPs. This table should be used to provide general BMP comparisons only and should not replace the evaluation performed by a professional consultant. For greater accuracy, only compare site suitability considerations within each of the Treatment BMP Categories.

Report Section	Treatment BMP Category	Treatment BMP	Site Suitability Considerations					Applicability for Special Design Districts	
			Drainage Area (Acres)[1]	Site Slope (%)	Depth to Seasonally High Groundwater (ft)	Hydrologic Soil Group	Horizontal Setback from Drinking Water Wells (ft)	Coastal Bluff Areas	Hillside Design District
6.5	**Biofiltration BMPs**	Bioretention	< 2	< 15; planter boxes are generally more suitable for steep slopes [2,3]	> 2 with underdrains; > 5 without underdrains	Underdrains may be provided for "C" and "D" soils	100 [6]	Acceptable if underdrains are included and if the site slope meets the criteria provided in this matrix table.	Acceptable if site slope meets the criteria of this matrix table. If site slopes exceed 7%, underdrains should be included regardless of the hydrologic soil group condition of the site.
		Vegetated Swale Filter	< 5	< 10 site slope; 1.5 to 6 longitudinal slope of swale [2,3]	> 2 with underdrains; > 5 without underdrains	Any	100 [6]		
		Vegetated Strip Filter	< 2	< 5 site slope; 2 to 15 longitudinal slope of strip	> 2	Any	N/A		
6.6	**Infiltration and Filtration BMPs**	Infiltration Trench & Basin	< 5	< 7 [2]	> 5	May not be feasible in "C" soils. Not suitable in "D" soils.	100	Infiltration BMPs not permissible in Coastal Bluff Areas.	Acceptable if a geotechnical investigation proves that the facility does not comprise the stability of the site slope or surrounding slopes.
		Dry Well	< 5	< 7 [2]	> 5	May not be feasible in "C" soils. Not suitable in "D" soils.	100		
		Sand Filter	< 10	< 15 [4]	> 2 with underdrains	Any	N/A	Acceptable if criteria for site slope is met.	
6.7	**Permeable Pavement BMPs**	Includes pervious concrete and asphalt concrete (AC), permeable pavers, subsurface reservoir beds, and granular materials	Drainage Area is equal to area of pervious pavement	< 5 [2,5]	> 2 with underdrains; > 5 without underdrains	Underdrains may be provided for "C" and "D" soils	100 [6]	Acceptable if underdrains are included and if the site slope meets the criteria provided in this matrix table.	Acceptable if site slope meets the criteria of this matrix table. If site slopes exceed 7%, underdrains should be included regardless of the hydrologic soil group condition of the site.
6.8	**Building BMPs**	Cistern/Rain Barrel	Depends on system size	Any	> 2 if tank is underground	Any	N/A	Acceptable if criteria for site slope is met.	
		Planter Box	Equal to roof drainage area	< 15 [4,5]	> 2 with underdrains; > 5 without underdrains	Underdrains may be provided for "C" and "D" soils	100 [6]		
		Vegetated Roof	Equal to roof drainage area	N/A	N/A	N/A	N/A		
6.9	**Retention and Detention BMPs**	Constructed Treatment Wetland	> 10	< 8 [2]	> 2	"A" soils may require pond liner; "B" soils may require infiltration testing	N/A	Acceptable if criteria for site slope is met.	
		Wet Retention Basin	> 10	< 15 [2]	> 2	"A" soils may require pond liner; "B" soils may require infiltration testing	N/A		
		Dry Extended Detention Basin	> 10	< 15 [2]	> 2	Any	N/A		
6.10	**Proprietary Devices**	Includes hydrodynamic devices, media filters, and biotreatment devices	*The site suitability requirements for specific proprietary devices must be provided by the manufacturer and should be verified by independent third-party sources and data or assessed by a professional consultant.*						

1 Drainage areas should be used as a general guideline only. Drainage areas can be larger or smaller in some instances.

2 If slope exceeds given limit or is within 200 feet from the top of a hazardous slope or landslide area, a geotechnical investigation is required.

3 If system is located within 50 feet of a sensitive steep slope on the uphill side or 10 feet from a structure, underdrains should be incorporated.

4 If system is fully contained and includes a liner, underdrain system, and overflow to a storm drain system, then slopes can exceed 15%.

5 If a gravel base is used for storage of runoff: (1) slopes should be restricted to 0.5% (steeper grades reduce storage capacity) and (2) underdrains should be used if within 50 feet of a sensitive steep slope.

6 Setbacks apply to systems without underdrains or systems underlain by "A" or B" hydrologic soil groups.

6.5 Suggested Strategies for Meeting the Storm Water Runoff Requirements

The storm water runoff requirements can be met simultaneously through the use of “treatment trains” (multiple BMPs in series) or by modifying traditional detention and/or water quality treatment BMPs to meet more than one storm water runoff requirement. It shall be noted that the volume reduction requirement may be reduced or not required for sites where infiltration of the volume reduction requirement is infeasible. The following guidance provides potential strategies for utilizing treatment trains and for modifying traditional detention and/or water quality treatment BMPs to meet the storm water runoff requirements. Note that the following guidance provides potential strategies and is not an exhaustive list. How the storm water runoff requirements are met for a project is at the discretion of the designer and City reviewers.

- All or part of the three storm water runoff requirements can be achieved by first routing runoff from impervious areas to biofiltration BMPs incorporated into pervious, landscaped areas of the site. Runoff from buildings can be retained and treated using building BMPs. Permeable pavement can be used to reduce the overall imperviousness of the site and provide for infiltration of runoff. If additional peak discharge reduction, volume reduction, and/or water quality treatment is required to meet the storm water runoff requirements, flows from these BMPs can be routed to infiltration and/or retention/detention BMPs.

- In cases where identified pollutants of concern cannot be reduced using storm water runoff BMPs that simultaneously meet volume reduction and/or peak discharge requirements, a treatment train approach can be employed to first achieve water quality treatment for the pollutants of concern using storm water runoff BMPs that target those pollutants and then effluent from the water quality treatment BMP can be routed to one or more infiltration and/or retention/detention BMP(s) to achieve the volume reduction and peak discharge requirements.

- Where site conditions do not allow for significant use of vegetative BMPs such as biofiltration and building BMPs but do allow for infiltration, all three requirements can be met by using a combination of permeable pavement and underground infiltration BMPs (e.g., infiltration trench) or underground infiltration BMPs alone. In general, if the site allows for infiltration BMPs to be used, volume reduction and water quality treatment requirements can both be met simultaneously regardless of the targeted pollutants of concern as infiltration BMPs provide the best water quality treatment for all pollutants of concern. In some cases, additional detention will be required to meet the peak discharge requirements, which can be achieved using retention/detention BMPs.

- If flow-based BMPs are chosen to achieve the water quality treatment requirement, treated effluent from the flow-based BMPs must be routed to one or more infiltration and/or retention/detention BMPs to achieve the volume reduction and peak discharge requirements with the exception of vegetated swale filters which can be modified to promote infiltration using a subsurface gravel drainage layer. In the modified vegetated swale instance, infiltration and/or retention/detention BMPs may also be required in combination with the modified swale to meet the volume reduction and peak discharge requirements.

- The City's Storm Water Permit and this Manual demonstrate a preference for using infiltration designs to capture and treat storm water. However, infiltration is not the only solution for meeting the City's storm water treatment requirements; the alternatives where infiltration is not recommended include flow-through treatment designs (such as planter boxes and/or vegetated swales with under drains) as well as rain barrels, cisterns, and tanks for containment and later use for landscaping irrigation. For sites where soil conditions limit feasibility of compliance, flow-based BMPs will likely be more practical than for sites with infiltrative soils.

- All or part of the three requirements (i.e., peak discharge reduction, volume reduction, water quality treatment) can be met by modifying traditional detention and/or water quality treatment BMPs to allow for greater infiltration. Such BMPs include dry extended detention (ED) basins, bioretention areas, and vegetated swale filters. Where infiltration is feasible, these BMPs can be retrofitted with a sand filter or planting media layer (dry ED basins) or a gravel drainage layer (bioretention and swales) beneath the BMP to allow for additional volume reduction and treatment of runoff. For these modified BMP types, the facility can be sized to infiltrate the volume reduction requirement and detain flows to meet the peak discharge requirement. The water quality treatment requirement will then likely be met without additional controls being necessary.

6.6 Biofiltration and Filtration BMPs

6.6.1 Bioretention

Figure 6-1: Bioretention Area –*Arroyo Burro Estuary Restoration Site*

Application

- Commercial, residential, mixed use, institutional, and subdivisions
- Parking lot islands, cul-de-sacs, traffic circles
- Road shoulders & medians

Advantages

- Provides high pollutant removal and volume reduction
- Can be integrated into landscape areas
- Relatively low maintenance

Limitations

- Not recommended for steep slopes
- Requires adequate soils for infiltration
- Adequate depth to groundwater required for infiltration

6.6.1.1 Description

Bioretention areas are vegetated and mulched (i.e., landscaped) shallow depressions that capture and temporarily store storm water runoff. The captured runoff infiltrates through the bottom of the depression and a layer of planting soil, approximately 2 to 4 feet deep, that has an infiltration rate capable of draining the bioretention area (to the bottom of the planting soil) within a specified design drawdown time (usually 10 to 72 hours). Bioretention areas also treat the storm water as it passes through the planting soil. After the storm water infiltrates through the soil media, it infiltrates into the subsoil, if site conditions allow for adequate infiltration and slope protection or the filtered water is directed towards a storm water conveyance system or other storm water runoff BMP via underdrain pipes, if site conditions do not allow for adequate infiltration or slope protection. Bioretention areas are designed to capture a specified design volume and can be configured on-line or off-line. On-line bioretention areas require an overflow system for passing larger storms. Off-line bioretention areas do not require an overflow system but do require freeboard. The planting soil is a mixture that includes mostly sand with smaller fractions of fines (e.g., silts and clays) and organic matter. As storm water passes through the planting soil, pollutants are filtered, adsorbed, biodegraded, and uptaken by plants. Storm water volume is reduced as it passes through the planting soil via evapotranspiration. If soil conditions allow underdrains to be omitted (i.e., infiltration rates are adequate and slope is not a concern), the remaining storm water passes through the planting soil and infiltrates into the subsoil. Partial infiltration (approximately 20-25%, depending on soil conditions) can still occur when underdrains are present as long as an impermeable interface is not present between the soil media and subsoil. Partial infiltration occurs in these cases since some of the storm water bypasses the underdrain and infiltrates into the subsoil (Strecker *et. al.*, 2004). Bioretention areas shall be planted with grasses, shrubs, and trees that can withstand short periods of saturation (i.e., 10 to 72 hours) followed by longer periods of drought. Bioretention areas are generally not applicable in areas with slopes steeper than 15%. In these cases, planter boxes are more appropriate (see Section 6.9.2).

6.6.1.2 Applicability, Performance, and Limitations

Table 6-3, Table 6-4, and Table 6-5 provide a summary of BMP performance, applicability, and limitations for bioretention areas. *It is important to note that information in these tables shall be used to provide general guidance for bioretention areas and shall not replace the evaluation performed by a water quality professional.*

Applicability and Performance

Table 6-3 and associated guidance provide general volume reduction capabilities and treatment effectiveness rankings for bioretention areas. Refer to Section 6.4 for the process that shall be used for selecting BMPs based on pollutants of concern. Refer to Table 6-1 to determine the ranking of bioretention areas for removal of pollutants of concern as compared with other storm water runoff BMPs provided in Chapter 6. Refer to Table 6-2 to assess the applicability of bioretention areas for your site based on site suitability considerations as compared with other storm water runoff BMPs provided in Chapter 6. Bioretention areas are volume-based BMPs intended, primarily, for water quality treatment and, depending on site slope and soil conditions, can provide high volume reduction (See Table 6-4). Where site conditions allow, the volume reduction capability of bioretention areas can be enhanced for achieving additional credit towards meeting the volume reduction requirement, $V_{reduction}$, by omitting underdrains and providing a gravel drainage layer beneath the bioretention area. Bioretention areas can be used to help meet the peak runoff discharge requirement. See Section 6.2 for specific storm water runoff requirements for Tier 3 projects.

Table 6-3: Volume Reduction & Treatment Effectiveness for Bioretention Areas

Storm Water Runoff BMP	Volume Mitigation (% of inflow)	Treatment Effectiveness for Pollutants of Concern[1]					
		Trash	Nutrients	Bacteria	Metals (particulate and dissolved fractions)	Sediment	Organics (hydro-carbons, oil, and grease)
Bioretention	◓	◓	●	◓	◓	◓	●
Volume/Treatment Effectiveness: ● = Very High, ◓ = High, ◉ = Moderate, ◒ = Low, ○ = Very Low							

[1] Effectiveness may change based on design variations; standard BMP designs have been assumed.

Bioretention areas remove pollutants through physical, chemical, and biological mechanisms. Specifically, they use absorption, microbial activity, plant uptake, sedimentation, and filtration. Bioretention areas provide relatively consistent and high pollutant removal for sediment, metals, and organic pollutants (e.g., hydrocarbons). Most of the sediment removal occurs in the top mulch layer while metals removal commonly occurs within the first 18 inches of the planting soil (Hseih and Davis, 2005; Hunt and Lord, 2006). Removal of nitrogen and phosphorus species is less consistent. Total phosphorus percent removal has been found to vary between a 240% increase (production) and a 99% decrease (removal) (Hunt et. al., 2006; Hseih and Davis, 2005). Greater total phosphorus removal can be achieved by utilizing low P-index (10-30) soil media (Hunt and Lord, 2006). Nitrate removal has been found to vary between a 1% and 80% decrease. Total kjeldhal nitrogen (TKN) has been found to vary between a 5% increase and 65% decrease. Greater nitrate and TKN removal can be achieved by reducing the infiltration rate within the planting soil to 1-2 in/hr and ensuring that the soil media is at least 3 feet deep (Hunt and Lord, 2006). Greater nitrate removal can also be achieved by incorporating a saturated layer within the soil media to promote anaerobic conditions for denitrification (Kim et. al., 2003). Limited data exists for bacteria removal in bioretention areas although most scientists and engineers agree that bacteria die-off occurs at the surface where storm water is exposed to sunlight and the soil can dry out; dense vegetation within the bioretention area can limit the penetration of sunlight and removal of bacteria (Hunt and Lord, 2006).

Site Suitability Recommendations and Limitations

Table 6-4 and associated guidance provide general considerations for assessing a site's suitability for bioretention.

Table 6-4: Site Suitability Considerations for Bioretention Areas

BMP	Tributary Area (Acres; Sq.Ft.)[1]	Site Slope (%)	Depth to Seasonally High Groundwater Table (ft)	Hydrologic Soil Group	Horizontal Setback from Drinking Water Wells (ft)
Bioretention	< 5 Acre; 43,560 Sq. Ft.	< 15; planter boxes are generally more suitable for steep slopes [2,3]	> 2 with underdrains; > 5 without underdrains	Underdrains may be provided for "C" and "D" soils	100 [4]

[1] Tributary area is the area of the site draining to the BMP. Tributary areas provided here shall be used as a general guideline only. Tributary areas can be larger or smaller in some instances.

[2] If bioretention area is located within 50 feet of a sensitive steep slope (on the uphill side) or 10 feet from a structure, underdrains are required.

[3] If site slope exceeds 15% or if the bioretention area is within 200 ft from the top of a hazardous slope or landslide area, a geotechnical investigation is required.

[4] Setbacks apply to bioretention areas without underdrains or bioretention areas underlain by "A" or "B" hydrologic soil groups.

Table 6-5 provides additional site applicability considerations for special design districts within the City including coastal bluff areas and hillside design districts.

Table 6-5: Applicability of Bioretention Areas for Special Design Districts

Coastal Bluff Area	Hillside Design District
Acceptable if: (1) facility is not designed to promote infiltration, (2) underdrains and an impermeable liner are provided regardless of hydrologic soil group (HSG) type, and (3) site slope meets the criteria in Table 6-4.	Acceptable if: (1) a geotechnical investigation proves that the facility does not compromise the stability of the site slope or surrounding slopes, or (2) the facility includes an impermeable liner, underdrain system, and an overflow to a storm water conveyance system, if the facility is on-line.

The following guidance provides additional site suitability recommendations and limitations for bioretention.

- The tributary area (area draining to the bioretention area) shall be less than 5 acres.
- If located in an area with soil infiltration rates less than 0.05in/hr or greater than 2.4 in/hr, an underdrain shall be provided.
- Groundwater levels shall be at least 2 ft lower than the bottom of the bioretention area if underdrains area provided and 5 ft lower than the bottom of the bioretention area if underdrains are not provided.
- If no underdrains are provided, bioretention areas shall not be placed within 100 feet of the drinking water well.
- If underdrains are provided, site must have adequate relief between land surface and the storm water conveyance system to permit vertical percolation through the soil media and collection and conveyance in underdrain to storm water conveyance system.
- Typically, bioretention areas require between 2 to 6 percent of the tributary area.
- If located in hotspot areas where environmental releases may occur (e.g., industrial sites, gas stations), bioretention areas shall have an underdrain.
- Bioretention areas located within 50 feet of a sensitive steep slope shall incorporate an underdrain. A geotechnical investigation and report must be provided to address the potential effects of infiltration on the steep slope if a bioretention area without an underdrain is sited within 200 feet of the slope or hazardous landslide area.

Multi-Use and Treatment Train Opportunities

Bioretention areas can be used to simultaneously meet the storm water runoff requirements, meet landscaping requirements, achieve aesthetic goals, enhance wildlife functions, and/or provide public education. The following is a list of settings where bioretention may be incorporated to meet more than one project-level or watershed-scale objective:

- Landscaped areas on individual lots
- Areas within loop roads or cul-de-sacs
- Landscaped parking lot islands
- Within rights-of-way along roads.
- Common landscaped areas in apartment complexes or other multi-family residential designs.
- In parks and along open space edges.

In addition, bioretention areas can be combined with other basic and storm water runoff BMPs to form a "treatment train" that can provide enhanced water quality treatment and reductions in runoff volume and rate. For example, runoff can be collected from a roadway in a vegetated swale that then flows to a bioretention area. Both facilities can be reduced in size based upon demonstrated performance for meeting the storm water runoff requirements as outlined in Section 6.2 and addressing targeted pollutants of concern. In addition, bioretention areas can serve the dual purpose of storm water management and landscape design and can significantly enhance the aesthetics of a site.

6.6.1.3 Design Criteria and Procedure

Bioretention areas shall be designed according to the current requirements of the City of Santa Barbara and the Santa Barbara County Flood Control and Water Conservation District. Standard design criteria for bioretention areas are listed in Table 6-6. A schematic of a bioretention area is provided in Figure 6-2.

Table 6-6: Bioretention Area Design Criteria

Design Parameter	Unit	Design Criteria
Water quality design volume, V_{wq}	ft^3	See Section 6.2 and Appendix C for calculating V_{wq}.
Volume reduction requirement, $V_{reduction}$	ft^3	See Section 6.2 and Appendix C for calculating $V_{reduction}$.
Pretreatment	-	Filter strip, vegetated swale, or forebay for all surfaces other than roofs; if sheet flow, max velocity = 1 ft/sec
Drawdown time of planting soil	hrs	48
Drawdown time of gravel drainage layer (if applicable)	hrs	72
Maximum ponding depth	inches	12
Planting soil depth	feet	2; 3 preferred
Stabilized mulch depth	inches	2 to 3
Planting media composition	-	60 to 70% sand, 15 to 25% compost, and 10 to 20% clean topsoil; organic content 8 to 12%; pH 5.5 to 7.5

Design Parameter	Unit	Design Criteria
Underdrain	-	6 inch. minimum diameter; 0.5% minimum slope
Overflow device	-	Required if system is on-line

Pretreatment

1. Bioretention areas shall use a filter strip, vegetated swale, or forebay to pretreat incoming flows from impervious surfaces. Bioretention areas that treat runoff from residential roofs or other "cleaner" surfaces do not require pretreatment.

2. If sheet flow is conveyed to the treatment area over stabilized grassed areas, the site must be graded in such a way that minimizes erosive conditions. Sheet flow velocities shall not exceed 1 foot per second.

Geometry and Size

1. Bioretention areas shall have a maximum ponding depth of 12 inches.

2. Planting soil depth shall be a minimum of 2 feet, although 3 feet is preferred. *Intent: The planting soil depth shall provide a beneficial root zone for the chosen plant palette and adequate water storage for the water quality design volume. A deeper planting soil depth will provide a smaller surface area footprint.*

3. Bioretention areas shall be designed to drain to below the planting soil depth in less than 48 hours. If a gravel drainage layer is included beneath the bioretention area planting soil, stored runoff in the drainage layer shall be designed to drain in less than 72 hours. Intent: 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.*

Sizing Methodology

Bioretention areas shall be sized to capture and treat the water quality design volume, V_{wq}, and where site conditions allow, shall also be sized to infiltrate the volume reduction requirement, $V_{reduction}$. See Section 6.2 and Appendix C for the storm water runoff requirements and calculations. Procedures for sizing infiltration BMPs are summarized below. A bioretention area sizing example is provided in Appendix D.

Step 1: Determine the design infiltration rate

The design infiltration rate, k_{design}, will differ depending on whether the bioretention area will have underdrains. If the bioretention area includes underdrains, then the design infiltration rate will be that of the planting media which shall be determined using lab infiltration testing (see Chapter 3). If the bioretention area does not include underdrains, then the design infiltration rate will be the limiting infiltration rate (slowest) of the planting media and the native subsoil. In most cases, the limiting infiltration rate will be that of the native subsoil.

Determining the design infiltration rate, k_{design}, of the native subsoil

The initial infiltration rate of the native subsoil will decline over time as the surface settles and becomes more compacted and as sediments accumulate in the pore spaces of the infiltration layer. Monitoring of actual facility performance has shown that the full-scale infiltration rate is far lower than the rate measured by small-scale testing as described in Chapter 3. It is important that adequate conservatism is incorporated in the selection of design infiltration rates. The design infiltration rate discussed here is the infiltration rate of the underlying soils and not the infiltration rate of the planting media (refer to the “Planting/Storage Media” section below for the recommended composition of the planting media for bioretention areas).

A simplified method may be used for determining the design infiltration rate by applying correction factors to the field measured infiltration rate. These factors take into account uncertainty in measurement procedure, depth to water table or impermeable strata, infiltration facility geometry, and long term reductions in permeability due to biofouling and accumulation of fines.

$$k_{design} = k_{measured} \times F_{testing} \times F_{plugging} \times F_{geometry} \qquad \text{(Equation 6-1)}$$

Where:

k_{design} = design infiltration rate (in/hr)

$k_{measured}$ = field measures infiltration rate (in/hr)

$F_{testing}$ = correction factor for testing method

$F_{plugging}$ = correction factor for soil plugging

$F_{geometry}$ = correction factor for facility geometry

$F_{testing}$ takes into account uncertainties in the testing method and is 0.3 for small-scale percolation tests and 0.5 for large-scale testing.

$F_{plugging}$ accounts for reductions in infiltration rates over the long term caused by plugging of soils. The factor is:

- 0.7 for loams and sandy loams
- 0.8 for fine sands and loamy sands
- 0.9 for medium sands
- 1.0 for coarse sands or cobbles or for any facility preceded by a full specification filter strip or vegetated swale.

$F_{geometry}$ accounts for the influence of facility geometry and depth to groundwater table or impervious strata on the actual infiltration rate. $F_{geometry}$ must be between 0.25 and 1.0 as determined by the following equation:

$$F_{geometry} = 4\,D/w + 0.05 \qquad \text{(Equation 6-2)}$$

Where:

D	=	depth from the bottom of the facility to the maximum seasonally high gro*undwater* table or nearest impervious layer, whichever is less (ft)
w	=	width of the facility (ft)

Note that adjusted infiltration rate (k_{design}) may be different for basins, trenches, and dry wells installed in the same location due to differences in dimension.

Step 2: Sizing Calculations

Bioretention areas can be sized using one of two methods: a simple sizing method or a routing modeling method. With either method, the runoff entering the facility must completely drain the ponding area and the planting media within 48 hours. If the bioretention areas includes a gravel drainage layer, the drainage layer must drain in 72 hours. The sizing of the gravel drainage layer is much like the sizing of the gravel storage layer for permeable pavement. See the permeable pavement Section 6.8 for these calculations. Bioretention areas provide storage above ground, in the voids of the planting media, and (if used) in the voids of gravel drainage layer.

Simple Sizing Method. If the bioretention area is to be designed with underdrains, the volume for design, V_{design}, is equal to V_{wq}. If the bioretention are is designed without underdrains where site conditions allow for infiltration, the volume for design, V_{design} is the greater of $V_{reduction}$ and V_{wq}. V_{design} will fill the available ponding depth, the void spaces in the planting media, and (if used) the gravel drainage layer. Determine the surface area of the bioretention area (bottom area) using the following equation based on Darcy's law.

$$A = \frac{(V_{design})(l)}{(t)(k_{design})(d+l)} \qquad \text{(Equation 6-3)}$$

(Adapted from Georgia Stormwater Manual: http://www.atlantaregional.com/environment/georgia-stormwater-manual)

Where:

V_{design}	=	design volume of runoff to be infiltrated (ft^3)
k_{design}	=	design infiltration rate (in/hr); if underdrains are provided, infiltration rate of planting media; if no underdrains provided, infiltration rate of the subsoil
d	=	ponding depth (ft)
l	=	depth of planting media (ft)
t	=	required drawdown time (hr); maximum is 48 hours

Routing Method. A continuous runoff model, such as US EPA's SWMM Model, can be used to optimally size a sand filter. A continuous simulation model consists of three components: (1) a representative long term period of rainfall data (≈ 20 years or greater) as the primary model input, (2) a model component representing the tributary area to the bioretention area that takes into account the amount of impervious area, soil types of the pervious area, vegetation, evapotranspiration, etc., and (3) a component that simulates the bioretention area. Using this method, the bioretention area shall be sized to capture and treat the water quality design volume, V_{wq}, or, if site conditions allow, the volume reduction requirement, $V_{reduction}$ from the post-development tributary area; whichever is larger.

The continuous simulation model routes predicted tributary runoff to the bioretention area, where treatment is simulated as a function of the infiltrative (flow) capacity of the bioretention area and the available storage volume above the bioretention area. In a continuous runoff model such as SWMM, the physical parameters of the bioretention area are represented with stage-storage-discharge relationships. Due to the computational power of ordinary desktop computers, long-term continuous simulations generally take only minutes to run. This allows the modeler to run several simulations for a range of bioretention area sizes, varying either the surface area of the bioretention area (and resulting flow capacity) or the storage capacity above the bioretention area, or both. Sufficient continuous model simulations shall be completed so that results encompass the water quality treatment and/or volume reduction capture goal.

Model results shall be plotted for both varying storage depths above the bioretention area and for varying bioretention area surface areas (and resulting flow capacity) while keeping all other parameters constant. The resulting relationship of percent capture as a function of bioretention area flow and storage capacity can be used to optimally size a bioretention area based on site conditions and constraints.

In addition to continuous simulation modeling, routing spreadsheets, and/or other forms of routing modeling that incorporate rainfall-runoff relationships and infiltrative (flow) capacities of bioretention areas may be used to size facilities. Alternative sizing methodologies shall be prepared with good engineering practices.

Flow Entrance and Energy Dissipation

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

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. Flow spreading trench around perimeter of bioretention area. May be filled with pea gravel (i.e., pea gravel diaphragm) or vegetated with 3:1 side slopes similar to a vegetated swale. A vertical-walled open trench may also be used at the discretion of the City.

4. Curb cuts/slotted wheel stops for roadside or parking lot areas. Curb cuts/slotted wheel stops shall include rock or other erosion protection material at flow entrance to dissipate

energy. Flow entrance shall 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.

5. Pipe flow entrance: Piped entrances, such as roof downspouts, shall include rock, splash blocks, or other erosion protection material at the entrance to dissipate energy and disperse flows.

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

Underdrains

If underdrains are required, then they must meet the following criteria:

1. 6-inch minimum diameter.

2. Underdrains must be made of slotted, polyvinyl chloride (PVC) pipe conforming to ASTM D 3034 or equivalent or corrugated high density polyethylene (HDPE) pipe conforming to AASHTO 252M or equivalent. *Intent: As 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 shall 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 shall be 0.04 to 0.1-inch and shall have a length of 1-inch to 1.25-inch. Slots shall be longitudinally spaced such that the pipe has a minimum of one square inch per lineal foot.

4. Underdrains shall be sloped at a minimum of 0.5%.

5. Rigid non-perforated observation pipes with a diameter equal to the underdrain diameter shall be connected to the underdrain every 250 to 300 feet to provide a clean-out port as well as an observation well to monitor dewatering rates. The wells/cleanouts shall be connected to the perforated underdrain with the appropriate manufactured connections. The wells/cleanouts shall extend 6 inches above the top elevation of the bioretention facility mulch, and shall be capped with a lockable screw cap. The ends of underdrain pipes not terminating in an observation well/cleanout shall also be capped.

6. The following aggregate shall be used to provide a gravel blanket and bedding for the underdrain pipe. Place the underdrain on a 3-foot wide bed of the aggregate at a minimum thickness of 6 inches and cover with the same aggregate 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

7. At the option of the designer, a geotextile fabric may be placed between the planting media and the drain rock. If a geotextile fabric is used it must meet the following minimum materials requirements. Another option is to place a thin, 2- to 4-inch layer of pure sand and a thin layer (nominally two inches) of choking stone (such as #8) between the planting media and the drain rock.

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

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, daylight to a vegetated dispersion area using an effective flow dispersion device, stored for reuse, or to a storm water conveyance system.

Overflow

If the bioretention area is on-line, an overflow device is required at the 12-inch ponding depth. Two options are provided:

Option 1: Vertical riser

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

2. The overflow riser(s) shall be 6 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 shall be 12 inches above the planting media, and be capped with a spider cap.

Option 3: Pea Gravel Curtain Drain (if underdrain is provided)

1. A pea gravel drain shall be installed on the downslope edge of the bioretention area.

2. The top surface of the drain shall be 12 inches above the planting media surface, and supported by 4:1 (H:V) berm of planting media on the upstream side.

3. The curtain drain will be 12" wide and at least as long as maximum width of the bioretention area.

4. The curtain drain will be connected directly to the gravel bed supporting the drainage pipe.

5. A geotextile meeting the specifications above shall be placed vertically between the curtain drain and the planting media.

Option 3: Flow spreader

1. A flow spreader shall be installed along a section of the exit edge or outflow section of the bioretention area.

2. The top surface of the flow spreader shall be 6 inches above the planting media surface.

Hydraulic Restriction Layers

Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, other infrastructure, or hotspot locations. Three types of restricting layers can be incorporated into bioretention designs:

1. Filter fabric can be placed along vertical walls to reduce lateral flows.

2. Clay (bentonite) liners can be used. If so, underdrain system is also required.

3. Geomembrane liners shall have a minimum thickness of 30 mils.

Planting/Storage Media

1. The planting media placed in the cell shall be highly permeable and high in organic matter (e.g., loamy sand mixed thoroughly with compost amendment) and a surface mulch layer.

2. Planting media shall consist of 60 to 70% sand, 15 to 25% compost, and 10 to 20% clean topsoil. The organic content of the soil mixture shall be 8% to 12%; the pH range shall be 5.5 to 7.5.

3. Sand shall be free of stones, stumps, roots or other similar objects larger than 5 millimeters, and have the following gradation:

Particle Size (ASTM D422)	% Passing
#4	100
#6	88-100

#8	79-97
#50	11-35
#200	5-15

4. Compost shall be free of stones, stumps, roots or other similar objects larger than ¾ inches; have a particle size of 98% passing through ¾" screen or smaller; and meet the following characteristics:

- Soluble Salt Concentration: < 10 mmhos/cm (dS/m)
- pH: 5.0-8.5
- Moisture: 30-60% wet weight basis
- Organic Matter: 30-65% dry weight basis
- Stability (Carbon Dioxide evolution rate): >80% relative to positive control
- Maturity (Seed emergence and seedling vigor): >80% relative to positive control
- Physical contaminants: < 1% dry weight basis

5. Topsoil shall be free of stones, stumps, roots or other similar objects larger than 2 inches, and have the following characteristics:

- Soluble salts: < 4.0 mmhos/cm (dS/m)
- pH range: 5.5 to 7.0
- Organic matter: > 5%
- Carbon to Nitrogen Ratio: < 20:1
- Moisture content: 25-55%

Particle Size (ASTM D422, D1140)	% Passing
3/4"	98
Sand (0.05 - 2.0 mm)	50-75
Silt (0.002 - 0.05 mm)	15-40
Clay	< 5

6. The bioretention area shall be covered with mulch when constructed and annually replaced to maintain adequate mulch depth. *Intent: this will help sustain nutrient levels, suppress weeds, and maintain infiltrative capacity.* Mulch shall be:

- Well-aged, shredded or chipped woody debris or plant material. Well-aged mulch is defined as mulch that has been stockpiled or stored for at least twelve (12) months. Compost meeting the requirements above may also be used (compost is less likely to float and is a better source for organic materials).

- Free of weed seeds, soil, roots, and other material that is not bole or branch wood and bark.

- Mulch depth shall be 2 to 3 inches thick (*intent: thicker applications can inhibit proper oxygen and carbon dioxide cycling between the soil and atmosphere*).

- Grass clippings or pure bark shall not be used as mulch.

7. Planting media design height shall be marked appropriately, such as a collar on the vertical riser (if installed), or with a stake inserted 2 feet into the planting media and notched to show bioretention surface level and ponding level.

8. The bioretention soil mix shall be tested and meet the following criteria:

Item	Criteria	Test Method
Corrected pH	5.5 – 7.5	ASTM D4972
Magnesium	Minimum 32 ppm	*
Phosphorus (Phosphate - P_2O_5)	Not to exceed 69 ppm	*
Potassium (K_2O)	Minimum 78 ppm	*
Soluble Salts	Not to exceed 500 ppm	*

* Use authorized soil test procedures.

Should the pH fall outside of the acceptable range, it may be modified with lime (to raise) or iron sulfate plus sulfur (to lower). The lime or iron sulfate must be mixed uniformly into the soil mix prior to use in bioretention areas.

Should the soil mix not meet the minimum requirement for magnesium, it may be modified with magnesium sulfate. Likewise, should the soil mix not meet the minimum requirement for potassium, it may be modified with potash. Magnesium sulfate and potash must be mixed uniformly into the soil mix prior to use in bioretention areas.

Limestone. Limestone shall contain not less than 85 percent calcium and magnesium carbonates. Dolomitic (magnesium) limestone shall contain at least 10 percent magnesium as magnesium oxide and 85 percent calcium and magnesium carbonates.

Limestone shall conform to the following gradation:

Sieve Size	Minimum Percent Passing By Weight
No. 10	100
No. 20	98
No. 100	50

Iron Sulfate. Iron sulfate shall be a constituent of an approved horticultural product produced as a fertilizer for supplying iron and as a soil acidifier.

Magnesium Sulfate. Magnesium sulfate shall be a constituent of an approved horticultural product produced as a fertilizer.

Potash. Potash (potassium oxide) shall be a constituent of an approved horticultural product produced as a fertilizer.

Gravel Drainage Layer

If site conditions allow (i.e., soil infiltration rate and site slope are adequate), the volume reduction capability bioretention areas can be enhanced by omitting the underdrain and installing an appropriately sized gravel drainage layer (typically a washed 57 stone) beneath the planting soil to achieve the desired volume reduction goals. The base of the drainage layer shall have zero slope (level). The drawdown time for the gravel drainage layer shall not exceed 72 hours. The planting soil and gravel layers shall be separated with a geotextile filter fabric (as specified above) or with 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 the same as for permeable pavement, see Section 6.8 for sizing calculations.

Vegetation

Bioretention area vegetation shall have the following characteristics:

1. Plant materials shall 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 tree, three shrubs, and three herbaceous groundcover species be incorporated to protect against facility failure due to disease and insect infestations of a single species. Plant rooting depths shall not damage the underdrain, if present. Slotted or perforated underdrain pipe shall be more than 5 feet from tree locations (if space allows).

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

4. Shade trees shall have a single main trunk. Trunks shall be free of branches below the following heights:

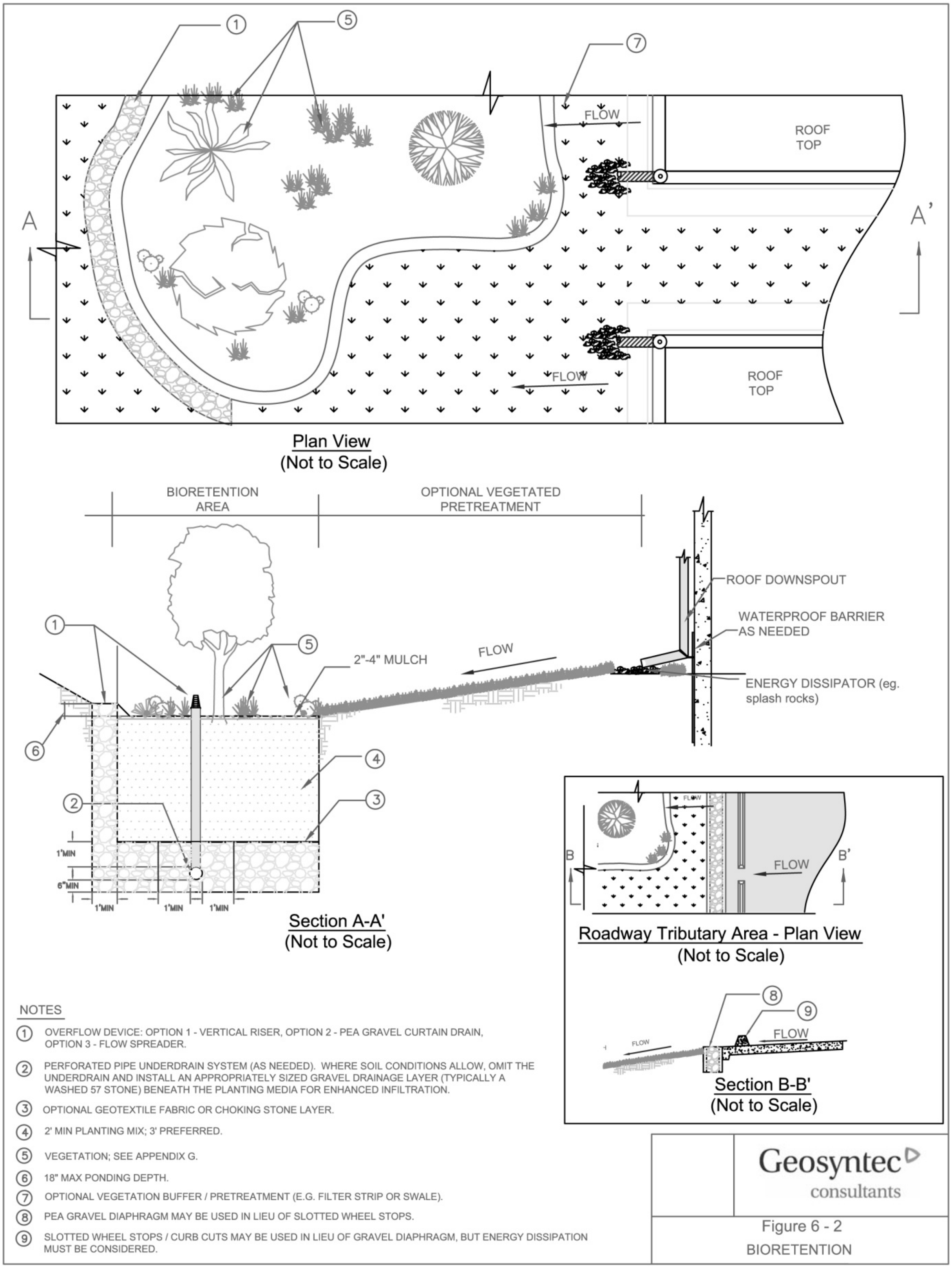
Caliper (in)	Height (ft)
1-1/2 to 2-1/2	5
3	6

5. See Appendix G for a recommended native plant list for bioretention areas, a list of local nurseries where these plants can be purchased, and a list of local and regional on-line resources. The plant list in Appendix G shall be used as a guide only and shall not replace project-specific planting recommendations provided by a landscape professional including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth. See Section 5.11 for more information on landscaping/planting recommendations and Section 5.10 for more information on soil amendment recommendations.

6.6.1.4 Construction Considerations

The use of treated wood or galvanized metal anywhere inside the facility is prohibited.

Figure 6-2: Bioretention Area Schematic



6.6.1.5 <u>Operations and Maintenance</u>

General Requirements

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 shall 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 H for a bioretention inspection and maintenance checklist). Properly designed facilities with appropriate flow velocities shall not have erosion problems except perhaps in extreme events. If erosion problems occur the following shall 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 shall become less frequent if the appropriate plant species and planting density have been used and, as a result, undesirable plants 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 areas 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 areas 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 areas 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 areas where heavy metal deposition is likely provides an additional level of protection for prolonged performance. If in question, have soil analyzed for fertility and pollutant levels.

Maintenance Standards

A summary of the routine and major maintenance activities recommended for bioretention areas is shown in Table 6-7. Detailed routine and major maintenance standards are listed in Table 6-8 and Table 6-9.

Table 6-7: Bioretention Maintenance Quick Guide

Inspection and Maintenance Activities Summary	
Routine Maintenance	• Repair small eroded areas and ruts by filling with gravel. Overseed bare areas to reestablish vegetation • Remove trash and debris and rake surface soils to mitigate ponding • Remove accumulated fine sediments, dead leaves, and trash to restore surface permeability • Remove any evidence of visual contamination from floatables such as oil and grease • Eradicate weeds and prune back excess plant growth that interferes with facility operation. Remove non-native vegetation and replace with native species • Remove sediment and debris accumulation near inlet and outlet structures to alleviate clogging • Clean and reset flow spreaders (if present) as needed to restore original function • Mow routinely to maintain ideal grass height and to suppress weeds • Periodically observe function under wet weather conditions
Major Maintenance	• Repair structural damage to flow control structures including inlet, outlet, and overflow structures • Clean out under-drain, if present, to alleviate ponding. Replace media if ponding or loss of infiltrative capacity persists and re-vegetate • Re-grade and re-vegetate to repair damage from severe erosion/scour channelization and to restore sheet flow • Photographs taken before and after major maintenance is encouraged

Table 6-8: Routine Maintenance – Bioretention

Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed	Frequency
Erosion	Splash pads or spreader incorrectly placed; eroded or scoured areas due to flow channelization, or higher flows.	No erosion on surface of basin. No erosion or scouring evident. For ruts or bare areas less than 12 inches wide, damaged areas repaired by filling with crushed gravel. The grass will creep in over the rock in time.	Annually prior to wet season. After major storm events (>0.75 in/24 hrs) if spot checks of some basins indicate widespread damage/ maintenance needs
Standing Water	When water stands in the basin between storms and does not drain freely (with 36- 48 hours after storm event).	Water drains completely from basin as designed and surface is clear of trash and debris. Underdrains (if installed) are cleared.	
Loss of surface permeability	Accumulation of fine sediments, dead leaves, trash and other debris on surface	Surface permeability restored. Surface layer removed and replaced with fresh mulch.	
Visual contaminants and pollution	Any visual evidence of oil, gasoline, contaminants or other pollutants.	No visual contaminants or pollutants present.	Monthly (or as dictated by agreement between County and landscape contractor
Vegetation	Weeds, excessive plant growth, plants interfering with basin operation, plants diseased or dying	Basin tidy, plants healthy and pruned. Any plants that interfere with function are removed. Invasive or non-acclimated plants replaced.	
Inlet/Overflow	Inlet/outlet areas clogged with sediment and/or debris.	Material removed so that there is no clogging or blockage of the inlet or overflow area.	
Trash and debris	Any trash and debris which exceed 5 cubic feet per 1,000 square feet (one standard garbage can).	Trash and debris removed and facility looks well kept.	

Table 6-9: Major Maintenance – Bioretention

Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed	Frequency
Standing water	When water stands in the basin between storms and does not drain freely (with 36- 48 hours after storm event).	planting media (sand, gravel, and topsoil) and vegetation removed and replaced.	Annually prior to wet season
Erosion/ Scouring	Bare spots greater than 12 inches	No erosion on surface of basin. Large bare areas are re-graded and reseeded/replanted.	As needed

6.6.2 Vegetated Swale Filter

Figure 6-3: Roadside Swale
Photo Credit: Geosyntec Consultants

Applications
- Commercial and institutional
- Multi-family and mixed use
- Parking lots, road shoulders and medians
- Open spaces, parks, golf courses

Advantages
- Combines stormwater treatment with runoff conveyance
- Often less cost than curb & gutter
- Volume & peak flow reduction
- Pollutant removal

Limitations
- Higher maintenance than curb and gutter
- Not applicable for steep slopes
- May interfere with flood control function of existing convevances and detention

6.6.2.1 Description

Vegetated swale filters (vegetated swales) are open, shallow channels with low-lying vegetation covering the side slopes and bottom that collect and slowly convey runoff flow to downstream discharge points. Vegetated swales provide pollutant removal through settling and filtration in the vegetation (usually grasses) lining the channels. In addition, they provide the opportunity for volume reduction through infiltration and evapotranspiration, and reduce the flow velocity in addition to conveying storm water runoff. Where soil conditions allow, volume reduction in vegetated swales can be enhanced by adding a gravel drainage layer underneath the swale allowing additional flows to be retained and infiltrated. Where slopes are shallow and soil conditions limit or prohibit infiltration, an underdrain system or low flow channel for dry weather flows may be required to minimize ponding and convey treated and/or dry weather flows to an acceptable discharge point.

An effective vegetated swale achieves uniform sheet flow through a densely vegetated area for a period at least 10 minutes. The vegetation in the swale can vary depending on its location within a development project and is the choice of the designer, depending on the functional criteria outlined below. 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.

A vegetated swale can be designed either on-line or off-line. On-line vegetated swales are used for conveying high flows as well as providing treatment of the water quality design flow rate, and can replace curbs, gutters, and storm drain systems. On-line vegetated swales are sized to treat flows up to the flow-based water quality treatment design flow rate, Q_{wq}, and act as a storm water conveyance channel for storms greater than the water quality design storm flow rate. No treatment is credited for storms that produce flow rates greater than Q_{wq} because the ratio of flow depth to vegetation height is small due to increased flow depths and decreased vegetation height (e.g., vegetation gets pushed horizontal when flow depths increase to greater than two-thirds of the vegetation height) which limits the amount of filtering that can occur for storms greater than the Q_{wq}. On-line vegetated swales shall be designed to convey flow rates up to the post-development peak storm water runoff discharge rate (flow rate) for the 100-yr 24-hour storm event, with appropriate freeboard (See Santa Barbara County Flood Control and Water Conservation District Standard Conditions of Project Plan Approval). Exceptions to the required freeboard are inlets or safe surface conveyances to carry excess water into a storm water conveyance system that might occur in parking lots, for example. Whenever possible, inflow shall be directed towards the upstream end of the swale as much as possible, but shall at a minimum occur evenly over the length of the swale. Flow velocities shall be limited in on-line swales as much as possible to minimize re-entrainment of sediment and associated pollutants.

If designed off-line, a flow diversion structure (i.e., flow splitter) is used to divert the Q_{wq} to the off-line vegetated swale designed to handle Q_{wq}. Freeboard for off-line swales is not required, but shall be provided if space is available.

6.6.2.2 <u>Applicability, Performance, and Limitations</u>

Table 6-10, Table 6-11, and Table 6-12 provide a summary of BMP performance, applicability, and limitations for vegetated swale filters. *It is important to note that information in these tables shall be used to provide general guidance for vegetated swale filters and shall not replace the evaluation performed by a water quality professional.*

Applicability and Performance

Table 6-10 and associated guidance provide general volume reduction capabilities and treatment effectiveness rankings for vegetated swale filters. Refer to Section 6.4 for the process that shall be used for selecting BMPs based on pollutants of concern. Refer to Table 6-1 to determine the ranking of vegetated swale filters for removal of pollutants of concern as compared with other storm water runoff BMPs provided in Chapter 6. Refer to Table 6-2 to assess the applicability of vegetated swale filters for your site based on site suitability considerations as compared with other storm water runoff BMPs provided in Chapter 6. Vegetated swales are flow-based BMPs intended, primarily, for water quality treatment and, depending on site slope and soil conditions, can provide some volume reduction. They can be designed to enhance infiltration for achieving credit towards meeting the volume reduction requirement, $V_{reduction}$. Where site conditions allow (See Table 6-11), the volume reduction capabilities of vegetated swales can be designed to enhance infiltration for achieving credit towards meeting the volume reduction requirement, $V_{reduction}$, by eliminating underdrains and providing a gravel drainage layer beneath the vegetated swale. Vegetated swales are <u>not</u> intended to be a primary BMP for meeting the peak runoff discharge requirement, although they do assist in reducing the peak runoff discharge rate by increasing the site's time of concentration, T_c, and decreasing runoff volumes and velocities. See Section 6.2 for specific storm water runoff requirements for Tier 3 projects.

Table 6-10: Volume Reduction & Treatment Effectiveness for Vegetated Swale Filters

Storm Water Runoff BMP	Volume Mitigation (% of inflow)	Treatment Effectiveness for Pollutants of Concern[1]					
		Trash	Nutrients	Bacteria	Metals (particulate and dissolved fractions)	Sediment	Organics (hydro-carbons, oil, and grease)
Vegetated Swale Filter	◉ (Moderate)	◒ (Low)	○ (Very Low)	◉ (Moderate)	◉ (Moderate)	◉ (Moderate)	◉ (Moderate)

Volume/Treatment Effectiveness: ● = Very High, ◓ = High, ◉ = Moderate, ◒ = Low, ○ = Very Low

[1] Effectiveness may change based on design variations; standard BMP designs have been assumed.

Vegetated swales are a good candidate for the removal of sediment and particulate bound pollutants through filtration. The effectiveness of vegetated swale filters can be enhanced by adding check dams or appropriate trees at approximately 50 foot increments along their length. These dams maximize the retention time within the swale, decrease flow velocities, and promote particulate settling. The incorporation of vegetated filter strips parallel to the top of the channel banks can help to treat sheet flows entering the swale.

Site Suitability Recommendations and Limitations

Table 6-11 and associated guidance provide general considerations for assessing a site's suitability for vegetated swales.

Table 6-11: Site Suitability Considerations for Vegetated Swale Filters

BMP	Tributary Area (Acres; Sq.Ft.)[1]	Site Slope (%)	Depth to Seasonally High Groundwater Table (ft)	Hydrologic Soil Group	Horizontal Setback from Drinking Water Wells (ft)
Vegetated Swale Filter	< 5 Acres; 217,800 Sq.Ft.	< 10 site slope; 1 to 6 longitudinal slope of swale [2,3]	> 2 with underdrains; > 5 without underdrains	Any [3]	100 [4]

[1] Tributary area is the area of the site draining to the BMP. Tributary areas provided here shall be used as a general guideline only. Tributary areas can be larger or smaller in some instances.

[2] If site slope exceeds 10% or if the swale is within 200 ft from the top of a hazardous slope or landslide area, a geotechnical investigation is required. If the longitudinal slope of the swale exceeds 6%, check dams (e.g., drop structures) shall be provided.

[3] If the swale is located within 50 feet of a sensitive steep slope on the uphill side or 10 feet from a structure, has a longitudinal slope less than 1.5% and has poorly drained soils (hydrologic soil groups "C" or "D"), or is located in a coastal bluff area or a hillside design district, underdrains shall be incorporated.

[4] Setbacks apply to systems without underdrains or systems underlain by "A" or "B" hydrologic soil groups.

Table 6-12 provides additional site applicability considerations for special design districts within the City including coastal bluff areas and hillside design districts.

Table 6-12: Applicability of Vegetated Swale Filters for Special Design Districts

Coastal Bluff Area	Hillside Design District
Acceptable if: (1) facility is not designed to promote infiltration, (2) underdrains and an impermeable liner are provided regardless of hydrologic soil group (HSG) type, and (3) site slope meets the criteria in Table 6-11.	Acceptable if: (1) a geotechnical investigation proves that the facility does not compromise the stability of the site slope or surrounding slopes, or (2) the facility includes an impermeable liner, underdrain system, and an oveflow to a storm water conveyance system, if the facility is on-line.

The following provides additional site suitability recommendations and limitations for vegetated swale.

- Limit the tributary area (area draining to the BMP) and associated longitudinal slope (parallel to the flow) to less than 5 acres and less than 10%, respectively. *Intent: reduces the potential for high flow velocity and concentrated, erosive flows entering the vegetated swale.*

- The longitudinal slope over the length of the swale can be up to 6% before concentrated, erosive flows become potentially problematic. Check dams (e.g., drop structures) shall be provided for slopes that exceed 6%.

- Mild longitudinal slope (<1.5%) over the length of the vegetated swale along with poorly drained soils including hydrologic soil groups "C" or "D" (e.g., silts and clays) can cause ponding. Underdrains shall be provided in these cases. In any case, longitudinal slope shall not be less than 1%. A soils report shall be provided to verify soils properties for swales less than 1.5%.

- Require at least 100 feet in length if the vegetated swale will be used to meet the water quality treatment requirements. The vegetated swale can be shorter than 100 feet if it is used for pretreatment.

- Cannot be applied in areas with highly erodible soils.

- Groundwater levels shall be at least 2 ft lower than the swale surface if underdrains are provided and 5 ft lower than the swale surface to ensure that the swale does not remain wet between storms.

- May not be applicable adjacent to industrial sites or locations where environmental releases may occur depending on the filtration capabilities of the swale.

- Shall not be located in areas with excessive shade to avoid poor vegetative growth. For moderately shaded areas, shade tolerant plants shall be used.

- Shall not be located near too many large trees that may drop leaves or needles. Excessive tree debris may smother the grass or impede the flow through the swale.

Multi-Use and Treatment Train Opportunities

A vegetated swale can be combined with other basic and storm water runoff BMPs to form a "treatment train" that provides enhanced water quality treatment and reductions in runoff volume and rate. For example, if a vegetated swale is placed upgradient of a dry extended detention (ED) basin, the rate and volume of water flowing to the dry ED basin can be reduced and the water quality enhanced. As another example, dry ED basins may be placed upstream a vegetated swale to reduce the size of the vegetated swale. In both cases, each facility can be reduced in size accordingly based upon demonstrated performance for meeting the storm water runoff requirements as outlined in Section 6.2 and addressing targeted pollutants of concern. In addition, vegetated swales can be incorporated into the landscape design of a site and can be aesthetically pleasing as well as functional. 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.

6.6.2.3 Design Criteria and Procedure

Vegetated swales shall be designed according to the current requirements of the City of Santa Barbara and the Santa Barbara County Flood Control and Water Conservation District. Standard design criteria for vegetated swale filters are listed in Table 6-13. A schematic of a vegetated swale is illustrated in Figure 6-5. Schematics of check dams and flow spreaders are illustrated in Figure 6-6.

Table 6-13: Vegetated Swale Filter Design Criteria

Design Parameter	Unit	Design Criteria
Water quality design flow rate, Q_{wq}	cfs	See Section 6.2 and Appendix C for calculating Q_{wq}.
Volume reduction requirement, $V_{reduction}$	ft^3	See Section 6.2 and Appendix C for calculating $V_{reduction}$
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	100 or at least 10 minute residence (contact) time
Maximum channel side slope	H:V	• 2:1 for total swale depth < 1 ft • 3:1 for total swale depth > 1 ft or for mowed grass swales
Minimum slope in flow direction	%	1 (provide underdrains for slopes between 1 and 1.5 that have poorly drained soils – hydrologic soil group "C" or "D".)
Maximum slope in flow direction	%	6.0 (provide check dams for slopes > 6.0)
Maximum flow velocity	ft/sec	1.0 (water quality treatment); 3.0 (flood conveyance)
Maximum depth of flow for water	inches	4 for infrequently mowed vegetated swales; 2 for frequently

Design Parameter	Unit	Design Criteria
quality treatment		mowed turf swales (ideally flow depth is 2 inches less than vegetation height)
Minimum residence (contact) time	minutes	>7 (provide sufficient length to yield minimum residence time)
Vegetation type	--	Varies (see vegetation section below and Appendix G)
Vegetation height	inches	4 to 6 (trim or mow to maintain height)

Geometry and Size

1. In general, trapezoidal channel shape shall 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 anticipated to be fairly shallow, generally less than 1-foot. Therefore, a side slope of 2:1 (H:V) can be used and is acceptable. Milder slopes are necessary for mowed turf swales (3H:1V max.).

3. Overall depth from the top of the side walls to the swale bottom shall be at least 12 inches.

4. Swale length shall be greater than 100 feet in length. Regardless of the recommended detention time, the swale shall be not less than 100 feet in length if the vegetated swale will be used to meet the water quality treatment requirements. The vegetated swale can be shorter than 100 feet if it is used for pretreatment. Length can be increased by meandering the swale.

5. The minimum swale bottom width shall be 2 feet to allow for ease of mowing.

6. The maximum swale bottom width shall be limited to 10 feet, unless a dividing berm is provided, then maximum bottom width can be 16 feet. Swale width is calculated without the diving berm. *Intent: 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 and 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.*

7. Swales that are required to convey flood as well as water quality flows shall be sized to convey the post-development peak storm water discharge rate for the 100-yr 24-hr storm event and include 2 feet of freeboard, unless it can be demonstrated that the swale freeboard is not needed because runoff would be safely be conveyed to an alternative drainage system (such as a parking lot).

8. Gradual meandering bends in the swale are desirable for aesthetic purposes and to promote slower flow.

Bottom Slope

1. The longitudinal slope (along the direction of flow) shall 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 shall be provided. A soils report to verify soils properties shall be provided for swales less than 1.5%.

3. If longitudinal slope exceeds 6%, check dams with vertical drops of 12 inches or less shall be provided to achieve a bottom slope of 6% or less between the drop structures.

4. The lateral (horizontal) slope at the bottom of the swale shall be zero (flat) to discourage channeling.

Water Depth and Dry Weather Flow Drain

1. Water depth shall not exceed 4 inches, except for frequently mowed turf swales (as in commercial or landscaped areas), the depth shall not exceed 2 inches.

2. The swale length must provide a minimum hydraulic residence time of 10 minutes.

3. If soil and slope conditions require, a low flow drain shall be provided for dry weather flows extending the entire length of the swale. The drain shall have a minimum depth of 6 inches, and a width no more than 5% of the calculated bottom swale width; the width of the drain shall be in addition to the required bottom width. If an anchored plate is used for flow spreading at the swale inlet, the plate wall shall have v-notches (maximum top width = 5% of swale width) or holes to allow preferential exit of low flows into the drain. If an underdrain or gravel drainage layer is installed as discussed below, the low flow drain shall be omitted.

Sizing Methodologies

The flow capacity of a vegetated swale is a function of the longitudinal slope (parallel to flow), the resistance to flow (e.g., 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 shall 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 peak of the water quality design storm intensity. Once design criteria have been selected, the resulting flow depth for the design water quality flow rate is checked. If the depth restriction is exceeded, swale parameters (e.g., longitudinal slope, width) are adjusted to reduce the flow depth.

A vegetated swale sizing example is provided in Appendix D.

Step 1: Select design flows and design volume reduction (if applicable)

Vegetated swales are flow-based BMPs and are designed based on the water quality design flow rate, Q_{wq}. If a gravel drainage layer is to be included for promoting infiltration and gaining credit towards the volume reduction requirement, $V_{reduction}$, see the gravel drainage layer discussion below. Sizing of the gravel drainage layer is not provided in these steps. For calculating the Q_{wq} and $V_{reduction}$, see Section 6.2 and Appendix C.

Step 2: Determine flow depth, d, and swale bottom width, b

There are two procedures for determining design flow depth, d, and swale bottom width, b. One is a spreadsheet procedure and the other is a graphical procedure. Both procedures use a trial and error method for solving Manning's equation for a trapezoidal open channel when the longitudinal channel slope, Manning's roughness, and design flow rate are known. The general Manning's equation is as follows assuming the design flow rate is Q_{wq}:

$$Q_{wq} = \frac{1.49}{n} AR^{\frac{2}{3}} s^{\frac{1}{2}}$$ (Equation 6-4)

Where:

Q_{wq} = design 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 channel slope (along direction of flow) (ft/ft)

For the purposes of the trial and error process, Manning's Equation can be rearranged as:

$$AR^{\frac{2}{3}} = (Q_{wq})(n)/(b^{\frac{8}{3}})(s^{\frac{1}{2}})$$ (Equation 6-5)

Spreadsheet Procedure

To determine the design flow depth, d, and bottom width, b, by the spreadsheet procedure, trial values of bottom width and flow depth are used to determine A, P, and R for the given channel cross section. Trial values of $AR^{2/3}$ are computed until the equality of Equation 6-5 is satisfied such that the design flow rate, Q_{wq}, is conveyed for the selected cross section and such that flow depth, bottom width, and channel slope are within acceptable ranges. The equations for A and R for a trapezoidal channel are provided here:

$$A = (b + zd)d$$ (Equation 6-6)

$$R = \frac{A}{P}$$ (Equation 6-7)

$$P = b + 2d(1 + z^2)^{0.5}$$ (Equation 6-8)

Graphical Procedure

A graphical procedure can also be used for simplifying trial and error solutions if the spreadsheet procedure is unavailable. The graphical procedure utilizes the trapezoidal channel capacity chart in Figure 6-4.

Step 2.1: Determine input data including design flow rate, Q_{wq}, Manning's n value, channel bottom depth, b, channel slope, s, and channel side slope, Z.

Step 2.2: Calculate the trapezoidal conveyance factor using the equation:

$$K_T = (Q_{wq})(n)/(b^{\frac{8}{3}})(s^{\frac{1}{2}}) \quad \text{(Equation 6-9)}$$

Where:

K_T	=	trapezoidal open channel conveyance factor
Q_{wq}	=	design flow rate (cfs)
n	=	Manning's roughness coefficient (unitless)
b	=	channel bottom width (ft)
s	=	longitudinal channel slope (along direction of flow) (ft/ft)

Step 2.3: Enter the x-axis of Figure 6-4 with the value of K_T calculated from Step 2.2 and draw a line vertically to the curve corresponding to the appropriate Z value from Step 2.1.

Step 2.4: From the point of intersection obtained in Step 2.3, draw a horizontal line to the y-axis and read the value of the normal depth of flow over the bottom width, d/b.

Step 2.5: Multiply the d/b from Step 2.4 by b to obtain normal depth of flow, d. Continue the trial and error process until the desired flow depth is obtained. Maximum flow depth for infrequently mowed vegetated swales shall be 4 inches and maximum flow depth for frequently mowed turf swales shall be 2 inches.

A minimum 2-foot bottom width is required. The maximum allowable bottom width is 10 feet; therefore, if the bottom width exceeds 10 feet, then one of the following steps is necessary to reduce the design bottom width:

a. Increase the longitudinal slope (s) to a maximum of 6 feet in 100 feet (0.06 feet per foot).

b. Increase the design flow depth (d) to a maximum of 4 inches.

c. Place a divider lengthwise along the swale bottom (Figure 6-6) 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.

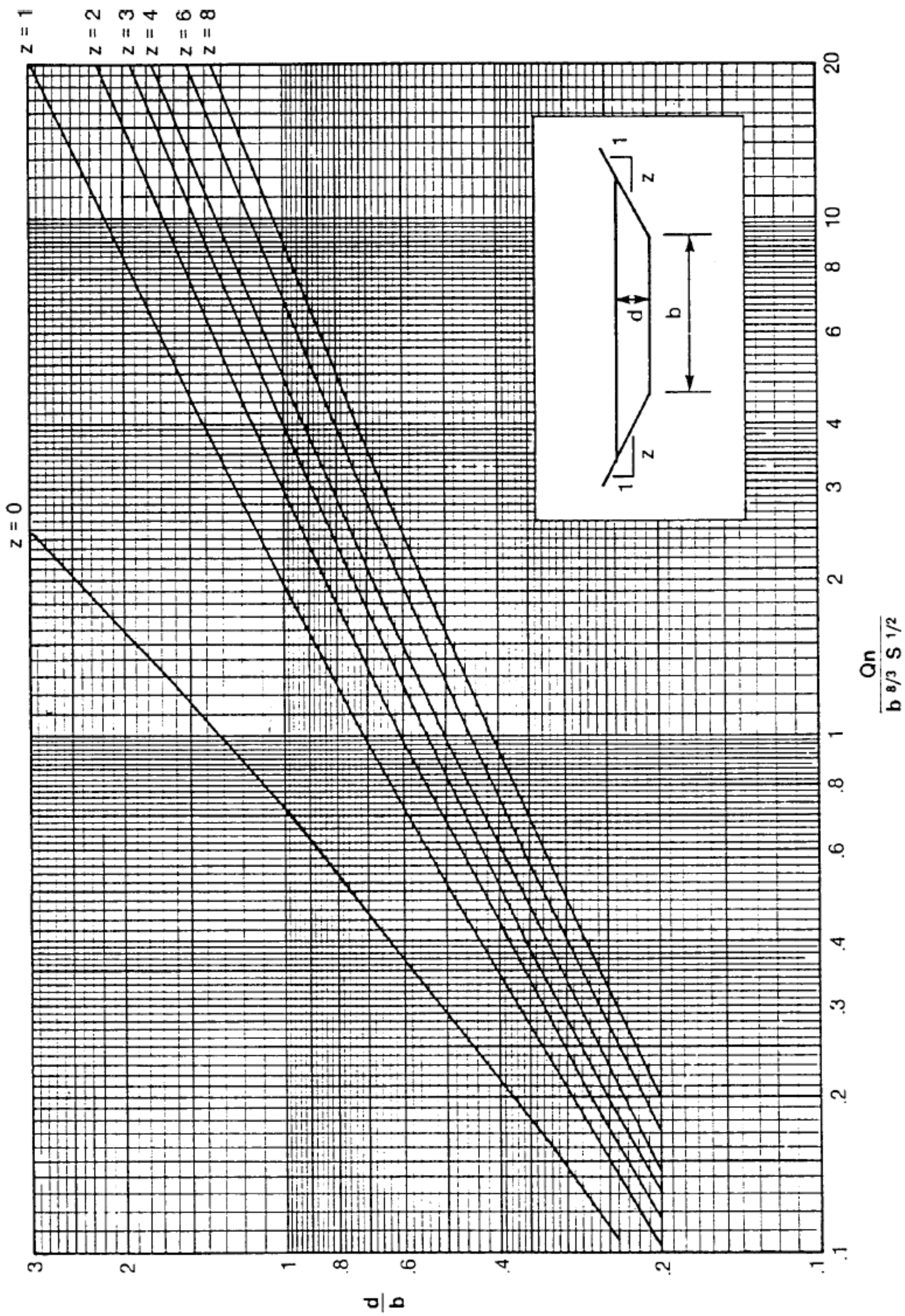


Figure 6-4: Trapezoidal Channel Capacity Chart

Step 3: Determine design flow velocity

To calculate the design flow velocity through the swale, use the flow continuity equation:

$$V_{wq} = Q_{wq} / A_{wq} \qquad \text{(Equation 6-10)}$$

Where:

V_{wq} = design flow velocity (fps)

A_{wq} = $bd + Zd^2$ = 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 10 minutes (600 seconds):

$$L = 600V_{wq} \qquad \text{(Equation 6-11)}$$

Where:

L = swale length (ft)

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 could 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, 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.

Step 5.1: Calculate the swale treatment top area based on the swale length calculated in Step 4:

$$A_{top} = (b_i + b_{slope})L_i \quad \text{(Equation 6-12)}$$

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.

Step 5.2: Use the swale top area and a reduced swale length L_f to increase the bottom width, using the following equation:

$$L_f = A_{top} / (b_f + b_{slope}) \quad \text{(Equation 6-13)}$$

Where:

L_f = reduced swale length (ft)

b_f = increased bottom width (ft)

Step 5.3: 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.

Step 5.4: Recalculate to assure that the 10 minute retention time is retained.

Step 6: Provide conveyance capacity for flows higher than Q_{wq}

Vegetated swales may be designed as flow-through channels (on-line) that convey flows higher than the water quality design flow rate, Q_{wq}, or they may be designed to incorporate a high-flow bypass (off-line) upstream of the swale inlet. A high-flow bypass, using a flow splitter structure, 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. Flow splitter design specifications are described in Appendix F.

Step 6.1: Check the swale size to determine whether the swale can convey the post-development peak storm water discharge rate for the 100-yr 24-hr storm event (See Section 6.2.3 and Appendix C).

Step 6.2: The post-development peak storm water runoff velocity 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 post-development peak storm water runoff 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.

Swale Inflow and Design Capacity

1. Whenever possible, inflow shall be directed towards the upstream end of the swale but shall, at a minimum, occur evenly over the length of the swale.

2. On-line vegetated swales shall be designed to convey flow rates up to the post-development peak storm water runoff discharge rate (flow rate) for the 100-yr 24-hour storm event, with appropriate freeboard (See Santa Barbara County Flood Control and Water Conservation District Standard Conditions of Project Plan Approval). Exceptions to the required freeboard are inlets or safe surface conveyances to carry excess water into a storm water conveyance system that might occur in parking lots, for example.

3. Off-line vegetated swales shall be designed to convey the flow-based water quality design flow rate, Q_{wq}, by using a flow diversion structure (e.g., flow splitter) which diverts the Q_{wq} to the off-line vegetated swale designed to handle Q_{wq}. Freeboard for off-line swales is not required, but shall be provided if space is available. Flow splitter design specifications are described in Appendix F.

Energy Dissipation

1. Vegetated swales may be designed either on-line or off-line. If the facility is on-line, velocities shall 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 water quality design flow rate shall not exceed 1.0 foot per second. *Intent: This maximum water quality design flow velocity 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 shall 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 storm water conveyance system.

5. A flow spreader (see “Flow Spreaders” below) shall 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 shall 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 shall 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 slightly above the elevation of the vegetated areas. Curb cuts shall be at least 12 inches wide to prevent clogging.

Flow Spreaders

1. An anchored plate flow spreader shall be provided at the inlet to the swale. Equivalent methods for spreading flows evenly throughout the width the swale are acceptable.

2. The top surface of the flow spreader plate shall 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 shall extend horizontally beyond the bottom width of the facility to prevent water from eroding the side slope and shall have a row of horizontal perforations at the base of the plate to prevent ponding for long durations. The horizontal extent shall 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 WQ facility (off-line swales).

4. Flow spreader plates shall be securely fixed in place.

5. Flow spreader plates may be made of either concrete, stainless steel, fiberglass reinforced plastic, or other durable material.

6. Anchor posts shall be 4-inch square concrete, tubular stainless steel, or other material resistant to decay.

Check Dams

If check dams are required, they can be designed out of a number of different materials, including riprap, earthen berms, or removal stop logs. Check dams must be placed as to achieve the desired slope (<6%) at a maximum of 50 feet apart. Check dams shall be no higher than 12 inches. If riprap is used, the material shall 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"	100
15"	75
9"	50
4"	10

Underdrains

If underdrains (not to be confused with a dry weather flow drain) are required, then they must meet the following criteria:

1. Underdrains must be made of slotted, polyvinyl chloride (PVC) pipe conforming to ASTM D 3034 or equivalent or corrugated high density polyethylene (HDPE) pipe conforming to AASHTO 252M or equivalent. *Intent: As 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.*

2. Slotted pipe shall 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 shall have a width of 0.04-inch to 0.1-inch and shall have a length of 1-inch to 1.25-inch. Slots shall be spaced such that the pipe has a minimum of one square inch per lineal foot.

3. The pipe must 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 must 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 shall be capped with a lockable screw cap.

4. The underdrain shall be placed parallel to the swale bottom and backfilled and bedded with six inches of drain rock. The following aggregate shall 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

5. The drain rock must be separated from the soil layer above with either a geotextile filter fabric meeting the following minimum materials requirements or with a thin, 2- to 4-inch layer of pure sand and a thin layer (nominally two inches) of choking stone (such as #8).

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

6. The underdrain must infiltrate into the subsurface or drain freely to an acceptable discharge point.

Gravel Drainage Layer

1. To increase volume reduction and if soil conditions allow (infiltration rate > 0.05 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 shall 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 shall have zero slope. The drawdown time in the gravel drainage layer shall not exceed 72 hours. The soil and gravel layers shall 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.

Swale Divider

1. If a swale divider is used, the divider shall 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 shall not be used. Selection of divider material must take into account maintenance activities, such as mowing.

2. The divider must have a minimum height of 1 inch greater than the water quality design water depth.

3. Earthen berms shall be no steeper than 2H:1V.

4. Material other than earth shall be embedded to a depth sufficient to be stable.

Soils

1. Swale soils shall be amended with 2 inches of well-rotted compost, unless the organic content is already greater than 10%. The compost shall 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 shall contain no un-sterilized manure, which can lead to high levels of pathogen indictors (coliform bacteria) in the runoff. See Section 5.10 for more guidance on soil amendments.

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 shall 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 shall 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 spring or summer. Use of a permanent irrigation system may help provide maximal water quality performance. Drought-tolerant grasses shall be specified to minimize irrigation requirements.

5. Vegetative cover shall be at least 4 inches in height, ideally 6 inches. Swale water depth shall ideally be 2 inches below the height of the shortest plant species and shall not exceed 4 inches.

6. Locate the swale in an area without excessive shade to avoid poor vegetative growth. For moderately shaded areas, shade tolerant plants shall be used.

7. Locate the swale away from large trees that may drop excessive leaves or needles. Excessive tree debris may smother the grass or impede the flow through the swale. Landscape planter beds shall be designed and located so that soil does not erode from the beds and enter a nearby swale.

8. See Appendix G for a recommended native plant list for vegetated swale filters, a list of local nurseries where these plants can be purchased, and a list of local and regional on-line resources. The plant list in Appendix G shall be used as a guide only and shall not replace project-specific planting recommendations provided by a landscape professional including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth. See Section 5.11 for more

information on landscaping/planting recommendations and Section 5.10 for more information on soil amendment recommendations.

6.6.2.4 Construction Recommendations

The use of treated wood or galvanized metal anywhere inside the facility is prohibited.

Figure 6-5: Vegetated Swale Filter Schematic

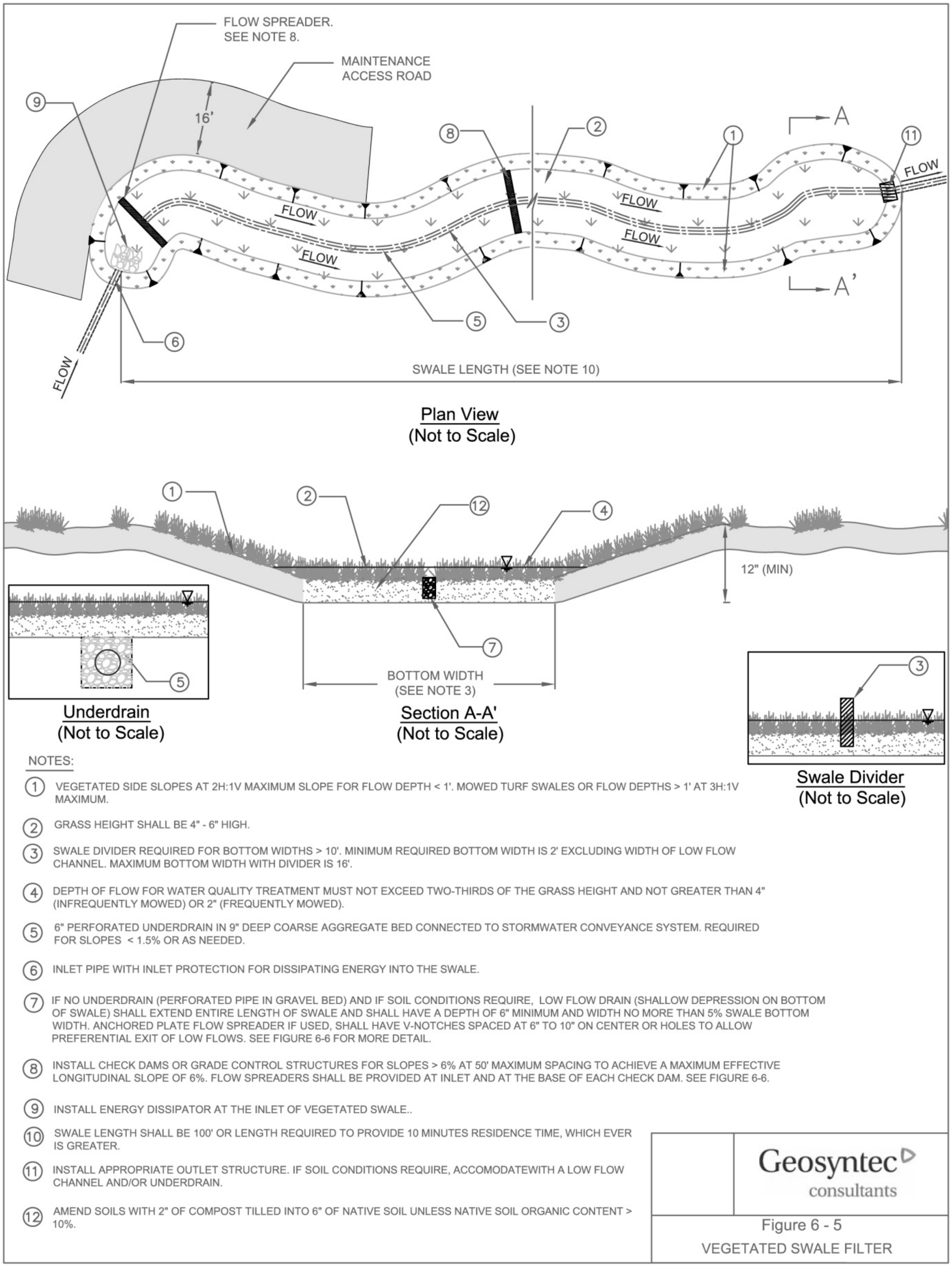
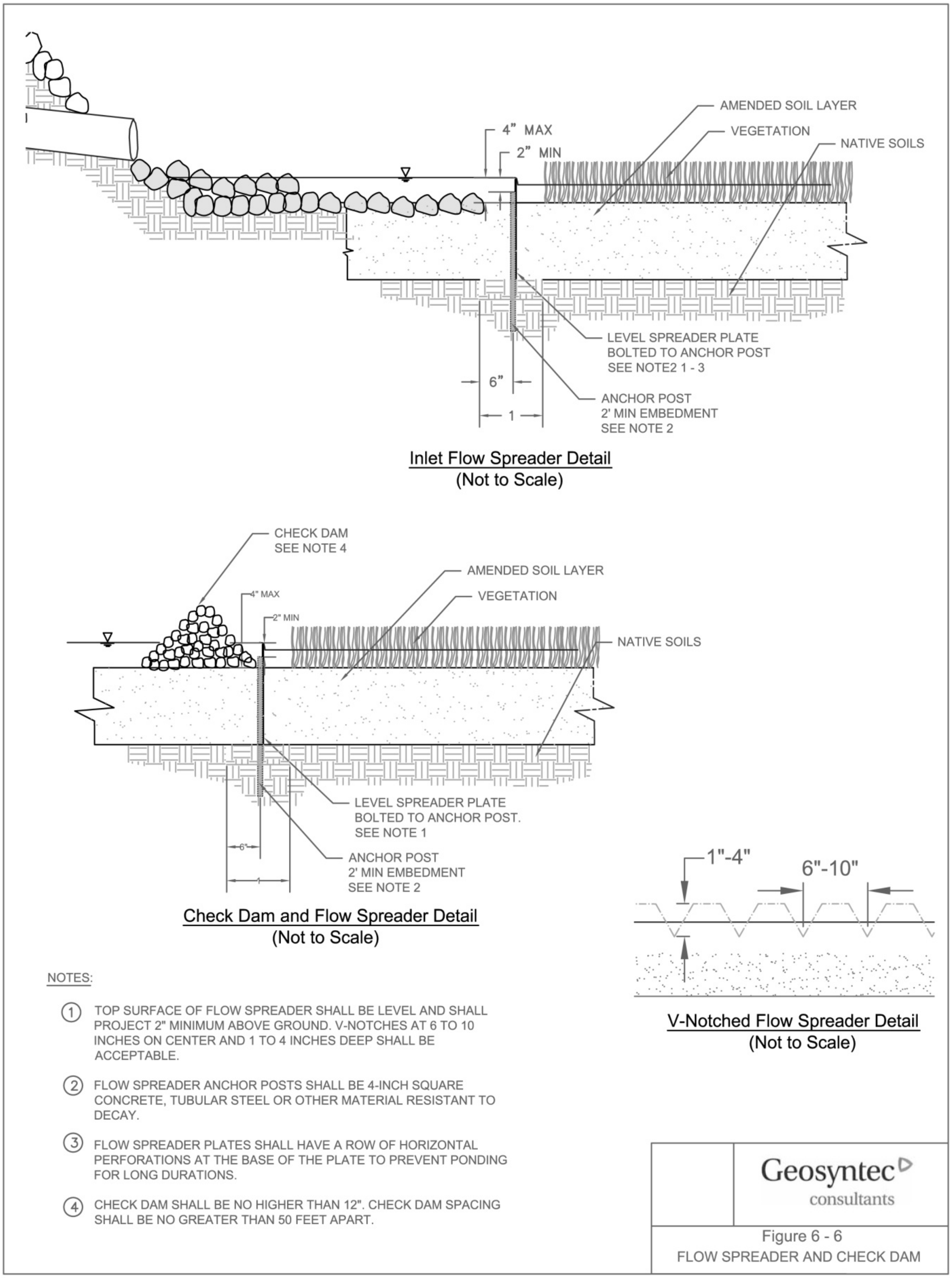


Figure 6-6: Flow Spreader and Check Dam Schematics



Operations and Maintenance

General Requirements

1. Inspect vegetated swales for erosion or damage to vegetation after every storm greater than 0.75" 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 shall be checked for debris and litter and areas of sediment accumulation (see Appendix H for a vegetated swale inspection and maintenance checklist).

2. Swale inlets (curb cuts or pipes) shall 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 shall provide even dispersion of flows across the swale. Sediments and debris shall be removed from the flow spreader if blocking flows. Splash pads shall be repaired if needed to prevent erosion. Spreader level shall be checked and re-leveled if necessary. See Figure 6-6 for a schematic and design specifications for flow spreaders.

4. Side slopes shall be maintained to prevent erosion that introduces sediment into the swale. Slopes shall be stabilized and planted using appropriate erosion control measures when native soil is exposed or erosion channels are forming.

5. Swales shall drain within 48 hours of the end of a storm. If a gravel drainage layer is incorporated underneath the swale to promote infiltration, this layer shall drain within 72 hours of the end of the storm. Till the swale if compaction or clogging occurs. The perforated underdrain pipe, if present, shall be cleaned if necessary.

6. Vegetation shall be healthy and dense enough to provide filtering while protecting underlying soils from erosion:
   - Mulch shall be replenished as needed to ensure survival of vegetation.
   - Vegetation, large shrubs or trees that interfere with landscape swale operation shall be pruned.
   - Fallen leaves and debris from deciduous plant foliage shall be removed.
   - Grassy swales shall be mowed to keep grass 4” to 6” in height. Grass clippings shall 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*) must be removed and replaced with non-invasive species. Invasive species shall never contribute more than 25% of the vegetated area.

- Dead vegetation shall be removed if greater than 10% of area coverage or when swale function is impaired. Vegetation shall be replaced and established before the wet season to maintain cover density and control erosion where soils are exposed.

7. Check dams (if present) shall control and distribute flow across the swale. Causes for altered water flow and/or channelization shall be identified and obstructions cleared. Check dams and swale shall be repaired if damaged.

8. The vegetated swale shall be well maintained; trash and debris, sediment, visual contamination (e.g., oils), noxious or nuisance weeds, shall all be removed.

Maintenance Standards

A summary of the routine and major maintenance activities recommended for vegetated swale filters is shown in Table 6-14. Detailed routine and major maintenance standards are listed in Table 6-15 and Table 6-16.

Table 6-14: Vegetated Swale Filter Maintenance Quick Guide

Inspection and Maintenance Activities Summary	
Routine Maintenance	• Remove excess sediment as needed • Trash and debris removal • Cleaning of underdrain (where applicable) and/or unclogging outlet to eliminate standing water • Clean and reset flow spreaders as needed to restore original function • Restore sunlight access to shaded regions. Remove overhanging tree branches as needed to prevent excessive shading. • Remove any evidence of visual contamination from floatables such as oil and grease • Mow routinely to maintain ideal grass height and to suppress weeds • Replace non-native vegetation with native species • Remove sediment and debris accumulation near inlet and outlet structures • Stabilize/repair minor erosion and scouring with gravel • Photographs taken before and after maintenance is encouraged
Major Maintenance	• Re-grade swale bottom and reseed to mitigate ponding of water between storms or excessive erosion and scouring • Install or replace low flow channel using pea gravel media to better convey nuisance flows • Re-vegetate bare exposed portions of the swale to restore vegetation to original level of coverage • De-thatch grass to remove accumulated sediment and aerate compacted areas to promote infiltration

Table 6-15: Routine Maintenance Standards - Vegetated Swale Filters

Defect or Problem	Condition When Maintenance is Needed	Results Expected and Maintenance to be Performed	Frequency
Sediment Accumulation	Sediment depth exceeds 2 inches or covers vegetation.	Sediment deposits shall be removed without significant disturbance of the vegetation. When finished, swale shall be level from side to side and drain freely toward outlet. There shall be no areas of standing water once inflow has ceased.	Annually prior to wet season After major storm events (>0.75 in/24 hrs) if spot checks of some basins indicate widespread damage/ maintenance needs
Trash and Debris Accumulation	Any trash and debris which exceed 5 cubic feet per 1,000 square feet (one standard garbage can).	Trash and debris removed from swale.	
Standing Water	When water stands in the swale between storms and does not drain freely.	There shall be no areas of standing water once inflow has ceased. Outlet structures and underdrain (if installed) shall drain freely.	
Flow Spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire swale width.	Spreader leveled and cleaned such that flows are distributed evenly over entire swale width.	
Excessive Shading	Vegetation growth is poor because sunlight does not reach swale.	Over-hanging limbs and brushy vegetation on side slopes are trimmed back.	
Erosion/ Scouring	Eroded or scoured swale bottom due to flow channelization or higher flows.	No erosion or scouring in swale bottom. For ruts or bare areas less than 12 inches wide, damaged areas repaired by filling with crushed gravel. Over time, the grass will have started to cover the rock.	
Visual contaminants and pollution	Any visual evidence of oil, gasoline, contaminants or other pollutants.	No visual contaminants or pollutants present.	

Defect or Problem	Condition When Maintenance is Needed	Results Expected and Maintenance to be Performed	Frequency
Vegetation length	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.	Vegetation trimmed or mowed and nuisance vegetation removed so that flow is not impeded. Vegetation/grass shall be trimmed/mowed to a height of 4 to 6 inches (depending on landscape requirements). Grass clippings removed.	Monthly (or as dictated by agreement between County and landscape contractor
Inlet/Outlet blockage	Inlet/outlet areas clogged with sediment and/or debris.	Material removed so that there is no clogging or blockage in the inlet and outlet area.	
Low flow channel overflow	Nuisance flows are ponding, swale is continually wet.	Low flow channel media is renewed to adequately convey nuisance flows.	

Table 6-16: Major Maintenance Standards - Vegetated Swale Filters

Defect or Problem	Condition When Maintenance is Needed	Results Expected and Maintenance to be Performed	Frequency
Standing Water	When water stands in the swale between storms and does not drain freely.	There shall be no areas of standing water once inflow has ceased. Any of the following may apply: improve grade from head to foot of swale, remove clogged check dams, add underdrains, or convert to a wet biofiltration swale.	Annual – preferably at end of wet season or as needed (infrequent)
Erosion/ Scouring	Eroded or scoured swale bottom due to flow channelization, or higher flows.	No erosion or scouring in swale bottom. If bare areas greater than 12 inches wide exist, re-grade, and re-seed.	After major storm events (>0.75 in/24 hrs) if spot checks of some basins indicate widespread damage/ maintenance needs
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.	No eroded or muddy channel on the bottom. A low-flow pea-gravel drain may be added to the length of the swale, or an underdrain installed.	

Defect or Problem	Condition When Maintenance is Needed	Results Expected and Maintenance to be Performed	Frequency
Poor Vegetation Coverage	When grass is sparse or bare or eroded patches occur in more than 10% of the swale bottom.	Vegetation coverage in more than 90% of the swale bottom. Poorly vegetated areas of the swale bottom shall be re-planted with plugs of grass from the upper slope and reseeded in locations where plugs were taken. Plugs shall be planted in the swale bottom with no gaps, or re-seeded into loosened, fertile soil.	Semi annual – at beginning and end of wet season

6.6.3 Vegetated Filter Strip

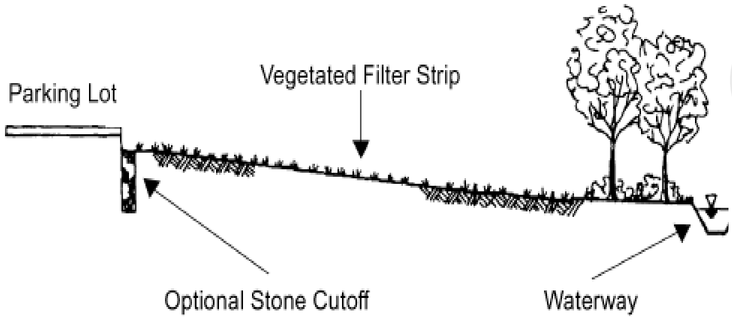


Figure 6-7: Vegetated Filter Strip Providing Pretreatment for a Bioretention Area

Photo Credit: New Jersey Storm Water BMP Manual

Applications

- Roads and highway shoulders
- Small parking lots
- Residential, commercial, or institutional landscaping

Advantages

- Good pre-treatment BMP
- Simple, aesthetically pleasing landscaping
- Low cost/maintenance

Limitations

- Must be sited adjacent to imperviousness surfaces
- May not be suitable for industrial sites
- Requires sheet flow across vegetated area

6.6.3.1 Description

Vegetated filter strips (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 rely on dense turf vegetation with a thick thatch, growing on a moderately permeable soil and are well suited to treat runoff from roads and highways, driveways, roof downspouts, small parking lots, and other impervious surfaces. They are also good for use as vegetated buffers between developed areas and natural drainages. These BMPs filter storm water immediately adjacent to impervious surfaces and are typically intended for pre-treatment and not as a standalone BMP. Filter strips decrease runoff velocity, filter out sediment and associated pollutants, and provide some infiltration into underlying soils. Filter strips are more effective when the runoff passes through the vegetation and thatch layer in the form of shallow, uniform "sheet flow".

6.6.3.2 Applicability, Performance, and Limitations

Table 6-17, Table 6-18, and Table 6-19 provide a summary of BMP performance, applicability, and limitations for Vegetated filter strips (filter strips). *It is important to note that information in these tables shall be used to provide general guidance for Vegetated filter strips and shall not replace the evaluation performed by a water quality professional.*

Applicability and Performance

Table 6-17 and associated guidance provide general volume reduction capabilities and treatment effectiveness for filter strips. Refer to Section 6.4 for the process that shall be used for selecting BMPs based on pollutants of concern. Refer to Table 6-1 to determine the ranking of filter strips for removal of pollutants of concern as compared with other storm water runoff BMPs provided in Chapter 6. Refer to Table 6-2 to assess the applicability of filter strips for your site based on site suitability considerations as compared with other storm water runoff BMPs provided in Chapter 6. Filter strips are flow-based BMPs intended for achieving water quality treatment and, depending on site slope and soil conditions, can provide some volume reduction (See Table 6-18). Filter strips are not intended to be a primary BMP for meeting the volume reduction, $V_{reduction}$, or peak runoff discharge requirements; although, they do assist in increasing a site's time of concentration, T_c, and reducing storm water runoff volumes and runoff discharge rates. See Section 6.2 for specific storm water runoff requirements for Tier 3 projects.

Table 6-17: Volume Reduction & Treatment Effectiveness for Vegetated Filter Strips

Storm Water Runoff BMP	Volume Mitigation (% of inflow)	Treatment Effectiveness for Pollutants of Concern[1]					
		Trash	Nutrients	Bacteria	Metals (particulate and dissolved fractions)	Sediment	Organics (hydro-carbons, oil, and grease)
Vegetated Filter Strip	Moderate	High	Low	Very Low	Moderate	Moderate	Moderate

Volume/Treatment Effectiveness: ● = Very High, ◓ = High, ⦿ = Moderate, ◒ = Low, ○ = Very Low

[1] Effectiveness may change based on design variations; standard BMP designs have been assumed.

Since runoff passes through filter strip vegetation in shallow, uniform flow, some volume reduction occurs although filter strips are not designed specifically for volume reduction. While some assimilation of dissolved constituents may occur, filter strips are generally more effective in trapping sediment and particulate-bound metals, nutrients, and pesticides. Nutrients that bind to sediment include phosphorus and ammonium; soluble nutrients include nitrate. Biological and chemical processes may help break down pesticides, uptake metals, and utilize nutrients that are trapped in the filter.

Site Suitability Recommendations and Limitations

Table 6-18 and associated guidance provide general considerations for assessing a site's suitability for filter strips.

Table 6-18: Site Suitability Considerations for Vegetated Filter Strips

BMP	Tributary Area (Acres; Sq.Ft.)[1]	Site Slope (%)	Depth to Seasonally High Groundwater Table (ft)	Hydrologic Soil Group	Horizontal Setback from Drinking Water Wells (ft)
Vegetated Filter Strip	< 2 Acres; 87,120 Sq.Ft.	< 5 site slope; 2 to 6 longitudinal slope of strip[2]	> 2	Any	N/A

[1] Tributary area is the area of the site draining to the BMP. Tributary areas provided here shall be used as a general guideline only. Tributary areas can be larger or smaller in some instances.

[2] If site slope exceeds that specified or if the system is within 200 ft from the top of a hazardous slope or landslide area, a geotechnical investigation is required.

Table 6-19 provides additional site suitability considerations for special design districts within the City including coastal bluff areas and hillside design districts.

Table 6-19: Applicability of Vegetated Filter Strips for Special Design Districts

Coastal Bluff Area	Hillside Design District
Acceptable if: (1) facility is not designed to promote infiltration, (2) underdrains and an impermeable liner are provided regardless of hydrologic soil group (HSG) type, and (3) site slope meets the criteria in Table 6-18.	Acceptable if: (1) a geotechnical investigation proves that the facility does not compromise the stability of the site slope or surrounding slopes, or (2) the facility includes an impermeable liner, underdrain system, and an oveflow to a storm water conveyance system, if the facility is on-line.

The following describes additional site suitability recommendations and limitations for Vegetated filter strip.

- Limit the tributary area and associated longitudinal slope (parallel to the flow) to less than 2 acres and less than 5%, respectively, reducing the potential for high flow velocity and concentrated, erosive flows from entering the filter strip.
- Maximum length (in the direction of flow towards the filter strip) of the tributary area shall be 150 feet.
- The lateral slope of the contributing area (parallel to the edge of the pavement) shall be 4% or less.
- The longitudinal slope over the length of the filter strip can be up to 6% before concentrated, erosive flows become potentially problematic.
- Mild longitudinal slope (< 2%) over the length of the filter strip can cause ponding.
- The use of filter strips is limited to areas where the vegetative cover is robust and diffuse, and where shallow flow characteristics are possible.
- Sheet flow - shallow, evenly-distributed flow across entire width of strip is required. Level slopes perpendicular to the direction of flow are required to achieve sheet flow.
- A uniformly graded thick vegetative cover is required to function properly.
- Availability of pervious area adjacent to impervious area – filter strips require sheet flow from impervious areas. Impractical in highly urban areas with little pervious ground.
- The filter strip shall be located away from building or excessive tree shadows to avoid poor plant growth.

- Groundwater levels shall be at least 2 ft lower than the strip surface to ensure that the filter strip does not remain wet between storms.
- May not be applicable adjacent to industrial sites or locations where spills may occur.
- Cannot be applied in areas with highly erodible soils.
- Avoid areas that are highly trafficked, both by automobiles and people.

Multi-Use and Treatment Train Opportunities

Filter strips are often used as pre-treatment devices for other larger capacity BMPs such as bioretention areas and assist by filtering sediment and associated pollutants prior to entering the larger capacity BMP preventing clogging and reducing the maintenance requirements for larger capacity BMPs. Filter strips provide an attractive and inexpensive vegetative storm water runoff BMP that can be easily incorporated into the landscape design of a site. Filter strips are commonly used in the landscape designs of residential, commercial, industrial, institutional, and roadway applications. They shall be located adjacent to the impervious areas that they are intended to treat.

6.6.3.3 Design Criteria and Procedure

The main challenge associated with filter strips is maintaining sheet flow, which is critical to performance of this BMP. If flows are concentrated, then little or no treatment of storm water 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. Principal design criteria for filter strips are listed in Table 6-20. A filter strip is illustrated schematically in Figure 6-8. A flow spreader device is illustrated schematically in Figure 6-6.

Table 6-20: Vegetated Filter Strip Design Criteria

Design Parameter	Unit	Design Criteria
Water quality design flow rate, Q_{wq}	cfs	Runoff produced from a 0.25 in/hr design rainfall intensity of at least four hour duration. See Section 6.2 and Appendix C for calculating the water quality design flow rate, Q_{wq}.
Minimum design flow depth	inches	1
Design residence time	minutes	10
Design flow velocity	ft/sec	< 1 ft/sec
Minimum width (perpendicular to flow direction)	feet	Equal to width of tributary area
Minimum length in flow direction	feet	15 (25 preferred); if sized for pretreatment only, filter strip can be a minimum of 4.
Maximum length in flow direction	feet	150
Maximum slope in flow direction	%	6

Design Parameter	Unit	Design Criteria
Minimum slope in flow direction	%	2
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

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 shall be located contiguous to the developed area.

2. If the filter strip is used to meet the water quality treatment requirements, the length (in direction of flow) shall 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 6%; 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) shall be 4% or less.

5. Grading shall 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 shall 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 shall be as flat as possible to encourage sheet flow and prevent channeling and erosion. For engineered filter strips, the facility surface shall be graded flat prior to placement of vegetation.

Sizing Methodology

The flow capacity of a 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 provided in Appendix D.

Step 1: Calculate the design flow rate

The design flow is calculated based on the water quality design flow rate, Q_{wq}, as described in Section 6.2 and Appendix C.

Step 2: Calculate the design flow depth

The design flow depth (d) is calculated based on the width and the slope (parallel to the flow path) using a modified Manning's equation as follows:

$$d = [Q_{wq} n_{wq} / 1.49 w s^{0.5}]^{0.6}$$ (Equation 6-14)

Where:

- d = design flow depth (ft)
- Q_{wq} = water quality design flow rate (cfs)
- w = width of strip perpendicular to flow which equals the width of impervious surface contributing to the filter strip (ft)
- s = slope (ft/ft) of strip parallel to flow, average over the whole width
- n_{wq} = Manning's roughness coefficient (0.25-0.3)

If d is greater than 1 inch, then a smaller slope is required, or a filter strip cannot be used.

Step 3: Calculate the design velocity

The design flow velocity is based on the design flow, design flow depth, and width of the strip:

$$v_{wq} = Q_{wq} / dw$$ (Equation 6-15)

Where:

- v_{wq} = water quality design flow velocity (ft/sec)
- Q_{wq} = water quality design flow rate (cfs)
- d = design flow depth (ft)
- w = width of strip perpendicular to flow which equals the width of impervious surface contributing to the filter strip (ft)

Step 4: Calculate the desired length of the filter strip

Determine the required length (L) to achieve a desired residence time of 10 minutes using:

$$L = 600 v_{wq}$$ (Equation 6-16)

Where:

- L = swale length (ft)
- v_{wq} = design water quality flow velocity (ft/sec)

If the filter strip is being sized to meet the water quality treatment requirement, the filter strip length shall be between 15 and 150 feet (with a minimum of 25 preferred). If the filter strip is designed for pretreatment, the minimum length shall be 4 feet. Therefore, if the length is calculated to be outside of this desired range and other design parameters cannot be altered to achieve the desired length, alternative BMPs, such as a vegetated swale filters, may be considered more appropriate.

Energy Dissipation / Level Spreading

Runoff entering a filter strip must not be concentrated. A flow spreader shall 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) shall be placed between the impervious area contributing flows and the filter strip, and meet the following requirements:
    a. The gravel flow spreader shall be a minimum of 6 inches deep and shall be 12 inches wide.
    b. The gravel shall be a minimum of 1 inch below the pavement surface. Intent: This allows sediment from the paved surface to be accommodated without blocking drainage onto the strip.
    c. 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.
    d. Along roadways, gravel flow spreaders must be placed and designed in accordance with County road design specifications for compacted road shoulders.

2. A notched curb spreader and through-curb port spreader 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. Openings in the curb shall be at regular intervals but at least every 6 feet. The width of each curb port opening shall be a minimum of 11 inches. Approximately 15 percent or more of the curb section length shall be in open ports, and no port shall discharge more than about 10 percent of the flow.
    b. Interrupted curbs are sections of curb placed to have gaps spaced at regular intervals along the total width of the treatment area. At a minimum, gaps shall be every 6 feet to allow distribution of flows into the treatment facility before they become too concentrated. The opening shall be a minimum of 11 inches. As a general rule, no opening shall discharge more than 10 percent of the overall flow entering the facility.

3. Energy dissipaters are needed in a filter strips 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.

Access

1. Access shall 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.

Water Depth and Velocity

1. The design water depth shall not exceed 1 inch.

2. Runoff flow velocities shall not exceed approximately 1 foot per second across the filter strip surface.

Soils

1. Filter strip soils shall be amended with 2 inches of well-rotted compost, unless the organic content is already greater than 10%. The compost shall 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 shall contain no un-sterilized manure which can lead to high levels of potentially pathogenic bacteria in the runoff. See Section 5.10 for more guidance on soil amendments.

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 shall be followed for filter strips:

1. Sod (turf) can be used instead of grass seed, as long as there is complete coverage.

2. Irrigation shall be provided to establish the grasses.

3. Grasses or turf shall be maintained at a height of 2 to 4 inches. Regular mowing is often required to maintain the turf grass cover.

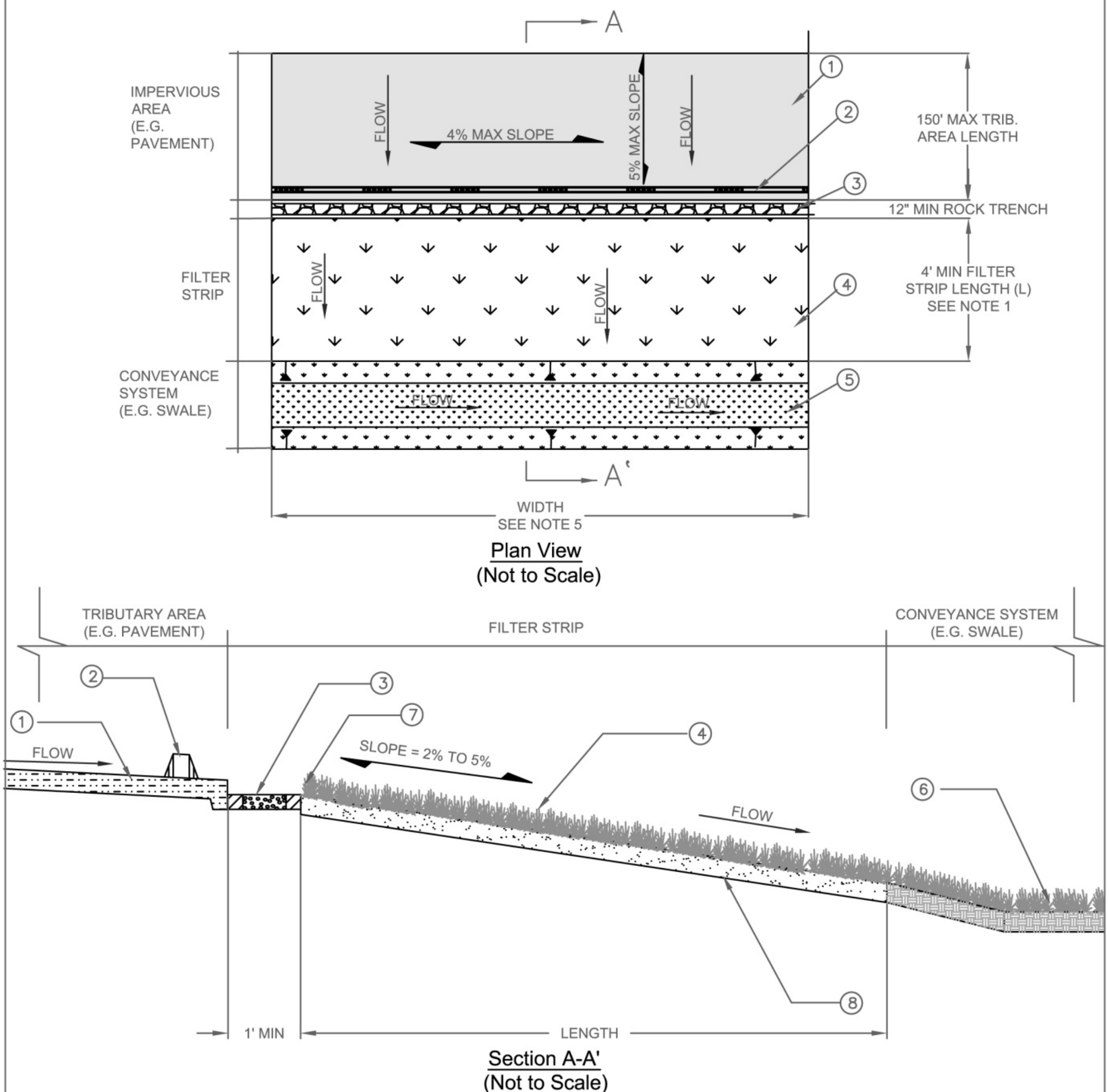
4. Trees or shrubs shall not be used in abundance because they shade the turf and impede sheet flow.

5. See Appendix G for a recommended native plant list for Vegetated filter strips, a list of local nurseries where these plants can be purchased, and a list of local and regional on-line resources. The plant list in Appendix G shall be used as a guide only and shall not replace project-specific planting recommendations provided by a landscape professional including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth. See Section 5.11 for more information on landscaping/planting recommendations and Section 5.10 for more information on soil amendment recommendations.

6.6.3.4 Construction Considerations

The use of treated wood or galvanized metal anywhere inside the facility is prohibited.

Figure 6-8: Vegetated Filter Strip Schematic



NOTES:

1. MAXIMUM LENGTH OF IMPERVIOUS TRIBUTARY AREA SHALL BE 150'.
2. OPTIONAL SLOTTED WHEEL STOPS OR CURB CUTS MAY BE USED.
3. GRAVEL TRENCH 6" DEEP BY 12" WIDE MIN SHALL BE PROVIDED.
4. VEGETATED FILTER STRIP SURFACE. SLOPE SHALL BE BETWEEN 2% TO 6%. WIDTH MUST BE EQUAL OR GREATER THAN THE WIDTH OF THE TRIBUTARY AREA.
5. CONVEYANCE SYSTEM WIDTH MUST BE EQUAL OR GREATER THAN THE WIDTH OF THE TRIBUTARY AREA.
6. INSTALL SWALE, OTHER STORMWATER RUNOFF BMP, OR STORMWATER CONVEYANCE SYSTEM DOWNSTREAM OF FILTER STRIP.
7. TOP OF FILTER STRIP SHALL BE 2" - 5" BELOW TOP OF ADJACENT PAVEMENT.
8. AMEND SOILS WITH 2" OF COMPOST TILLED INTO 6" OF NATIVE SOIL UNLESS NATIVE SOIL ORGANIC CONTENT > 10%.

Geosyntec consultants

Figure 6 - 8
VEGETATED STRIP FILTER

6.6.3.5 Operations and Maintenance

General Requirements

Vegetated filter strips (filter strips) mainly require vegetation management; therefore little special training is needed for maintenance crews. Typical maintenance activities and frequencies include:

1. Inspect filter 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 filter strip is ready for winter. However, additional inspection after periods of heavy runoff is most desirable. The strip shall be checked for debris and litter and areas of sediment accumulation (see Appendix H for vegetated filter strip inspection and maintenance checklist).

2. Mow as frequently as necessary (at least twice a year) for safety and aesthetics or to suppress weeds and woody vegetation.

3. Trash tends to accumulate in strip areas, particularly along roadways. The need for litter removal shall be determined through periodic inspection. Litter shall always be removed prior to mowing.

4. Regularly inspect vegetated buffer strips for pools of standing water. 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.

5. Activities that lead to ruts or depressions on the surface of the filter strip shall be prevented or the integrity of the strip shall be restored by leveling and reseeding. Examples are vehicle tracks, utility maintenance, and pedestrian (short-cut) tracks.

Maintenance Standards

A summary of the routine and major maintenance activities recommended for Vegetated filter strips is shown in Table 6-21. Detailed routine and major maintenance standards are listed in Table 6-22 and Table 6-23.

Table 6-21: Vegetated Filter Strip Maintenance Quick Guide

Inspection and Maintenance Activities Summary	
Routine Maintenance	• Remove excess sediment as needed • Stabilize/repair minor erosion and scouring with crushed gravel • Remove trash and debris • Remove any evidence of visual contamination from floatables such as oil and grease • Mow routinely to maintain ideal grass height and to suppress weeds • Irrigate as necessary to maintain healthy grass cover • Remove non-native vegetation and re-vegetate with native species • Photographs taken before and after maintenance is encouraged
Major Maintenance	• Regrade and revegetate to repair damage from severe erosion/scour channelization and to restore sheet flow • Clean and reset flow spreaders as needed to restore original function

Table 6-22: Routine Maintenance – Vegetated Filter Strips

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Sediment Accumulation	Sediment depth exceeds 2 inches or covers vegetation.	Sediment deposits removed and surface re-leveled in order to maintain sheet flow over the filter strip.	Semi-annually, prior to wet season and after the wet season After major storm events (>0.75 in/24 hrs) if spot checks indicate widespread damage/ maintenance needs
Erosion/Scouring	Eroded or scoured areas due to flow channelization, or higher flows.	No erosion or scouring evident. For ruts or bare areas less than 12 inches wide, damaged areas repaired by filling with crushed gravel. The grass will creep in over the rock in time.	
Flow spreader clogged/uneven	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire filter width.	Spreader leveled and cleaned so that flows are spread evenly over entire filter width.	
Visual contaminants and pollution	Any visual evidence of oil, gasoline, contaminants or other pollutants.	No visual contaminants or pollutants present.	
Aesthetics	Minor vegetation removal and thinning. Mowing berms and surroundings	Facility is well kept.	Semi-annually (or as dictated by agreement between County and landscape contractor) Litter removal and mowing frequency is dependent on site conditions and desired aesthetics and shall be done at a frequency to meet those objectives
Vegetation length, nuisance weeds	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.	Grass mowed, nuisance vegetation controlled, such that flow is not impeded. Grass mowed to a height between 2-4 inches and clippings removed.	
Trash and Debris Accumulation	Trash and debris accumulated on the filter strip.	Trash and debris removed from filter strip and flow spreading devices.	
Noxious Weeds	Any evidence of noxious weeds.	All noxious weeds eradicated and future establishment controlled with use of Integrated Pest Management (IPM) techniques, if applicable. See http://www.ipm.ucdavis.edu for more information.	

Table 6-23: Major Maintenance – Vegetated Filter Strip

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Erosion/Scouring	Bare spots greater than 12 inches	No erosion visible. Large, bare areas greater than 12 inches wide re-graded and re-seeded.	As needed

6.6.4 Sand Filter

Figure 6-9: Volleyball Court Sand Filter

Applications

- Roads, highways, parking lots
- Commercial and industrial
- Roof runoff
- Golf courses and open spaces

Advantages

- Efficient removal of pollutants
- Good retrofit capability
- Good for highly impervious areas

Limitations

- High maintenance burden
- Not recommended for runoff with high sediment content
- Usually little volume reduction
- Relatively costly

6.6.4.1 Description

A sand filter operates much like a bioretention area; however, instead of filtering storm water through planting soils, storm water is filtered through a constructed sand bed with an underdrain system. Runoff enters the filter and spreads over the surface. As flows increase, water backs up on the surface of the filter where it is held until it can percolate through the sand. The treatment pathway is vertical (downward through the sand). High flows in excess of the design volume simply spill out over the top of the pool or over a designed spillway. Water that has percolated through the sand is collected via a perforated underdrain system before being conveyed to the downstream storm drainage system. As storm water passes through the sand, pollutants are trapped in the small pore spaces between sand grains or are adsorbed to the sand surface. Over time, bacteria can grow in the sand bed and provide some biological treatment. However, continuous dry weather flows would be required to maintain the moisture required by the bacteria.

Because they have few site constraints besides head requirements, sand filters can be used on development sites where the use of other structural controls may be precluded. However, sand filter systems can be relatively expensive to construct and install.

There are three general sand filter designs:

1. **Surface Sand Filter** – the surface sand filter is a ground-level open air structure that consists of pretreatment (e.g., vegetated BMP, proprietary device, or sediment forebay) and a filter bed chamber with perforated drain pipe under the filter bed that diverts filtered flows to another BMP type, storm water conveyance system, or is daylighted and dispersed over a pervious area. This system can treat drainage areas up to 10 acres in

size and is typically located off-line. Surface sand filters can be designed as an excavation with earth embankments or as a concrete or block structure.

2. **Perimeter Sand Filter** – The perimeter sand filter is an enclosed filter system typically constructed just below grade in a vault along the edge of an impervious area such as a parking lot. The system consists of a sedimentation (pretreatment) chamber and a sand bed filter. Runoff flows into the structure through a series of inlet grates located along the top of the control. Perforated drain pipes under the sand filter bed divert flows to another BMP type, storm water conveyance system, or are daylighted and dispersed over a pervious area.

3. **Underground Sand Filter** – The underground sand filter is primarily for extremely space limited and high density areas and consists of a three-chamber system. The initial chamber is a sedimentation (pretreatment) chamber that temporarily stores runoff and utilizes a wet pool to capture sediment. The sedimentation chamber is connected to the sand filter chamber by a submerged wall that protects the filter bed from oil and trash. Perforated drain pipes under the sand filter bed extend into the third chamber that collects filtered runoff. Flows beyond the filter capacity are diverted through an overflow weir, which carries flow to another BMP type, the storm water conveyance system, or is daylighted and dispersed over a pervious area.

6.6.4.2 Performance, Applicability, and Limitations

Table 6-24, Table 6-25, and Table 6-26 provide a summary of BMP performance, applicability, and limitations for sand filters. *It is important to note that information in these tables shall be used to provide general guidance for sand filters and shall not replace the evaluation performed by a water quality professional.*

Applicability and Performance

Table 6-24 and associated guidance provide general volume reduction capabilities and treatment effectiveness for sand filters. Refer to Section 6.4 for the process that shall be used for selecting BMPs based on pollutants of concern. Refer to Table 6-1 to determine the ranking of sand filters for removal of pollutants of concern as compared with other storm water runoff BMPs provided in Chapter 6. Refer to Table 6-2 to assess the applicability of sand filters for your site based on site suitability considerations as compared with other storm water runoff BMPs provided in Chapter 6. Sand filters are volume-based BMPs intended, primarily, for treating the water quality design volume, V_{wq} (See Table 6-24). In most cases, sand filters are enclosed concrete or block structures with underdrains; therefore, only minimal volume reduction occurs via evaporation as storm water percolates through the filter to the underdrain. Hybrid sand filters combined with dry extended detention basins (as described in Section 6.10.3), can be designed with or without underdrains and utilize the sand filter as a filtration and storage layer allowing storm water to be detained and filtered (if underdrains are included) or, if site conditions allow, infiltrated into the subsoil (if underdrains are omitted). In this hybrid case, volume reduction can be achieved. With the exception of sand filters that allow for significant infiltration, sand filters are generally <u>not</u> intended to be used to meet the peak runoff discharge requirement. See Section 6.2 for specific storm water runoff requirements for Tier 3 projects.

Table 6-24: Volume Reduction & Treatment Effectiveness for Sand Filters

Storm Water Runoff BMP	Volume Mitigation (% of inflow)	Treatment Effectiveness for Pollutants of Concern[1]					
		Trash	Nutrients	Bacteria	Metals (particulate and dissolved fractions)	Sediment	Organics (hydro-carbons, oil, and grease)
Sand Filter	⦿	○	●	●	◓	◓	◓
Volume/Treatment Effectiveness: ● = Very High, ◓ = High, ⦿ = Moderate, ◒ = Low, ○ = Very Low							

[1] Effectiveness may change based on design variations; standard BMP designs have been assumed.

Pollutants including metals, phosphorus, and pesticides are generally trapped in the small pore spaces between sand grains or are adsorbed to the sand surface within the filter.

Site Suitability Recommendations and Limitations

Table 6-25 and associated guidance provide general considerations for assessing a site's suitability for sand filters.

Table 6-25: Site Suitability Considerations for Sand Filters

BMP	Tributary Area (Acres)[1]	Site Slope (%)	Depth to Seasonally High Groundwater Table (ft)	Hydrologic Soil Group	Horizontal Setback from Drinking Water Wells (ft)
Sand Filter	< 10	< 15 [2]	> 2 with underdrains; > 5 without underdrains	Any	100 [3]

[1] Tributary area is the area of the site draining to the BMP. Tributary areas provided here shall be used as a general guideline only. Tributary areas can be larger or smaller in some instances.

[2] If system is fully contained and includes a liner, underdrain system, and overflow to a storm drain system, then slopes can exceed 15%.

[3] Setbacks apply to systems without underdrains or systems underlain by "A" or B" hydrologic soil groups.

Table 6-26 provides additional site applicability considerations for special design districts within the City including coastal bluff areas and hillside design districts.

Table 6-26: Applicability of Sand Filters for Special Design Districts

Coastal Bluff Area	Hillside Design District
Acceptable if: (1) facility is not designed to promote infiltration, (2) underdrains and an impermeable liner are provided regardless of hydrologic soil group (HSG) type, and (3) site slope meets the criteria in Table 6-25.	Acceptable if: (1) a geotechnical investigation proves that the facility does not compromise the stability of the site slope or surrounding slopes, or (2) the facility includes an impermeable liner, underdrain system, and an oveflow to a storm water conveyance system, if the facility is on-line.

The following section provides additional site suitability recommendations and limitations for sand filters.

- Limit the tributary area and site slope to less than 10 acres and less than 15%, respectively; these criteria reduce the potential for high flow velocity and concentrated, erosive flows from entering the sand filter.
- If designed with underdrains and an impermeable interface between the sand filter bed and the subsoil (e.g., concrete or block structure), depth to seasonally high groundwater table shall be at least 2 feet and there is no setback requirement from drinking water wells.
- If designed for infiltration (i.e., without underdrains), depth to seasonally high groundwater table shall be at least 5 feet and the horizontal setback from drinking water wells shall be 100 feet.
- The sand filter shall be located away from trees producing leaf litter or areas contributing significant eroded sediment to prevent clogging.
- If used in hot spot areas (e.g., industrial sites, gas stations), and underdrain and impermeable interface between the sand filter bed and the subsoil (e.g., concrete or block structure) is required to protect from infiltration into the subsoil.
- Sand filters shall be placed off-line to prevent scouring of the filter bed by high flows. The overflow structure must be designed to pass the water quality design flow rate, Q_{wq}.
- Sand filters are generally not recommended to treat runoff with high sediment concentrations which may clog the filter; pretreatment is essential. In addition, high loading rates may also cause premature clogging of the filter.
- Site must have adequate relief between land surface and storm water conveyance system to permit vertical percolation through the sand filter and collection and conveyance in the perforated underdrain to storm water conveyance system; four feet of elevation difference is recommended between the inlet and outlet of the filter.

Multi-Use and Treatment Train Opportunities

Sand filters are generally not suitable for multi-use. However, some innovative designs are possible, such as combining a sand filter with a dry extended detention basin (see Section 6.10.3) or incorporating a sand filter into a volleyball court. Both of these applications can encourage infiltration if site conditions allow and require significant pretreatment to remove coarse solids, trash and debris, and oil and grease. Recreational multi-use facilities must be inspected after every storm and may require a greater maintenance frequency than dedicated sand filters as to ensure aesthetics and public safety are not compromised. Effluent from a sand filter may also be routed to another storm water runoff BMP to form a “treatment train” that can provide enhanced water quality treatment and reductions in runoff volume and rate to meet the storm water runoff requirements as outlined in Section 6.2.

6.6.4.3 Design Criteria and Procedure

The main challenge associated with sand filters is maintaining its filtration capacity, which is critical to performance of this BMP. If flows entering the sand filter are high and have high sediment concentrations, erosion and clogging of the sand filter are likely. Contribution of eroded soils or leaf litter may also reduce the infiltration and associated treatment capacity of the structure. A schematic of a surface sand filter is illustrated in Figure 6-10.

Principal design criteria for sand filters are listed in Table 6-27.

Table 6-27: Sand Filter Design Criteria

Design Parameter	Unit	Design Criteria
Water quality design volume, V_{wq}	ft^3	See Section 6.2.3 and Appendix C for calculating the water quality design volume, V_{wq}
Length to width ratio	L:W	1.5:1
Filter bed depth	inches	24; 36 preferred
Max ponding depth above filter bed	feet	6
Hydraulic conductivity of sand, k	in/hr	1 (equal to 2 ft/day)
Underdrains	-	6 inch minimum diameter; 0.5% minimum slope
Side slopes	H:V	4:1 (H:V) Interior and 2:1 (H:V) Exterior

Pretreatment

Pretreatment must be provided for sand filters in order to reduce the sediment load entering the filter. Pretreatment refers to design features that provide settling of large particles before runoff reaches a management practice, easing the long-term maintenance burden. To ensure that pretreatment mechanisms are effective, designers shall incorporate a pretreatment BMP such as vegetated storm water runoff BMP, proprietary device, or sedimentation forebay. Examples of vegetated storm water runoff BMPs and proprietary BMPs that maybe appropriate include:

- Vegetated filter strips (See Section 6.6.3)
- Vegetated swale filters (See Section 6.6.2)
- Hydrodynamic separators (See Section 6.11 – Proprietary Devices)

Sizing and Geometry

1. Sand filters shall be sized to capture and filter the water quality design volume, V_{wq} (see Section 6.2.3 and Appendix C for further detail).

2. Sand filters may be designed in any geometric configuration, but rectangular with a 1.5:1 length-to-width ratio or greater is preferred.

3. Filter bed depth must be at least 24 inches, but 36 inches is preferred.

4. Depth of water storage over the filter bed shall be 6 feet maximum.

5. Sand filters shall be placed off-line to prevent scouring of the filter bed by high flows. The overflow structure must be designed to pass the water quality design storm.

Sizing Methodology of the Sand Filter Bed

A sand filter is volume-based BMP designed with two parts: (1) a temporary storage reservoir to store runoff, and (2) a sand filter bed through which the stored runoff must percolate. Usually the storage reservoir is simply placed directly above the filter, and the floor of the reservoir pond is the top of the sand filter bed. For this case, the storage volume also determines the hydraulic head over the filter surface, which increases the rate of flow through the sand.

Two methods are available for sizing sand filters: a simple method and a routing modeling method. The simple method uses standard values to define filter hydraulic characteristics for determining the sand surface area. This method is useful for planning purposes, for a first approximation to begin iterations in the detailed method, or when use of the detailed computer model is not desired or not available. The simple method very often results in a larger filter than the routing method. For the routing modeling method, refer to Section 6.6.1 – Bioretention Areas. A sand filter design example using the simple method is provided in Appendix D.

<u>Background</u>

Sand filter design is based on Darcy's law:

$$Q_{wq} = kiA \qquad \text{(Equation 6-17)}$$

Where:

Q_{wq} = the water quality design flow, Q_{wq} (cfs)
k = hydraulic conductivity of filter bed (ft/sec)
A = surface area perpendicular to the direction of flow (ft^2)
i = hydraulic gradient (ft/ft) for a constant head and constant media depth, computed as follows:

$$i = \frac{h+l}{l} \qquad \text{(Equation 6-18)}$$

Where:

h = average depth of water above the filter bed (ft), defined for this design as d/2
d = maximum storage depth above the filter bed (ft)
l = thickness of filter bed (ft)

Darcy's law underlies both the simple and the routing methods of design. The filtration rate v (ft/sec), or more correctly, $1/v$, is the direct input in the sand filter design. The relationship between the filtration rate v and hydraulic conductivity, k, is revealed by equating Darcy's law and the equation of continuity, $Q = vA$. Specifically:

$Q = kiA$ and $Q = vA$ So, $vA = kiA$ or:

$$v = ki$$ (Equation 6-19)

Note that $v \neq k$ – that is, the filtration rate is not the same as the hydraulic conductivity, but they do have the same units (distance per time). *k* can be equated to *v* by dividing *v* by the hydraulic gradient *i*, which is defined above.

The hydraulic conductivity, *k,* does not change with head nor is it dependent on the thickness of the media; it is only dependent on the characteristics of the media and the fluid. A hydraulic conductivity of 1 inch per hour is used to design the sand filter and is based on bench-scale tests of conditioned rather than clean sand (KCSWDM, 2005). This design hydraulic conductivity represents the average sand bed condition as silt is captured and held in the sand bed.
Unlike the hydraulic conductivity, the filtration rate, *v,* changes with head and media thickness, although the media thickness is constant in the sand filter design.

Simple Sizing Method

The simple sizing method does not route flows through the filter. It determines the size of the filter based on the simple assumption that inflow is immediately discharged through the filter as if there were no storage volume. An adjustment factor (0.7) is applied to compensate for the greater filter size resulting from this method. Even with the adjustment factor, the simple method generally produces a larger filter size than the routing method.

Step 1: Calculate storage depth

Determine the maximum water storage depth, *d*, above the sand filter. This depth is defined as the depth at which water begins to overflow the temporary storage reservoir, and it depends on the site topography and hydraulic constraints. The depth is chosen by the designer, but shall be 6 feet or less.

Step 2: Calculate the design volume

Determine water quality design volume, V_{wq} (see Section 6.2.3 and Appendix C).

Step 3: Calculate the sand filter area

Determine the sand filter area, A_{sf}, using the following equation (based on Darcy's law):

$$A_{sf} = \frac{V_{wq} R L}{k_{design} t \left(h + L\right)}$$ (Equation 6-20)

Where:

A_{sf} = surface area of the sand filter bed (ft^2)

V_{wq} = water quality design volume (ft^3)

R = routing adjustment factor (use R = 0.7)

L = sand bed depth (ft)

k_{design} = design hydraulic conductivity (use 2 ft/day which is equal to 1 in/hr)

t = drawdown time (use 1 day)

h = average depth of water above the filter (ft), (use $d/2$ with d determined from Step 1)

Sand Specification

Ideally the effective diameter of the sand, d_{10}, shall be just small enough to ensure a good quality effluent while preventing penetration of storm water particles to such a depth that they cannot be removed by surface scraping (~2-3 inches). This effective diameter usually lies in the range 0.20-0.35 mm. In addition, the coefficient of uniformity, $Cu = d_{60}/d_{10}$, shall be less than 3.

The sand in a filter shall consist of a medium sand with very little fines meeting ASTM C 33 size gradation (by weight) or equivalent as given in the table below.

U.S. Sieve Size	Percent Passing
3/8 inch	100
U.S. No. 4	95 to 100
U.S. No. 8	80 to 100
U.S. No. 16	50 to 85

Underdrains

1. Several underdrain systems can be used in a sand filter design:
   a. Central underdrain collection pipe with lateral collection pipes in an 8 inch minimum gravel backfill or drain rock bed.
   b. Longitudinal pipes in an 8 inch minimum gravel backfill or drain rock bed, with a collection pipe at the outfall.
   c. Small sand filters may utilize a single underdrain pipe in an 8 inch minimum gravel backfill or drain rock bed.

2. All underdrain pipes and connectors must be 6 inches or greater so they can be cleaned without damage to the pipe. Clean-out risers with diameters equal to the underdrain pipe must be placed at the terminal ends of all pipes and extend to the surface of the filter. A valve box shall be provided for access to the cleanouts and the cleanout assembly must be water tight to prevent short circuiting of the sand filter.

3. The underdrain pipe must be sized and perforated as to ensure free draining of the sand filter bed. Round perforations must be at least 1/2-inch in diameter and the pipe must be laid with holes downward.

4. The maximum perpendicular distance between any two lateral collection pipes or from the edge of the filter and the collection pipes shall be 9 feet.

5. All pipes must be placed with a minimum slope of 0.5%.

6. The invert of the underdrain outlet must be above the seasonal high groundwater level.

7. At least 8 inches of gravel backfill must be maintained over all underdrain piping, and at least 6 inches must be maintained on both side and beneath the pipe to prevent damage by heavy equipment during maintenance. Either drain rock or gravel backfill may be used between pipes.

8. The bottom gravel layer shall have a diameter at least 2 times the size of the openings into the drainage system. The grains shall be hard, preferably rounded, with a specific gravity of at least 2.5, and free of clay, debris and organic impurities.

9. Either a geotextile fabric or a two-inch transition gradation layer (i.e., choking stone layer) must be placed between the sand layer and the drain rock or gravel backfill layer. If a geotextile is used, one inch of drain rock or gravel backfill shall be place above the fabric. This allows for a transitional zone between sand and gravel and may reduce pooling of water at the liner interface. The geotextile must 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

Flow Spreading

1. A flow spreader shall be installed at the inlet along one side of the filter to evenly distribute incoming runoff across the filter and to prevent erosion of the filter surface.
   a. If the sand filter is curved or an irregular shape, a flow spreader shall be provided for a minimum of 20 percent of the filter perimeter.
   b. If the length-to-width ratio of the filter is 2:1 or greater, a flow spreader must be located on the longer side and for a minimum length of 20 percent of the facility perimeter.
   c. In other situations, use good engineering judgment in positioning the spreader.

2. Erosion protection shall be provided along the first foot of the sand bed adjacent to the flow spreader. Geotextile weighted with sand bags at 15-foot intervals may be used. Quarry spalls (small rock) may also be used.

Vegetation

1. The use of vegetation in sand filters is optional. However, no top soil shall be added to the sand filter bed because the fine-grained materials (silt and clay) reduce the hydraulic capacity of the filter.

2. Growing grass or other vegetation requires the selection of species that can tolerate the demanding environment of a sand filter bed. Plants not receiving sufficient dry weather flows must be able to withstand long periods of drought during summer periods, followed by periods of saturation during storm events. A landscape design professional shall be consulted for advice on species selection

3. A sod grown in sand may be used on the sand surface as long as there is no clay in the sand substrate and the particle size gradation of the substrate meets the sand filter specifications. No other sod shall be used due to the high clay content in most sod soils.

4. To prevent uses that could compact and damage the filter surface, permanent structures are not permitted on sand filters (e.g., playground equipment).

5. A sand filter can add aesthetics to a site and shall be incorporated into a project's landscape design. Interior side slopes may be stepped with flat areas to provide informal seating with a game or play area below. Perennial beds may be planted above the overflow water surface elevation. However, large shrubs and trees are not recommended as shading limits evaporation and falling leaves can clog the filter surface. If a sand filter area is intended for recreational uses, such as a volleyball area, the interior side slopes of the filter embankment shall be no steeper than 4:1 and may be stepped.

6. Landscaping outside of the facility must 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, shall not be used within 50 feet of pipes or manmade structures. Weeping willow (*Salix babylonica*) shall 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- http://www.cdfa.ca.gov/phpps/ipc/encycloweedia/encycloweedia_hp.htm or the California Invasive Plant Council website at www.cal-ipc.org.

7. See Appendix G for a recommended native plant list for sand filters, a list of local nurseries where these plants can be purchased, and a list of local and regional on-line resources. The plant list shall be used as a guide only and shall not replace project-specific planting recommendations provided by a landscape professional including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth. See Section 5.11 for more information on landscaping/planting recommendations and Section 5.10 for more information on soil amendment recommendations.

Emergency Overflow Structure

Sand filters shall be placed off-line, but an emergency overflow must still be provided in the event the filter becomes clogged. The overflow structure must be able to safely convey flows from the water quality design storm to the downstream storm water conveyance system or other acceptable discharge point (Figure 6-32).

Side Slopes

1. Interior side slopes above the water quality design depth and up to the emergency overflow water surface shall be no steeper than 4:1 (H:V), unless stabilization has been approved by a licensed civil engineer and the City.

2. Exterior side slopes shall be no steeper than 2:1 (H:V), unless stabilization has been approved by a licensed civil engineer and the City.

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 City.

4. Landscaped slopes must 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 engineer and approved by the City.

Embankments

Earthworks and berm embankments shall be performed in accordance with the latest edition of the "Greenbook Standard Specifications for Public Works Construction".

1. Embankments are earthen slopes or berms used for detaining or redirecting the flow of water.

2. Typically, the top width of berm embankments are at least 20 feet, but narrower embankments may be plausible if approved by the civil engineer and the City.

3. Top of berm shall be 2 feet minimum below the water quality design water surface and shall be keyed into embankment a minimum of 1 foot on both sides.

4. Basin berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a licensed civil engineer) free of loose surface soil materials, roots, and other organic debris.

5. The berm embankment shall be constructed of compacted soil (95% minimum dry density, modified proctor method per ASTM D1557), placed in 6-inch lifts.

6. Basin berm embankments greater than 4 feet in height must 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 engineer.

7. The berm embankment shall 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 shall be planted on downstream embankment slopes. See vegetation section below.

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. In accordance with the Santa Barbara Flood Control District *Standard Conditions of Project Plan Approval*, facilities to be dedicated to the City, perimeter fencing (minimum height of 42 inches) shall 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 shall be designed and constructed in accordance with current policies of the Santa Barbara County Flood Control District and must 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.

Right-of-Way

1. Constructed treatment wetlands and associated access roads to be maintained by the City shall be dedicated in fee or in an easement to the City with appropriate access.

Maintenance Access

1. Ownership of the basin and maintenance thereof is the responsibility of the developer/applicant. A maintenance agreement with the City is required to ensure adequate performance and allow the City emergency access to the facilities.

2. Maintenance access road(s) shall 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 must be in or at the edge of the access road.

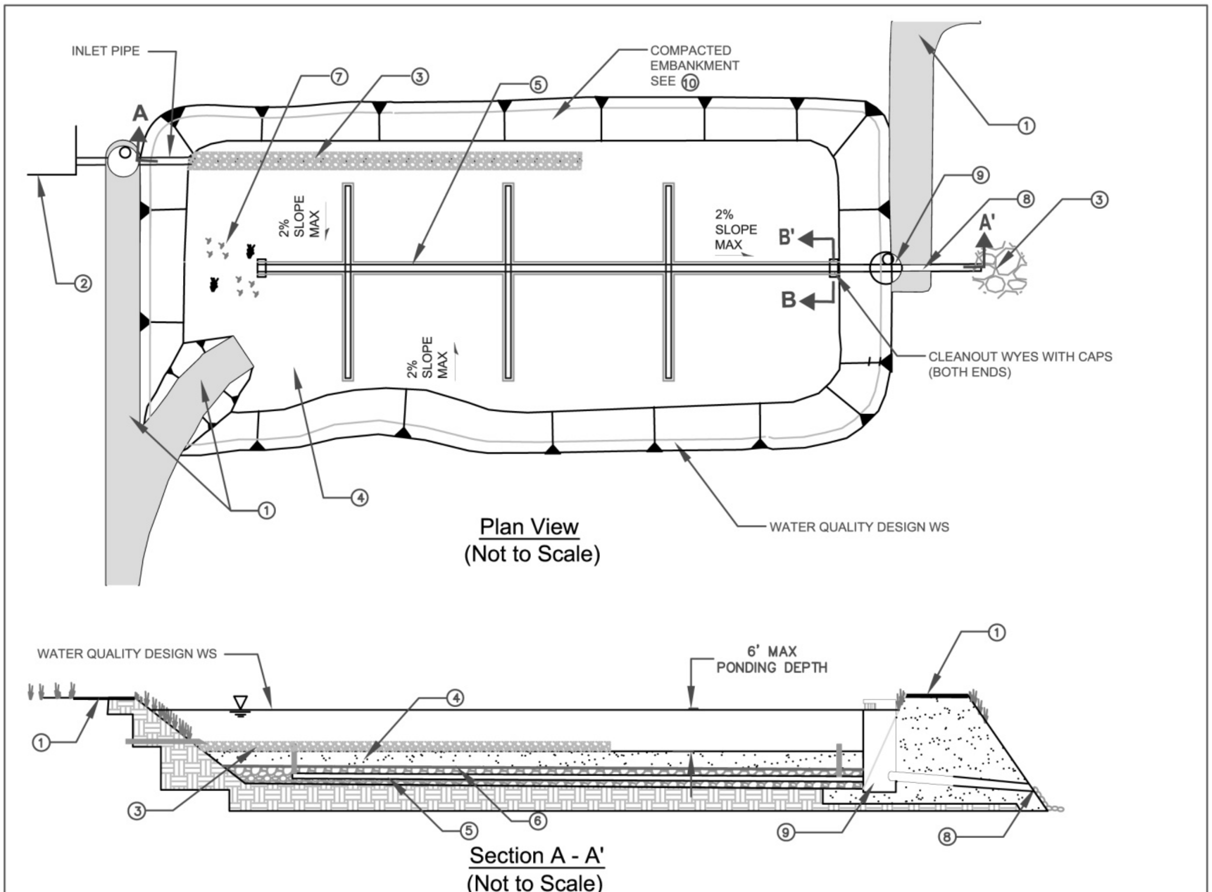
3. A graded 16-foot wide access ramp into the basin shall be constructed near the basin outlet. An access ramp is required for removal of sediment with a backhoe or loader and truck. The ramp must extend to the basin bottom to avoid damage to vegetation planted on the basin slope. A 16-foot wide commercial driveway approach shall be provided where curb and gutter front the maintenance ramp.

4. All access ramps and roads shall be provided in accordance with the current policies of the Flood Control District.

6.6.4.4 <u>Construction Considerations</u>

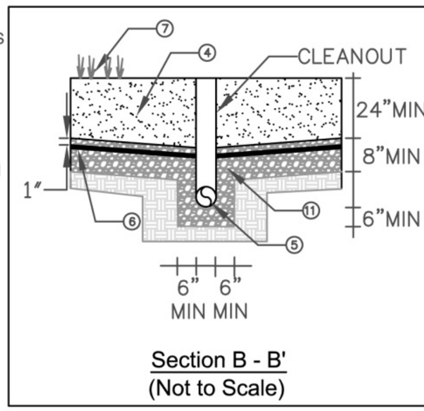
The use of treated wood or galvanized metal anywhere inside the facility is prohibited.

Figure 6-10: Sand Filter Schematic



NOTES:

1. INSTALL MAINTENANCE ACCESS ROAD AND RAMP TO BOTTOM OF SAND FILTER. MAINTENANCE RAMP SHOULD BE PAVED. WIDTH SHALL BE A MINIMUM OF 16' AND SLOPE SHALL NOT EXCEED 12%.
2. UPSTREAM PRETREATMENT SHALL BE PROVIDED. RECOMMENDED PRETREATMENT OPTIONS INCLUDE SEDIMENTATION / HYDRODYNAMIC DEVICES AND VEGETATED BMPS. IN THE ABSENCE OF PRETREATMENT, INCLUDE SEDIMENT FOREBAY WITH VOLUME EQUAL TO 10-20% OF TOTAL SAND FILTER VOLUME.
3. FLOW SPREADER TO EVENLY DISTRIBUTE FLOWS ALONG AT LEAST 20% OF PERIMETER.
4. FILTER BED SHALL BE A 24" MINIMUM SAND LAYER ON TOP OF 8" MINIMUM GRAVEL OR DRAIN ROCK BACKFILL.
5. 6" MINIMUM DIAMETER PERFORATED PIPE UNDERDRAIN. INSTALL AT 0.5% MINIMUM SLOPE.
6. INSTALL GEOTEXTILE FABRIC OR TRANSITIONALLY GRADED AGGREGRATE BETWEEN SAND AND GRAVEL LAYER.
7. VEGETATION MAY BE PLANTED ON TOP OF FILTER BED. NO TOP SOIL SHALL BE ADDED TO FILTER BED.
8. SIZE OUTLET PIPE STRUCTURE TO PASS WATER QUALITY DESIGN STORM AND INCLUDE AN EMERGENCY OVERFLOW.
9. EMERGENCY OVERFLOW STRUCTURE.
10. INTERIOR SIDE SLOPES SHALL NOT EXCEED 4H:1V AND EXTERIOR SIDE SLOPES SHALL NOT EXCEED 2H:1V UNLESS APPROVED BY A LICENSED CIVIL ENGINEER. FENCING SHALL BE PROVIDED FOR EMBANKMENT SIDE SLOPES GREATER THAN 6H:1V OR IF THE DEPTH EXCEEED 2'.
11. GRAVEL SHALL HAVE A DIAMETER AT LEAST 2 TIMES THE SIZE OF THE OPENINGS INTO THE UNDERDRAIN PIPE.



Geosyntec consultants

Figure 6 - 10
SAND FILTER

6.6.4.5 Operations and Maintenance

General Requirements

Sand filters are subject to clogging by fine sediment, oil and grease, and other debris (e.g., trash and organic matter such as leaves). Filters and pretreatment facilities shall be inspected every 6 months during the first year of operation (see Appendix H for a sand filter inspection and maintenance checklist). Inspections shall also occur immediately following a storm event to assess the filtration capacity of the filter. Once the filter is performing as designed, the frequency of inspection may be reduced to once per year.

Most of the maintenance shall be concentrated on the pretreatment practices, the filter strips and vegetated swales upstream of the sand filter to ensure that sediment does not reach the sand filter. Regular inspection shall determine if the sediment removal structures require routine maintenance.

Maintenance Standards

A summary of the routine and major maintenance activities recommended for sand filters is shown in Table 6-28. Detailed routine and major maintenance standards are listed in Table 6-29 and Table 6-30.

Table 6-28: Sand Filter Maintenance Quick Guide

Inspection and Maintenance Activities Summary	
Routine Maintenance	• Remove trash and debris • Repair and re-seed erosion near inlet • Remove any evidence of visual contamination from floatables such as oil and grease • Clean under-drain and outlet piping to alleviate ponding and restore infiltrative capacity if needed • Clean and reset flow spreaders as needed to maintain even distribution of low flows • Remove minor sediment accumulation, debris, and obstructions near inlet and outlet structures as needed • Mow, weed, and trim routinely(where applicable) to maintain ideal grass height and to suppress weeds
Major Maintenance	• Clean out under-drains if present to alleviate ponding. Replace filter bed media if ponding or loss of infiltrative capacity persists and re-vegetate as needed • Reset settled piping, add fill material to maintain original pipe flow line elevations • Repair structural damage to flow control structures including inlet, outlet, and overflow structures

Table 6-29: Routine Maintenance – Sand Filters

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Trash & Debris	Any trash and debris which exceed 5 cubic feet per 1,000 square feet of filter bed 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.	Trash and debris cleared from site.	Annually prior to wet season After major storm events (>0.75 inches/24 hrs) if spot checks indicate widespread damage/maintenance needs Litter removal is dependent on site conditions and desired aesthetics and shall be done at a frequency to meet those objectives
Inlet erosion	Visible evident of erosion occurring near flow spreader outlets.	Eroded areas repaired/reseeded.	
Slow drain time	Standing water long after storm has passed (after 24 to 48 hours) and/or flow through the overflow pipes occurs frequently.	Water drains within 48 hours. This is achieved through cleaning or backflushing the drainage pipe, removing accumulated litter on surface or removing and renewing top 1-2" of filter media. If this does not cure problem then see major maintenance.	
Concentrated Flow	Flow spreader uneven or clogged so that flows are not uniformly distributed across the sand filter.	Level the spreader and clean so that flows are spread evenly over the sand filter bed.	
Appearance of poisonous, noxious or nuisance vegetation	Excessive grass and weed growth. Noxious weeds, woody vegetation establishing, Turf growing over rock filter	Mowing, weeding and trimming to restore function and prevent noxious and nuisance plants from establishing	Monthly (or as dictated by agreement between County and landscape contractor)

Table 6-30: Major Maintenance – Sand Filters

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Standing Water	Standing water long after storm has passed (after 24 to 48 hours), and/or flow through the overflow pipes occurs frequently.	Design infiltration rate achieved, either through excavation and filter media replacement or sediment removal from existing media. If the underdrain is clogged, filter fabric must be removed and the pipe cleaned.	As needed
Tear in Filter Fabric	When there is a visible tear or rip in the filter fabric allowing water to bypass the fabric.	Filter fabric repaired and/or replaced.	
Pipe Settlement	If piping has visibly settled more than 1 inch.	Pipe is returned to original height. Add fill material to bring pipe back to grade. If erosion is evident around pipe, inspect for cracks or leaks.	

6.7 Infiltration BMPs

Figure 6-11: Infiltration Basin
Photo Credit: Pennsylvania Stormwater BMP Manual

Applications

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

Performance

- Efficient removal of trash and sediment
- High volume reduction
- Simple; low cost
- Can integrate with parks

Limitations

- Requires large pervious area
- High maintenance requirement; clogging potential is high
- Potential groundwater contamination

6.7.1 Description

Infiltration BMPs included in this manual include infiltration basins, infiltration trenches, and drywells. In general, infiltration BMPs are similar to storm water detention systems but are constructed with a highly permeable base that is specifically designed to infiltrate runoff. It is usually not practical to infiltrate runoff at the same rate that it is generated; therefore, these facilities generally include both a storage component and a drainage component.

Infiltration basins are usually shallow with flat, vegetated bottoms and side slopes and can be incised by excavating a depression below the existing grade or constructed above grade by constructing a perimeter berm.

Infiltration trenches are long, narrow, rock-filled trenches that receive storm water runoff from small drainage areas. These facilities may include a shallow depression at the surface, but the majority of runoff is stored in the void space between the stones and infiltrates through the sides and bottom of the trench.

Drywells are similar to infiltration trenches in their design and function. A dry well is a subsurface storage facility designed to temporarily store and infiltrate runoff, primarily from rooftops or other impervious areas with low sediment loading. A dry well may be either a small excavated pit filled with aggregate or a prefabricated storage chamber or pipe segment.

Pretreatment BMPs such as vegetated swale filters, Vegetated filter strips, and sediment forebays, basins, and manholes minimize sediment loads to infiltration facilities are recommended to increase longevity and reduce the maintenance burden of infiltration facilities.

6.7.2 Performance, Applicability, and Limitations

Table 6-17 provide a summary of BMP performance, applicability, and limitations for infiltration BMPs. *It is important to note that information in these tables shall be used to provide general guidance for infiltration BMPs and shall not replace the evaluation performed by a water quality professional.*

Performance

Table 6-31 and associated guidance provide general volume reduction capabilities and treatment effectiveness for infiltration BMPs. Refer to Section 6.4 for the process that shall be used for selecting BMPs based on pollutants of concern. Refer to Table 6-1 to determine the ranking of infiltration BMPs for removal of pollutants of concern as compared with other storm water runoff BMPs provided in Chapter 6. Refer to Table 6-2 to assess the applicability of infiltration BMPs for your site based on site suitability considerations as compared with other storm water runoff BMPs provided in Chapter 6. Infiltration BMPs are volume-based BMPs that, depending on site conditions, can be designed to meet all or part of the water quality treatment and volume reduction requirements (see Table 6-31). Infiltration BMPs also assist in meeting the peak runoff discharge rate requirements (see "Additional Control Functions" section below). See Section 6.2 for specific storm water runoff requirements for Tier 3 projects.

Table 6-31: Volume Reduction & Treatment Effectiveness for Infiltration BMPs

Storm Water Runoff BMP	Volume Mitigation (% of inflow)	Treatment Effectiveness for Pollutants of Concern[1]					
		Trash	Nutrients	Bacteria	Metals (particulate and dissolved fractions)	Sediment	Organics (hydro-carbons, oil, and grease)
Infiltration Facilities	●	●	●	●	●	●	●
Volume/Treatment Effectiveness: ● = Very High, ◓ = High, ◉ = Moderate, ◒ = Low, ○ = Very Low							

[1] Effectiveness may change based on design variations; standard BMP designs have been assumed.

Infiltration BMPs are good candidates for the removal of sediment, particulate bound pollutants, and bacteria. Sedimentation of coarse particles shall however, be minimized through the use of appropriate pretreatment devices to prevent clogging. In general, it is assumed that infiltration BMPs located in areas with acceptable infiltration rates and the required minimum depth to groundwater, provide for complete reduction of pollutants before the infiltrated runoff reaches groundwater through sedimentation, filtration, adsorption, and biodegradation which occur as runoff infiltrates through the BMP and then through the subsoil.

Site Suitability Recommendations and Limitations

Table 6-32 and associated guidance provide general considerations for assessing a site's suitability for infiltration BMPs.

Table 6-32: Site Suitability Considerations for Infiltration BMPs

BMP	Tributary Area (Acres)[1]	Site Slope (%)	Depth to Seasonally High Groundwater Table (ft)	Hydrologic Soil Group	Horizontal Setback from Drinking Water Wells (ft)
Infiltration Facilities	< 5 Acres; 217,800 Sq. Ft.	< 7 [2]	> 5	May not be feasible in "C" soils. Not suitable in "D" soils.	100

[1] Tributary area is the area of the site draining to the BMP. Tributary areas provided here shall be used as a general guideline only. Tributary areas can be larger or smaller in some instances.

[2] If site slope exceeds that specified or if the system is within 200 ft from the top of a hazardous slope or landslide area (on the uphill side), a geotechnical investigation and report addressing slope stability shall be prepared by a licensed civil engineer.

Table 6-33 provides additional site applicability considerations for special design districts within the City, including coastal bluff areas and hillside design districts.

Table 6-33: Applicability of Infiltration BMPs for Special Design Districts

Coastal Bluff Area	Hillside Design District
Infiltration BMPs are not permissible in Coastal Bluff Areas.	Acceptable if a geotechnical investigation proves that the facility does not compromise the stability of the site slope or surrounding slopes.

Due to the potential to cause slope instability, impact surrounding engineering structures, and contaminate groundwater, an extensive soil assessment and potential geotechnical investigation for slope stability must be undertaken early in the site planning process to verify site suitability for the installation of infiltration BMPs. Soil infiltration rates and the seasonally high groundwater table depth shall be evaluated to ensure that conditions are satisfactory for proper operation of an infiltration BMP (see Chapter 3).

The applicant must demonstrate through infiltration testing, soil logs, and the written opinion of a licensed civil engineer that sufficiently permeable soils exist on-site to allow the construction of a properly functioning infiltration BMP. An additional geotechnical investigation may be required if the facility is placed in an area that could potential cause slope instability.

The following site suitability and geotechnical recommendations and limitations shall be considered before choosing to use infiltration BMPs.

- In general, tributary area shall be limited to less than 5 acres to limit the size of the infiltration BMP and limit loading rates of sediment which can cause premature clogging. If tributary areas are greater than 5 acres, significant pretreatment shall be provided.

- The upstream tributary area shall be stabilized to minimize sediment delivery to the infiltration BMP.

- Pretreatment for coarse sediment removal is required in all instances. High loading rates may clog quickly if flows are not adequately pretreated.

- Infiltration BMPs require a minimum soil infiltration rate of 0.05 inches/hour. If infiltration rates exceed 2.4 inches/hour, then the runoff shall be fully treated in an upstream BMP prior to infiltration to protect groundwater quality. In addition, shallow confining layers or bedrock may inhibit infiltration. The design infiltration rate shall account for clogging and compaction over time by multiplying the field measured infiltration rate by an appropriate correction factor as described in the design criteria and procedure section below. Preferably, measurements of groundwater levels shall be made during the time when water level is expected to be at a maximum (i.e., toward the end of the wet season). If this is not feasible, indications of the seasonally high groundwater table shall be identified during soil testing (see Chapter 3).

- Groundwater separation must be at least 5 feet between bottom of the basin, trench, or dry well and the measured seasonally high groundwater surface elevation. The separation between the bottom of the facility and bedrock shall be at least 3 feet.

- If the site slope exceeds 7%, a geotechnical investigation and report addressing slope stability is required.

- An infiltration facility must not be located within 50 feet of a 2:1 (H:V) or greater slope. If the infiltration facility is within 200 feet of a hazardous steep slope or mapped landslide area, a geotechnical investigation and report is required.

- Infiltration BMPs shall be located at least 100 feet away from drinking water wells, waterbodies, and septic system leach fields.

- Infiltration BMPs shall be located at least 20 feet from any structural foundation. The 20 foot setback may be reduced to a minimum of 5 feet if geotechnical investigations address the potential impacts of the facility on adjacent structural foundations.

- Infiltration BMPs are not suitable to collect runoff from hotspot sites that use or store chemicals or hazardous materials unless hazardous and toxic materials are prevented from contaminating the runoff. [*Note: Infiltration BMPs are not suitable for industrial sites or locations where spills can occur. In these areas, other BMPs that do not allow for interaction with the groundwater table shall be used*].

- Infiltration BMPs are not suitable for un-remediated "brownfield sites" where there is known groundwater or soil contamination.

Additional Control Functions

Infiltration basins can be designed to provide flow control by providing storage capacity in excess of that provided by infiltration and incorporating outlet controls. The additional storage and outlet structure shall be provided per the requirements outlined in the Dry Extended Detention Basins section of this document (see Section 6.10.3). Note that the selected outlet structure shall not be designed to drain the design volume intended for infiltration and shall be similar to outlet structures that maintain a permanent pool (see Section 6.10.2 – Wet Retention Basins).

Multi-Use Opportunities

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

6.7.3 Design Criteria and Procedure

The main challenge associated with infiltration BMPs is preventing system clogging and subsequent infiltration inhibition. Principal design criteria for infiltration BMPs are listed in Table 6-34. Schematics of infiltration BMPs are illustrated in Figure 6-12 (infiltration basins), Figure 6-13, (infiltration trench), and Figure 6-14 (dry well).

Table 6-34: Infiltration BMP Design Criteria

<table>
<tr><th>Design Parameter</th><th>Unit</th><th colspan="2">Design Criteria</th></tr>
<tr><td>Water quality design volume, V_{wq}</td><td>ft^3</td><td colspan="2">See Section 6.2 and Appendix C for calculating V_{wq}.</td></tr>
<tr><td>Volume reduction requirement, $V_{reduction}$</td><td>ft^3</td><td colspan="2">See Section 6.2 and Appendix C for calculating $V_{reduction}$.</td></tr>
<tr><td>Design drawdown time</td><td>hr</td><td colspan="2">72</td></tr>
<tr><td>Pretreatment</td><td>-</td><td colspan="2">Filter strip, vegetated swale, proprietary device, or sedimentation forebay for all surfaces other than roofs; if sheet flow, max velocity = 1 ft/sec</td></tr>
<tr><td>Design infiltration rate, k_{design}</td><td>in/hr</td><td colspan="2">Shall be corrected for testing method, potential for clogging and compaction over time, and facility geometry</td></tr>
<tr><td>Maximum depth of facility, d_{max}</td><td>ft</td><td colspan="2">Defined by the design infiltration rate and the design drawdown time (includes ponding depth and depth of media)</td></tr>
<tr><td rowspan="3">Surface area of facility, A</td><td rowspan="3">ft^2</td><td>Infiltration Basin</td><td>Based on depth of ponding</td></tr>
<tr><td>Infiltration Trench</td><td>Based on depth of ponding (if applicable) and depth of trench media</td></tr>
<tr><td>Dry Well</td><td>Based on depth of dry well media</td></tr>
<tr><td>Facility geometry</td><td>-</td><td>Infiltration Basin</td><td>Forebay (if applicable), 25% of facility volume; flat bottom slope</td></tr>
</table>

Design Parameter	Unit	Design Criteria	
		Infiltration Trench	Max 24 inches wide and max 5 feet deep; max 3% bottom slope
		Dry Well	Geometry varies; max 10 feet deep; flat bottom slope
Filter media diameter (trenches and dry wells)	inches	1.5 – 3 (gravel); prefabricated media may also be used	
Vegetation	-	Required for infiltration basins	
Underdrain	-	6 inch. minimum diameter; 0.5% minimum slope	
Overflow device	-	Required if system is on-line	

Soil Assessment and Site Geotechnical Investigation Reports

The soil assessment report shall:

- State whether the site is suitable for the proposed infiltration BMP
- Recommend a design infiltration rate (see the "Design Infiltration Rate" section below).
- Identify the seasonally high depth to groundwater table surface elevation
- Provide a good understanding of how the storm water runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water.

If a geotechnical investigation and report are required, the report shall:

- Provide a written opinion by a professional civil engineer describing whether the infiltration BMP will compromise slope stability.
- Identify potential impacts to nearby structural foundations.

Pretreatment

Pretreatment is required for 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 most all structural storm water BMPs, but it is particularly important for infiltration BMPs. To ensure that pretreatment mechanisms are effective, designers shall incorporate sediment reduction practices. Sediment reductions BMPs may include vegetated swales, vegetated filter strips, sedimentation basins or forebays, sedimentation manholes and hydrodynamic separation devices. The use of at least two pretreatment devices is highly recommended for infiltration facilities.

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

- Vegetated filter strip (Section 6.6.2)
- Vegetated swale filter (Section 6.2.2)
- Proprietary devices (Section 6.11)

Geometry and Sizing

Infiltration Basins

1. Infiltration basins shall 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 pretreament unit (e.g., vegetated swale, filter strip, hydrodynamic device) to reduce sediment loads entering the infiltration basin. The sediment forebay, if present, shall have a volume equal to 25% of the total infiltration basin volume.

3. The forebay shall be designed with a minimum length to width ratio of 2:1 and must completely drain to the main basin through an 8-inch minimum low-flow outlet within 10 minutes.

4. All inlets shall enter the sediment forebay. If there are multiple inlets, the length-to-width ratio shall be based on the average flowpath length for all inlets.

5. Side-slopes shall be no steeper than 3H:1V.

Infiltration Trenches

1. Infiltration trenches shall be at least 24 inches wide and 3 to 5 feet deep.

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

3. The filter bed media layers shall have the following composition and thickness:

    a. Top layer – If storm water runoff enters the top of the trench via sheet flow at the ground surface then the top 2 inches shall be pea gravel with a thin 2- to 4-inch layer of pure sand and 2-inch layer of chocking stone (e.g., #8) or equivalent geotextile fabric layer placed between the top layer and the middle layer to capture sediment before entering the trench. If storm water runoff enters the trench from an underground pipe, pretreatment prior to entry into the trench is required. The top layer over the trench shall be 12 inches of surface soil (i.e., overburden)

    b. Middle layer (3-5 feet of washed 1.5 to 3-inch gravel). Void space shall be in the range of 30 percent to 40 percent.

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

4. One or more observation wells shall be installed, depending on trench length, 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.

Dry Wells

1. Dry well configurations vary but generally they have length and width dimensions closer to square than infiltration trenches. Pre-fabricated dry-wells are often circular. The surface area of the dry well must be large enough to infiltrate the storage volume in 72 hours based on the maximum depth allowable, d_{max}.

2. The bottom slope shall be level.

3. Maximum 10 feet deep.

4. The filter bed media layers are the same as for infiltration trenches unless prefabricated dry wells and/or media are used. The porosity of gravel media systems is generally 30-40% and is 80-95% for prefabricated media systems.

5. If dry well receives runoff from an underground pipe (i.e., runoff does not enter the top of the dry well from the ground surface), a fine mesh screen shall be installed at the inlet. The inlet elevation shall be 18 inches below the ground surface (i.e., below 12 inches of surface soil and 6 inches of dry well media).

6. An observation wells shall 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.

Sizing Methodology

Infiltration facilities shall be sized to capture and infiltrate all or part of the volume reduction requirement, $V_{reduction}$ or the water quality design volume, V_{wq}, whichever is larger (see Section 6.2 and Appendix C for further detail). Procedures for sizing infiltration BMPs are summarized below. An infiltration BMP sizing example is provided in Appendix D.

Step 1: Determine the design infiltration rate of the native subsoil

See the Bioretention Area Section 6.6.1 for the method used to determine the design infiltration rate of the native subsoil.

Step 2: Size the infiltration BMP

As with sand filters, infiltration BMPs can be sized using one of two methods: a simple sizing method or a routing modeling method. With either method, the runoff entering the facility must be completely infiltrated within 72 hours. Infiltration basins provide the majority of storage above ground while infiltration trenches and dry wells provide the majority of storage in the voids of the rock fill. The simple sizing procedures provided below can be used for infiltration basins, infiltration trenches, or dry wells. For the routing modeling method, refer to the Bioretention Area Section 6.6.1.

Determine the size of the required infiltrating surface by assuming the design runoff volume (i.e., all or part of the water quality design volume, V_{wq}, or the volume reduction requirement, $V_{reduction}$, whichever is larger) will fill the available ponding depth plus the void spaces based on the computed porosity of the filter media (normally about 32% for gravel). Note, dry wells generally do not have a ponding depth; therefore, the design runoff volume shall fill the available void spaces based only on the porosity of the filter media.

Determine the maximum depth of runoff that can be infiltrated within the required drain time (72 hr) as follows:

$$d_{max} = \frac{k_{design}}{12} \times t \qquad \text{(Equation 6-21)}$$

Where:

t	=	required drain time (hrs) [Use 72 hours]
k_{design}	=	infiltration rate of underlying soils (in/hr)
d_{max}	=	the maximum depth of water that can be infiltrated within the required drain time (ft)

Choose the ponding depth (d_p) and/or trench depth (d_t) such that:

$$d_{max} \geq d_p \qquad \text{For Infiltration Basins} \qquad \text{(Equation 6-22)}$$

$$d_{max} \geq n_t d_t + d_p \qquad \text{For Infiltration Trenches} \qquad \text{(Equation 6-23)}$$

$$d_{max} \geq n_t d_t \qquad \text{For Dry Wells} \qquad \text{(Equation 6-24)}$$

Where:

d_p	=	ponding depth (ft)
n_t	=	trench fill aggregate porosity (unitless)
d_t	=	depth of trench fill (ft)
d_{max}	=	the maximum depth of water that can be infiltrated within the required drain time (ft)

Calculate infiltrating surface area (filter bottom area) required:

$$A = \frac{V_{design}}{(\frac{Tk_{design}}{12} + d_p)} \qquad \text{For Infiltration Basins} \qquad \text{(Equation 6-25)}$$

$$A = \frac{V_{design}}{(\frac{Tk_{design}}{12} + n_t d_t + d_p)} \qquad \text{For Infiltration Trenches} \qquad \text{(Equation 6-26)}$$

$$A = \frac{V_{design}}{(\frac{Tk_{design}}{12} + n_t d_t)} \qquad \text{For Dry Wells} \qquad \text{(Equation 6-27)}$$

(Adapted from Georgia Stormwater Manual**:** http://www.atlantaregional.com/environment/georgia-stormwater-manual)

Where:

V_{design}	=	design volume of runoff to be infiltrated (ft^3)
n_t	=	trench or dry well media porosity (unitless); [commonly, n_t = 0.32 for gravel]
k_{design}	=	design infiltration rate (in/hr)
d_p	=	ponding depth (ft)
d_t	=	depth of trench fill (ft)
T	=	fill time (time to fill infiltration BMP with water) (hrs) [use 2 hours for most designs]
A	=	surface area of infiltration BMP (ft^2)

Embankments

1. Embankments are earthen slopes or berms used for detaining or redirecting the flow of water.

2. Top of berm shall be 2 feet minimum below the water quality design water surface and shall be keyed into embankment a minimum of 1 foot on both sides.

3. Typically, the top width of berm embankments is at least 20 feet, but narrower embankments may be plausible if approved by a licensed civil engineer and the Santa Barbara County Flood Control District.

4. Basin berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a licensed civil engineer) free of loose surface soil materials, roots, and other organic debris.

5. Basin berm embankments greater than 4 feet in height must 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 engineer.

6. The berm embankment shall be constructed of compacted soil (95% minimum dry density, modified proctor method per ASTM D1557), placed in 6-inch lifts.

7. Low growing native or non-invasive perennial grasses shall be planted on downstream embankment slopes. See vegetation specifications below and Appendix G Plant List.

Drainage

1. The bottom of infiltration bed must be native soil, over-excavated to at least one foot in depth and replaced uniformly without compaction. Amending the excavated soil with 2-4 inches (~15-30%) of coarse sand is recommended.

2. The use of vertical piping, either for distribution or infiltration enhancement shall not be allowed to avoid device classification as a Class V injection well per 40 CFR146.5(e)(4).

3. The hydraulic conductivity of the subsurface layers shall be sufficient to ensure a maximum 72-hr drawdown time. An observation well shall be incorporated to allow observation of drain time.

4. For infiltration basins, an underdrain shall be installed within the bottom layer to provide drainage in case of standing water. The underdrain shall be operated by opening a valve, which shall be closed during normal operation. Cleanouts shall be provided for the underdrain. See Sand Filter Section 6.6.4 for specifications for underdrains.

Emergency Overflow

1. There must be an overflow route for storm water 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 storm water conveyance system or other acceptable discharge point.

Vegetation

Infiltration Basin

1. A thick mat of drought tolerant grass shall 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 crusts that accumulate from sedimentation of fine particulates.

2. Grass may need to be irrigated during establishment.

3. For infiltration basins, landscaping is required outside of the basin and must 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, shall not be used within 50 feet of pipes or manmade structures. Weeping willow (*Salix babylonica*) shall 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- http://www.cdfa.ca.gov/phpps/ipc/encycloweedia/encycloweedia_hp.htm or the California Invasive Plant Council website at www.cal-ipc.org.

4. See Appendix G for a recommended native plant list for infiltration BMPs, a list of local nurseries where these plants can be purchased, and a list of local and regional on-line resources. The plant list shall be used as a guide only and shall not replace project-specific planting recommendations provided by a landscape professional including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth. See Section 5.11 for more information on landscaping/planting recommendations and Section 5.10 for more information on soil amendment recommendations.

Infiltration Trench and Dry Well

1. Infiltration trenches shall be kept free of vegetation.

2. Trees and other large vegetation shall be planted away from trenches and dry wells such that drip lines do not overhang infiltration beds.

Maintenance Access

Infiltration Basin

1. Infiltration basins require maintenance access provisions similar to dry extended detention basins (see Section 6.10.3).

2. A 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 must be in or at the edge of the access road.

3. 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.

4. Access roads shall meet the following design criteria:

5. A graded 16-foot wide maintenance ramp shall be provided that extends to the bottom of the sand filter near the outlet.

6. A 16-foot wide commercial driveway approach shall be provided where curb and gutter front the maintenance ramp.

Infiltration Trench and Dry Well

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

2. An access road along the length of the trench or dry well is required unless the trench is located along an existing road or parking lot that can be safely used for maintenance access.

3. If the infiltration facility becomes plugged and fails, then access is needed to excavate the facility to remove and replace the top layer or the filter bed media, as well as to increase all dimensions of the facility by 2 inches to provide a fresh surface for infiltration. To prevent damage and compaction, access must be able to accommodate a backhoe working at “arms length”.

6.7.4 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.

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

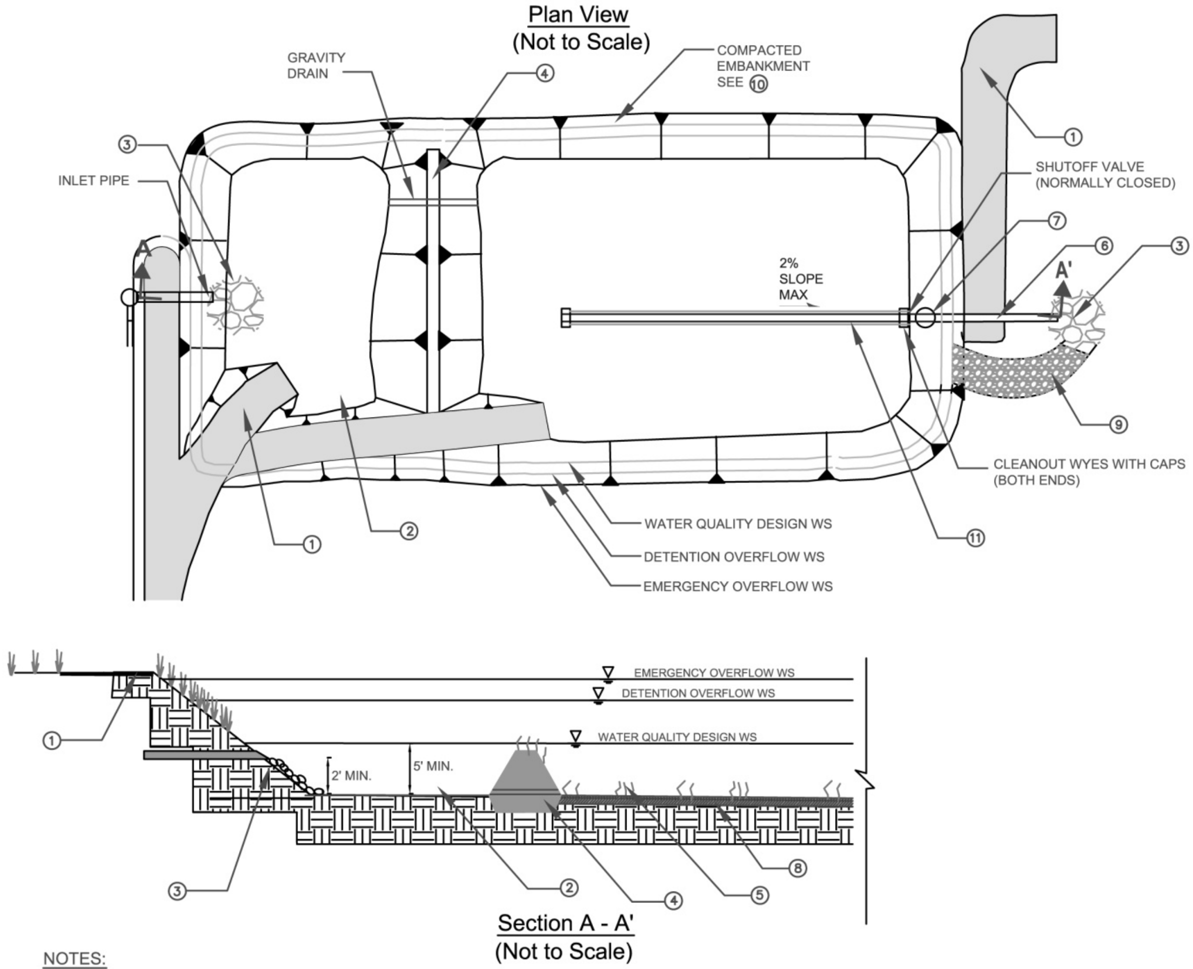
1. The entire area draining to the facility must be stabilized before construction begins. If this is impossible, a diversion berm must be placed around the perimeter of the infiltration site to prevent sediment entrance during construction.

2. Infiltration BMPs shall not be hydraulically connected to the storm water conveyance system until all contributing tributary areas are stabilized as shown on the Contract Plans and to the satisfaction of the Engineer. Infiltration BMPs shall not be used as sediment control facilities.

3. Compaction of the subgrade with heavy equipment shall 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 shall be restored by tilling or aerating prior to placing the infiltrative bed.

4. The exposed soils must be inspected by a civil engineer after excavation to confirm that soil conditions are suitable.

Figure 6-12: Infiltration Basin Schematic



NOTES:

1. MAINTENANCE RAMP SHOULD BE PAVED. WIDTH SHALL BE A MINIMU OF 16' AND SLOPE SHALL NOT EXCEED 12%. MAINTENANCE RAMP SHOULD PROVIDE ACCESS TO BOTH THE FIRST CELL AND MAIN BASIN.
2. UPSTREAM PRETREATMENT SHALL BE PROVIDED. SEDIMENT FOREBAY WITH VOLUME EQUAL TO 25% OF TOTAL INFILTRATION BASIN VOLUME MAY BE USED IN LIEU OF UPSTREAM PRETREATMENT. DEPTH SHALL BE 4' TO 8' PLUS AN ADDITIONAL 1 FOOT MIN SEDIMENT STORAGE DEPTH.
3. RIPRAP APRON OR OTHER ENERGY DISSIPATION.
4. EXTEND EARTHEN BERM ACROSS ENTIRE WIDTH OF THE INFILTRATION BASIN.
5. INFILTRATION BASIN BOTTOM AND SIDE SLOPES SHALL BE PLANTED WITH DROUGHT TOLERANT VEGETATION. DEEP ROOTED VEGETATION PREFERRED FOR BASIN BOTTOM. NO TOPSOIL SHALL BE ADDED TO INFILTRATION BASIN BED.
6. SIZE OUTLET PIPE TO PASS 100-YEAR PEAK FLOW FOR ON-LINE INFILTRATION BASINS AND WATER QUALITY PEAK FLOW FOR OFF-LINE INFILTRATION BASINS. OUTLET PIPE DIAMETER SHALL BE A MINIMUM OF 18".
7. WATER QUALITY OUTLET STRUCTURE. SEE FIGURE 6-25 AND FIGURE 6-26 FOR DETAILS.
8. OVER EXCAVATE BASIN BOTTOM 1 FOOT. RE-PLACE EXCAVATED MATERIAL UNIFORMLY WITHOUT COMPACTION. AMENDING EXCAVATED MATERIAL WITH 2" - 4" OF COARSE SAND IS RECOMMENDED FOR SOILS WITH BORDER LINE INFILTRATION CAPACITY.
9. INSTALL EMERGENCY OVERFLOW SPILLWAY AS NEEDED. SEE FIGURE 6-32 FOR DETAILS.
10. EMBANKMENT SIDE SLOPES SHALL BE NO STEEPER THAN 4H:1V BOTH OUTSIDE AND INSIDE. FENCING SHOULD BE PROVIDED FOR EMBANKMENT SLIDE SLOPES GREATER THAN 6H:1V OR DEPTH EXCEEDS 2'.
11. INSTALL OPTIONAL 6" MINIMUM DIAMETER PERFORATED PIPE UNDERDRAIN. INSTALL AT 0.5% MINIMUM SLOPE.

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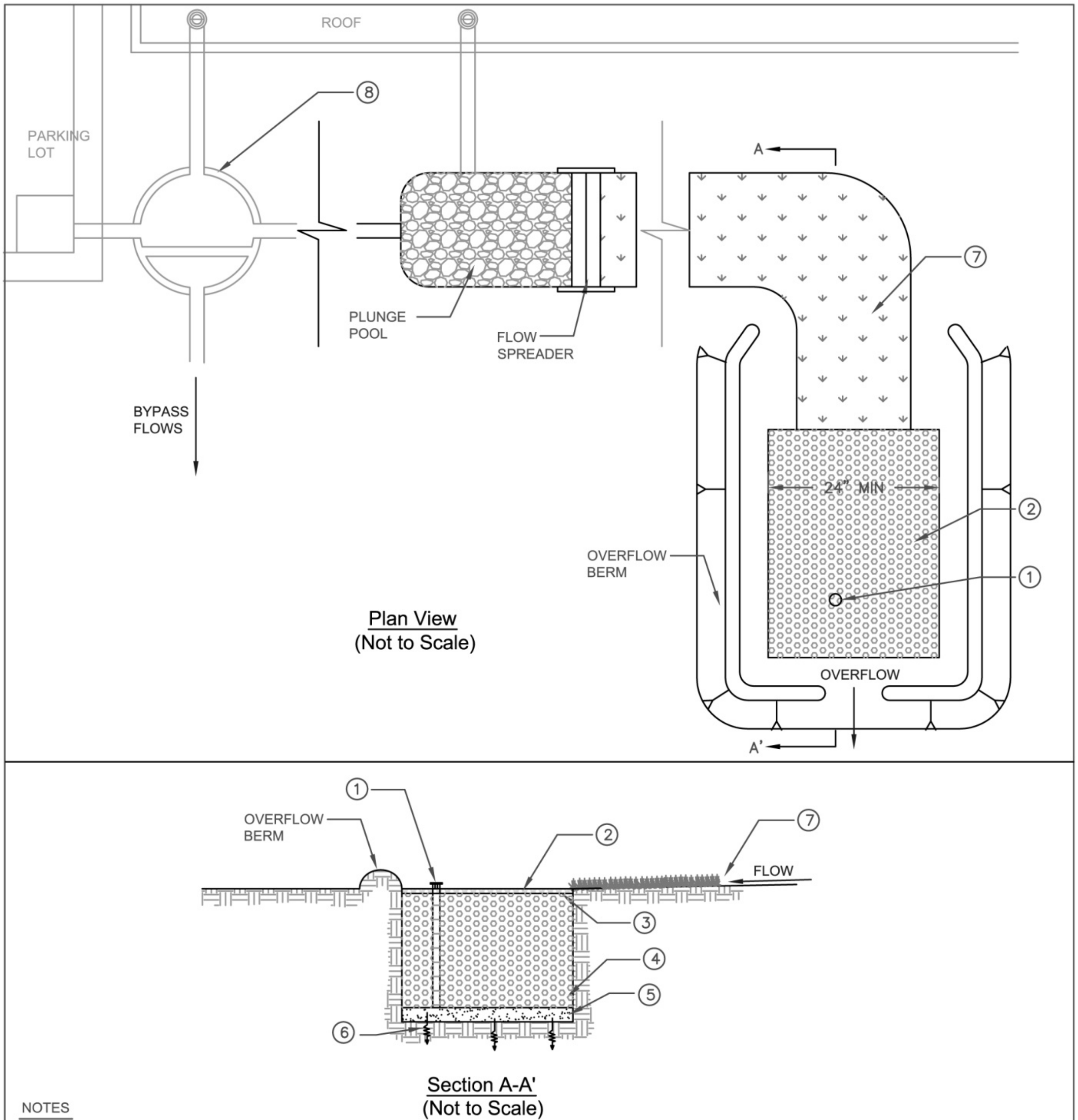
Figure 6 - 12
INFILTRATION BASIN

Figure 6-13: Infiltration Trench Schematic



NOTES

1. OBSERVATION WELL WITH LOCKABLE ABOVE-GROUND CAP.
2. 2" PEA GRAVEL FILTER LAYER.
3. PROVIDE FILTER FABRIC OR CHOKING STONE LAYER IF NO PRETREATMENT IS PROVIDED.
4. 3' - 5' DEEP TRENCH FILLED WITH 1.5" - 3.0" DIAMETER CLEAN GRAVEL WITH 30% - 40% VOIDS.
5. 6" DEEP SAND FILTER LAYER, CHOKING STONE LAYER, OR FABRIC EQUIVALENT.
6. RUNOFF INFILTRATES THOUGH UNDISTURBED SUBSOILS AT A MINIMUM RATE OF 0.5" PER HOUR.
7. RUNOFF FILTERS THROUGH GRASS FILTER STRIP OR VEGETATED SWALE.
8. OPTIONAL FLOW CONTROL DEVICE FOR OFF-LINE CONFIGURATIONS.

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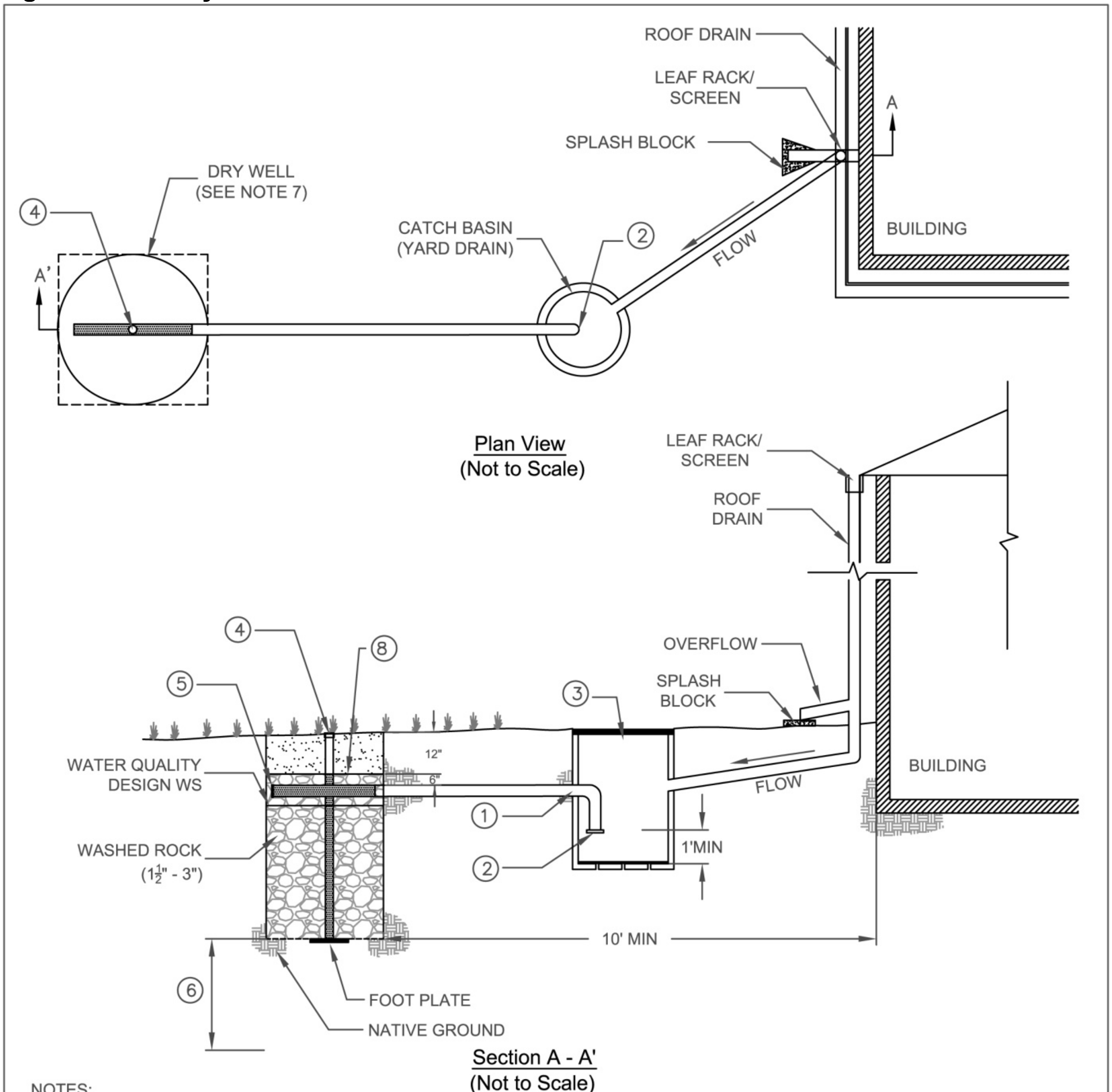
Figure 6 - 13
INFILTRATION TRENCH

Figure 6-14: Dry Well Schematic



NOTES:

1. MINIMUM 4" - 6" DIAMETER PVC PIPE. INSTALL AT FLAT SLOPE.
2. INSTALL FINE MESH SCREEN AT INLET TO DRY WELL. SET INLET ELEVATION AT 1' MINIMUM ABOVE CATCH BASIN BOTTOM.
3. CATCH BASIN (YARD DRAIN) INSTALLED WITH A SOLID LID FLUSH WITH GROUND SURFACE.
4. 4-6" VERTICAL PERFORATED PVC INSPECTION WELL WITH SCREW LID (NUT DOWN) FLUSH WITH GROUND SURFACE.
5. CAP END OF 4-6" HORIZONTAL PERFORATED PVC DISPERSION PIPE.
6. MINIMUM 10' ABOVE SEASONAL HIGH GROUNDWATER TABLE AND 3' ABOVE BEDROCK.
7. DRY WELL CONFIGURATION MAY VARY (E.G. PRE-FAB MAY BE CIRCULAR).
8. FILTER FABRIC OR CHOKING STONE LAYER SHALL BE PLACED ON TOP OF THE DRY WELL TO SEPARATE IT FROM THE TOPSOIL AND PREVENT CLOGGING.

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Figure 6 - 14
DRY WELL

6.7.5 Operations and Maintenance

General Requirements

Infiltration facility maintenance shall include frequent inspections to ensure that water infiltrates into the subsurface completely within the recommended infiltration time of 72 hours or less after a storm (see Appendix H 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 shall 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 or in the observation well of the infiltration trench or dry well more than 48 hours after a major storm, the infiltration facility may be clogged. Maintenance activities triggered by a potentially clogged facility include:

3. 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 City's jurisdiction, additional pretreatment operations (e.g., trash racks, vegetated swales, etc.) may be necessary.

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

5. For trenches and drywells, assess the condition of the top aggregate layer for sediment buildup and crusting. Remove top layer of pea gravel and sediment capture layer (i.e., sand and chocking stone layer or geotextile fabric) and replace. If slow draining conditions persist, entire trench or dry well may need to be excavated and replaced.

6. For trenches and drywells, if there is a tear in the filter fabric (if applicable), repair or replace.

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

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

9. Site vegetation shall be maintained as frequently as necessary to maintain the aesthetic appearance of the site, and as follows:

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

11. Slope areas that have become bare shall be revegetated and eroded areas shall be regraded prior to being revegetated.

12. Grass shall be mowed to 4”-9” high and grass clippings shall be removed.

13. Fallen leaves and debris from deciduous plant foliage shall be raked and removed.

14. 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*) must be removed and replaced with non-invasive species. Invasive species shall 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- http://www.cdfa.ca.gov/phpps/ipc/encycloweedia/encycloweedia_hp.htm or the California Invasive Plant Council website at www.cal-ipc.org.

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

16. For infiltration basins, sediment build-up exceeding 50% of the forebay capacity shall be removed. Sediment from the remainder of the basin shall be removed when 6 inches of sediment accumulates. Sediments shall 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 and the source of the contaminated sediments shall be investigated and mitigated to the extent possible.

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

Maintenance Standards

A summary of the routine and major maintenance activities recommended for infiltration BMPs is shown in Table 6-35. Detailed routine and major maintenance standards are listed in Table 6-36 and Table 6-37.

Table 6-35: Infiltration BMP Maintenance Quick Guide

Inspection and Maintenance Activities Summary	
Routine Maintenance	• Remove trash and debris as required • Repair and re-seed erosion near inlet if necessary • Remove any visual evidence of contamination from floatables such as oil and grease • Observation of drawdown times of BMP surface or within observation wells as applicable • Clean underdrain (if present) and outlet piping to alleviate ponding and restore infiltrative capacity. • Check for debris/sediment accumulation, rake surface and remove sediment (if any) and evaluate potential sources of sediment and debris • Remove minor sediment accumulation in pretreatment BMP and at the surface of the BMP, if applicable • Remove debris and obstructions near inlet and outlet structures as needed • Mow routinely to maintain ideal grass height and to suppress weeds • Periodically observe function under wet weather conditions • Photographs taken before and after maintenance is encouraged
Major Maintenance	• For basins, remove top layer of native soil to restore infiltrative capacity. Add soil amendments to promote infiltration • For trenches and drywells, remove top layer of pea gravel and sediment capture layer (i.e., sand and chocking stone layer or geotextile fabric). If slow draining conditions persist, entire trench or dry well may need to be excavated and replaced. • For trenches and drywells, if a tear is found in the geotextile filter fabric, if applicable, repair or replace. • Facilities shall be inspected annually prior to the beginning of the wet season. • For infiltration basins, remove sediment when build-up exceeds 50% of the forebay capacity. Sediment from the remainder of the basin shall be removed when 6 inches of sediment accumulates. • Following sediment removal activities, replanting and/or reseeding of vegetation may be required for reestablishment.

Table 6-36: Routine Maintenance – Infiltration BMPs

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Trash & Debris	Any trash and debris which exceed 5 cubic feet per 1,000 square feet (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.	Trash and debris cleared from site.	Annually prior to wet season. After major storm events (>0.75 in/24 hrs) if spot checks indicate widespread damage/ maintenance needs. Litter removal is dependent on site conditions and desired aesthetics and shall be done at a frequency to meet those objectives.
Inlet erosion	Visible evidence of erosion occurring near inlet structures.	Eroded areas repaired/reseeded	
Visual contaminants and pollution	Any evidence of oil, gasoline, contaminants or other pollutants.	No contaminants or pollutants present.	
Slow drain time	Standing water long after storm has passed (after 48 to 72 hours), or visual inspection of wells (if available) indicates that design drain times are not being achieved.	Water drains within 48 to 72 hours. Drainage pipe is cleared, accumulated litter on surface is removed, and top 1-2” of pea gravel and sediment capture layer is replaced.	
Inlets blocked	Trash and debris or sediment blocking inlet structures.	Inlets clear and free of trash and debris.	
Appearance of poisonous, noxious or nuisance vegetation	Excessive grass and weed growth. Noxious weeds, woody vegetation establishing, Turf growing over rock filter.	Vegetation is mowed or trimmed to restore function. Weeds are removed to prevent noxious and nuisance plants from becoming established.	Monthly (or as dictated by agreement between County and landscape contractor).

Table 6-37: Major Maintenance – Infiltration BMPs

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Standing Water	Standing water long after storm has passed (after 24 to 48 hours), or visual inspection of wells (if available) indicates that design drain times are not being achieved	Design infiltration rate restored, either through excavation and replacement of filter media or surface sediment removal. If applicable, underdrain cleaned, reset or replaced.	As needed
Tear in Filter Fabric	When there is a visible tear or rip in the filter fabric allowing water to bypass the fabric.	Filter fabric repaired and/or replaced.	
Sediment Removal	Sediment build-up in forebay exceeds 50% of the forebay capacity and/or 6 inches of accumulation in the basin.	Sediment is removed, capacity of forebay and/or basin restored, and areas are replanted and/or reseeded as necessary to reestablish vegetation.	

6.8 Permeable Pavement BMPs

Figure 6-15: Permeable Pavers

Applications

- Parking Lots & Driveways
- Low traffic roads
- Boat ramps
- Golf cart paths

Advantages

- Allows runoff to infiltrate into subsoil; groundwater recharge
- Easily integrated into existing infrastructure

Limitations

- Not ideal for high traffic areas
- Not suitable for stormwater hotspot sites
- Requires extensive maintenance

6.8.1 Description

Permeable pavements are alternatives to conventional impervious asphalts and concretes. However, permeable pavements allow water to pass through them into a subsurface gravel layer that doubles as a storage/infiltration area and a structural base layer. Where site conditions allow, the subsurface gravel layer (open-graded base/sub-base) is configured to allow water to infiltrate into the surrounding subsoil. If site conditions do not allow for infiltration, the water is detained in the gravel storage layer and then routed to a storm water conveyance system. In either case, the initial infiltration through the surface layers increases the time of concentration, T_c, provides some filtering of pollutants, and decreases the peak flows. Only when the water is allowed to infiltrate does it significantly decrease the runoff volume. Depending on the infiltration rate measured during the Soil Assessment (see Chapter 3) and the type of land use (i.e., hotspot areas), it may be necessary to install an impermeable liner around the base layer as well as an underdrain system. There are several styles of permeable pavement available, including those that are poured in place (i.e., porous concrete and porous asphalt), and modular paving systems (i.e., interlocking concrete, grass and gravel pavers).

Pour in place permeable pavements

Pour in place permeable pavements are poured where they will ultimately be used and allowed to setup (cure) in place. Typically, the pore spaces in the pavement make up about 10% of the total surface area. Porous asphalt and porous concrete are similar to each other in that the porosity is created by removing the small aggregate or fine particles from the conventional recipe, which leaves stable air pockets (gaps through the material) for water to drain through into the subsurface. Porous concrete is rougher than its conventional counterpart, and unlike oil-based asphalt will not release harmful chemicals into the environment. These types of permeable pavements shall only be used in areas of slow and low traffic (e.g., parking lots, low traffic streets, pedestrian areas, etc.).

Modular paving systems

There are several varieties of pavers that allow for infiltration, including (but not limited to) interlocking concrete pavers, grass pavers, and gravel pavers. Typically, the pore spaces in the pavement make up about 10% of the total surface area. Interlocking concrete pavers are not porous themselves, rather the mechanism that allows them to interlock creates voids and gaps between the pavers that are filled with a pervious material and can withstand heavy loads. Grass and gravel pavers are nearly identical to each other in structure (rigid grid of concrete or durable plastic) but differ in their load bearing support capacities. The grids are embedded in the soil to support the loads that are applied, thereby preventing compaction, reducing rutting and erosion. Grass pavers are generally filled with a mix of sand, gravel, and soil to support vegetation growth (e.g., grass, low-growing groundcovers, etc.), which provides habitat, pollutant removal, and reduces storm water runoff volumes and rates. Grass pavers are good for low-traffic areas, while gravel pavers are good for high-frequency, low speed traffic areas. Gravel pavers differ from grass pavers in that they are filled with gravel (often underlain with a geotextile fabric to prevent the migration of the gravel into the subbase) which support greater loads and higher traffic volumes.

6.8.2 Performance, Applicability, and Limitations

Table 6-38 provides a summary of BMP performance, applicability, and limitations for permeable pavement areas. *It is important to note that information in these tables shall be used to provide general guidance for permeable pavement areas and shall not replace the evaluation performed by a water quality professional.*

Applicability and Performance

Table 6-38 and associated guidance provide general volume reduction capabilities and treatment effectiveness rankings for permeable pavement areas. Refer to Section 6.4 for the process that shall be used for selecting BMPs based on pollutants of concern. Refer to Table 6-1 to determine the ranking of permeable pavement BMPs for removal of pollutants of concern as compared with other storm water runoff BMPs provided in Chapter 6. Refer to Table 6-2 to assess the applicability of permeable pavement BMPs for your site based on site suitability considerations as compared with other storm water runoff BMPs provided in Chapter 6. Permeable pavement areas are volume-based BMPs intended, primarily, for water quality treatment and, depending on site slope and soil conditions, can provide high volume reduction (see Table 6-38). Where site conditions allow for infiltration (i.e., omitting underdrain), the volume reduction capability of permeable pavement areas can be used to meet the volume reduction requirement, $V_{reduction}$. In addition, for permeable pavement areas where underdrains are used with an impermeable liner, additional depth may be added to the subsurface gravel layer (open-graded base/sub-base) to provide additional storage and detention capacity. Permeable pavement areas can also be used to help meet the peak runoff discharge requirement. See Section 6.2 for specific storm water runoff requirements for Tier 3 projects.

Table 6-38: Volume Reduction & Treatment Effectiveness for Permeable Pavement

Storm Water Runoff BMP	Volume Mitigation (% of inflow)	Treatment Effectiveness for Pollutants of Concern[1]					
		Trash	Nutrients	Bacteria	Metals (particulate and dissolved fractions)	Sediment	Organics (hydro-carbons, oil, and grease)
Permeable Pavement	◓	○	◉	◓	◓	●	◓
Volume/Treatment Effectiveness: ● = Very High, ◓ = High, ◉ = Moderate, ◒ = Low, ○ = Very Low							

[1] Effectiveness may change based on design variations; standard BMP designs have been assumed.

Permeable pavement areas remove pollutants through physical, chemical, and biological mechanisms. Specifically, they use infiltration, absorption, microbial activity, plant uptake, sedimentation, and filtration. The subsurface gravel layer and subsoil beneath the facility (if designed for infiltration) adsorb pollutants to the aggregate and soil particles. In addition, biological degradation and chemical precipitation also lower pollutant concentrations. As the water filters through the permeable pavement layer, the subsurface gravel layer, and the subsoil, particulates and suspended solids are physically removed through filtration. The degree of infiltration, filtration, and adsorption in the subsoil is dictated by the soil type (i.e., clayey soils will adsorb and filter more pollutants than sandy soils, while sandy soils will infiltrate the water more quickly). The removal of nitrogen depends on the degree of infiltration into the subsoil where microbial activity can convert nitrogen. Vegetation that is present in grass pavers increases the amount of biological treatment by providing treatment within the structure itself. Other permeable pavement surfaces can also provide biological treatment within the structure itself and to different degrees depending on the level of pollutants in the source water and the permeable pavement type. Microbial bacteria will begin forming over time within the pavement pore spaces providing treatment as the water flows through.

Site Suitability Recommendations and Limitations

Table 6-39 and associated guidance provide general considerations for assessing a site's suitability for permeable pavement.

Table 6-39: Site Suitability Considerations for Permeable Pavement

BMP	Tributary (Site) Area (Acres)[1]	Site Slope (%)	Depth to Seasonally High Groundwater Table (ft)	Hydrologic Soil Group	Horizontal Setback from Drinking Water Wells (ft)
Permeable Pavement	< 5 [2]	< 5 [3,4]	> 2 with underdrains; > 5 without underdrains	Underdrains shall be provided for "C" and "D" soils	100 [5]

[1] Tributary area is the area of the site draining to the BMP. Tributary areas provided here shall be used as a general guideline only. Tributary areas can be larger or smaller in some instances.

[2] Impervious surfaces draining to the BMP are limited to surfaces immediately adjacent to the permeable pavement, rooftop runoff, or other surfaces that do not contain significant sediment loads.

[3] If slope exceeds given limit or is within 200 feet from the top of a hazardous slope or landslide area, a geotechnical investigation is required.

[4] If a gravel base is used for storage of runoff: (1) slopes shall be restricted to 0.5% (steeper grades reduce storage capacity) and (2) underdrains shall be used if within 50 feet of a sensitive steep slope.

[5] Setbacks apply to systems without underdrains or systems underlain by "A" or B" hydrologic soil groups.

Table 6-40 provides additional site applicability considerations for special design districts within the City including coastal bluff areas and hillside design districts.

Table 6-40: Applicability of Permeable Pavement for Special Design Districts

Coastal Bluff Area	Hillside Design District
Acceptable if: (1) the facility is fully contained with an impermeable liner, underdrain system, and overflow to a storm water conveyance system, and (2) the site slope meets the criteria provided in Table 6-39.	Acceptable if: (1) a geotechnical investigation proves that the facility does not compromise the stability of the site slope or surrounding slopes, or (2) the facility is fully contained with an impermeable liner, underdrain system, and overflow to a storm water conveyance system.

The following describes additional site suitability recommendations and limitations for permeable pavement.

- The tributary area (area draining to the permeable pavement) shall be less than 5 acre
- If located on a site with a slope greater than 2%, the permeable pavement area shall be terraced to prevent lateral flow through the subsurface
- If located in an area with soil infiltration rates less than 0.05 in/hr or greater than 2.4 in/hr, an underdrain shall be provided.

- Seasonal high groundwater table shall be at least 2 ft lower than the bottom of the permeable pavement system if underdrains area provided and 5 ft lower than the bottom of the permeable pavement system if underdrains are not provided.
- If no underdrains and no impermeable membrane, permeable pavement areas shall not be placed within 100 feet of a drinking water well or a structural foundation (upgradient), or within 10 feet of a structural foundation (downgradient).
- If underdrains are provided, site must have adequate relief between land surface and the storm water conveyance system to permit vertical percolation through the gravel drainage layer (open-graded base/sub-base) and underdrain to the storm water conveyance system.
- Shall not be located in hotspot areas where environmental releases may occur (e.g., commercial sites, gas stations).
- Permeable pavement located within 50 feet of a sensitive steep slope shall incorporate an underdrain. A geotechnical investigation and report must be provided to address the potential effects of infiltration on steep slopes if the permeable pavement area promotes infiltration (i.e., does not have underdrains) and is within 200 feet of the slope or mapped landslide area.
- Porous concrete and porous asphalt shall not be located in areas where sand tends to accumulate. Sand will clog the surface.
- Gravel-pave must be at least 200 feet from the street for driveways and parking areas preventing gravel from being displaced from vehicle tires onto streets. If the driveway or parking area is to be used for fire access, approval must be provided from the City fire department. Gravel-pave shall not be placed on walkways that are required to be handicap accessible.
- The type of pedestrian traffic shall be considered when determining which type of permeable pavement to use in a particular locations (e.g., pavers may not be a good option for locations where people will be walking wearing high heels)

Multi-Use and Treatment Train Opportunities

Permeable pavement areas can be applied in various settings, including:

- Individual lot driveways, walkways
- Parking lots, overflow parking lots
- Low-traffic roads
- High-traffic (with low speeds) roads/lots
- Golf cart paths
- Within right-of-ways along roads
- In parks and along open space edges

In addition, permeable pavement areas can be combined with other basic and storm water runoff BMPs to form a “treatment train” that can provide enhanced water quality treatment and reductions in runoff volume and rate. For example, overflow from permeable pavement can be directed to a vegetated swale or a bioretention area for further treatment, volume reduction, and, flow control. Both facilities can be reduced in size based upon demonstrated performance for meeting the storm water runoff requirements as outlined in Section 6.2 and addressing targeted pollutants of concern.

6.8.3 Design Criteria and Procedure

The main challenge associated with permeable pavement is sediment removal, which is critical to performance of this BMP. A schematic illustrating permeable pavement is provided in Figure 6-16.

Principal design criteria for permeable pavement are listed in Table 6-41.

Table 6-41: Permeable Pavement Design Criteria

Design Parameter	Unit	Design Criteria
Water quality design volume, V_{wq}	ft^3	See Section 6.2 and Appendix C for calculating V_{wq}.
Volume reduction requirement, $V_{reduction}$	ft^3	Only applicable for configurations that do not use underdrains. See Section 6.2 and Appendix C for calculating $V_{reduction}$.
Pretreatment	-	Runoff from pervious areas shall be minimized but, if provided, a vegetated swale or filter strip shall be provided for all runoff from off-site sources that are not directly adjacent to the permeable pavement.
Drawdown time of gravel drainage layer	hrs	72 (maximum)
Minimum depth to bedrock	ft	3
Minimum depth to seasonal high water table	ft	2 (with underdrains); 5 (without underdrains)
Maximum site slope	%	5
Infiltration rate of subsoil	in/hr	0.05 (minimum); 2.4 (maximum)
Underdrain	-	6 inch minimum diameter; 0.5% minimum slope
Overflow device	-	Required

Pretreatment

1. Depending on how and where permeable pavement will be used, pretreatment of the runoff entering the pavement may be necessary. This is particularly important when the pavement will be accepting run-on from pervious areas or areas that are not completely stabilized. If this is the case, then the run-on shall be treated prior to contacting the permeable pavement. Without adequate pretreatment, the life of the permeable pavement may be significantly decreased.

2. If sheet flow is conveyed to the treatment area over stabilized grassed areas, the site must be graded in such a way that minimizes erosive conditions.

Geometry and Size

1. Permeable pavement shall be sized to capture and treat the water quality design volume, V_{wq}. Where site conditions allow for infiltration, the permeable pavement may also be sized to infiltrate the volume reduction requirement, $V_{reduction}$. For permeable pavement designs that allow for partial infiltration (i.e., there is a permeable membrane between the gravel layer and subsoil), then 20% of the design detention volume, $V_{detention}$, of the subsurface gravel layer (open-graded base/sub-base) can be assumed to infiltrate allowing partial infiltration permeable pavement facilities to gain credit towards meeting the volume reduction requirement. See Section 6.2 and Appendix C for further detail.

2. Depth of each layer shall be determined by a licensed civil engineer based on analyses of not only the hydrology and hydraulics, but also the structural requirements of the site.

3. Permeable pavement (including the base layers) shall be designed to drain in less than 72 hours. Intent: 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.*

Sizing Methodology

Permeable pavement shall be sized to capture and treat the water quality design volume, V_{wq}, and where site conditions allow, shall also be sized to infiltrate the volume reduction requirement, $V_{reduction}$. See Section 6.2 and Appendix C for specific sizing requirements and calculation methodologies. Procedures for sizing permeable pavement are summarized below. A permeable pavement sizing example is provided in Appendix D.

Step 1: Calculate the volume required for sizing

The volume required for sizing the subsurface gravel layer (open-graded base/sub-base) depends on whether the system will be designed for no infiltration, partial infiltration, or full infiltration:

1. **No infiltration -** if underdrains are required and no infiltration is acceptable into the subsoil (i.e., an impermeable membrane must be used), the volume of the gravel drainage layer shall be sized to accommodate the water quality design volume, V_{wq}.

2. **Partial infiltration** - If underdrains are required but partial infiltration is acceptable (i.e., a permeable membrane may be used and the soil type is of type B or C), the gravel drainage layer can be sized to accommodate the water quality design volume, V_{wq}, plus an additional 20% of V_{wq}. This would be advantageous if the volume reduction requirement, $V_{reduction}$, is greater than V_{wq} since it provides an additional credit towards meeting the volume reduction requirement. In this situation, it is assumed that 20% of the volume in the drainage layer will infiltrate into the subsoil rather than enter the underdrain and; therefore, a credit is given of $0.2*V_{wq}$ towards meeting the volume reduction requirement.

3. **Full infiltration** - If underdrains are not provided and infiltration is allowed, the design volume, V_{design}, is the larger of the water quality design volume, V_{wq}, and the volume reduction requirement, $V_{reduction}$.

Step 2: If underdrains are incorporated, determine the required depth of the gravel drainage layer (open-graded base/sub-base). If underdrains will not be incorporated, skip to Step 3.

If underdrains are incorporated, the gravel drainage layer may be designed depending on whether there is no infiltration or partial infiltration. If there is no infiltration, $V_{design} = V_{wq}$. If there is partial infiltration, $V_{design} = V_{wq} + 0.2*V_{wq}$.

$$d_{min} = \frac{V_{design}}{A * n}$$ (Equation 6-28)

Where:

d_{min}	=	minimum depth of gravel drainage layer (feet)
V_{design}	=	design volume of runoff to be treated/infiltrated (ft^3)
n	=	gravel drainage layer porosity (unitless)
A	=	surface area of gravel drainage layer (ft^2)

Step 3: If underdrains will not be incorporated, calculate the design infiltration rate, k_{design}, of the native subsoil

See the Bioretention Area Section 6.6.1 for the method used to determine the design infiltration rate of the native subsoil.

Step 4: Sizing calculations for permeable pavement if no underdrains are incorporated.

As with infiltration BMPs, permeable pavement can be sized using one of two methods: a simple sizing method or a routing modeling method. With either method, the runoff entering the facility must be completely infiltrated within 72 hours. Permeable pavement provides all of its storage in the voids of the gravel drainage layer (open-graded base/sub-base). The simple sizing procedure is described below. For the routing modeling method, refer to the Bioretention Area Section 6.6.1.

Simple Method. Determine the size of the required infiltrating surface by assuming the design runoff volume (i.e., all or part of the water quality design volume, V_{wq}, or the volume reduction requirement, $V_{reduction}$, whichever is larger) will fill the available void spaces based on the computed porosity of the gravel drainage layer media (normally about 32% for gravel).

Determine the maximum depth of runoff that can be infiltrated within the required drain time (72 hr) as follows:

$$d_{max} = \frac{k_{design}}{12} \times t \qquad \text{(Equation 6-29)}$$

Where:

t	=	required drain time (hrs) [Use 72 hours]
k_{design}	=	infiltration rate of native subsoil soils (in/hr)
d_{max}	=	the maximum depth of water that can be infiltrated within the required drain time (ft)

Choose the gravel drainage layer depth (l) such that:

$$d_{max} \geq n \times l \qquad \text{(Equation 6-30)}$$

Where:

n	=	gravel drainage layer porosity (unitless)
l	=	depth of gravel drainage layer (ft)
d_{max}	=	the maximum depth of water that can be infiltrated within the required drain time (ft)

Calculate the infiltrating surface area (filter bottom area) required:

$$A = \frac{V_{design}}{\frac{Tk_{design}}{12} + nl} \qquad \text{(Equation 6-31)}$$

(Adapted from Georgia Stormwater Manual: http://www.georgiastormwater.com/vol2/3-2-5.pdf)

Where:

V_{design}	=	design volume of runoff to be infiltrated (ft^3)
n	=	gravel drainage layer porosity (unitless)
k_{design}	=	design infiltration rate (in/hr)
l	=	depth of gravel drainage layer (ft)
T	=	fill time (time to fill infiltration BMP with water) (hrs) [use 2 hours for most designs]
A	=	surface area of gravel drainage layer (ft^2)

Permeable Pavement Material Layer

This is the top layer and consists of either poured in place materials (i.e., porous concrete and porous asphalt), or modular paving materials (i.e., interlocking concrete, grass and gravel pavers). The thicknesses of these layers vary depending on design. Concrete pavers shall have a minimum thickness of 3 1/8".

Bedding Course Layer

1. A layer of smaller sized aggregate (e.g., No. 8) just under the permeable pavement provides a level surface for installing the permeable pavement and also acts as a filter to trap particles and help prevent the reservoir layer from clogging.

2. Bedding course layer is typically about 1.5" to 3" inches deep and may be underlain by a geotextile fabric or choking stone to prevent the smaller sized aggregate from migrating into the larger aggregate base layer.

Geotextile Layer

If a geotextile fabric is used, it must meet the minimum materials requirements shown in the table below.

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

Liner Layer

Geomembrane liners shall have a minimum thickness of 30 mils.

Subsurface Gravel Layer

1. Must be designed to function as a support layer as well as a reservoir layer
   a. Consideration must be given to the soil conditions as well as the expected loads
2. This layer may be divided into two layers, a filter layer that underlies the choking layer and a reservoir layer (typically washed, open-graded No. 57 aggregate without any fine sands)

3. If infiltration or partial infiltration is allowed, a geotextile fabric, choking stone, or both shall be placed on top of the subsurface gravel layer. If no infiltration is allowed, an impermeable liner shall surround the subsurface gravel layer. See above for typical specifications for each.

4. The subsurface gravel layer shall have zero slope (i.e., level).

5. The drawdown time for the subsurface gravel layer shall not exceed 72 hours.

Underdrains

If site conditions allow (i.e., soil infiltration rate and site slope are adequate), the volume reduction capability of permeable pavement areas can be enhanced by omitting the underdrain.

If underdrains are required, then they must meet the following criteria:

1. 6-inch minimum diameter.

2. Underdrains must be made of slotted, polyvinyl chloride (PVC) pipe conforming to ASTM D 3034 or equivalent or corrugated high density polyethylene (HDPE) pipe conforming to AASHTO 252M or equivalent. *Intent: As 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 shall 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 shall be 0.04 to 0.1-inch and shall have a length of 1-inch to 1.25-inch. Slots shall be longitudinally spaced such that the pipe has a minimum of one square inch per lineal foot.

4. Underdrains shall be sloped at a minimum of 0.5%.

5. Rigid non-perforated observation pipes with a diameter equal to the underdrain diameter shall be connected to the underdrain every 250 to 300 feet to provide a clean-out port as well as an observation well to monitor dewatering rates. The wells/cleanouts shall be connected to the perforated underdrain with the appropriate manufactured connections. The wells/cleanouts shall be placed flush with the pavement surface and shall be capped with a lockable screw cap. The ends of underdrain pipes not terminating in an observation well/cleanout shall also be capped.

6. The following aggregate gradation (i.e., drain rock) shall be used to provide a gravel blanket and bedding for the underdrain pipe. Place the underdrain on a 3-foot wide bed of the drain rock at a minimum thickness of 6 inches and cover with the same aggregate 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

7. At the option of the designer, a geotextile fabric may be placed between the subsurface gravel layer and the drain rock although it is preferable to place the geotextile fabric between the permeable pavement material and the subsurface gravel layer for easier maintenance if the geotextile becomes clogged. If a geotextile fabric is used it must meet the minimum materials requirements as discussed above. Another option is to place a thin, 2- to 4-inch layer of pure sand and a thin layer (nominally two inches) of choking stone (such as #8) between the subsurface gravel layer and the drain rock.

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, daylight to a vegetated dispersion area using an effective flow dispersion device, stored for reuse, or to a storm water conveyance system.

Overflow

An overflow mechanism is required. Two options are provided:

Option 1: Perimeter control

1. Flows in excess of the design capacity of the permeable pavement system will require an overflow system connected to a downstream conveyance or other storm water runoff BMP. In addition, if the pavement becomes clogged and infiltration decreases to the point that there is ponding, the runoff will migrate off of the pavement via overland flow instead of infiltrating into the subsurface gravel layer. There are several options for handling overflow using perimeter controls such as:
   a. Perimeter vegetated swale
   b. Perimeter bioretention
   c. Storm drain inlets
   d. Rock filled trench that funnels flow around pavement and into the subsurface gravel layer

Option 2: Overflow pipe(s)

1. A vertical pipe shall be connected to the underdrain.
2. The diameter, location, and quantity vary with design and shall be determined by a licensed civil engineer
3. Shall be located away from vehicular traffic.
4. May incorporate an observational and/or cleanout well.
5. Top of overflow pipe shall be covered with a screen fastened over the overflow inlet.

6.8.4 Construction Considerations

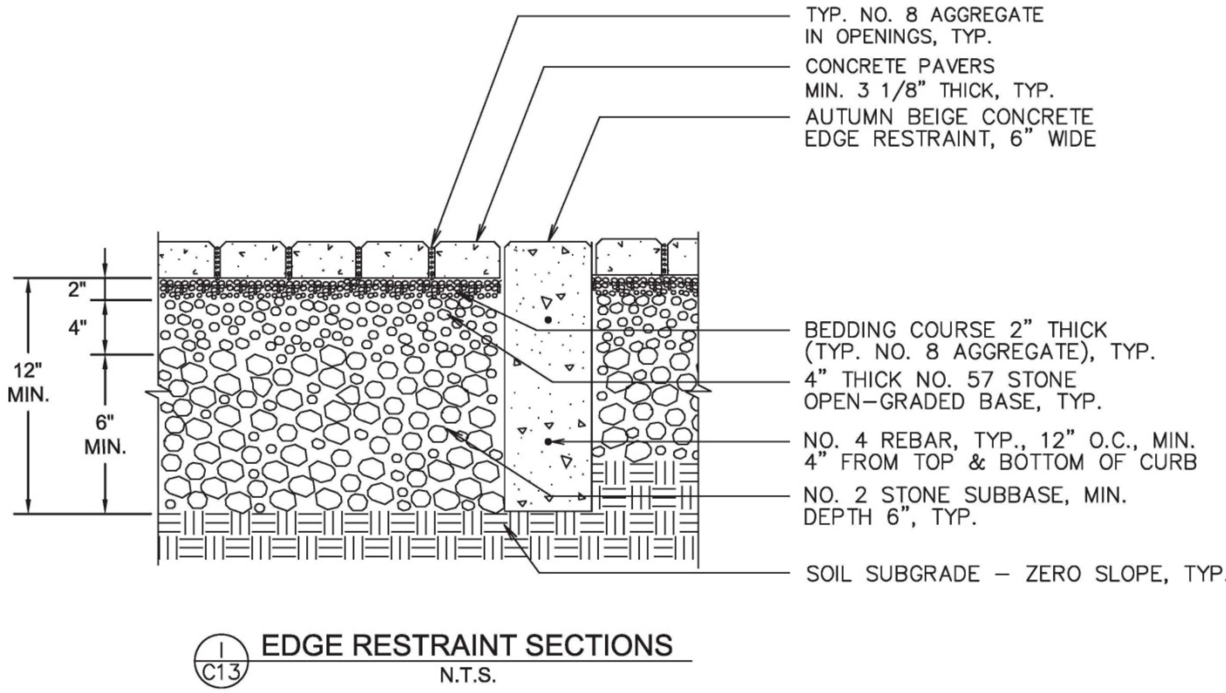
1. Permeable pavement shall be laid close to level, the bottom of the base layers must be level to ensure uniform infiltration.
2. Permeable pavement surfaces shall not be used to store site materials, unless the surface is well protected from accidental spillage or other contamination.
3. To prevent/minimize soil compaction in the area of the permeable pavement installation, use light equipment with tracks or oversized tires.

4. Divert storm water from the area as needed (before and during installation)

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

6. Vehicular traffic shall be prohibited for at least 2 days after installation.

Figure 6-16: Permeable Pavement Schematic



All gravel base below the pavers is open graded, crushed aggregate. This means the gravel is not mixed with sand so there are open spaces between the rocks for water storage, and it is angular so the gravel pieces lock together once compacted. This design example uses a minimum 6" layer of No. 2 (2"-4") gravel sits on top of a level soil subgrade. On top of that is a 4" thick layer of No. 57 (1/4"-1") gravel. On top of that is a 2" layer of No. 8 aggregate (1/8"-1/2") which serves as a bedding layer for the permeable pavers. This No. 8 aggregate is also placed between the pavers.

6.8.5 Operations and Maintenance

General Requirements

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 shall 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 (3-4 times per year, or more frequently depending on site 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; also, to help prolong the functional period of the pavement.

4. Inspect for vegetation growth on pavement and remove when present.

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

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

7. Spot clogging of porous concrete may be remedied by drilling 0.5" holes every few feet in the concrete.

8. Interlocking pavers that are damaged shall be replaced.

9. Maintain landscaped areas; reseed bare areas.

Maintenance Standards

A summary of the routine and major maintenance activities recommended for permeable pavement is shown in Table 6-42. Detailed routine and major maintenance standards are listed in Table 6-43 and Table 6-44.

Table 6-42: Permeable Pavement Maintenance Quick Guide

Inspection and Maintenance Activities Summary	
Routine Maintenance	• Clean area of trash and debris accumulations • Prevent the washing of soil onto the pavement • Clean area of sediments; vacuum sweep frequently (3-4 times/year) • Check that paving is draining properly • Maintain landscaped areas o Seed bare areas • Inspect outlets
Major Maintenance	• Restore infiltration rates caused by clogging • Repair any signs of deterioration, roughening, ruts or depressions • Sub-surface layers may require cleaning and/or replacing

Table 6-43: Routine Maintenance – Permeable Pavement

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Sediment Accumulation	Sediment is visible	Sediment deposits removed	Semi-annually, prior to wet season and after the wet season After major storm events (>0.75 in/24 hrs) if spot checks indicate widespread damage/ maintenance needs
Missing gravel/sand fill	There are noticeable gaps in between pavers	There are not gaps in between pavers	
Weeds/mosses filling voids	Vegetation is growing in/on permeable pavement	No vegetation growth	

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Trash and Debris Accumulation	Trash and debris accumulated on the permeable pavement.	Trash and debris removed from permeable pavement.	Monthly or quarterly (or as dictated by agreement between City and landscape contractor) Litter removal frequency is dependent on site conditions and desired aesthetics and shall be done at a frequency to meet those objectives
Dead or dying vegetation in adjacent landscaping	Vegetation is dead or dying leaving bare soil prone to erosion	Vegetation is managed and soil is stabilized	
Surface clog	Clogging is evidenced by ponding on the surface	Well draining surface	Ongoing
Overflow clog	• Excessive build up 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	Well draining system with adequate flow out	
Visual contaminants and pollution	Any visual evidence of oil, gasoline, contaminants or other pollutants.	No visual contaminants or pollutants present.	
Erosion	Tributary area • Exhibits signs of erosion • Noticeably not completely stabilized	Tributary area completely stabilized	

Table 6-44: Major Maintenance – Permeable Pavement

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Deterioration/ Roughening	Integrity of pavement is compromised (i.e., cracks, depressions, crumbling, etc.)	Smooth and even surface	As needed
Subsurface Clog	Clogging is evidenced by ponding on the surface and is not remedied by addressing surface clogging.	Well draining system; excavation of pavement and gravel drainage layer is required.	

6.9 Building BMPs

6.9.1 Cistern/Rain barrel

Figure 6-17: Typical Above Ground Cistern

Applications

- Any type of land use, provided adequate end use of water
- Collect rooftop runoff

Advantages

- Volume & peak flow reduction
- Collects stormwater for alternative on-site uses

Limitations

- Only treat rooftop runoff
- Must be monitored regularly to ensure that there is adequate storage capacity
- Regulatory obstacles may limit reuse opportunities

6.9.1.1 Description

Cisterns are large rain barrels (Section 5.6). While rain barrels are less than 100 gallons, cisterns range from 100 to 10,000 gallons in capacity. Cisterns collect and temporarily store runoff from rooftops for later use as irrigation and/or other non-potable uses. The following components are required for installing and utilizing a cistern: (1) pipes that divert rooftop runoff to the cistern, (2) an over flow for when the cistern if full, (3) a pump, and (4) a distribution system to get the water to where it is intended to be used.

6.9.1.2 Applicability, Performance, and Limitations

Cisterns come in a variety of materials, which shall be chosen based on its location (aboveground or underground) and the size required.

Applicability and Performance

Building BMPs are generally intended for achieving volume reduction and flow control of roof drainage. Depending on the rate of water use from the cistern, it may be emptied, remain full, or be somewhere between empty and full when the next storm event takes place. It is only effective for volume reduction if the cistern is emptied between storm events. In most cases, it is not practical to capture all of the water quality treatment volume, V_{wq}, or volume reduction requirement, $V_{reduction}$, using cisterns as they would be impractically large. Treatment effectiveness of cisterns (and other building BMPs) are not comparable to other BMPs in Chapter 6 that treat runoff from a wide range of impervious surfaces that generally have higher pollutant concentrations than cisterns which mainly capture roof runoff. In general, cisterns provide little pollutant reduction although irrigation of stored roof runoff may have nutrients and small amounts of metals which may be used by the vegetation or adsorbed by soil particles.

Site Suitability Recommendations and Limitations

Table 6-45 and associated guidance provide general considerations for assessing a site's suitability for cisterns.

Table 6-45: Site Suitability Considerations for Cisterns

BMP	Tributary Area (Acres; Sq.Ft.)[1]	Site Slope (%)	Depth to Seasonally High Groundwater Table (ft)	Hydrologic Soil Group	Horizontal Setback from Drinking Water Wells (ft)
Cistern/Rain Barrel	Depends on system size	Any	> 2 if tank is underground	Any	N/A

[1] Tributary area is the area of the site draining to the BMP. Tributary areas provided here shall be used as a general guideline only. Tributary areas can be larger or smaller in some instances.

Table 6-46 provides additional site applicability considerations for special design districts within the City including coastal bluff areas and hillside design districts.

Table 6-46: Applicability of Cisterns for Special Design Districts

Coastal Bluff Area	Hillside Design District
Acceptable if a geotechnical investigation is provided to ensure that the facility does not compromise the stability of the site slope or surrounding slopes. If the stored rain water is to be used for irrigation, City staff will determine how much (if any) water application to the bluff is appropriate.	Acceptable if a geotechnical investigation is provided to ensure that the facility does not compromise the stability of the site slope or surrounding slopes. If the stored rain water is to be used for irrigation, City staff will determine how much (if any) water application to the sloped property is appropriate.

The following describes additional site suitability recommendations for cisterns.

- Shall not be located on uneven or sloped surfaces.
- If installed on a sloped surface, the base where the cistern will be installed shall be leveled prior to installation.
- Shall be secured in place.

Multi-Use and Treatment Train Opportunities

A cistern can be combined into a treatment train to provide enhanced water quality treatment and reductions in runoff volume and rate. For example, if a green roof is placed upgradient of a cistern, the rate and volume of water flowing to the cistern can be reduced and the water quality enhanced. Each facility can be reduced in size accordingly based upon demonstrated performance for meeting the storm water runoff requirements as outlined in Section 6.2 and addressing targeted pollutants of concern. In addition, cisterns can be incorporated into the landscape design of a site and can be aesthetically pleasing as well as functional.

6.9.1.3 Design Criteria and Procedure

Cisterns shall be designed according to the current requirements of the City of Santa Barbara and the Santa Barbara County Flood Control and Water Conservation District.

Cistern Sizing

In most cases, it is not practical to capture all of the water quality treatment volume, V_{wq}, or volume reduction requirement, $V_{reduction}$, using cisterns as they would be impractically large. Cisterns are intended to capture and store runoff for use later. However, the effectiveness of a cistern for reducing runoff volumes and peaks depends on the cisterns effective storage capacity (i.e., the volume available for storage at the beginning of each event). Therefore, the size required varies based, not only on precipitation, but also usage. Cisterns may be operated in different configurations as discussed in the rain barrel section (Section 5.6). Due to the intricacies involved in considering a variable storage capacity, cisterns may only be sized to meet the volume reduction requirement using a continuous simulation model with a long-term precipitation record.

6.9.1.4 Construction Considerations

The foundation housing the cistern must be adequate to support the weight of the cistern and the water it will store.

6.9.1.5 Operations and Maintenance

General Requirements

1. Inspect cisterns, associated pipes, and valve connections for leaks.
2. Clean gutters and filters of debris that has accumulated and is obstructing flow into the cistern.
3. Clean and remove accumulated sediment annually.
4. Check cistern for stability and anchor if necessary.
5. Slopes in the vicinity of the cistern shall be stabilized and planted using appropriate erosion control measures when native soil is exposed or erosion channels are forming.
6. The cistern shall be well maintained; trash and debris, sediment, visual contamination (e.g., oils), and noxious or nuisance weeds shall all be removed.
7. If cistern is underground, ensure that manhole is accessible, operational, and secure.

Maintenance Standards

A summary of the routine and major maintenance activities recommended for cistern filters is shown in Table 6-47.

Table 6-47: Cistern Maintenance Quick Guide

Inspection and Maintenance Activities Summary	
Routine Maintenance	• Remove sediment and debris accumulation near inlet and outlet structures • Trash and debris removal • Remove any evidence of visual contamination from floatables such as oil and grease • Check cistern stability, anchor if necessary • Stabilize/repair minor erosion and scouring with gravel • Photographs taken before and after maintenance is encouraged
Major Maintenance	• Replace broken screens, spigots, valves, level sensors, etc. • Repair or replace damaged cistern

6.9.2 Planter Box

Figure 6-18: Planter Box

Photo Credit: The Low Impact Development Center

Applications

- Commercial, institutional, and residential
- Most commonly used in urban areas adjacent to buildings and sidewalks

Advantages

- Combines stormwater treatment with runoff conveyance
- Volume & peak flow reduction
- Pollutant removal
- Does not require a setback from building foundation

Limitations

- May require additional support on steep slopes
- Must be constructed with underdrain system to convey excess water to stormwater conveyance system

6.9.2.1 Description

Planter boxes, either elevated or at ground level, are designed to capture and temporarily store storm water runoff. Planter boxes are comprised of a variety of materials (usually chosen to be the same material as the adjacent building or sidewalk). The boxes are filled with gravel on the bottom (to house the underdrain system), planting soil media, and vegetation. Planter boxes may also require splash blocks for flow energy dissipation and geotextile filter fabric or choking stone to reduce clogging of the underdrain system. The storm water infiltrates into the soil where it is used by the plants, stored and filtered, if the runoff volume is large the storm water may even pond on the surface for a limited period of time. Planter boxes are intended to be placed next to buildings and installed with underdrains and an impervious liner. Once the soil becomes saturated, the excess water collects in the underdrain system where it may be routed to a storm water conveyance system or another storm water runoff BMP, such as a vegetated swale filter. Planter boxes are very similar in design to bioretention areas (see Section 6.6.1 for additional information) but are more practical for steep slope applications where the planter boxes can be terraced.

6.9.2.2 Applicability, Performance, and Limitations

Planter boxes are uniquely suited for redevelopment in urban areas. In addition, planter boxes are suitable for sites where infiltration practices are impractical or discouraged. Planter boxes are often designed to capture runoff from rooftop downspouts of commercial, industrial, and residential structures and offer peak discharge rate reduction and moderate volume reduction of roof drainage via evapotranspiration.

Applicability and Performance

Building BMPs are generally intended for reducing peak runoff discharge rates and providing volume reduction of roof drainage. While planter boxes do provide water quality treatment, treatment effectiveness of planter boxes (and other building BMPs) are not comparable to other storm water runoff BMPs in Chapter 6 that treat runoff from a wide range of impervious surfaces that generally have higher pollutant concentrations. If planter boxes are placed adjacent to a building, the area between the building foundation and the planter will need to be waterproofed so that the foundation is not compromised.

Site Suitability Recommendations and Limitations

Table 6-48 and associated guidance provide general considerations for assessing a site's suitability for planter boxes.

Table 6-48: Site Suitability Considerations for Planter Boxes

BMP	Tributary Area (Acres; Sq.Ft.)[1]	Site Slope (%)	Depth to Seasonally High Groundwater Table (ft)	Hydrologic Soil Group	Horizontal Setback from Drinking Water Wells (ft)
Planter Box	0.35 Acres; 15,000 Sq.Ft.	< 15 [4]	> 2	Any	N/A

[4] If system is fully contained and includes a liner, underdrain system, and overflow to a storm water conveyance system, then slopes can exceed 15%.

Table 6-49 provides additional site applicability considerations for special design districts within the City including coastal bluff areas and hillside design districts.

Table 6-49: Applicability of Planter Boxes for Special Design Districts

Coastal Bluff Area	Hillside Design District
Acceptable if: (1) the facility is fully contained with an impermeable liner, underdrain system, and overflow to a storm water conveyance system, and (2) the site slope meets the criteria provided in Table 6-48.	Acceptable if: (1) the facility is fully contained with an impermeable liner, underdrain system, and overflow to a storm water conveyance system, and (2) the site slope meets the criteria provided in Table 6-48.

The applicability of planter box areas is limited by the following site characteristics:

- The tributary area (area draining to the planter box area) shall be less than 15,000 sq. ft.
- Groundwater levels shall be at least 2 ft lower than the bottom of the planter box area
- Site must have adequate relief between land surface and the storm water conveyance system to permit vertical percolation through the planting media and underdrain to the storm water conveyance system
- Shall not be located in areas with excessive shade to avoid poor vegetative growth. For moderately shaded areas, shade tolerant plants shall be used.

- Shall not be located near large trees that may drop leaves or needles. Excessive tree debris may smother the grass or impede the flow through the swale.

Multi-Use and Treatment Train Opportunities

A planter box can be used in a treatment train to provide enhanced water quality treatment and reductions in runoff volume and rate. For example, if a planter box is placed upgradient of a cistern, the rate and volume of water flowing to the cistern can be reduced and the water quality enhanced. As another example, a planter box could be placed downstream of a downspout that drains the green roof. In both cases, each facility can be reduced in size accordingly based upon demonstrated performance for meeting the storm water runoff requirements as outlined in Section 6.2 and addressing targeted pollutants of concern. In addition, planter boxes can be incorporated into the landscape design of a site and can be aesthetically pleasing as well as functional.

6.9.2.3 Design Criteria and Procedure

Planter boxes shall be designed according to the current requirements of the City of Santa Barbara and the Santa Barbara County Flood Control and Water Conservation District. Standard design criteria for planter boxes are listed in Table 6-50. A planter box schematic is illustrated in

Table 6-50: Planter Box Design Criteria

Design Parameter	Unit	Design Criteria
Water quality design volume, V_{wq}	ft^3	See Section 6.2 and Appendix C for calculating V_{wq}.
Volume reduction requirement, $V_{reduction}$	ft^3	See Section 6.2 and Appendix C for calculating $V_{reduction}$.
Drawdown time of planting soil	hrs	48
Maximum ponding depth	inches	12
Planting soil depth	feet	2; 3 preferred
Stabilized mulch depth	inches	2 to 3
Planting media composition	-	60 to 70% sand, 15 to 25% compost, and 10 to 20% clean topsoil; organic content 8 to 12%; pH 5.5 to 7.5
Underdrain	-	6 inch. minimum diameter; 0.5% minimum slope
Overflow device	-	Required

Geometry and Size

1. Planter boxes areas shall be sized to capture and treat the water quality design volume, V_{wq}, with a 12-inch maximum ponding depth. See Section 6.2 and Appendix C for further detail on the storm water runoff requirements and associated calculations.

2. Planting soil depth shall be a minimum of 2 feet, although 3 feet is preferred. *Intent: The planting soil depth shall provide a beneficial root zone for the chosen plant palette and*

adequate water storage for the water quality design volume. A deeper planting soil depth will provide a smaller surface area footprint.

3. Planter boxes shall be designed to drain to below the planting soil depth in less than 48 hours. Intent: 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 to provide proper soil conditions for biodegradation and retention of pollutants.*

Sizing Methodology

Planter boxes are sized the same as bioretention areas with underdrains using parameters appropriate for planter boxes. See the Bioretention Area Section 6.6.1 for appropriate sizing calculations and the bioretention area sizing example in Appendix D.

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, shall include rock, splash blocks, or other erosion protection material 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 shall not be placed directly in the entrance flow path.

Underdrains

If underdrains are required, then they must meet the following criteria:

1. 6-inch minimum diameter.

2. Underdrains must be made of slotted, polyvinyl chloride (PVC) pipe conforming to ASTM D 3034 or equivalent or corrugated high density polyethylene (HDPE) pipe conforming to AASHTO 252M or equivalent. *Intent: As 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 shall 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 shall be 0.04 to 0.1-inch and shall have a length of 1-inch to 1.25-inch. Slots shall be longitudinally spaced such that the pipe has a minimum of one square inch per lineal foot.

4. Underdrains shall be sloped at a minimum of 0.5%.

5. Rigid non-perforated observation pipes with a diameter equal to the underdrain diameter shall be connected to the underdrain every 250 to 300 feet to provide a clean-out port as well as an observation well to monitor dewatering rates. The wells/cleanouts shall be

connected to the perforated underdrain with the appropriate manufactured connections. The wells/cleanouts shall extend 6 inches above the top elevation of the planter box mulch, and shall be capped with a lockable screw cap. The ends of underdrain pipes not terminating in an observation well/cleanout shall also be capped.

6. The following aggregate shall be used to provide a gravel blanket and bedding for the underdrain pipe. Place the underdrain on a 3-foot wide bed of the aggregate at a minimum thickness of 6 inches and cover with the same aggregate 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

7. At the option of the designer, a geotextile fabric may be placed between the planting media and the drain rock. If a geotextile fabric is used it must meet the following minimum materials requirements. Another option is to place a thin, 2- to 4-inch layer of pure sand and a thin layer (nominally two inches) of choking stone (such as #8) between the planting media and the drain rock.

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

8. The underdrain must drain freely to an acceptable discharge point. The underdrain can be connected to a downstream open conveyance (vegetated swale), to a planter box cell as part of a connected treatment system, stored for reuse, or to a storm water conveyance system.

Overflow

An overflow device is required to be set at 2" below the top of the planter. The most common option is a vertical riser, described below.

Vertical riser

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

2. The overflow riser(s) shall be 6 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 shall be 6 inches above the planting media, and be capped with a spider cap.

Hydraulic Restriction Layers

Infiltration pathways need to be restricted due to the close proximity of foundations. Three types of restricting layers can be incorporated into planter box designs:

1. Filter fabric can be placed along vertical walls to reduce lateral flows.

2. Clay (bentonite) liners can be used. If so, underdrain system is also required.

3. Geomembrane liners shall have a minimum thickness of 30 mils.

Planting/Storage Media

1. The planting media placed in the cell shall be highly permeable and high in organic matter (e.g., loamy sand mixed thoroughly with compost amendment) and a surface mulch layer.

2. Planting media shall consist of 60 to 70% sand, 15 to 25% compost, and 10 to 20% clean topsoil. The organic content of the soil mixture shall be 8% to 12%; the pH range shall be 5.5 to 7.5.

3. Sand shall be free of stones, stumps, roots or other similar objects larger than 5 millimeters, and have the following gradation:

Particle Size (ASTM D422)	% Passing
#4	100
#6	88-100
#8	79-97
#50	11-35
#200	5-15

4. Compost shall be free of stones, stumps, roots or other similar objects larger than ¾ inches; have a particle size of 98% passing through ¾" screen or smaller; and meet the following characteristics:
   - Soluble Salt Concentration: < 10 mmhos/cm (dS/m)
   - pH: 5.0-8.5
   - Moisture: 30-60% wet weight basis
   - Organic Matter: 30-65% dry weight basis
   - Stability (Carbon Dioxide evolution rate): >80% relative to positive control
   - Maturity (Seed emergence and seedling vigor): >80% relative to positive control

- Physical contaminants: < 1% dry weight basis

5. Topsoil shall be free of stones, stumps, roots or other similar objects larger than 2 inches, and have the following characteristics:

- Soluble salts: < 4.0 mmhos/cm (dS/m)
- pH range: 5.5 to 7.0
- Organic matter: > 5%
- Carbon to Nitrogen Ratio: < 20:1
- Moisture content: 25-55%

Particle Size (ASTM D422, D1140)	% Passing
3/4"	98
Sand (0.05 - 2.0 mm)	50-75
Silt (0.002 - 0.05 mm)	15-40
Clay	< 5

6. The planter box area shall be covered with mulch when constructed and annually replaced to maintain adequate mulch depth. *Intent: this will help sustain nutrient levels, suppress weeds, and maintain infiltrative capacity.* Mulch shall be:
   - Well-aged, shredded or chipped woody debris or plant material. Well-aged mulch is defined as mulch that has been stockpiled or stored for at least twelve (12) months. Compost meeting the requirements above may also be used (compost is less likely to float and is a better source for organic materials).
   - Free of weed seeds, soil, roots, and other material that is not bole or branch wood and bark.
   - Mulch depth shall be 2 to 3 inches thick (*intent: thicker applications can inhibit proper oxygen and carbon dioxide cycling between the soil and atmosphere*).
   - Grass clippings or pure bark shall not be used as mulch.

7. Planting media design height shall be marked appropriately, such as a collar on the vertical riser (if installed), or with a stake inserted 2 feet into the planting media and notched to show planter box surface level and ponding level.

8. The planter box soil mix shall be tested and meet the following criteria:

Item	Criteria	Test Method
Corrected pH	5.5 – 7.5	ASTM D4972
Magnesium	Minimum 32 ppm	*
Phosphorus (Phosphate - P_2O_5)	Not to exceed 69 ppm	*
Potassium (K_2O)	Minimum 78 ppm	*
Soluble Salts	Not to exceed 500 ppm	*

* Use authorized soil test procedures.

Should the pH fall outside of the acceptable range, it may be modified with lime (to raise) or iron sulfate plus sulfur (to lower). The lime or iron sulfate must be mixed uniformly into the soil mix prior to use in planter boxes.

Should the soil mix not meet the minimum requirement for magnesium, it may be modified with magnesium sulfate. Likewise, should the soil mix not meet the minimum requirement for potassium, it may be modified with potash. Magnesium sulfate and potash must be mixed uniformly into the soil mix prior to use in planter boxes.

Limestone. Limestone shall contain not less than 85 percent calcium and magnesium carbonates. Dolomitic (magnesium) limestone shall contain at least 10 percent magnesium as magnesium oxide and 85 percent calcium and magnesium carbonates.

Limestone shall conform to the following gradation:

Sieve Size	Minimum Percent Passing By Weight
No. 10	100
No. 20	98
No. 100	50

Iron Sulfate. Iron sulfate shall be a constituent of an approved horticultural product produced as a fertilizer for supplying iron and as a soil acidifier.

Magnesium Sulfate. Magnesium sulfate shall be a constituent of an approved horticultural product produced as a fertilizer.

Potash. Potash (potassium oxide) shall be a constituent of an approved horticultural product produced as a fertilizer.

Vegetation

Planter box vegetation shall have the following characteristics:

1. Plant materials shall 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 tree, three shrubs, and three herbaceous groundcover species be incorporated to protect against facility failure due to disease and insect infestations of a single species. Plant rooting depths shall not damage the underdrain. Slotted or perforated underdrain pipe shall be more than 5 feet from tree locations (if space allows).

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

4. Shade trees shall have a single main trunk. Trunks shall be free of branches below the following heights:

Caliper (in)	Height (ft)
1-1/2 to 2-1/2	5
3	6

5. See Appendix G for a recommended native plant list for planter boxes, a list of local nurseries where these plants can be purchased, and a list of local and regional on-line resources. The plant list shall be used as a guide only and shall not replace project-specific planting recommendations provided by a landscape professional including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth. See Section 5.11 for more information on landscaping/planting recommendations and Section 5.10 for more information on soil amendment recommendations.

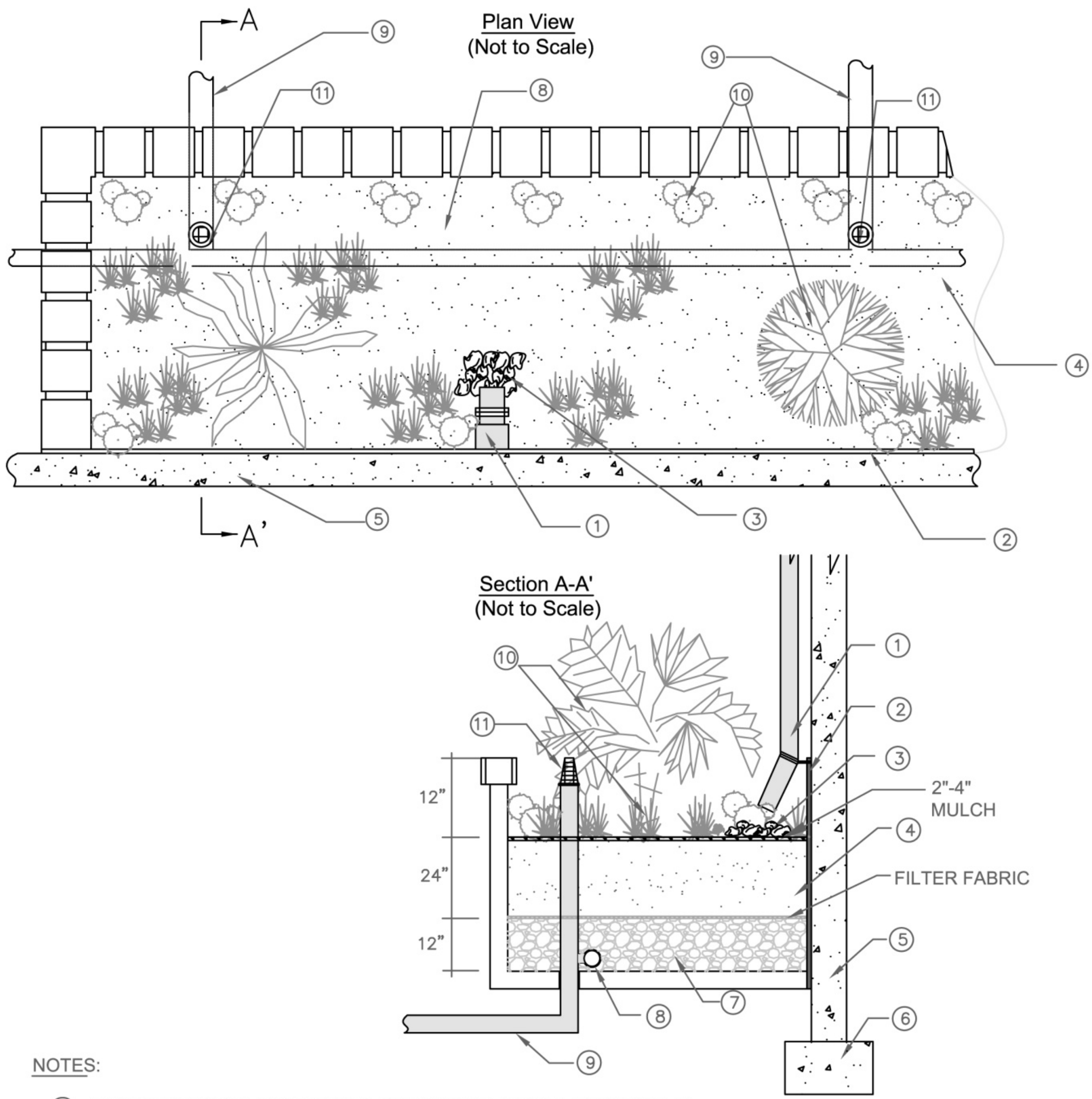
6.9.2.4 <u>Construction Considerations</u>

1. The use of treated wood or galvanized metal anywhere inside the facility is prohibited.

2. Material of planter boxes shall be selected carefully to blend in and enhance aesthetics of adjacent structures (buildings and sidewalks).

3. Plants shall be selected carefully to minimize maintenance and function properly.

Figure 6-19: Planter Box Schematic



NOTES:

1. ROOF DOWNSPOUT OR OTHER STORM WATER DELIVERY SYSTEM.
2. WATERPROOF BARRIER.
3. ENERGY DISSIPATOR (E.G. SPLASH ROCKS).
4. SOIL MIX (SEE PLANTING MEDIA SECTION).
5. BUILDING.
6. FOUNDATION. INSTALL FOUNDATION DRAINS AS NEEDED.
7. GRAVEL (3/8" TO 5/8" OR APPROVED EQUAL).
8. PERFORATED PIPE SHALL RUN ENTIRE LENGTH OF PLANTER.
9. CONNECTION TO DOWNSTREAM CONVEYANCE SYSTEM, OTHER STORMWATER RUNOFF BMP, OR PERVIOUS AREA.
10. PLANTS; SEE APPENDIX G.
11. SET OVERFLOW 2" BELOW THE TOP OF THE PLANTER.
12. ALLOWABLE PONDING DEPTH SHALL BE LESS 12" OR LESS.

Geosyntec consultants

Figure 6 - 19
PLANTER BOX

6.9.2.5 Operations and Maintenance

General Requirements

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 shall 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 H for an inspection and maintenance checklist, use the checklist for bioretention areas). Properly designed facilities with appropriate flow velocities shall not have erosion problems except perhaps in extreme events. If erosion problems occur, the following shall 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 shall 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 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 heavy metal deposition is likely (e.g., contributing areas that 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. Estimates from metal attenuation research suggest that metal accumulation should not present an environmental concern for at least 20 years in planter boxes. Replacing mulch in planter boxes where heavy metal deposition is likely provides an additional level of protection for prolonged performance. If in question, have soil analyzed for fertility and pollutant levels.

Maintenance Standards

A summary of the routine and major maintenance activities recommended for planter boxes is shown in Table 6-51. Detailed routine and major maintenance standards are listed in Table 6-52 and Table 6-53.

Table 6-51: Planter Box Maintenance Quick Guide

Inspection and Maintenance Activities Summary	
Routine Maintenance	• Repair small eroded areas and ruts by filling with gravel. Overseed bare areas to reestablish vegetation • Remove trash and debris and rake surface soils to mitigate ponding • Remove accumulated fine sediments, dead leaves and trash to restore surface permeability • Remove any evidence of visual contamination from floatables such as oil and grease • Eradicate weeds and prune back excess plant growth that interferes with facility operation. Remove non-native vegetation and replace with native species • Remove sediment and debris accumulation near inlet and outlet structures to alleviate clogging • Clean and reset flow spreaders (if present) as needed to restore original function • Periodically observe function under wet weather conditions
Major Maintenance	• Repair structural damage to flow control structures including inlet, outlet, and overflow structures • Clean out under-drain, to alleviate ponding. Replace media (if ponding or loss of infiltrative capacity persists) and re-vegetate • Re-grade and re-vegetate to repair damage from severe erosion/scour channelization • Photographs taken before and after major maintenance is encouraged

Table 6-52: Routine Maintenance – Planter Boxes

Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed	Frequency
Erosion	Splash pads or spreader incorrectly placed; eroded or scoured areas due to flow channelization, or higher flows.	No erosion on surface of basin. No erosion or scouring evident. For ruts or bare areas less than 12 inches wide, damaged areas repaired by filling with crushed gravel.	Annually prior to wet season. After major storm events (>0.75 in/24 hrs) if spot checks of some planter boxes indicate widespread damage/ maintenance needs
Standing Water	When water stands in the basin between storms and does not drain freely (with 36- 48 hours after storm event).	Water drains completely from basin as designed and surface is clear of trash and debris. Underdrains are cleared.	
Loss of surface permeability	Accumulation of fine sediments, dead leaves, trash and other debris on surface	Surface permeability restored. Surface layer removed and replaced with fresh mulch.	
Visual contaminants and pollution	Any visual evidence of oil, gasoline, contaminants or other pollutants.	No visual contaminants or pollutants present.	Monthly (or as dictated by agreement between County and landscape contractor
Vegetation	Weeds, excessive plant growth, plants interfering with basin operation, plants diseased or dying	Basin tidy, plants healthy and pruned. Any plants that interfere with function are removed. Invasive or non-acclimated plants replaced.	
Inlet/Overflow	Inlet/outlet areas clogged with sediment and/or debris.	Material removed so that there is no clogging or blockage of the inlet or overflow area.	
Trash and debris	Any trash and debris which exceed 5 cubic feet per 1,000 square feet (one standard garbage can).	Trash and debris removed and facility looks well kept.	

Table 6-53: Major Maintenance – Planter boxes

Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed	Frequency
Standing water	When water stands in the basin between storms and does not drain freely (with 36- 48 hours after storm event).	Planting media (sand, gravel, and topsoil) and vegetation removed and replaced.	Annually prior to wet season
Erosion/ Scouring	Bare spots greater than 12 inches	No erosion on surface of basin. Large bare areas are re-graded and reseeded/replanted.	As needed

6.9.3 Green Roof

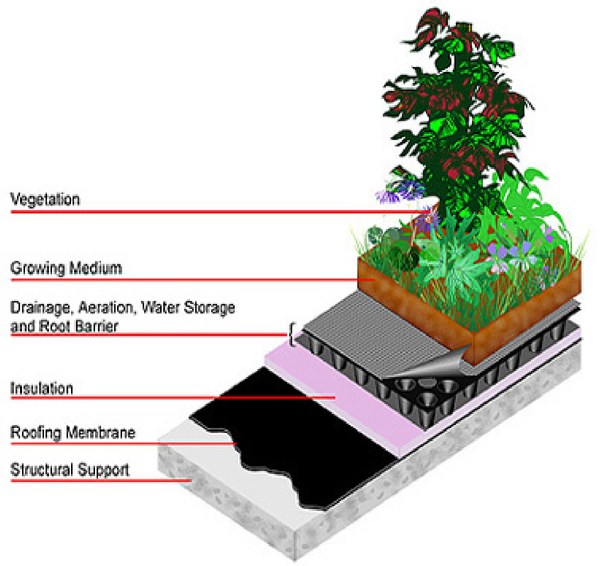


Figure 6-20: Typical Cross Section of a Green Roof
Figure Credit: American Wick

Applications

- Residential
- Commercial and institutional
- Rooftops and decks above building structures

Advantages

- Combines stormwater treatment with runoff conveyance
- Volume & peak flow reduction
- Pollutant removal

Limitations

- Heavier than conventional roofs may require additional support
- Not applicable for completely flat roofs

6.9.3.1 Description

Green roofs are also known as ecoroofs and vegetated roof covers. Green roofs are roofing systems that layer a soil/vegetative cover over a waterproofing membrane. 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 maintenance. A green roof mimics pre-development conditions by limiting the impervious area created by development. Green roofs filter, absorb, and evapotranspire precipitation to help mitigate the effects of urbanization on water quality and delivery of excess runoff to the local storm water conveyance systems.

6.9.3.2 Applicability, Performance, and Limitations

A green roof's applicability is limited to rooftops or decks above building structures.

Applicability and Performance

Green roofs help control nitrogen as plants uptake nitrogen as they grow. In addition, pollutants adsorb to clay and organic matter in the soil layer, vegetation slows down the water, and the foliage collects dust. While study results are limited, it has been estimated that over 80% of TSS removal, 95% of cadmium, copper and lead, and 16% of zinc may be retained in green roof soils (London Ecology Unit, 1993; Georgia SWMM, 2001). The soil layer characteristics (i.e., composition and depth) greatly dictate the performance of the roof.

Green roofs (and other building BMPs) are generally intended for achieving moderate volume reduction and flow control. Green roofs do provide quantifiable reduction in volume; however, they are not explicitly sized to meet the water quality treatment or volume reduction requirements. Rather, the volume reduction is accounted for implicitly in the calculations by assuming that the roof area is pervious rather than impervious when calculating a runoff coefficient for the site. Treatment effectiveness of green roofs (and other building BMPs) are not comparable to other BMPs that treat runoff from a wide range of impervious surfaces that generally have higher pollutant concentrations. Green roofs are not intended to be a primary BMP for meeting the peak runoff discharge requirement, although they do assist in reducing the peak runoff discharge rate by increasing the site's pervious area and decreasing runoff volumes and velocities. See Section 6.2 for specific storm water runoff requirements for Tier 3 projects.

Site Suitability Recommendations and Limitations

Table 6-54 and associated guidance provide general considerations for assessing a site's suitability for planter boxes.

Table 6-54: Site Suitability Considerations for Green Roofs

BMP	Tributary Area (Acres; Sq.Ft.)[1]	Site Slope (%)	Depth to Seasonally High Groundwater Table (ft)	Hydrologic Soil Group	Horizontal Setback from Drinking Water Wells (ft)
Green roofs	Equal to roof tributary area	N/A	N/A	N/A	N/A

[1] Tributary area is the area of the site draining to the BMP. Tributary areas provided here shall be used as a general guideline only. Tributary areas can be larger or smaller in some instances.

Table 6-55 provides additional site applicability considerations for special design districts within the City including coastal bluff areas and hillside design districts.

Table 6-55: Applicability of Planter Boxes for Special Design Districts

Coastal Bluff Area	Hillside Design District
Acceptable if overflow is captured in another acceptable BMP or if it is conveyed safely to a storm water conveyance system.	Acceptable if overflow is captured in another acceptable BMP or if it is conveyed safely to a storm water conveyance system.

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

- Shall not be located on steep roofs (>25%)
- Roof supports must be sufficient to support additional roof weight

Multi-Use and Treatment Train Opportunities

A green roof can be combined into a treatment train to provide enhanced water quality treatment and reductions in runoff volume and rate. For example, if a green roof is placed upgradient of a cistern, the rate and volume of water flowing to the cistern can be reduced and the water quality enhanced. As another example, a bioretention unit could be placed downstream of a downspout that drains the green roof. In both cases, each facility can be reduced in size accordingly based upon demonstrated performance for meeting the storm water runoff requirements as outlined in Section 6.2 and addressing targeted pollutants of concern. In addition, green roofs can serve as aesthetic roof top garden areas and patios with outdoor seating.

6.9.3.3 Design Criteria and Procedure

Green Roofs shall be designed according to the current requirements of the City of Santa Barbara and the Santa Barbara County Flood Control and Water Conservation District. Standard design criteria for green roofs are listed in Table 6-56.

Table 6-56: Green Roof Design Criteria

Design Parameter	Unit	Design Criteria
Soil depth range	inch	2 – 6 (depends on whether roof is designed to be extensive or intensive)
Saturated soil weight	lbs. / sq. ft.	10 – 25
Maximum roof slope	%	25
Minimum roof slope	--	Flat
Vegetation type	--	Varies (see vegetation section below and Appendix G)
Vegetation height	--	Varies (see vegetation section below)

Sizing

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

Green Roof Components

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. This is especially a concern for retrofit projects; so for retrofits, a licensed structural engineer shall be consulted to determine the current structural support present and what may need to be added to support the additional weight of 10 to 25 pounds per square foot. For new projects, the structural support concern shall be addressed during the design phase.

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; they 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.

Drainage Layer

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

Soil Considerations

Soils are 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, see Section 5.10 for additional information on soil amendments. The soil mix used shall not contain any clay.

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 shall be about 90% 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 shall be specified. A mixture of drought tolerant, self-sustaining (perennial or self-sowing without need for fertilizers, herbicides, and or pesticides) is most effective. Plants selected shall 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 is dependent of 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. Use of a permanent irrigation system may help provide maximal water quality performance. Drought-tolerant plants shall be specified to minimize irrigation requirements.

3. Vegetation shall cover at least 90% of the total area

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

5. See Appendix G for a recommended native plant list for green roofs, a list of local nurseries where these plants can be purchased, and a list of local and regional on-line resources. The plant list shall be used as a guide only and shall not replace project-specific planting recommendations provided by a landscape professional including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth. See Section 5.11 for more information on landscaping/planting recommendations and Section 5.10 for more information on soil amendment recommendations.

Drain

1. There must be a drain pipe (gutter) to convey runoff safely from the roof to another basic or storm water runoff BMP, a pervious area, or the storm water conveyance system. See Section 5.3 Disconnecting Downspouts for more detail on directing roof drainage.

6.9.3.4 Construction Recommendations

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

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

6.9.3.5 Operations and Maintenance

General Requirements

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, plants shall 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 shall not require any routine maintenance.

3. The roofing membrane must be inspected routinely, as it is a crucial element of the green roof. In addition, routine 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 correct combination of waterproofing barrier, root barrier, and drainage systems are not selected. Inspecting for a leak in the roofing system is 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" 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 shall be checked for debris, litter, and signs of clogging.

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

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

7. Fallen leaves and debris from deciduous plant foliage shall 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*) must 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- http://www.cdfa.ca.gov/phpps/ipc/encycloweedia/encycloweedia_hp.htm or the California Invasive Plant Council website at www.cal-ipc.org.

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

Maintenance Standards

A summary of the routine and major maintenance activities recommended for green roofs is shown in Table 6-57.

Table 6-57: Green Roofs Maintenance Quick Guide

Inspection and Maintenance Activities Summary	
Routine Maintenance	• Trash and debris removal • Inspect roofing membrane for signs of damage • Inspect for leaks in roofing system • Inspect drainage paths for clogging, clean if necessary • Inspect for signs of erosion or damage to vegetation • Cleaning of drain (where applicable) and/or unclogging outlet to eliminate ponding water • Remove weeds and dead vegetation • Re-plant areas where weeds and dead vegetation were removed • Replace non-native vegetation with native species • Photographs taken before and after maintenance is encouraged
Major Maintenance	• Clean and or replace drainage layer • Re-vegetate bare exposed portions of the swale to restore vegetation to original level of coverage • Repair/Replace waterproof roofing membrane

6.10 Retention and Detention BMPs

6.10.1 Constructed Treatment Wetland

Figure 6-21: Constructed Treatment Wetland at University of California, Santa Barbara

Applications

- Regional detention & treatment
- Roads, highways, parking lots, commercial, residential
- Parks, open spaces, and golf courses

Advantages

- Enhanced pollutant removal
- Aesthetically pleasing
- Creates wildlife habitat
- Treatment of large tributary areas

Limitations

- Requires year-round base flow
- Requires large footprint
- Concerns regarding vector infestation

6.10.1.1 Description

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 storm water runoff, aquatic vegetation, wetland soils, and the associated physical, chemical, and biological unit processes are a fundamental part of constructed treatment wetlands. Therefore, it is critical that dry weather base flows exceed evaporation and infiltration losses to prevent loss of aquatic vegetation and to avoid stagnation and vector problems. In situations where dry weather flows are inadequate to support the treatment wetland size, an additional source of water may be needed during summer months. Otherwise, the wetland shall be sized based on the available base flow. In addition to water quality treatment, constructed wetlands can be designed for flow control by including extended detention above the permanent pool elevation.

Constructed treatment wetlands are generally designed as plug flow systems where the water already present in the permanent pool is displaced by incoming flows with minimal mixing and no short circuiting. Plug flow describes the hypothetical condition of storm water moving through the wetland in such a way that older "slugs" of water (meaning water that's been in the wetland for longer) are displaced by incoming slugs of water with little or no mixing in the direction of flow. Short circuiting occurs when quiescent areas or "dead zones" develop in the wetland where pockets of water remain stagnant, causing other volumes to bypass using shorter paths through the basin (e.g., incoming storm water slugs bypass these zones). Water quality benefits are also improved when the permanent wet pool volume is significantly greater than the water quality volume, resulting in longer residence times. If flow control using extended detention is desired for meeting peak discharge requirements, the wetland will first displace water present in the permanent pool with incoming flows (usually equal to or greater than the water quality treatment volume) and will then fill the wetland above the permanent pool elevation and allow the water level to drop back to the permanent pool elevation allowing higher flows to discharge from the wetland at rates required for meeting the peak runoff discharge requirements.

It is important to note the difference between constructed treatment wetlands and mitigation wetlands that are constructed as part of mitigation requirements. Constructed mitigation wetlands are intended to provide fully functional habitat similar to the habitat they replace. Constructed treatment wetlands are intended for water quality treatment and, when applicable, flow control. They shall be designed to capture and treat pollutants to protect receiving waters, including natural wetlands and other ecologically significant habitat. The accumulation of pollutants in sediment and vegetation of constructed treatment wetlands may impact the health of aquatic biota. As such, periodic sediment and vegetation removal within constructed treatment wetlands may be required. Constructed treatment wetlands can provide opportunities for wildlife enhancement, education, and aesthetics.

Factors that favor the selection of storm water wetlands over other kinds of BMPs include enhanced treatment capability (including dry-weather flow treatment), aesthetics, and the ability to mitigate large tributary areas. Factors that may limit the use of storm water wetland basins include overly permeable soils and/or non-existent base flows, public acceptance with regard to the potential for vector infestation, large footprint to tributary area ratios (up to 12% percent of tributary area, dependant on overall imperviousness of the tributary area) and high initial capital cost of implementation.

6.10.1.2 Performance, Applicability, and Limitations

Table 6-58, Table 6-59, and Table 6-60 provide a summary of BMP performance, applicability, and limitations for constructed treatment wetlands. *It is important to note that information in these tables shall be used to provide general guidance for constructed treatment wetlands and shall not replace the evaluation performed by a water quality professional.*

Applicability and Performance

Table 6-58 and associated guidance provide general volume reduction capabilities and treatment effectiveness for constructed treatment wetlands. Refer to Section 6.4 for the process that shall be used for selecting BMPs based on pollutants of concern. Refer to Table 6-1 to determine the ranking of constructed treatment wetlands for removal of pollutants of concern as compared with other storm water runoff BMPs provided in Chapter 6. Refer to Table 6-2 to assess the applicability of constructed treatment wetlands for your site based on site suitability considerations as compared with other storm water runoff BMPs provided in Chapter 6. Constructed treatment wetlands are volume-based BMPs intended to provide water quality treatment and, when applicable, control of the peak runoff discharge rate using extended detention above the wetland permanent pool (see Table 6-58). Although constructed treatment wetlands can produce significant volume reduction though evapotranspiration in the summer months, credit towards meeting the volume reduction requirement, $V_{reduction}$, is not given for constructed treatment wetlands because little volume reduction occurs during the winter months when storm water runoff is highest. See Section 6.2 for specific storm water runoff requirements for Tier 3 projects.

Table 6-58: Volume Reduction & Treatment Effectiveness for Treatment Wetland

Storm Water Runoff BMP	Volume Mitigation (% of inflow)	Treatment Effectiveness for Pollutants of Concern[1]					
		Trash	Nutrients	Bacteria	Metals (particulate and dissolved fractions)	Sediment	Organics (hydro-carbons, oil, and grease)
Constructed Treatment Wetland	◓	◓	◉	◒	●	◓	●
Volume/Treatment Effectiveness: ● = Very High, ◓ = High, ◉ = Moderate, ◒ = Low, ○ = Very Low							

[1] Effectiveness may change based on design variations; standard BMP designs have been assumed.

Constructed treatment wetlands have very high pollutant removal efficiencies and use multiple processes to treat storm water runoff including sedimentation, filtration, adsorption, plant uptake, and microbial/chemical biodegradation and precipitation. Sedimentation and filtration assist in the removal of total suspended solids (i.e., a surrogate for sediment), floating debris, trash, soil-bound phosphorus, and some soil-bound pathogens. Adsorption to soil particles assists in removal of dissolved metals and soluble phosphorus. Microbial processes (e.g., nitrification and dentrification) and chemical processes (e.g., precipitation) assist in removal of nitrogen, organics, pathogens, and metals. Plants can uptake small amounts of nutrients including nitrogen and phosphorus and, depending on plant type, can uptake varying amounts of metals. Some plant types can uptake large quantities of metals; this is called phytoremediation. Exposure to sunlight and dryness on the edges of the wetland and in areas that do not consistently stay wet assist in removal of pathogens (Hunt and Doll, 2000).

Site Suitability Recommendations and Limitations

Table 6-59 provides general considerations for assessing a site's suitability for constructed treatment wetlands.

Table 6-59: Site Suitability Considerations for Treatment Wetlands

BMP	Tributary Area (Acres)[1]	Site Slope (%)	Depth to Seasonally High Groundwater Table (ft)	Hydrologic Soil Group	Horizontal Setback from Drinking Water Wells (ft)
Constructed Treatment Wetland	> 5 Acres; 435,600 Sq.Ft.	< 8 [2]	N/A	"A" soils may require pond liner; "B" soils may require infiltration testing	N/A

[1] Tributary area is the area of the site draining to the BMP. Tributary areas provided here shall be used as a general guideline only. Tributary areas can be larger or smaller in some instances.

[2] If site slope exceeds that specified or if the system is within 200 ft from the top of a hazardous slope or landslide area (on the uphill side), a geotechnical investigation and report addressing slope stability shall be prepared by a licensed civil engineer.

Table 6-60 provides additional site suitability considerations for special design districts within the City, including coastal bluff areas and hillside design districts.

Table 6-60: Applicability of Treatment Wetlands for Special Design Districts

Coastal Bluff Area	Hillside Design District
Generally not acceptable in Coastal Bluff Areas	Acceptable if: (1) a geotechnical investigation proves that the facility does not compromise the stability of the site slope or surrounding slopes, or (2) the facility meets the site slope criteria in Table 6-59 and the facility is fully contained with an impermeable liner and overflow to a storm water conveyance system.

The following provides additional site suitability guidelines and 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 shall 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 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.

Multi-Use and Treatment Train Opportunities

Provided that the constructed treatment wetland has adequate storage, the wetland may be combined with a flow control basin to provide both water quality control and peak flow control. Wetlands can also be designed with wildlife viewing areas and walking trails around the perimeter to provide passive recreation. Flows may enter a constructed treatment wetland from a pretreatment BMP such as a vegetated swale filter or Vegetated filter strip. The vegetated swales and filter strips not only filter course sediments but also increase the site's time of concentration, T_c, thereby providing infiltration and evapotranspiration as well as reductions in site runoff discharge rates prior to entering the constructed treatment wetland.

6.10.1.3 Design Criteria and Procedure

The main challenge associated with constructed treatment wetlands is maintaining base flow to support vegetation. A constructed treatment wetland is illustrated schematically in Figure 6-22.

Constructed treatment wetlands shall be designed according to the current policies of the City and the County of Santa Barbara Flood Control District. Principal design criteria for constructed treatment wetlands are listed in Table 6-61.

Table 6-61: Treatment Wetland Design Criteria

Design Parameter	Unit	Design Criteria
Water quality design volume, V_{wq}	ft^3	See Section 6.2.3 and Appendix C
Drawdown time for extended detention (over permanent pool)	hours	36-48
Sediment forebay volume	%	10-20 of total basin volume
Depth of sediment forebay	feet	4-8 (1 foot of sediment storage required)
Depth of wetland basin	feet	Varies see facility geometry section below
Maximum residence time	Days	7 (dry weather)
Freeboard (minimum)	inches	12 (off-line); 24 (on-line)
Flow path length to width ratio	L:W	3:1 (min.) 4:1 (preferred)
Side slope (maximum)	H:V	4:1 Interior; 2:1 Exterior; 3:1 Landscaped
Vegetation Type	--	Varies see vegetation section below and Appendix G
Vegetation Height	--	Varies see vegetation section below
Buffer zone (minimum)	feet	25
Maintenance access ramp width	feet	16
Minimum outflow device diameter	inches	18

Sizing for Meeting the Storm Water Runoff Requirements

Constructed treatment wetlands can be sized to meet all or part of the water quality design volume and peak runoff discharge rate requirements as outlined in Section 6.2 and Appendix C. A constructed treatment wetland sizing example is provided in Appendix D.

Maintaining peak runoff discharge rate requirement

The constructed treatment wetland can be designed with extended detention to provide sufficient storage for meeting all or part of the peak runoff discharge requirement for the 2-year through the 100-year, 24-hr design storm.

Volume reduction requirement

The volume reduction requirement cannot be met with constructed treatment wetlands.

Water quality treatment volume requirement

The constructed treatment wetland can be designed to treat all or part of the water quality treatment volume with a 36 to 48 hour drawdown time.

Sizing for Meeting the Storm Water Runoff Requirements

Wet retention basins can be sized to meet all or part of the water quality design volume and peak runoff discharge rate requirements as outlined in Section 6.2 and Appendix C. A wet retention basin sizing example is provided in Appendix D.

Maintaining peak runoff discharge rate requirement

The wet retention basin can be designed with extended detention (above the permanent pool) to provide sufficient storage for meeting all or part of the peak runoff discharge requirement for the 2-year through the 100-year, 24-hr design storm.

Volume reduction requirement

The volume reduction requirement cannot be met with constructed treatment wetlands.

Water quality treatment volume requirement

The constructed treatment wetland can be designed with or without extended detention (above the permanent pool) to treat all or part of the water quality treatment volume. If extended detention is provided, the drawdown time shall between 36 to 48 hours.

Geometry and Size

In most cases, the constructed treatment wetland permanent pool shall be sized to be greater than or equal to the water 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 water 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. See Section 6.2 and Appendix C for water quality design volume and peak runoff discharge requirements and calculations. A constructed treatment wetland design example is provided in Appendix D. The extended detention portion of the wetland above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see Section 6.10.3 for dry ED basin sizing guidelines).

1. Constructed treatment wetlands shall 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 shall be between 4 and 8 feet.

4. One foot of sediment storage shall be provided in the sediment forebay.

5. The “berm” separating the two basins shall be uniform in cross-section and shaped such that its downstream side gradually slopes to the main wetland basin.

6. The top of berm shall be either at the water quality design water surface or submerged 1 foot below the water quality design water surface, as with wet retention basins. Correspondingly, the side slopes of the berm must meet the following criteria:

   a. If the type of the berm is at the water quality design water surface, the berm side slopes shall 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 shall 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 shall be a minimum of 3:1, 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 shall 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 shall be designed such that the residence time for dry weather flows is no greater than 7 days. *Intent: Minimize vector and stagnation issues.*

Water Supply

Water balance calculations shall 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 shall 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 shall be provided to maintain the wetland water surface elevation throughout the year. The water supply shall be of sufficient quantity and quality to not have an adverse impact on the wetland water quality. Water that meets drinking water standards shall be assumed to be of sufficient quality.

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 shall determine whether a liner is required. The following conditions can be used as a guideline.

2. The wetland basin must retain water for at least 10 months of the year.

3. The sediment forebay must 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 must 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) must be placed over the liner (see soil amendment Section 5.10). If a synthetic material is used, a soil depth of 2 feet is recommended to prevent damage to the liner during planting.

Buffer Zone

A minimum of 25 feet buffer shall be provided around the top perimeter of the constructed treatment wetlands.

Energy Dissipation

1. The inlet to the constructed treatment wetland shall 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 shall 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 storm water conveyance system or hardened channel.

Vegetation

1. The wetland cell(s) shall 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 must 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, shall not be used within 50 feet of pipes or manmade structures. Weeping willow (*Salix babylonica*) shall 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- http://www.cdfa.ca.gov/phpps/ipc/encycloweedia/encycloweedia_hp.htm or the California Invasive Plant Council website at www.cal-ipc.org.

3. See Appendix G for a recommended native plant list for constructed treatment wetlands, a list of local nurseries where these plants can be purchased, and a list of local and regional on-line resources. The plant list shall be used as a guide only and shall not replace project-specific planting recommendations 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. See Section 5.11 for more information on landscaping/planting recommendations and Section 5.10 for more information on soil amendment recommendations.

Outlet Structure

An outlet pipe and outlet structure shall be provided. The outlet pipe may be a perforated standpipe strapped to a manhole (see Figure 6-25) 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) (see Figure 6-26). The grate or birdcage openings provide an overflow route should the basin outlet pipe become clogged.

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 water 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 (Section 6.10.3) and Appendix E for further detail on outlet sizing.

Emergency Spillway

An emergency overflow spillway in addition to the primary overflow outlet (as described above) is required. The emergency spillway shall 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 shall be sized for flows greater than the basin design volume (e.g., water quality design volume). The spillway shall be constructed with reinforced concrete and provide for adequate energy dissipation downstream. The spillway shall 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 shall 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 storm water runoff discharge rate (see Appendix E 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 shall be provided.
2. The emergency overflow spillway shall be armored to withstand the energy of the spillway flows (Figure 6-32). The spillway shall be constructed of grouted rip-rap.
3. The minimum freeboard shall be 1 foot above the maximum water surface elevation over the emergency spillway.

Side Slopes

1. Interior side slopes above the water quality design depth and up to the emergency overflow water surface shall be no steeper than 4:1 (H:V), unless stabilization has been approved by a licensed civil engineer and the City.

2. Exterior side slopes shall be no steeper than 2:1 (H:V), unless stabilization has been approved by a licensed civil engineer and the City.

3. For any slope (interior or exterior) steeper than 2:1 (H:V), a geotechnical investigation and report must be submitted and approved by the City.

4. Landscaped slopes must 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 engineer and approved by the City.

Embankments

1. Earthworks and berm embankments shall 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 shall be 2 feet minimum below the water quality design water surface and shall be keyed into embankment a minimum of 1 foot on both sides.

4. Typically, the top width of berm embankments is at least 20 feet, but narrower embankments may be plausible if approved by the civil engineer and the City.

5. Basin berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a licensed civil engineer) free of loose surface soil materials, roots, and other organic debris.

6. Basin berm embankments greater than 4 feet in height must 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 engineer.

7. The berm embankment shall 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 shall be planted on downstream embankment slopes. See vegetation section below.

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. In accordance with the Santa Barbara Flood Control District *Standard Conditions of Project Plan Approval*, facilities to be dedicated to the City, perimeter fencing (minimum height of 42 inches) shall 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 shall be designed and constructed in accordance with current policies of the Santa Barbara County Flood Control District and must 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.

Right-of-Way

1. Constructed treatment wetlands and associated access roads to be maintained by the City shall be dedicated in fee or in an easement to the City with appropriate access.

Maintenance Access

1. Ownership of the basin and maintenance thereof is the responsibility of the developer/applicant. A maintenance agreement with the City is required to ensure adequate performance and allow the City emergency access to the facilities.

2. Maintenance access road(s) shall 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 must be in or at the edge of the access road.

3. A graded 16-foot wide access ramp into the basin shall be constructed near the basin outlet. An access ramp is required for removal of sediment with a backhoe or loader and truck. The ramp must extend to the basin bottom to avoid damage to vegetation planted on the basin slope. A 16-foot wide commercial driveway approach shall be provided where curb and gutter front the maintenance ramp.

4. All access ramps and roads shall be provided in accordance with the current policies of the Flood Control District.

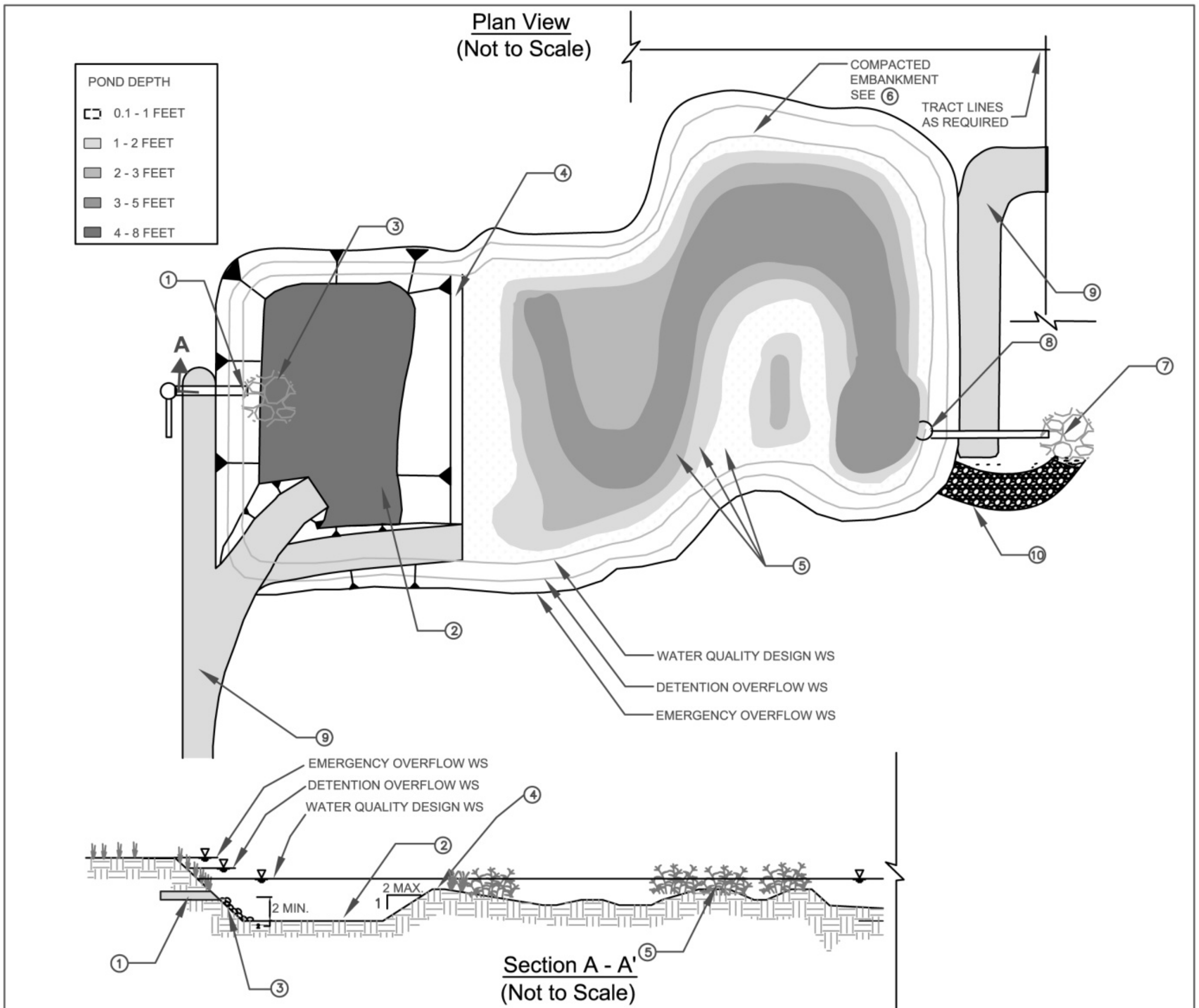
Vector Control

1. A Mosquito Management Plan or Service Contract must be approved or waived by the Santa Barbara Coastal Vector Control District for any facility that maintains a pool of water for 72 hours or more.

6.10.1.4 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.

Figure 6-22: Constructed Treatment Wetland Schematic



NOTES:

1. INLET PIPE SHOULD BE SUBMERGED WITH A MINIMUM OF 2' DISTANCE FROM THE BOTTOM.
2. SEDIMENT FOREBAY. FOREBAY VOLUME SHALL EQUAL 10% TO 20% 0F TOTAL WETLAND VOLUME. FOREBAY DEPTH SHALL BE 4' TO 8' PLUS AN ADDITIONAL I' MIN SEDIMENT STORAGE DEPTH.
3. RIPRAP APRON OR OTHER INLET ENERGY DISSIPATION.
4. BERM AT WATER QUALITY DESIGN WATER SURFACE ELEVATION OR SUBMERGED 1' BELOW WATER QUALITY DESIGN WATER SURFACE ELEVATION. EXTEND BERM ACROSS ENTIRE WIDTH OF THE WETLAND AND SHALL BE KEYED INTO EMBANKMENT A MINIMUM OF 1' ON BOTH SIDES.
5. WETLAND VEGETATION PLANTING SCHEME MUST BE DESIGNED BY A WETLAND ECOLOGIST OR QUALIFIED LANDSCAPE PROFESSIONAL.
6. EMBANKMENT SIDE SLOPES SHALL BE NO STEEPER THAN 2H:1V OUTSIDE AND 4H:1V INSIDE. FENCING SHOULD BE PROVIDED FOR EMBANKMENT SLOPES GREATER THAN 6H:1V OR IF BASIN DEPTH EXCEED 2'.
7. SIZE OUTLET PIPE TO PASS 100-YEAR PEAK FLOW FOR ONLINE AND WATER QUALTIY PEAK FLOW FOR OFFLINE BASINS. OUTLET PIPE DIAMETER SHALL BE A MINIMUM OF 18".
8. WATER QUALITY OUTLET STRUCTURE. SEE FIGURE 6-25 AND FIGURE 6-26 FOR DETAILS.
9. MAINTENANCE RAMP SHOULD BE PAVED. WIDTH SHALL BE A MINIMUM OF 16' AND SLOPE SHALL NOT EXCEED 12%. MAINTENANCE RAMP SHOULD PROVIDE ACCESS TO BOTH THE FOREBAY AND MAIN BASIN.
10. INSTALL EMERGENGY OVERFLOW SPILWAY AS NEEDED. SEE FIGURE 6-32 FOR DETAILS.

Geosyntec consultants

Figure 6 - 22
CONSTRUCTED TREATMENT WETLAND

6.10.1.5 Operations and Maintenance

General Requirements

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 shall be inspected annually and inspections after major storm events are encouraged (see Appendix H for a constructed treatment wetland inspection and maintenance checklist). Trash and debris shall be removed as needed, but at least annually prior to the beginning of the wet season.

2. Site vegetation shall 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 shall be pruned or removed.

4. Slope areas that have become bare shall be revegetated and eroded areas shall 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*) must be removed and replaced with non-invasive species. Invasive species shall 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- http://www.cdfa.ca.gov/phpps/ipc/encycloweedia/encycloweedia_hp.htm or the California Invasive Plant Council website at www.cal-ipc.org.

6. Dead vegetation shall 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 shall 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 shall be removed. Sediments shall 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.

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

Maintenance Standards

A summary of the routine and major maintenance activities recommended for wetland basins is shown in Table 6-62. Detailed routine and major maintenance standards listed in Table 6-63 and Table 6-64 are intended to be measures to determine if maintenance actions are required as identified through inspection. They are not intended to be measures of the facility's required condition at all times between inspections. In other words, exceedance of these thresholds or measures at any time between inspections and/or scheduled maintenance does not constitute a violation of these standards. These standards are violated only when an inspection identifies required maintenance action that has not been scheduled before the next regular inspection.

Table 6-62: Treatment Wetland Maintenance Quick Guide

Inspection and Maintenance Activities Summary	
Routine Maintenance	• Trash and debris removal • Remove minor sediment accumulation near inlet and outlet structures • Stabilize/repair eroded banks and fill in animal burrows if present • Remove any evidence of visual contamination from floatables such as oil and grease • Eliminate pests and conditions suitable for creating ideal breeding habitat • Install or repair pond liner to ensure that first cell maintains a permanent pool • Remove algae mats as often as needed to prevent coverage of more than 20% of wetland surface • Mow berms routinely if applicable to maintain aesthetic appeal and to suppress weeds
Major Maintenance	• Remove dead, diseased, or dying trees and woody vegetation that interfere with facility maintenance. • Correct problems associated with berm settlement • Repair berm/dike breaches and stabilize eroded parts of the berm • Repair and rebuild spillway as needed to reverse the effects of severe erosion • Remove sediment build up in forebay and main wetland area to restore original sediment holding capacity • Re-grade main wetland bottom to restore bottom slope and eliminate the incidence of standing pools • Aerate compacted areas to promote infiltration if volume reductions are desired • Repair or replace gates, fences, flow control structures, and inlet/outlet structures as needed to maintain full functionality

Table 6-63: Routine Maintenance Standards – Treatment Wetlands

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Trash & Debris	Any trash and debris which exceed 5 cubic feet per 1,000 sf of wetland 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.	Trash and debris cleared from site.	Annually prior to wet season After major storm events (>0.75 in/24 hrs) if spot checks of some basins indicate widespread damage/ maintenance needs
Sediment Accumulation	Sediment accumulation in wetland 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.	Sediment cleaned out.	
Erosion	Erosion of wetland's side slopes and/or scouring of wetland bottom.	Slopes shall be stabilized using appropriate erosion control measure(s) and repair methods.	
Oil Sheen on Water	Prevalent and visible oil sheen.	No oil sheen present.	
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.	Vectors controlled per Santa Barbara Coastal Vector Control District. A Mosquito Management Plan or Service Contract must be presented to the Vector Management District for any facility that maintains a pool of water for 72 hours or more.	
Water Level	First cell empty, doesn't hold water.	Line the first cell to maintain at least 4 feet of water. The first cell must remain full to control turbulence of the incoming flow and reduce sediment resuspension.	

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Aesthetics	Minor vegetation removal and thinning. Mowing berms and surroundings	Facility is well kept.	Monthly (or as dictated by agreement between County and landscape contractor)
Noxious Weeds	Any evidence of noxious weeds.	Eradicate all noxious weeds; control and prevent the spread of all noxious weeds. Use Integrated Pest Management techniques, if applicable. See http://www.ipm.ucdavis.edu for more information.	

Table 6-64: Major Maintenance Standards – Treatment Wetlands

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
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.	Trees do not hinder maintenance activities. Remove dead, diseased, or dying trees. (Use a certified Arborist to determine health of tree or removal requirements).	Annual or as needed (infrequent) After major storm events (>0.75 in/24 hrs) if spot checks of some basins indicate widespread damage/ maintenance needs.
Settling of Berm	If settlement is apparent. Settling can be an indication of more severe problems with the berm or outlet works. A civil engineer shall be consulted to determine the source of the settlement if the dike/berm is serving as a dam.	Dike is built back to the design elevation.	
Piping through Berm	Discernable water flow through basin berm. Ongoing erosion with potential for erosion to continue. A licensed civil engineer shall be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved and berm stability achieved.	

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
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.	Trees and large shrubs shall be removed. All dead roots shall be removed if practical. Otherwise, dead roots shall be removed to a minimum of 36 inches below grade and replaced with cement grout to 12 inches below grade. The top 12 inches of the root holes shall be filled with compacted, in-situ soils. The area facility engineer may require additional root removal if necessary for dam safety or maintenance purposes.	
Erosion on Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.	Rocks and pad depth are restored to design standards.	
Gate/Fence Damage	Damage to gate/fence, including missing locks and hinges	Gate/Fence repaired.	

6.10.2 Wet Retention Basins

Figure 6-23: Wet Retention Basin with Vegetation Along Perimeter

Applications

- Regional detention & treatment
- Roads, highways, parking lots, commercial, residential
- Parks, open spaces, and golf courses

Advantages

- Efficient removal of pollutants adsorbed to sediments
- Can provide treatment for large tributary areas

Limitations

- Require regular base flows if water level is to be maintained
- Large footprint area required
- Not permitted near steep slopes

6.10.2.1 Description

Wet retention 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 storm water treatment facility in addition to an aesthetic water feature. Wetponds 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. Wetponds can be designed to provide extended detention of incoming flows using the volume above the permanent pool surface.
The applications for wet retention basins are similar to those of dry extended detention (ED) basins and include peak flow attenuation (with ED), varying amounts of volume reduction, and pollutant removal. The main pollutant removal mechanism in wet retention basins is sedimentation; other pollutant reduction processes occurring in wet retention basins include dilution, adsorption, biological and chemical processes such as microbially-mediated biodegradation and precipitation, plant uptake, and storage. The permanent pool of water in the wet retention basins improves treatment of fine particulates and associated pollutants and provides treatment of dry weather flows (nuisance flows). Permanent pools also allow wet retention basins to be designed as aesthetically pleasing water features with additional recreational, wildlife habitat, and educational benefits. Compared to an ED basin of equal volume, a well-designed wet retention basin provides improved water quality treatment by increasing the average hydraulic residence time of storm water in the facility.

Wet retention basins work best under plug flow conditions where the water already present in the permanent pool is displaced by incoming flows with minimal mixing and no short circuiting.

Plug flow describes the hypothetical condition of storm water moving through the basin in such a way that older "slugs" of water (meaning water that's been in the basin for longer) are displaced by incoming slugs of water with little or no mixing in the direction of flow. Short circuiting occurs when quiescent areas or "dead zones" develop in the basin where pockets of water remain stagnant, causing other volumes to bypass using shorter paths through the basin (e.g., incoming storm water slugs bypass these zones). Water quality benefits are also improved when the permanent wet pool volume is significantly greater than the water quality volume, resulting in longer residence times.

Of specific concern in Southern California is the drying of permanent pools due to lack of sufficient base flow to balance evaporation and infiltration. While water quality and aesthetics are sacrificed through loss of the permanent pool, it is acceptable for wet retention basins to dry out for part of the year. Even without a permanent pool, wet retention basins will still provide water quality benefits through capture and infiltration of nuisance flows. However, lakes shall be designed to maintain a permanent pool of water year-round to support the riparian and aquatic vegetation. Consequently, lakes are only appropriate where base flows are sufficient to maintain the permanent pool, or an additional source of water supply (e.g., potable, reclaimed, etc.) is available to supplement base flows during critical periods.

6.10.2.2 Performance, Applicability, and Limitations

Table 6-65, Table 6-66, and Table 6-67 provide a summary of BMP performance, applicability, and limitations for wet retention basins. *It is important to note that information in these tables shall be used to provide general guidance for wet retention basins and shall not replace the evaluation performed by a water quality professional.*

Applicability and Performance

Table 6-65 and associated guidance provide general volume reduction capabilities and treatment effectiveness for wet retention basins. Refer to Section 6.4 for the process that shall be used for selecting BMPs based on pollutants of concern. Refer to Table 6-1 to determine the ranking of constructed treatment wetlands for removal of pollutants of concern as compared with other storm water runoff BMPs provided in Chapter 6. Refer to Table 6-2 to assess the applicability of constructed treatment wetlands for your site based on site suitability considerations as compared with other storm water runoff BMPs provided in Chapter 6. Wet retention basins are volume-based BMPs intended to provide water quality treatment and, when extended detention is provided, attenuate peak runoff discharge rates (see Table 6-65). Although wet retention basins can produce significant volume reduction though evapotranspiration in the summer months (although not as much as constructed treatment wetlands), credit towards meeting the volume reduction requirement, $V_{reduction}$, is not given for wet retention basins because little volume reduction occurs during the winter months when storm water runoff is highest. See Section 6.2 for specific storm water runoff requirements for Tier 3 projects.

Table 6-65: Volume Reduction & Treatment Effectiveness for Wet Retention Basins

Storm Water Runoff BMP	Volume Mitigation (% of inflow)	Treatment Effectiveness for Pollutants of Concern[1]					
		Trash	Nutrients	Bacteria	Metals (particulate and dissolved fractions)	Sediment	Organics (hydro-carbons, oil, and grease)
Wet Retention Basin	◓	◓	◉	◒	●	◓	●
Volume/Treatment Effectiveness: ● *= Very High,* ◓ *= High,* ◉ *= Moderate,* ◒ *= Low,* ○ *= Very Low*							

[1] Effectiveness may change based on design variations; standard BMP designs have been assumed.

Research has shown that wet retention basins have a very high removal rate for sediment, often 70 percent and higher for total suspended solids (TSS), provided the basin is well-maintained. This is because the runoff slows down as it enters the basin and the sediment, as well as sediment bound pollutants such as phosphorus, metals, and pesticides, are removed through sedimentation. Wet retention basins are not as efficient at removal of nitrate-nitrogen as constructed treatment wetlands due to less opportunity for anaerobic denitrification to occur.

Site Suitability Recommendations and Limitations

Table 6-66 provides general guidance for assessing a site's suitability for wet retention basins.

Table 6-66: Site Suitability Considerations for Wet Retention Basins

BMP	Tributary Area (Acres)[1]	Site Slope (%)	Depth to Seasonally High Groundwater Table (ft)	Hydrologic Soil Group	Horizontal Setback from Drinking Water Wells (ft)
Wet Retention Basins	> 10 Acres; 435,600 Sq.Ft.	< 15 [2]	N/A	"A" soils may require pond liner; "B" soils may require infiltration testing	N/A

[1] Tributary area is the area of the site draining to the BMP. Tributary areas provided here shall be used as a general guideline only. Tributary areas can be larger or smaller in some instances.

[2] If site slope exceeds that specified or if the system is within 200 ft from the top of a hazardous slope or landslide area (on the uphill side), a geotechnical investigation and report addressing slope stability shall be prepared by a licensed civil engineer. In addition, for swales, if the longitudinal slope exceeds 6%, check dams shall be provided.

Table 6-67 provides additional site suitability considerations for special design districts within the City including coastal bluff areas and hillside design districts.

Table 6-67: Applicability of Wet Retention Basins for Special Design Districts

Coastal Bluff Area	Hillside Design District
Generally not acceptable in Coastal Bluff Areas.	Acceptable if: (1) a geotechnical investigation proves that the facility does not compromise the stability of the site slope or surrounding slopes, or (2) the facility meets the site slope criteria in Table 6-66 and the facility is fully contained with an impermeable liner and overflow to a storm water conveyance system.

The following provides additional site suitability recommendations and limitations related to wet retention basins.

- Wet retention 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 retention basins must not interfere with flood control functions of existing conveyance and detention structures.

- If wet retention 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 retention 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.

Multi-Use and Treatment Train Opportunities

Provided adequate surcharge storage, a wet retention basin may be combined with a flood control basin to provide both water quality control and peak flow control. This type of basin is termed an extended detention (ED) wet retention basin. Wet retention basins can also be designed with wildlife viewing areas and walking trails around the perimeter to provide passive recreation. Flows may enter a wet retention basin from a pretreatment BMP such as a vegetated swale filter or Vegetated filter strip. The vegetated swales and filter strips not only filter course sediments but also increase the site's time of concentration, T_c, thereby providing some infiltration and evapotranspiration as well as reducing the site's runoff discharge rates.

6.10.2.3 Design Criteria and Procedure

The main challenge associated with wet retention basins is maintaining desired water levels. A wet retention basin is illustrated schematically in Figure 6-24.

Wet retention basins shall be designed according to the current policies of the City and the County of Santa Barbara Flood Control District. Principal design criteria for a wet retention basin are listed in Table 6-68.

Table 6-68: Wet Retention Basin Design Criteria

Design Parameter	Unit	Design Criteria
Maintaining peak runoff discharge rate requirement	cfs	See Section 6.2.1 and Appendix C, must be used with a extended detention
Water quality design volume, V_{wq}	ft^3	See Section 6.2.3 and Appendix C
Drawdown time for extended detention (over permanent pool)	hours	48
Depth without sediment storage	feet	4 (first cell minimum) 8 (any cell maximum)
Maximum residence time	Days	7 (dry weather)
Freeboard (minimum)	inches	12 (off-line); 24 (on-line)
Flow path length to width ratio	L:W	1.5:1 (min.) 2:1 (preferred)
Side slope (maximum)	H:V	4:1 (H:V) Interior and 2:1 (H:V) Exterior
Longitudinal slope	percentage	1 (forebay) and 0-2 (main basin)
Vegetation Type	--	Varies see vegetation section below and Appendix G
Vegetation Height	--	Varies see vegetation section below
Buffer zone (minimum)	feet	25
Maintenance access ramp width	feet	16
Minimum outflow device diameter	inches	18

Sizing for Meeting the Storm Water Runoff Requirements

Wet retention basins can be sized to meet all or part of the water quality design volume and peak runoff discharge rate requirements as outlined in Section 6.2 and Appendix C. A wet retention basin sizing example is provided in Appendix D.

Maintaining peak runoff discharge rate requirement

The wet retention basin can be designed with extended detention (above the permanent pool) to provide sufficient storage for meeting all or part of the peak runoff discharge requirement for the 2-year through the 100-year, 24-hr design storm.

Volume reduction requirement

The volume reduction requirement cannot be met with constructed treatment wetlands.

Water quality treatment volume requirement

The constructed treatment wetland can be designed with or without extended detention (above the permanent pool) to treat all or part of the water quality treatment volume. If extended detention is provided, the drawdown time shall be between 36 to 48 hours.

Geometry and Size

1. If there is no extended detention provided, wet retention 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. If extended detention is provided above the permanent pool and the basin is designed for water quality treatment only, then the permanent pool volume shall be a minimum of 10 percent of the water 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 to meet the peak runoff discharge requirements. The extended detention portion of the wet retention basin above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see Section 6.10.3 for dry ED basin sizing guidelines).

2. The wet retention basin shall be divided into two cells separated by a berm or baffle. The first cell shall contain between 25 to 35 percent of the total volume. The berm or baffle volume shall not count as part of the total volume. *Intent: The full-length berm or baffle reduces short-circuiting and promotes plug flow. Use of a pipe and full-width manifold system to introduce water into the second cell is possible on a case-by-case basis if deemed necessary and approved by the City.*

3. Wet retention basins with wetpool 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 shall be provided in the first cell. The sediment storage shall have a minimum depth of 1 foot. This volume shall not be included as part of the required water quality volume.

5. The minimum depth of the first cell shall be 4 feet, exclusive of sediment storage requirements. The depth of the first cell may be greater than the depth of the second cell.

6. The maximum depth of each cell shall not exceed 8 feet (exclusive of sediment storage in the first cell).

7. For wet retention basin depths in excess of 6 feet, some form of recirculation shall be provided, such as a fountain or aerator, to prevent stratification, stagnation and low dissolved oxygen conditions.

8. Interior side slopes above the permanent pool shall be 4:1 (H:V).

9. The edge of the basin shall 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 shall 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 shall 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 waters edge will minimize very shallow areas that can support mosquitoes.*

10. At least 25% of the basin area shall 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 shall be provided, such as a fountain or aerator, to prevent stratification, stagnation and low dissolved oxygen conditions.

11. A wet retention basin shall 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 shall 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.

12. Inlets and outlets shall be placed to maximize the flowpath through the facility. The flowpath length-to-width ratio shall 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.*

13. All inlets shall enter the first cell. If there are multiple inlets, the length-to-width ratio shall be based on the average flowpath length for all inlets.

14. The minimum freeboard shall 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.

15. The maximum residence time for dry weather flows shall be 7 days. *Intent: Vector control.*

Internal Berms and Baffles

1. A berm or baffle shall extend across the full width of the wet retention basin and be keyed into the basin side slopes. If the berm embankments are greater than 4 feet in height, the berm must 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 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 shall 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 must 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 shall 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 engineer. If a baffle or retaining wall is used, it shall be submerged one foot below the permanent pool surface to discourage access by pedestrians.

5. Internal earthen berms 6 feet high or less shall have a minimum top width 6 feet or as recommended by a civil engineer.

Water Supply

1. Water balance calculations shall 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 shall 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 shall be provided to maintain the basin water surface elevation throughout the year. The water supply shall be of sufficient quantity and quality to not have an adverse impact on the wet retention basin water quality. Water that meets drinking water standards shall be assumed to be of sufficient quality.

3. Wet retention basin may be designed as seasonal ponds where the water balance and water supply conditions make it infeasible to sustain a permanent wet retention basin.

Soils Considerations

Wet retention 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 shall 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) must be placed over the liner (see soil amendment Section 5.10). If a synthetic material is used, a soil depth of 2 feet is recommended to prevent damage to the liner during planting.

Buffer Zone

A minimum of 25 feet buffer shall be provided around the top perimeter of the wet retention basin. The portion of the access road outside of the maximum water level may be included as part of the buffer.

Water Quality Design Features

1. Wet retention basins that are located in publicly-accessible or highly visible locations shall 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. Water quality design features will result in higher quality water in the BMP and lower discharges of pollutants downstream.

2. Wet retention basins in publicly-accessible or highly visible locations shall 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 retention 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.

Energy Dissipation

1. The inlet to the wet retention basin shall 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 shall 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 from the wet retention basin unless the basin discharges to a storm water conveyance system or hardened channel.

Vegetation

A plan shall be prepared that indicates how aquatic, temporarily submerged areas (extended detention wet retention basins) and terrestrial areas will be stabilized with vegetation.

1. If the second cell of the wet retention basin is 3 feet or shallower, the bottom area shall be planted with emergent wetland vegetation.

2. Emergent aquatic vegetation shall be planted to cover 25-75% of the area of the permanent pool.

3. Outside of the basin, native vegetation adapted for site conditions shall be used in non-irrigated sites.

4. The area surrounding a wet retention basin must be landscaped to minimize erosion and must 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, shall not be used within 50 feet of pipes or manmade structures. Weeping willow (*Salix babylonica*) shall 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- http://www.cdfa.ca.gov/phpps/ipc/encycloweedia/encycloweedia_hp.htm or the California Invasive Plant Council website at www.cal-ipc.org.

7. See Appendix G for a recommended native plant list for wet retention basins, a list of local nurseries where these plants can be purchased, and a list of local and regional on-line resources. The plant list shall be used as a guide only and shall not replace project-specific planting recommendations provided by a landscape professional including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth. See Section 5.11 for more information on landscaping/planting recommendations and Section 5.10 for more information on soil amendment recommendations.

Outlet Structure

1. An outlet pipe and outlet structure shall be provided. The outlet pipe may be a perforated standpipe strapped to a manhole (see Figure 6-25) 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) (see Figure 6-26). The grate or birdcage openings provide an overflow route should the basin outlet pipe become clogged.

2. For extended detention wet retention basin, outlet structures shall be designed to provide 12 to 48 hour emptying time for the water quality volume above the permanent pool.

3. The basin outlet pipe shall be sized, at a minimum, to pass flows greater than the water 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.

4. See the dry extended detention section (Section 6.10.3) and Appendix E for further detail on outlet sizing.

Emergency Spillway

An emergency overflow spillway in addition to the primary overflow outlet (as described above) is required. The emergency spillway shall 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 shall be sized for flows greater than the basin design volume (e.g., water quality design volume). The spillway shall be constructed with reinforced concrete and provide for adequate energy dissipation downstream. The spillway shall 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://www.water.ca.gov/damsafety/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 shall 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., water 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 shall be provided. See Appendix E for further detail on basin/pond outlet sizing.
2. The emergency overflow spillway shall be armored to withstand the energy of the spillway flows (Figure 6-32). The spillway shall be constructed of grouted rip-rap.
3. The minimum freeboard shall be 1 foot above the maximum water surface elevation over the emergency spillway.

Side Slopes

1. Interior side slopes above the water quality design depth and up to the emergency overflow water surface shall be no steeper than 4:1 (H:V), unless stabilization has been approved by a licensed civil engineer and the City.
2. Exterior side slopes shall be no steeper than 2:1 (H:V), unless stabilization has been approved by a licensed civil engineer and the City.
3. For any slope (interior or exterior) steeper than 2:1 (H:V), a geotechnical investigation and report must be submitted and approved by the City.
4. Landscaped slopes must 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 engineer and approved by the City.

Embankments

1. Earthworks and berm embankments shall 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 shall be 2 feet minimum below the water quality design water surface and shall 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 engineer and the City.

5. Basin berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a licensed civil engineer) free of loose surface soil materials, roots, and other organic debris.

6. The berm embankment shall 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 must 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 engineer.

8. The berm embankment shall 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 shall be planted on downstream embankment slopes. See vegetation section below.

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. In accordance with the Santa Barbara Flood Control District *Standard Conditions of Project Plan Approval*, facilities to be dedicated to the City, perimeter fencing (minimum height of 42 inches) shall 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 shall be designed and constructed in accordance with current policies of the Santa Barbara County Flood Control District and must 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.

Right-of-Way

1. Constructed treatment wetlands and associated access roads to be maintained by the City shall be dedicated in fee or in an easement to the City with appropriate access.

Maintenance Access

1. Ownership of the basin and maintenance thereof is the responsibility of the developer/applicant. A maintenance agreement with the City is required to ensure adequate performance and allow the City emergency access to the facilities.
2. Maintenance access road(s) shall 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 must be in or at the edge of the access road.
3. A graded 16-foot wide access ramp into the basin shall be constructed near the basin outlet. An access ramp is required for removal of sediment with a backhoe or loader and truck. The ramp must extend to the basin bottom to avoid damage to vegetation planted on the basin slope. A 16-foot wide commercial driveway approach shall be provided where curb and gutter front the maintenance ramp.
4. All access ramps and roads shall be provided in accordance with the current policies of the Flood Control District.

Vector Control

1. A Mosquito Management Plan or Service Contract must be approved or waived by the Santa Barbara Coastal Vector Control District for any facility that maintains a pool of water for 72 hours or more.

Design Requirements Specific to Lakes

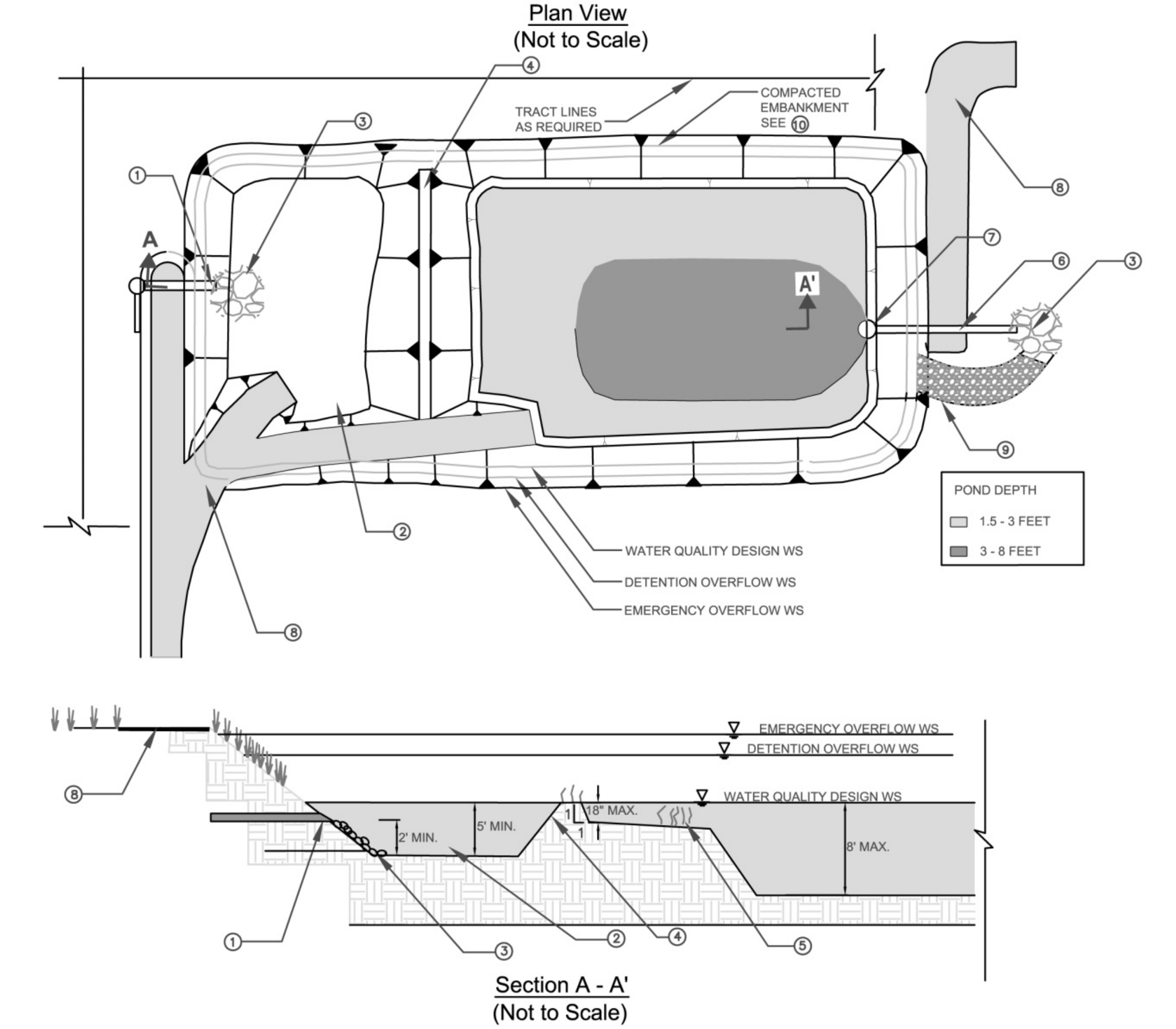
Lakes designed to provide treatment may be used for storm water quality management, but will not be publicly maintained. Many of the wet retention basin design specifications discussed above are applicable to lakes such as the outlet works and maintenance access, but specific design features are also required. For example, a consistent water supply is required to maintain the wet pool in the lake year-round and to flush the system during spring and fall turnover to reduce the potential for the build-up of salts and nutrients in the lake. The wet retention basin shall also be sized as three times the water quality design volume so that the water quality does not drastically fluctuate during such events. Lakes shall also have depths greater than 8 feet, and preferably up to 15 feet at the center, to reduce light penetration, maintain a lower average temperature, allow for temperature stratification, and minimize evaporation. Lakes may be exempt from the fencing requirements applicable to wet retention basins if they exceed one acre in surface area and are used for recreational purposes. Additional design elements specific to lakes to provide storm water treatment and to maintain the water quality in the lake include wetland planters, lake biofilter beds, dry weather flow pretreatment, aeration, and storm water retention.

Submerged wetland planters may be constructed on shelves or floating rafts within the lake to assist in promoting overall water quality through filtering. Lake biofilters, through which lake water is circulated and distributed by a slotted-pipe system, shall consist of separate, self-contained, submerged gravel beds placed at terminal ends of the lake geometry. A naturally occurring biomass of microorganisms coats the gravel and reduces nutrients that would otherwise promote algae growth in the lake. Pretreatment filters also shall be provided to treat all dry weather flows prior to entering the lake. In addition, fine-bubble diffusion aerators and recirculation pumping shall be installed to reintroduce oxygen into the system and increase overall dissolved-oxygen content. Adequate capacity shall be provided in the lake to maintain a permanent pool, retain the water quality design storm, and provide storage of runoff for irrigation reuse.

6.10.2.4 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.

Figure 6-24: Wet Retention Basin Schematic



NOTES:

1. INLET PIPE SHOULD BE SUBMERGED WITH A MINIMUM OF 2' DISTANCE FROM THE BOTTOM.
2. FIRST CELL VOLUME SHALL EQUAL 25% TO 35% OF TOTAL WETPOND VOLUME. DEPTH SHALL BE 4' TO 8' PLUS AN ADDITIONAL I' MIN SEDIMENT STORAGE DEPTH FOR THE FIRST CELL.
3. RIPRAP APRON OR OTHER ENERGY DISSIPATION.
4. BERM SHALL EXTEND ACROSS ENTIRE WIDTH OF THE WETPOND AND SHALL BE KEYED INTO EMBANKMENT A MINIMUM OF 1' ON BOTH SIDES.
5. EMERGENT VEGETATION SHALL BE PLANTED IN REGIONS OF THE POND THAT ARE 3' DEEP OR LESS.
6. SIZE OUTLET PIPE TO PASS 100-YEAR PEAK FLOW FOR ON-LINE PONDS AND WATER QUALITY PEAK FLOW FOR OFF-LINE PONDS. MINIMUM DIAMETER OF OUTLET PIPE SHALL BE 18".
7. WATER QUALITY OUTLET STRUCTURE. SEE FIGURE 6-25 AND FIGURE 6-26 FOR DETAILS.
8. INSTALL PAVED MAINTENANCE ACCESS ROAD.WIDTH SHALL BE A MINIMUM OF 16' AND SLOPE SHALL NOT EXCEED 12%. SHALL PROVIDE ACCESS TO BOTH THE FIRST CELL AND MAIN BASIN.
9. INSTALL EMERGENCY OVERFLOW SPILLWAY AS NEEDED. SEE FIGURE 6-32 FOR DETAILS.
10. EMBANKMENT SIDE SLOPES SHALL BE NO STEEPER THAN 2H:1V OUTSIDE AND 4H:1V INSIDE. FENCING (MINIMUM HEIGHT OF 42") SHALL BE REQUIRED ON ALL BASINS EXCEEDING TWO FEET IN DEPTH OR WHERE INTERIOR SIDE SLOPES ARE GREATER THAN 6H:1V.

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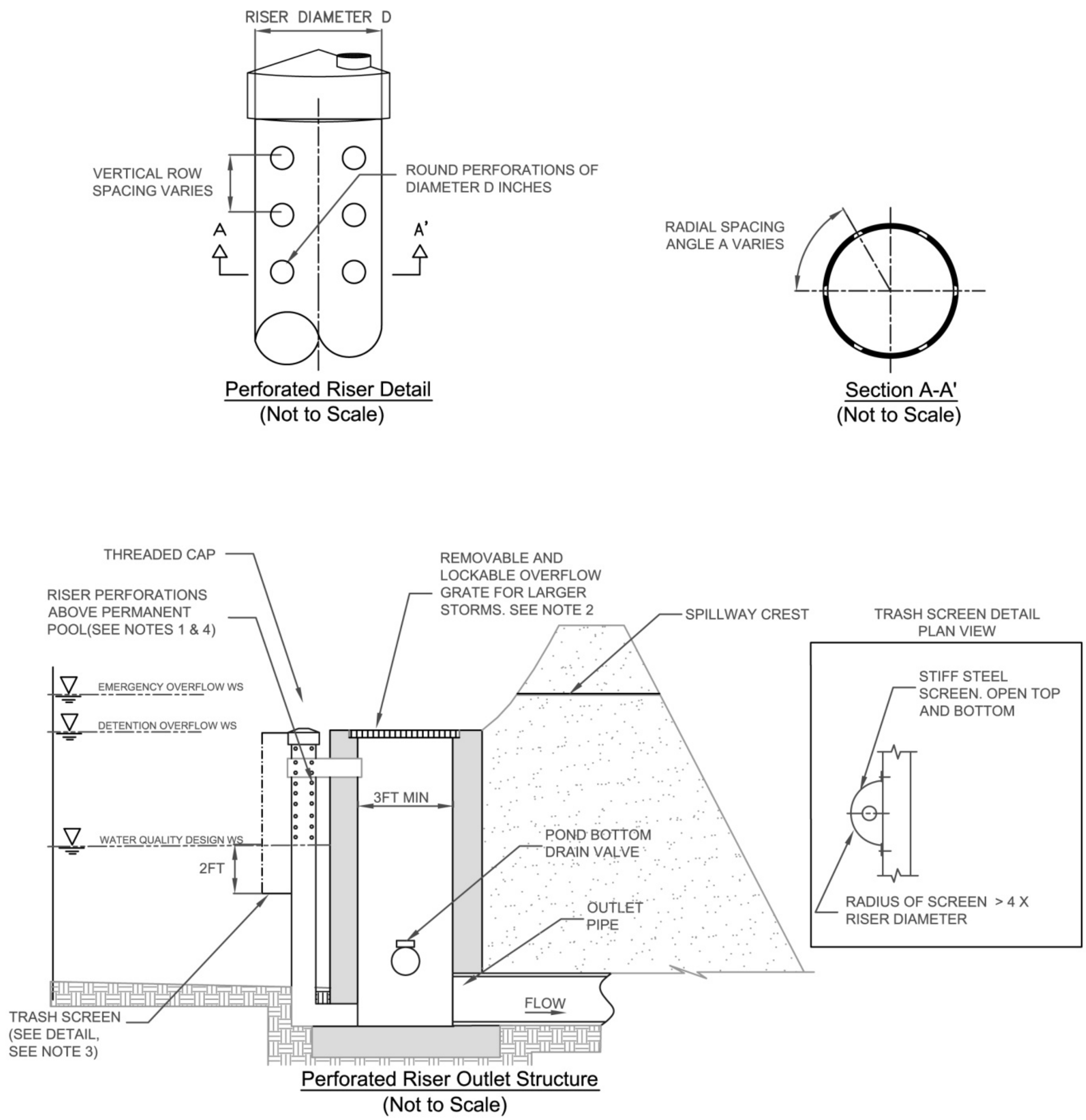
Figure 6 - 24
WET RETENTION BASIN

Figure 6-25: Riser Outlet Schematic – Option 1



NOTES:

1. RISER PIPE SHALL BE SIZED TO PROVIDE 36 TO 48-HOUR FULL BRIM DRAW DOWN TIME FOR THE WATER QUALITY DESIGN VOLUME.
2. TOTAL OUTLET CAPACITY: 100-YEAR PEAK FLOW FOR ON-LINE BASINS AND WATER QUALITY DESIGN FLOW FOR OFF-LINE BASINS. MINIMUM DIAMETER OF OUTLET PIPE SHALL BE 18".
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".

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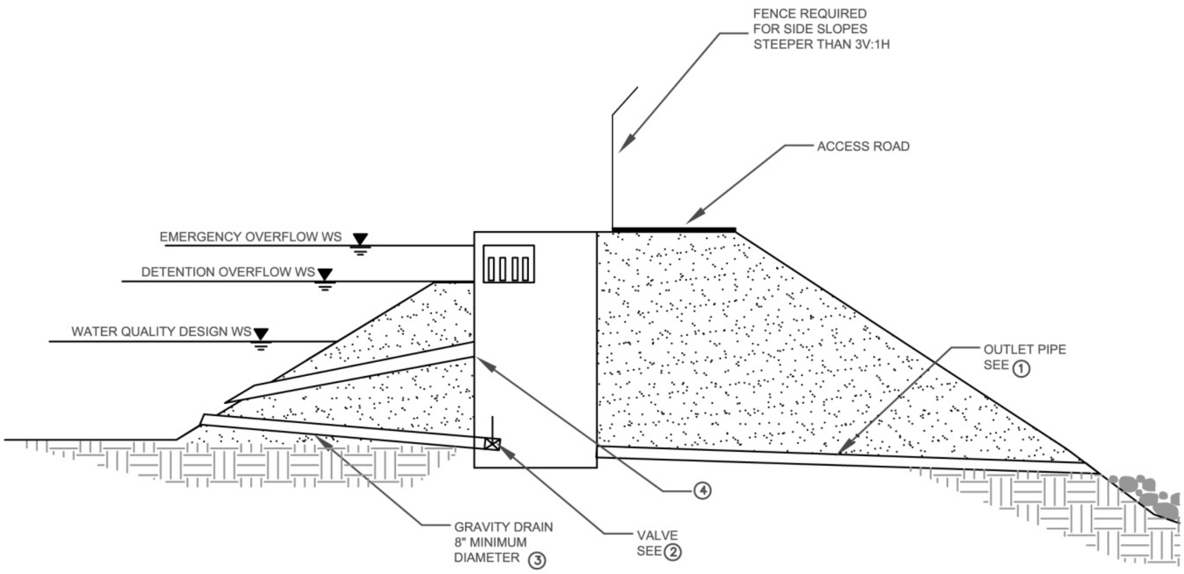
Figure 6 - 25

RISER OUTLET - OPTION 1

Figure 6-26: Inverted Pipe Outlet Schematic – Option 2



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 WATER QUALITY DESIGN WATER SURFACE.

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Figure 6 - 26
INVERTED PIPE OUTLET - OPTION 2

6.10.2.5 Operations and Maintenance

General Requirements

Maintenance is of primary importance if wet retention 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 wet retention basin shall be inspected at a minimum annually and inspections after major storm events are encouraged (see Appendix H for a wet retention basin inspection and maintenance checklist). Trash and debris shall be removed as needed, but at least annually prior to the beginning of the wet season.

2. Site vegetation shall be maintained as frequently as necessary to maintain the aesthetic appearance of the site, and as follows:

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

4. Slope areas that have become bare shall be revegetated and eroded areas shall be regraded prior to being revegetated.

5. Grass shall be mowed and grass clippings shall be removed.

6. Fallen leaves and debris from deciduous plant foliage shall 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*) must 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- http://www.cdfa.ca.gov/phpps/ipc/encycloweedia/encycloweedia_hp.htm or the California Invasive Plant Council website at www.cal-ipc.org.

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

9. Sediment buildup exceeding 1.5 inches in the first cell shall be removed (or 6 inches above the sediment storage depth which is recommended to be 1 foot). Sediment from the second basin cell shall be removed when 6 inches of sediment accumulates.

10. Sediments shall be tested for hazardous 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.

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

Maintenance Standards

A summary of the routine and major maintenance activities recommended for wet retention basins is shown in Table 6-69. Routine and major maintenance standards listed in Table 6-70 and Table 6-71 are intended to be measures to determine if maintenance actions are required as identified through inspection. They are not intended to be measures of the facility's required condition at all times between inspections. In other words, exceedance of these thresholds or measures at any time between inspections and/or scheduled maintenance does not constitute a violation of these standards. These standards are violated only when an inspection identifies required maintenance action that has not been scheduled before the next regular inspection.

Table 6-69: Wet Retention Basin Maintenance Quick Guide

Inspection and Maintenance Activities Summary	
Routine Maintenance	• Trash and debris removal • Remove minor sediment accumulation near inlet and outlet structures • Stabilize/repair eroded banks and fill in animal burrows if present • Remove any evidence of visual contamination from floatables such as oil and grease • Eliminate pests and conditions suitable for creating ideal breeding habitat • Remove algae mats as often as needed to prevent coverage of more than 20% of basin surface • Mow berms routinely if applicable to maintain aesthetic appeal and to suppress weeds • Periodically observe function under wet weather conditions • Photographs taken before and after maintenance is encouraged
Major Maintenance	• Remove dead, diseased, or dying trees and woody vegetation that interfere with facility maintenance • Install or repair basin liner to ensure that first cell maintains a permanent pool • Correct problems associated with berm settlement • Remove trees, large shrubs and roots from downstream slope of embankments. • Repair berm/dike breaches and stabilize eroded parts of the berm • Repair and rebuild spillway as needed to correct severe erosion damage • Remove sediment build up in forebay and main basin area to restore original sediment holding capacity • Re-grade main basin bottom to restore bottom slope and eliminate the incidence of standing pools • Aerate compacted areas to promote infiltration if volume reductions are desired • Repair or replace gates, fences, flow control structures, and inlet/outlet structures as needed to maintain full functionality

Table 6-70: Routine Maintenance Standards – Wet Retention Basin

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
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.	Trash and debris cleared from site.	Annually prior to wet season After major storm events (>0.75 in/24 hrs) if spot checks of some basins indicate widespread damage/ maintenance needs
Sediment Accumulation	Sediment accumulation in basin bottom that exceeds the depth of the design sediment zone plus 6 inches, usually in the first cell.	Sediment cleaned out.	
Erosion	Erosion of basin's side slopes and/or scouring of basin bottom.	Slopes shall be stabilized using appropriate erosion control measure(s) and repair methods.	
Oil Sheen on Water	Prevalent and visible oil sheen.	Oil sheen removed using absorbent boom or skimmer.	
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.	Vectors controlled per Santa Barbara Coastal Vector Control District. A Mosquito Management Plan or Service Contract must be presented to the Vector Management District for any facility that maintains a pool of water for 72 hours or more.	
Water Level	First cell empty, doesn't hold water.	Line the first cell to maintain at least 4 feet of water. Although the second cell may drain, the first cell must remain full to control turbulence of the incoming flow and reduce sediment resuspension.	
Algae Mats	Algae mats over more than 20% of the water surface.	Algae mats removed using rake or other skimming device.	

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Aesthetics	Minor vegetation removal and thinning. Mowing berms and surroundings	Facility is well kept.	Monthly (or as dictated by agreement between County and landscape contractor)
Noxious Weeds	Any evidence of noxious weeds.	Eradicate all noxious weeds; control and prevent the spread of all noxious weeds. Use Integrated Pest Management techniques, if applicable. See http://www.ipm.ucdavis.edu for more information.	

Table 6-71: Major Maintenance Standards – Wet Retention Basin

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
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.	Trees do not hinder maintenance activities. Remove dead, diseased, or dying trees. (Use a certified Arborist to determine health of tree or removal requirements).	Annual or as needed (infrequent) After major storm events (>0.75 in/24 hrs) if spot checks of some basins indicate widespread damage/ maintenance needs.
Settling of Berm	If settlement is apparent. Settling can be an indication of more severe problems with the berm or outlet works. A civil engineer shall be consulted to determine the source of the settlement if the dike/berm is serving as a dam.	Dike is built back to the design elevation.	
Piping through Berm	Discernable water flow through basin berm. Ongoing erosion with potential for erosion to continue. A licensed civil engineer shall be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved and berm stability achieved.	

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
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.	Trees and large shrubs shall be removed. All dead roots shall be removed if practical. Otherwise, dead roots shall be removed to a minimum of 36 inches below grade and replaced with cement grout to 12 inches below grade. The top 12 inches of the root holes shall be filled with compacted, in-situ soils. The area facility engineer may require additional root removal if necessary for dam safety or maintenance purposes.	
Erosion on Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.	Rocks and pad depth are restored to design standards.	
Gate/Fence Damage	Damage to gate/fence, including missing locks and hinges	Gate/Fence repaired.	

6.10.3 Dry Extended Detention Basins

Figure 6-27: Dry ED Basin ***(dual use; playing field when dry)***

Applications

- Roads and highways
- Commercial developments
- Office building developments
- Multi-family developments

Performance/Advantages

- Efficient removal of pollutants adsorbed to sediments
- Potentially significant volume mitigation

Limitations

- Requires large tributary area
- Must be sited in areas where current flood control structures are not adversely affected

6.10.3.1 Description

Dry extended detention (ED) basins (e.g., dry ponds, extended detention basins, detention ponds, or extended detention ponds) are basins whose outlets have been designed to detain the water quality design volume, V_{wq}, 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. Where soil conditions allow, they can also be modified to achieve volume reduction goals by including a sand filter layer beneath the basin to detain and infiltrate additional runoff. The slopes, bottom, and forebay of dry ED basins are typically vegetated. Without the addition of a sand filter beneath the basin, considerable storm water volume reduction can still occur, depending on the infiltration capacity of the subsoil. Data from the International BMP Database have shown that as much as 30 percent of storm water volume captured by dry extended detention basins can be lost to infiltration (Strecker et al., 2004).

Dry ED basins can be designed either on-line or off-line. If it is designed just for water quality treatment, it is recommended that the basin be off-line from flood conveyance. For off-line basins, a flow diversion structure (i.e., flow splitter) is used to divert the water quality design volume to the basin. For on-line basins, storm events exceeding the water quality design volume will be routed through the basin and discharged from a primary overflow structure at rates that do not exceed pre-development rates for storms up to the 100-year, 24-hr design storm. Storm events that exceed the 100-year design storm will exit the basin over an emergency spillway. If basins are to be on-line, they must be designed to pass the appropriate flood without damage to the basin, as well as to minimize re-entrainment of pollutants. In both types of basins, influent flows enter a sediment forebay where coarse solids are first removed prior to flowing into the main cell of the basin where finer sediment and associated pollutants settle as storm water is detained and slowly released through a controlled outlet structure. Dry weather flows and very low storm flows are often infiltrated within the basin. If standing water is a concern due to dry weather flows, a low flow drain can be installed to convey the dry weather flows out of the basin and to another storm water runoff BMP, storm water conveyance system, or other acceptable discharge point.

6.10.3.2 Performance, Applicability, and Limitations

Table 6-72, Table 6-73, and Table 6-74 provide a summary of BMP performance, applicability, and limitations for dry ED basins. *It is important to note that information in these tables shall be used to provide general guidance for dry ED basins and shall not replace the evaluation performed by a water quality professional.*

Applicability and Performance

Table 6-72 and associated guidance provide general volume reduction capabilities and treatment effectiveness for dry ED basins. Refer to Section 6.4 for the process that shall be used for selecting BMPs based on pollutants of concern. Refer to Table 6-1 to determine the ranking of constructed treatment wetlands for removal of pollutants of concern as compared with other storm water runoff BMPs provided in Chapter 6. Refer to Table 6-2 to assess the applicability of constructed treatment wetlands for your site based on site suitability considerations as compared with other storm water runoff BMPs provided in Chapter 6. Dry extended detention basins are volume-based BMPs intended to provide: (1) water quality treatment, (2) varying levels of volume reduction depending on site conditions and design, and (3) control of the peak runoff discharge rate (see Table 6-72). Dry weather flows and small storm flows are often infiltrated within the basin. If site conditions allow, a hybrid sand filter or planting media layer placed beneath the dry extended detention basin (as described in this section), can be designed to increase the infiltration capacity of the basin. In this hybrid case or when the detention basin is underlain by infiltrative soils, credit can be gained towards meeting the volume reduction requirement, $V_{reduction}$, as described below in the basin sizing section. See Section 6.2 for specific storm water runoff requirements for Tier 3 projects.

Table 6-72: Volume Reduction & Treatment Effectiveness for Dry ED Basins

Storm Water Runoff BMP	Volume Mitigation (% of inflow)	Treatment Effectiveness for Pollutants of Concern[1]					
		Trash	Nutrients	Bacteria	Metals (particulate and dissolved fractions)	Sediment	Organics (hydro-carbons, oil, and grease)
Dry Extended Detention Basin	◉	◓	◒	◓	◒	◉	◉
Volume/Treatment Effectiveness: ● = Very High, ◓ = High, ◉ = Moderate, ◒ = Low, ○ = Very Low							

[1] Effectiveness may change based on design variations; standard BMP designs have been assumed.

Water quality treatment is provided in the sediment forebay and the main cell. The sediment forebay provides removal of coarse solids prior to flow entering the main cell of the basin where finer sediment and associated pollutants settle as storm water is detained and slowly released through a controlled outlet structure.

Site Suitability Recommendations and Limitations

Table 6-73 and associated guidance provide general considerations for assessing a site's suitability for dry ED basins.

Table 6-73: Site Suitability Considerations for Dry Extended Detention Basins

BMP	Tributary Area (Acres)[1]	Site Slope (%)	Depth to Seasonally High Groundwater Table (ft)	Hydrologic Soil Group	Horizontal Setback from Drinking Water Wells (ft)
Dry Extended Detention Basin	> 5	< 15 [2]	> 2 if infiltration is not significant; > 5 when basin is designed to achieve volume reduction requirements	Any	100 when basin is designed to achieve volume reduction requirements

[1] Tributary area is the area of the site draining to the BMP. Tributary areas provided here shall be used as a general guideline only. Tributary areas can be larger or smaller in some instances.

[2] If slope exceeds given limit or is within 200 feet from the top of a hazardous slope or landslide area, a geotechnical investigation is required.

Table 6-74 provides additional site applicability considerations for special design districts within the City including coastal bluff areas and hillside design districts.

Table 6-74: Applicability of Dry ED Basins for Special Design Districts

Coastal Bluff Area	Hillside Design District
Generally not acceptable in Coastal Bluff Areas.	Acceptable if: (1) a geotechnical investigation proves that the facility does not compromise the stability of the site slope or surrounding slopes, or (2) the facility meets the site slope criteria in Table 6-73 and the facility is fully contained with an impermeable liner and overflow to a storm water conveyance system.

The following describes additional site suitability recommendations and limitations for dry extended detention basins.

- The tributary area associated with a dry ED basin shall be greater than 10 acres. Use of dry ED basins may be limited in high density locations where insufficient space is available to achieve reductions in storm water runoff discharge flow rate, volume, and/or pollutants.

- Site slope shall be less than 15% due to slope instability and landslide potential. If slopes exceed this limit, a geotechnical investigation is required.

- The location of dry ED basins shall not be within 200 feet from the top of a hazardous slope or landslide area. If so, a geotechnical investigation is required.

- For dry ED basins that do have significant infiltration (i.e., not designed to achieve the volume reduction requirements), maximum groundwater levels shall be at least 2 ft lower than the bottom the dry ED basin to prevent the base from remaining wet between storms. If the dry ED basin is designed for significant infiltration (i.e., designed to achieve the volume reduction requirements), maximum groundwater levels shall be at least 5 ft lower than the bottom of the basin to minimize water quality impacts to groundwater.

- Dry ED basins shall not be designed for significant infiltration in areas of high industrial activity or other locations where a heightened threat of groundwater contamination may exist.

- Dry ED basins shall not be placed within a blue-line (i.e., first order) stream.

Multi-Use and Treatment Train Opportunities

A dry ED basin can sometimes be retrofitted into existing flood control basins or integrated into the design of a park, athletic field, or other green space. Hybrid dry ED basins that incorporate a sand filter or planting media underneath the basin are an option for increasing volume reduction. The hybrid dry ED basin and sand filter or planting media system can also have recreational use by using the system as a volleyball court. Both of these applications can encourage infiltration if site conditions allow and require significant pretreatment to remove coarse solids, trash and debris, and oil and grease. Perforated risers, multiple orifice plate outlets, or similar multi-stage outlets are required for flood control retrofit applications to ensure adequate detention time for small storms while still providing peak flow attenuation for the flood design storms. Recreational multi-use facilities must be inspected after every storm and may require a greater maintenance frequency than dedicated water quality basins as to ensure aesthetics and public safety are not compromised. Any planned multi-use facility may be required to obtain special approval from the City.

Dry ED basins can also be combined with other basic and storm water runoff BMPs to form a "treatment train" that provides enhanced water quality treatment and reductions in runoff volume and rate. For example, a vegetated swale can be placed upgradient of a dry ED basin, allowing the rate and volume of water flowing to the dry ED basin to be reduced and the water quality enhanced. As another example, dry ED basins may be placed upstream of a vegetated swale to reduce the size of the vegetated swale. In both cases, each facility can be reduced in size accordingly based upon demonstrated performance for meeting the storm water runoff requirements as outlined in Section 6.2 and addressing targeted pollutants of concern.

6.10.3.3 Design Criteria and Procedure

Dry ED basins shall be designed according to the current policies of the City and the County of Santa Barbara Flood Control District. Standard design criteria for dry ED basins are listed in Table 6-75.

Table 6-75: Dry Extended Detention Basin Design Criteria

Design Parameter	Unit	Design Criteria
Maintaining peak runoff discharge rate requirement	cfs	See Section 6.2.1 and Appendix C
Design volume reduction requirement, $V_{reduction}$	acre-feet	See Section 6.2.2 and Appendix C
Water quality design volume, V_{wq}	acre-feet	See Section 6.2.3 and Appendix C
Forebay basin size	acre-feet	25% of total basin volume
Drawdown time for V_{wq}	hours	Top 50%: 12-16 hrs; Bottom 50%: 24-32 hrs
Freeboard (minimum)	inches	12; for off-line facilities
Flow path length to width ratio	L:W	3:1; can be achieved using internal berms
Side slope (maximum)	H:V	4:1 (H:V) Interior and 2:1 (H:V) Exterior
Longitudinal slope	percentage	1 (forebay) and 0-2 (main basin)
Low flow channel geometry [1]	feet	Of 'sufficient size' (see footnote below)
Maintenance access ramp width	feet	16
Minimum outflow device diameter	inches	18

Sizing for Meeting the Storm Water Runoff Requirements

Dry extended detention basins can be sized to meet all or part of the storm water runoff requirements as outlined in Section 6.2 and Appendix C. A schematic of a standard dry ED basin is illustrated in Figure 6-28. A dry ED basin sizing example is provided in Appendix D.

Maintaining peak runoff discharge rate requirement

The dry ED basin can be designed with sufficient storage to meet all or part of the peak runoff discharge requirement for the 2-year through the 100-year, 24-hr design storm.

Volume reduction requirement

If the dry ED basin is underlain by a subsoil with an infiltration of 0.5 in/hr or greater (as determined using the methods outlined in Chapter 3), a volume reduction of 15 percent of storm water volume captured by dry ED basin can be credited towards the volume reduction requirement, $V_{reduction}$.

If the dry ED basin is combined with a sand filter, a larger volume reduction can be credited towards the volume reduction requirement, $V_{reduction}$, based on the demonstrated design and performance of the system.

<u>Water quality treatment volume requirement</u>

The dry ED basin can be designed to treat the water quality treatment volume with a 36 to 48 hour drawdown time

Geometry and Size

1. The total basin volume shall be increased an additional 5% of the water quality design volume to account for sediment accumulation. If the basin is designed only for water quality treatment then the basin volume would be 105% of the water quality design volume, V_{wq}. Freeboard is in addition to the total basin volume.

2. The minimum freeboard shall 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 shall 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 shall be approximately trapezoidal with a maximum side slope of 4:1 (H:V) on interior slopes and 2:1 (H:V) on exterior slopes unless specifically permitted by the County (see Side Slopes below). Shallower side slopes are necessary if the basin is designed to have recreational uses during dry weather conditions.

5. All dry ED basins shall be free draining and a low flow channel shall 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 shall 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 shall 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 shall 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 shall slope 2% toward the center low flow channel.

7. A basin shall be large enough to allow for equipment access via a graded 16-foot wide access ramp. If the total basin volume is such that the basin bottom is less than 16 feet wide, an alternative BMP shall be considered or the Santa Barbara County Flood Control District shall be contacted for approval. See Maintenance Access below.

Soils Considerations

1. Dry ED basins can be used with almost all soils and geology, with minor design adjustments for rapidly percolating soils (sandy or gravelly soils with infiltration rate > 2.4 in/hr). If rapidly percolating soils are present, dry ED basins shall be lined with compacted low permeability soil or use another other type of liner to prevent rapid, untreated infiltration.

2. The slopes of the detention basin shall be analyzed for slope stability using rapid drawdown conditions and shall meet the minimum standards set by the Santa Barbara County Flood Control District. A 1.5 static factor of safety shall be used. Seismic analysis is not required due to the temporary storage of water in the basin.

3. The infiltration capability of the dry ED basin can be enhanced by incorporating soil amendments. See Section 5.10 for more information.

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 shall be installed at the inlet to the sediment forebay. Flow velocity into the basin forebay shall 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.

Sediment Forebay

As untreated storm water 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 shall be sized so that 25% of the total basin volume is in the forebay and 75% of the total basin volume is in the main portion of the basin.

2. A gravity drain outlet from the forebay (2" minimum diameter) must 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 shall be offset (horizontally) from the inflow streamline to prevent short-circuiting.

4. Permanent steel post depth markers shall be placed in the forebay to define sediment removal limits at 50% of the forebay sediment storage depth.

Vegetation

Vegetation within the dry ED basin provides erosion protection from wind and water and biofiltration of storm water. The City shall review and approve any proposed basin landscape plan prior to implementation and following guidelines shall be followed:

1. The bottom and slopes of the dry ED basin shall be vegetated. A mix of erosion-resistant plant species that effectively bind the soil shall be used on the slopes and a diverse selection of plants that thrive under the specific site, climatic, and watering conditions shall be specified for the basin bottom. The basin bottom shall not be planted with trees, shrubs, or other large woody plants that may interfere with sediment removal activities. The basin shall be free of floating objects. Only native perennial grasses, forbs, or similar vegetation that can be replaced via seeding shall be used on the basin bottom.

2. Landscaping outside of the basin is required for all dry ED basins and must 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, shall not be used within 50 feet of pipes or manmade structures. Weeping willow (*Salix babylonica*) shall 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- http://www.cdfa.ca.gov/phpps/ipc/encycloweedia/encycloweedia_hp.htm or the California Invasive Plant Council website at www.cal-ipc.org.

3. See Appendix G for a recommended native plant list for dry extended detention basins, a list of local nurseries where these plants can be purchased, and a list of local and regional on-line resources. The plant list shall be used as a guide only and shall not replace project-specific planting recommendations provided by a landscape professional including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth. See Section 5.11 for more information on landscaping/planting recommendations and Section 5.10 for more information on soil amendment recommendations.

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 0.05 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 shall be less than 72 hours. The base of the sand filter or planting media layer shall 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. See Sections 6.6.4

for sizing calculations for sand filters and Section 6.6.1 for sizing calculations for bioretention areas. The depth of water in the dry ED basin shall not exceed 6 feet.

Outlet Structure and Drawdown Time

A drawdown time of 36 to 48 hours shall be provided for the water quality design volume, V_{wq}. 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 shall 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. *Intent: 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 storm water runoff discharge rates for the 2- through 100-year 24-hour storm events as required by the Santa Barbara County Flood Control District. 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) shall 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).

The outlet structure can be placed in the basin with a debris screen (Figure 6-29) or housed in a standard manhole (Figure 6-30 and Figure 6-31). If a multiple orifice structure is used, an orifice restriction (if necessary) shall 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 shall be removable for emergency situations. A removable trash rack shall be provided at the outlet. Orifice plates and trash racks shall be galvanized. Mounting hardware shall utilize stainless steel bolts.

Note that a primary overflow (typically a riser pipe connected to the outlet works) shall be sized to pass flows larger than the water 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.

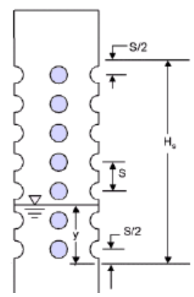
Perforated Risers Outlet Sizing Methodology

The following attributes influence the perforated riser outlet sizing calculations**:**

- Shape of the basin (e.g., trapezoidal)
- Depth and volume of the basin
- Elevation / depth of first row of holes
- Elevation / depth of last row of holes
- Size of perforations
- Number of rows or perforations and number of perforations per row
- Desired drawdown time (e.g., 16 hour and 32 hour draw down for top half and bottom half respectively, 48 hour total drawdown time for the water quality design volume)

The governing the rate of discharge from a perforated riser structure can be calculated using Equation 6-32 below:

$$Q = C_p \frac{2A_p}{3H_s} \sqrt{2g} H^{3/2} \quad \text{(Equation 6-32)}$$



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 6-32 may be used as shown below in Equation 6-33 and Equation 6-34:

$$Q = kH^{3/2} \quad \text{(Equation 6-33)}$$

Where:

$$k = C_p \frac{2A_p}{3H_s} \sqrt{2g} \quad \text{(Equation 6-34)}$$

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 (Figure 6-29 and Figure 6-30). The steps needed to size a perforated riser outlet are illustrated in Appendix E.

Multiple Orifice Outlet Sizing Methodology

The following attributes influence multiple orifice outlet sizing calculations**:**

- Shape of the basin (e.g., trapezoidal)
- Depth and volume of the basin
- Elevation of each orifice
- Desired draw-down time (e.g., 16 hour and 32 hour draw down times for top half and bottom half respectively, 48 hour drawdown time for water quality design volume)

The rate of discharge from a single orifice can be calculated using Equation 6-35.

$$Q = CA(2gH)^{0.5} \qquad \text{(Equation 6-35)}$$

Where:

Q	=	orifice flow discharge
C	=	discharge coefficient
A	=	cross-sectional area of orifice or pipe (ft^2)
g	=	acceleration due to gravity (32.2 ft/s^2)
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 (Figure 6-31). The steps needed to size a dual orifice outlet are outlined in Appendix E; multiple orifices may be provided and sized using a similar approach.

Emergency Spillway

An emergency overflow spillway in addition to the primary overflow outlet (as described above) is required. The emergency spillway shall 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 shall be sized for flows greater than the basin design volume (e.g., water quality design volume). The spillway shall be constructed with reinforced concrete and provide for adequate energy dissipation downstream. The spillway shall 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://www.water.ca.gov/damsafety/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 shall 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 storm water 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 shall be provided.

2. The emergency overflow spillway shall be armored to withstand the energy of the spillway flows (Figure 6-32). The spillway shall be constructed of grouted rip-rap.

3. The minimum freeboard shall be 1 foot above the maximum water surface elevation over the emergency spillway.

Side Slopes

1. Interior side slopes above the water quality design depth and up to the emergency overflow water surface shall be no steeper than 4:1 (H:V), unless stabilization has been approved by a licensed civil engineer and the City.

2. Exterior side slopes shall be no steeper than 2:1 (H:V), unless stabilization has been approved by a licensed civil engineer and the City.

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 City.

4. Landscaped slopes must 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 engineer and approved by the City.

Embankments

1. Earthworks and berm embankments shall 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 shall be 2 feet minimum below the water quality design water surface and shall 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 engineer and the City.

5. Basin berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a licensed civil engineer) free of loose surface soil materials, roots, and other organic debris.

6. The berm embankment shall 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 must 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 engineer.

8. The berm embankment shall 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 shall be planted on downstream embankment slopes. See vegetation section below.

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. In accordance with the Santa Barbara Flood Control District *Standard Conditions of Project Plan Approval*, facilities to be dedicated to the City, perimeter fencing (minimum height of 42 inches) shall be required on all basins exceeding two feet in depth or where interior side slopes are steeper than 6:1 (H:V).

3. If fences are required, fences shall be designed and constructed in accordance with current policies of the Santa Barbara County Flood Control District and must 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.

Right-of-Way

1. Constructed treatment wetlands and associated access roads to be maintained by the City shall be dedicated in fee or in an easement to the City with appropriate access.

Maintenance Access

1. Ownership of the basin and maintenance thereof is the responsibility of the developer/applicant. A maintenance agreement with the City is required to ensure adequate performance and allow the City emergency access to the facilities.

2. Maintenance access road(s) shall 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 must be in or at the edge of the access road.

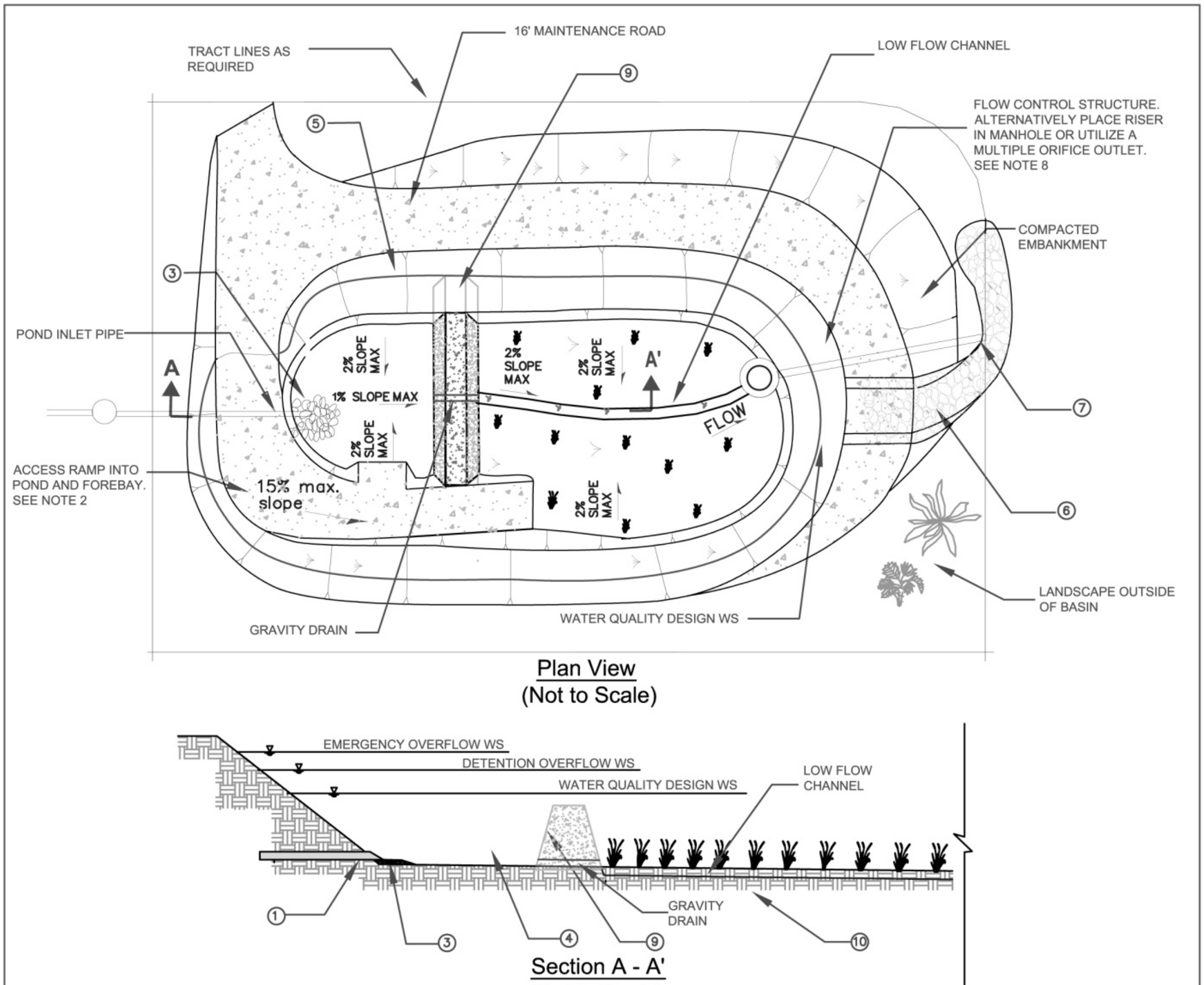
3. A graded 16-foot wide access ramp into the basin shall be constructed near the basin outlet. An access ramp is required for removal of sediment with a backhoe or loader and truck. The ramp must extend to the basin bottom to avoid damage to vegetation planted on the basin slope. A 16-foot wide commercial driveway approach shall be provided where curb and gutter front the maintenance ramp.

4. All access ramps and roads shall be provided in accordance with the current policies of the Flood Control District.

6.10.3.4 Construction Considerations

The use of treated wood or galvanized metal anywhere inside the facility is prohibited. The use of galvanized fencing is permitted by the Flood Control District.

Figure 6-28: Dry Extended Detention Basin Schematic



NOTES:

1. INLET PIPE SHALL BE DESIGNED AND LOCATED SO THAT NON-EROSIVE VELOCITIES OCCUR IN THE FOREBAY.
2. MAINTENANCE RAMP SHOULD BE PAVED AND SHOULD BE 16' WIDE. SLOPE SHOULD NOT EXCEED 12%. MAINTENANCE RAMP SHOULD PROVIDE ACCESS TO BOTH THE FOREBAY AND MAIN BASIN.
3. RIPRAP APRON OR OTHER INLET ENERGY DISSIPATION SHALL BE PROVIDED SUCH THAT VELOCITIES IN THE FOREBAY ARE < 4 FT/S.
4. SEDIMENT FOREBAY SHOULD BE SIZED TO PROVIDE 25% OF THE TOTAL BASIN VOLUME.
5. INTERIOR SIDE SLOPES SHALL NOT EXCEED 4:1 AND EXTERIOR SIDE SLOPES SHALL NOT EXCEED 2:1 UNLESS APPROVED BY A LICENSED CIVIL ENGINEER.
6. EMERGENCY SPILLWAY MUST BE SIZED TO PASS 100-YEAR PEAK FLOW FOR ON-LINE BASINS, AND WATER QUALITY DESIGN FLOW FOR OFF-LINE BASINS. SEE FIGURE 6-32.
7. OUTLET PIPE SHALL BE A MINIMUM 18". ENERGY DISSIPATION SHALL BE PROVIDED UNLESS DISCHARGE IS TO PIPE OR HARDENED CHANNEL.
8. OUTLET STRUCTURE SHOULD BE SIZED TO DRAIN WATER QUALITY VOLUME IN 36 - 48 HOURS (SEE FIGURE 6-29) FOR PERFORATED RISER DETAILS). ALTERNATIVELY PLACE OUTLET STRUCTURE IN A MANHOLE AND UTILIZE PERFORATED RISER OUTLET (SEE FIGURE 6-30) OR MULTIPLE ORIFICE OUTLET (SEE FIGURE 6-31).
9. INSTALL EARTHEN BERM OR EQUIVALENT. TOP OF BERM SHALL BE 2' MINIMUM BELOW WATER QUALITY DESIGN WS BERM SHALL BE KEYED INTO EMBANKMENT A MINIMUM OF 1' ON BOTH SIDES.
10. IF SOIL CONDITIONS ALLOW, INSTALL AN APPROPRIATELY SIZED SAND FILTER LAYER BENEATH THE DRY EXTENDED DETENTION BASIN FOR ENHANCED INFILTRATION.

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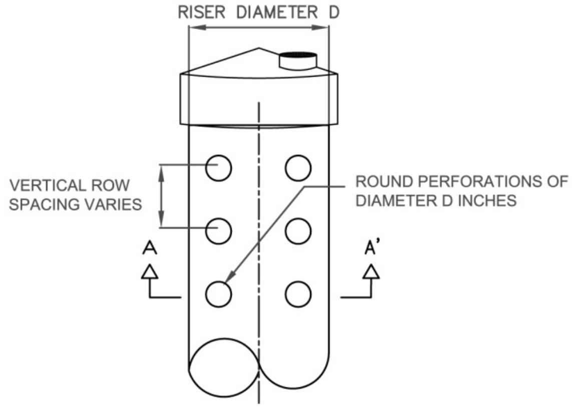
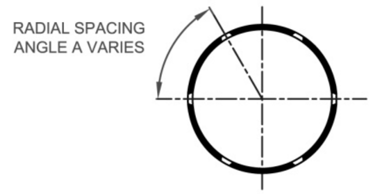
Figure 6 - 28

DRY EXTENDED DETENTION BASIN

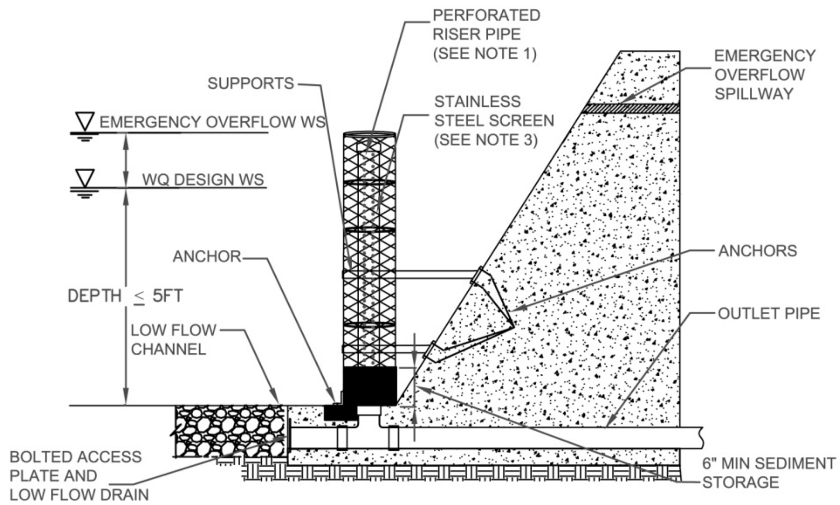
Figure 6-29: Perforated Riser Outlet Schematic – Option 1



Perforated Riser Detail
(Not to Scale)



Section A-A'
(Not to Scale)



Perforated Riser Outlet Structure
(Not to Scale)

NOTES:

1. RISER PIPE SHALL BE SIZED TO PROVIDE 36 TO 48-HOUR FULL BRIM DRAW DOWN TIME FOR THE WATER QUALITY DESIGN VOLUME.
2. TOTAL OUTLET CAPACITY: 100-YEAR PEAK FLOW FOR ON-LINE BASINS AND WATER QUALITY DESIGN FLOW FOR OFF-LINE BASINS. MINIMUM DIAMETER OF OUTLET PIPE SHALL BE 18".
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".

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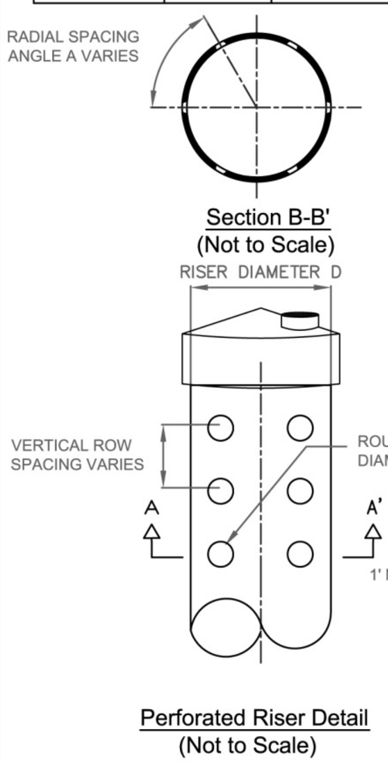
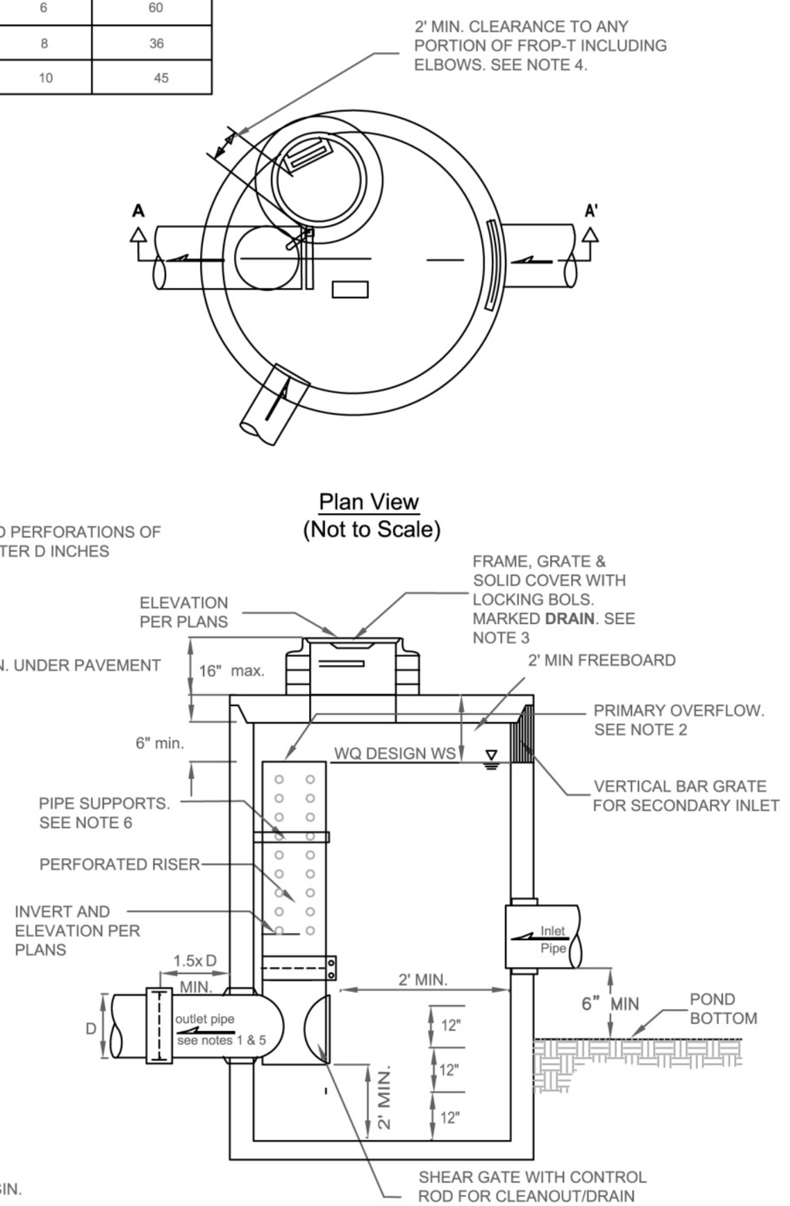
Figure 6 - 29
PERFORATED RISER OUTLET - OPTION 1

Figure 6-30: Perforated Riser Outlet Schematic – Option 2

Smooth Plastic Riser Standard Dimensions (Wyoming NRCS)

Max Orifice Diameter D (inches)	Pipe Diameter (inches)	Min Wall Thickness (inches)	No. of vertical rows of perforations	Radial Spacing of Vertical Rows A (Degrees)
3½	8	0.15	6	60
5½	10	0.20	8	36
6	12	0.25	10	45





Section A - A'
(Not to Scale)

NOTES:

1. USE A MINIMUM OF A 54" DIA TYPE 2 CATCH BASIN.
2. OUTLET CAPACITY: 100-YEAR PEAK FLOW FOR ON-LINE BASINS. MINIMUM DIAMETER OF OUTLET PIPE SHALL BE 18".
3. METAL PARTS: CORROSION RESISTANT. NON-GALVANIZED PARTS PERFERRED. GALVANIZED PIPE PARTS TO HAVE ASPHALT TREATMENT.
4. "FROP-T"=FLOW RESTRICTOR/OIL POLLUTION CONTROL DEVICE.
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)

Adapted from KC/SWM New Design Manual Figure 5.3.4.A. Flow Restrictor (tee)

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Figure 6 - 30

PERFORATED RISER OUTLET - OPTION 2

Figure 6-31: Multiple Orifice Outlet Schematic – Option 3

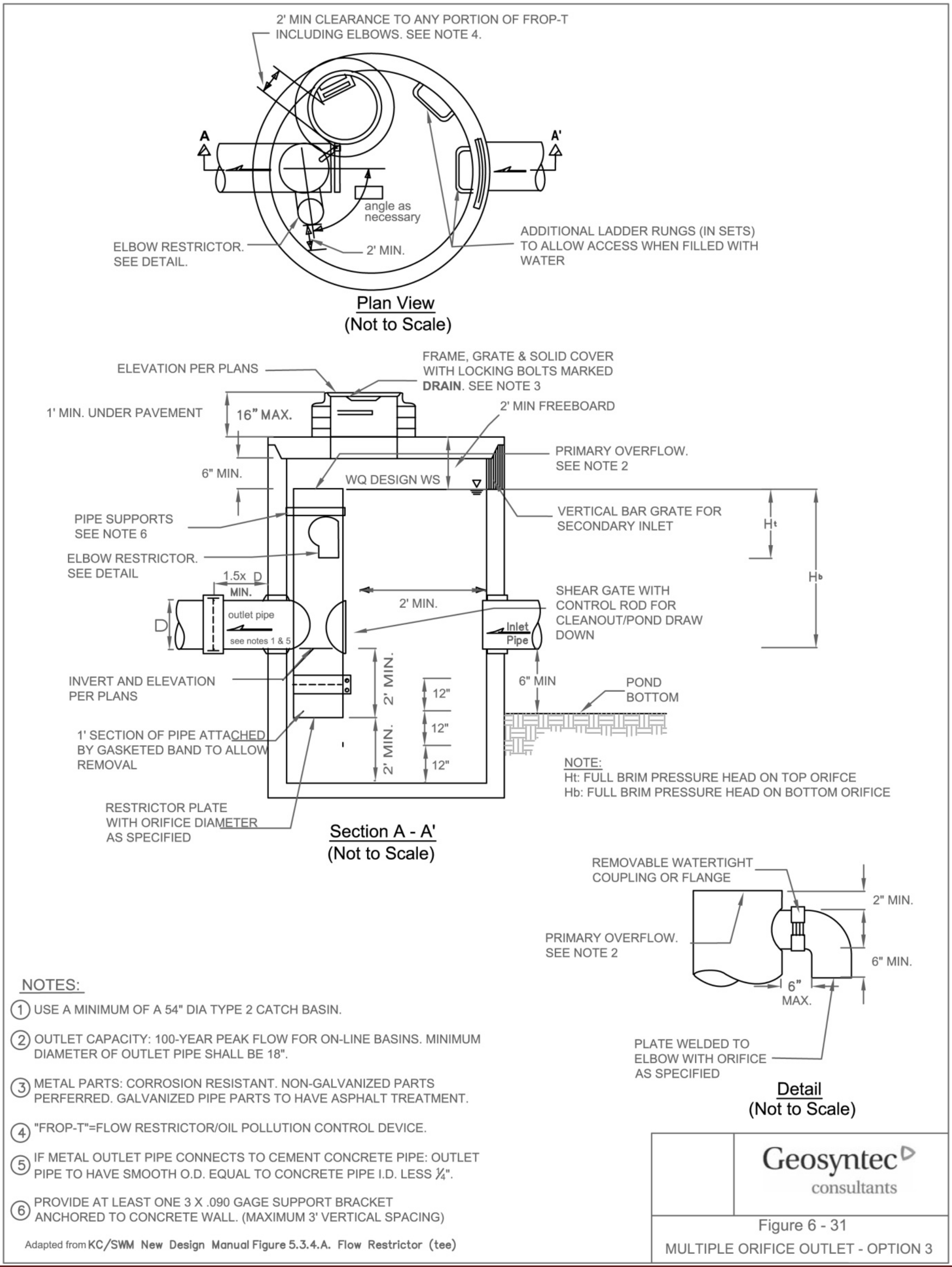
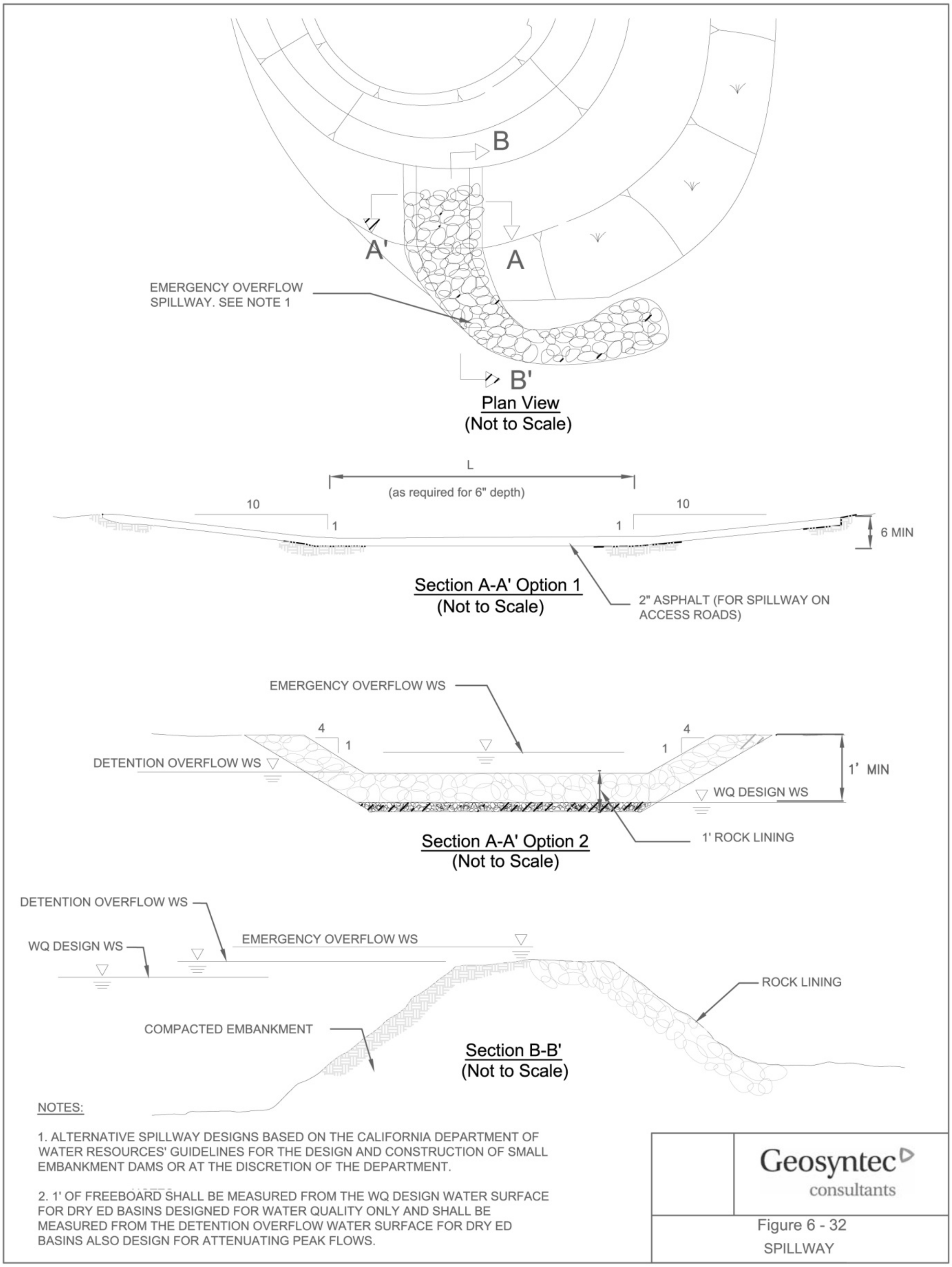


Figure 6-32: Emergency Spillway Schematic



6.10.3.5 Operations and Maintenance

General Requirements

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 shall be inspected annually and inspections after major storm events are encouraged. Trash and debris shall be removed as needed, but at least annually prior to the beginning of the wet season (see Appendix H for dry extended detention basin inspection and maintenance checklist).

2. Site vegetation shall be maintained as follows:

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

4. Slope areas that have become bare shall be revegetated and eroded areas shall be regraded prior to being revegetated.

5. Grass shall be mowed to 4”-9” high and grass clippings shall be removed.

6. Fallen leaves and debris from deciduous plant foliage shall 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*) must be removed and replaced with non-invasive species. Invasive species shall 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- http://www.cdfa.ca.gov/phpps/ipc/encycloweedia/encycloweedia_hp.htm or the California Invasive Plant Council website at www.cal-ipc.org.

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

9. No herbicides or other chemicals shall be used to control vegetation.

10. Sediment buildup exceeding 50% of the forebay capacity shall be removed. Sediment from the remainder of the basin shall be removed when 6 inches of sediment accumulates. Sediments shall 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.

Maintenance Standards

A summary of the routine and major maintenance activities recommended for dry extended detention ponds is shown in Table 6-76. The routine and major maintenance standards listed in Table 6-77 and Table 6-78 are intended to be measures to determine if maintenance actions are required as identified through inspection. They are not intended to be measures of the facility's required condition at all times between inspections. In other words, exceedance of these thresholds or measures at any time between inspections and/or scheduled maintenance does not constitute a violation of these standards. These standards are violated only when an inspection identifies required maintenance action that has not been scheduled before the next regular inspection.

Table 6-76: Dry Extended Detention Basin Maintenance Quick Guide

Inspection and Maintenance Activities Summary	
Routine Maintenance	• Trash and debris removal • Remove any evidence of visual contamination from floatables such as oil and grease • Remove minor sediment accumulation near inlet and outlet structures • Stabilize/repair eroded banks and fill in animal burrows if present • Minor structural repairs to inlet/outlet structures, valves, sluice gates, pumps, fences, locks, access hatches shall be inspected and kept functional • Eliminate pests and conditions that promote breeding of pests • Periodically observe function under wet weather conditions • Photographs taken before and after maintenance is encouraged
Major Maintenance	• Remove dead, diseased, or dying trees and woody vegetation that interfere with facility maintenance • Clean-out underdrains • Correct problems associated with berm settlement • Repair berm/dike breaches and stabilize eroded parts of the berm • Repair and rebuild spillway as needed to reverse the effects of severe erosion • Remove sediment build up in forebay and main basin area to restore original sediment holding capacity • Regrade main basin bottom to restore bottom slope and eliminate the incidence of standing pools • Aerate compacted areas to promote infiltration if volume reductions are desired • Repair or replace gates, fences, flow control structures, and inlet/outlet structures as needed to maintain full functionality

Table 6-77: Routine Maintenance Standards - Extended Detention Basins

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
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.	Trash and debris cleared from site.	Annually prior to wet season After major storm events (>0.75 in/24 hrs) if spot checks of some basins indicate widespread damage/ maintenance needs
Inlet / outlet sediment accumulation	Minor sediment accumulation that affects flow through the facility.	Sediment cleaned out.	
Erosion of banks and channels	Rilling over 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted berm embankment.	Slopes shall be stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction.	
Visual contaminants and pollution	Any evidence of oil, gasoline, contaminants or other pollutants.	No visual evidence of contaminants or pollutants present.	
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.	Vectors controlled per Mosquito and Vector Management District of Santa Barbara County standards. A Mosquito Management Plan or Service Contract must be presented to the Vector Management District for any facility that maintains a pool of water for 72 hours or more.	
Aesthetics	Minor vegetation removal and thinning. Mowing berms and surroundings	Facility is well kept and able to handle dry-weather flows without causing a nuisance (visual eye sore, stagnate water, etc.)	Monthly (or as dictated by agreement between City and landscape

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Noxious Weeds	Any evidence of noxious weeds.	Eradicate all noxious weeds; control and prevent the spread of all noxious weeds. Use Integrated Pest Management techniques, if applicable. See http://www.ipm.ucdavis.edu/ for more information on pest and weed management.	contractor)

Table 6-78: Major Maintenance Standards - Extended Detention Basins

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
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.	Trees do not hinder maintenance activities. Remove dead, diseased, or dying trees. (Use a certified Arborist to determine health of tree or removal requirements)	Annual or as needed (infrequent) After major storm events (>0.75 in/24 hrs) if spot checks of some basins indicate widespread damage/ maintenance needs.
Settling of berm	If settlement is apparent. Settling can be an indication of more severe problems with the berm or outlet works. A civil engineer shall be consulted to determine the source of the settlement if the dike/berm is serving as a dam.	Dike is built back to the design elevation.	
Piping through berm	Discernable water flow through basin berm. Ongoing erosion with potential for erosion to continue. A licensed civil engineer shall be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved and berm stability achieved. Report of annual burrows.	

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
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.	Trees and large shrubs shall be removed. All dead roots shall be removed if practical. Otherwise, dead roots shall be removed to a minimum of 36 inches below grade and replaced with cement grout to 12 inches below grade. The top 12 inches of the root holes shall be filled with compacted, in-situ soils. The area facility engineer may require additional root removal if necessary for dam safety or maintenance purposes.	
Erosion on Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.	Rocks and pad depth are restored to design standards.	
Sediment accumulation	Sediment buildup exceeding 50% of the forebay capacity. Six inches or more of accumulated sediment across basin bottom.	Basin capacity restored.	
Standing water	Low flow channel is not draining, standing pools of water are observed.	No standing pools of water in low flow channel.	
Gate/Fence Damage	Damage to gate/fence, including missing locks and hinges	Gate/Fence repaired.	

6.11 Proprietary Devices

Figure 6-33: Filterra Tree Box Filter

Photo Credit: Filterra Bioretention Systems

Applications

- Roads, highways, parking lots
- Commercial and mixed use
- Industrial
- Residential

Advantages

- Can be selected to target specific contaminants
- Often smaller footprint required

Limitations

- Must be purchased from private sector firm
- May require more maintenance
- Performance must be verified by third party

6.11.1 Description

Proprietary devices are commercial products that typically aim to provide storm water treatment in space-limited applications, often using patented innovative technologies. The most commonly encountered classes of proprietary storm water management controls include hydrodynamic separation, catch basin insert technologies, cartridge filters, and proprietary biotreatment devices.

Hydrodynamic separation devices (alternatively, swirl concentrators) 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 devices were originally developed for combined sewer overflows (CSOs), where they were used primarily to remove coarse inorganic solids. Hydrodynamic separation has been adapted for storm water 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. For more information on specific hydrodynamic devices and their vendors refer to Table 6-79.

Catch basin inserts are manufactured filters or fabric placed in a drop inlet to remove sediment and debris and may include sorbent media to remove floating oils and grease. There are a multitude of inserts of various shapes and configurations, typically falling into one of three groups: socks, boxes, and trays. The sock-type filters are typically constructed of a fabric, usually polypropylene. The fabric may be attached to a frame or the grate of the inlet may hold the sock. Socks are meant for vertical (drop) inlets. Boxes are constructed of plastic or wire mesh. Typically a polypropylene “bag” is placed in the wire mesh box and the bag takes the form of the box. Most box products are one box; that is, settling and filtration through media occur in the same box. Other products consist of one or more trays or mesh grates. The trays may hold different types of media. Filtration media vary by manufacturer. Types include polypropylene, porous polymer, treated cellulose, and activated carbon. Inserts are an easy and inexpensive retrofitting option because drain inlets are already a component of most standard drainage systems. Inserts are usually only suitable for mitigating relatively small tributary areas (less than 1 acre); however, depending on the size of the project, this structure normally does not meet BMP requirements for water quality treatment but does assist with pretreatment. For more information on specific catch basin inserts and their vendors refer to Table 6-79.

Cartridge filters typically consist of a series of vertical filters contained in a vault or catch basin that provide treatment through filtration and sedimentation. The 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. The performance and capacity of a cartridge filter installation depends on the properties of the media contained in the cartridges. Cartridge filter manufacturers often provide an array of media types each with varying properties, targeting various pollutants and a range of particle sizes. Commonly used media include media that target solids, such as perlite, and media that target both dissolved and non-dissolved constituents, such as compost leaf media, zeolite, and iron-infused polymers. Manufacturers try to distinguish their products through innovative cartridge designs that aim at providing self cleaning and draining, uniform loading, and clog resistance allowing the devices to function properly over a wide range of hydraulic loadings and pollutant concentrations. For more information on specific cartridge filter models and their vendors refer to Table 6-79.

Proprietary biotreatment devices are devices that are manufactured to mimic natural systems such as bioretention areas by incorporating plants, soil, and microbes engineered to provide treatment at higher flow rates or volumes and with smaller footprints than their natural counterparts. Incoming flows are typically filtered through a planting media (mulch, compost, soil, plants, microbes, etc) and either infiltrated or collected by an underdrain and delivered to the storm water conveyance system. Tree box filters are an increasingly common type of proprietary biotreatment device that are installed at curb level and filled with a bioretention type soil. For low to moderate flows they operate similarly to bioretention systems and are bypassed during high flows. Tree box filters are highly adaptable solutions that can be used in all types of development and in all types of soils but are especially applicable to dense urban parking lots, street, and roadways. Tributary areas for biotreatment devices tend to be limited to 0.25 to 1.0 acres. For more information on specific biotreatment devices and their vendors refer to Table 6-79.

The vendors of the various proprietary BMPs provide detailed documentation for device selection, sizing, and maintenance requirements. Tributary area sizes are limited to the capacities of the largest available model. The latest manufacturer supplied documentation must be used for sizing and selection of all proprietary devices. Links to the websites of a number of vendors of proprietary devices are included in Table 6-79.

6.11.2 Performance, Applicability, and Limitations

The treatment effectiveness of specific proprietary devices must be provided by the manufacturer and shall be verified by independent third-party sources and data or assessed by a water quality professional. The Santa Barbara County Flood Control District requires that proprietary devices used in the County be accompanied by a certification from a licensed civil engineer that the device will maintain an effluent quality of 10-30 mg/L of total suspended solids with no visible oily sheen under design operating conditions. The following provides general performance guidance for the different proprietary devices.

Hydrodynamic Devices

Hydrodynamic separation devices are effective for removal of course sediment, trash, and debris, and are useful as pretreatment in combination with other BMP types that target smaller particle sizes. Hydrodynamic devices 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.

Catch Basin Inserts

Catch basin inserts come in such a wide range of configurations that it is practically impossible to generalize the expected performance. Inserts shall 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.

Cartridge Filters

Cartridge filters have been proven to provide efficient removals of both dissolved and non-dissolved constituents. Cartridge filters are, however, less adept at handling high flow rates as compared to catch basin inserts and hydrodynamic devices, mainly due to the enhanced treatment provided through the filtration mechanism.

Biotreatment Devices

Proprietary biotreatment devices are relatively new compared to the other types of proprietary treatment devices included in this document. Therefore, there are fewer third party studies on proprietary biotreatment devices and the available performance information is mostly vendor-supplied. Tree box filters remove pollutants through the same processes as bioretention and reduce runoff volume and peak discharge rate for small frequently occurring storms and are not intended to capture and or detain large volumes. According to the vendors, like their natural counterparts, proprietary biotreatment devices are highly efficient at mitigating dissolved metals, nutrients, and suspended solids.

More detailed performance information is available from the vendors of each class of proprietary device. The performance numbers are typically presented as percent removals rather than effluent quality measurements and can be found on the vendor websites using the links provide in Table 6-79.

6.11.3 Design Criteria and Procedure

Proprietary BMP vendors are constantly updating and expanding their product lines, so 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 below.

The City of Santa Barbara does not keep a list of "approved" proprietary BMPs; however, in general, any proprietary device BMP must meet the following minimum standards:

1. The device shall be accompanied by a certification from a licensed civil engineer that the device will maintain effluent quality of 10-30 mg/L of total suspended solids with no visible oily sheen under design operating conditions;

2. It must not adversely affect the level of flood protection provided by the drainage system - head loss must be verifiable by the County Flood Control District;

3. It shall be selected to have high or very high treatment effectiveness for the primary pollutants of concern (as identified in Section 6.3).

4. It shall be vector-resistant, or not pond water for more than 72 hours after the end of a storm;

5. It shall not worsen water quality by resuspending trash, sediments, or bacteria (through regrowth), or by leaching heavy metals or semi-volatile organic compounds during subsequent storms;

6. If it is to be an underground device with access shafts, it must: (a) meet or exceed American Public Works Association (APWA) standards, (b) be reasonably accessible by a qualified maintenance worker, (c) have ladder rungs, have the ability to withstand lateral soil pressures, (d) have provisions for confined space entry, and (e) have safety guard rails around the rim;

7. It shall have no plastic or fiberglass interior parts that would break or shatter in the path of direct flow;

8. Its pipes, conduits and vaults shall not be more than 20 feet below ground and be easily accessible by a vacuum truck hose for clean-out; and

9. It shall provide means to block off the inflow and tail water backflow to isolate the device for safe maintenance and repair of the unit.

Sizing

Hydrodynamic devices, catch basin inserts, and cartridge filters are flow-based BMPs and therefore, shall be sized to capture and treat the water quality design flow rate if used as a standalone BMP. Proprietary biotreatment devices, on the other hand include, both volume-based and flow-based BMPs. Volume-based proprietary devices shall be sized to capture and treat the water quality design volume if used as a standalone BMP.

Auxiliary components of proprietary devices such as sorbent media, screens, baffles, and sumps are selected based on site 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, 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.

6.11.4 Operation and Maintenance

Hydrodynamic Separation Devices

Hydrodynamic separators do not have any moving parts and are consequently not maintenance intensive. Maintenance is important, however, to ensure that they are operating as efficiently as possible. Proper maintenance involves frequent inspections throughout the first year of installation, especially after major storm events. The systems are considered full when the sediment level is within one foot of the unit's top, at which point it must be cleaned out. Removal of sediment can be performed with a sump vac or vacuum truck. Some hydrodynamic separator systems may contribute to mosquito breeding if they hold standing water between storms for longer than 72 hours. Refer to the manufacturer's guidelines for inspection and maintenance activities.

Catch Basin Inserts

Catch basin inserts can be maintenance intensive due to their susceptibility for accumulating trash and debris. Regular maintenance activities include cleanup and removal of accumulated trash and sediment, while major maintenance activities include replacing filter media (if used) and/or repairing/replacing geotextile fabrics. There are a number of proprietary catch basin inserts and proper maintenance procedures that shall be determined based on manufacturer's recommendations for the selected catchbasin insert.

Cartridge filters

Maintenance activities include periodically removing captured trash, debris, and sediment from the vault floor, typically twice per year depending on the accumulation rate using a sump vac or vacuum truck. The media in media filters has to be replaced when it becomes saturated; typically about once every other year depending on the pollutant accumulation rate. The manufacturers of these devices typically provide contract operations and maintenance services.

All storm water vaults containing cartridge filters that have standing water for longer than 72 hours can become a breeding area for mosquitoes. Manufacturers have developed systems to completely drain the vault, such as a perforated pipe installed in the bottom of the vault that is encased in a filter sock to prevent clogging.

Biotreatment Devices

Maintenance of biotreatment devices can be provided by the manufacturers and typically consists of routine inspection and hand removal of accumulated trash and debris. As opposed to other proprietary treatment devices, no vacuum trucks or mechanical maintenance is needed.

Online Resources

Table 6-79 provides a list of links to the websites of several proprietary storm water management controls manufacturers current as of April 2008. The products listed in Table 6-79 are proprietary and nonproprietary products that are meant to improve or eliminate pollution associated with urban runoff and storm water. The phrase "Best Management Practice" is a common term used in Federal, State, and local regulations to label these types of products, activities, and services. Usage of the term does not imply that some products, activities, or services are better than others, or that the City of Santa Barbara evaluates or decides which product, activity, or service shall be listed. The inclusion of vendors, manufacturers, and products on this list in no way represents an endorsement or guarantee of effectiveness as a result of the use of these products, nor for any compliance issues regarding the Americans with Disabilities Act. Please contact the vendor and follow the manufacturers' specifications for proper preparation, installation, and maintenance of these products.

Table 6-79: Proprietary Device Manufacturer Websites

Category	Device	Manufacturer	Website
Hydrodynamic Device	BayFilter	BaySaver Inc.	www.baysaver.com
	V2B1™ Stormwater Treatment System	Environment 21, LLC	www.env21.com
	Aqua-Swirl™ Concentrator	Aquashield, Inc.	www.aquashieldinc.com
	Vortechs™, CDS ™, VortSentry™, VortSentry™ HS	Contech Stormwater Solutions	www.contech-cpi.com/stormwater/products/14
	Downstream Defender™	H.I.L. Technology, Inc.	www.hydro-international.biz/us/stormwater_us/downstream.php
	Continuous Deflection Separation(CDS) Unit,	CDS Technologies, Inc.	www.CDStech.com
	CrystalStream	CrystalStream Technologies	www.crystalstream.com
Catch Basin Insert	Curb Inlet Basket, Grate Inlet Skimmer	Suntree Technologies Inc.	www.suntreetech.com
	Ultra-CurbGuard, Hydro-Kleen	UltraTech International, Inc.	www.spillcontainment.com/stormwater
	The Hydro-Cartridge®	Advanced Aquatic International, Inc.	www.hydro-cartridge.com
	Streamguard™ Catch Basin Insert	Bowhead Manufacturing Co.	www.b-bmarketingcorp.com/streamguard.htm
	Aqua-Guard™ Catch Basin Insert	Aquashield, Inc.	www.aquashieldinc.com
	Ultra-Urban Filter	AbTech Industries	www.abtechindustries.com
	FloGard+Plus,	KriStar Enterprises, Inc.	www.kristar.com

Category	Device	Manufacturer	Website
	Triton™	Contech Stormwater Solutions	www.contech-cpi.com/stormwater/products/14
Cartridge Filter	MFS™ StormFilter™	Contech Stormwater Solutions	www.contech-cpi.com/stormwater/products/14
Proprietary Biotreatment	Filterra	Americast	www.filterra.com
	StormTreat Systems	StormTreat Systems Inc	www.stormtreat.com/home.htm

Note: Web links last accessed in April 2008.