6.6 Biofiltration and Filtration BMPs

6.6.1 Bioretention

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.

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

Figure 6-1: Bioretention Area - Arroyo Burro Estuary Restoration Site
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, \( V_{\text{reduction}} \), 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**

<table>
<thead>
<tr>
<th>Storm Water Runoff BMP</th>
<th>Volume Mitigation (% of inflow)</th>
<th>Treatment Effectiveness for Pollutants of Concern¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trash</td>
<td>Nutrients</td>
</tr>
<tr>
<td>Bioretention</td>
<td>🍃</td>
<td>🍃</td>
</tr>
</tbody>
</table>

*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

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

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

<table>
<thead>
<tr>
<th>Coastal Bluff Area</th>
<th>Hillside Design District</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>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 online.</td>
</tr>
</tbody>
</table>

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 are 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

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Unit</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water quality design volume, $V_{wq}$</td>
<td>ft³</td>
<td>See Section 6.2 and Appendix C for calculating $V_{wq}$.</td>
</tr>
<tr>
<td>Volume reduction requirement, $V_{\text{reduction}}$</td>
<td>ft³</td>
<td>See Section 6.2 and Appendix C for calculating $V_{\text{reduction}}$.</td>
</tr>
<tr>
<td>Pretreatment</td>
<td>-</td>
<td>Filter strip, vegetated swale, or forebay for all surfaces other than roofs; if sheet flow, max velocity = 1 ft/sec</td>
</tr>
<tr>
<td>Drawdown time of planting soil</td>
<td>hrs</td>
<td>48</td>
</tr>
<tr>
<td>Drawdown time of gravel drainage layer (if applicable)</td>
<td>hrs</td>
<td>72</td>
</tr>
<tr>
<td>Maximum ponding depth</td>
<td>inches</td>
<td>12</td>
</tr>
<tr>
<td>Planting soil depth</td>
<td>feet</td>
<td>2; 3 preferred</td>
</tr>
<tr>
<td>Stabilized mulch depth</td>
<td>inches</td>
<td>2 to 3</td>
</tr>
<tr>
<td>Planting media composition</td>
<td>-</td>
<td>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</td>
</tr>
</tbody>
</table>
### Bioretention

#### Design Parameter

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Unit</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underdrain</td>
<td>-</td>
<td>6 inch. minimum diameter; 0.5% minimum slope</td>
</tr>
<tr>
<td>Overflow device</td>
<td>-</td>
<td>Required if system is on-line</td>
</tr>
</tbody>
</table>

#### 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, $k_{\text{design}}$, 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, $k_{\text{design}}$, 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.

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

Where:

- $k_{\text{design}}$ = design infiltration rate (in/hr)
- $k_{\text{measured}}$ = field measured infiltration rate (in/hr)
- $F_{\text{testing}}$ = correction factor for testing method
- $F_{\text{plugging}}$ = correction factor for soil plugging
- $F_{\text{geometry}}$ = correction factor for facility geometry

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

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

$$F_{\text{geometry}} = 4 \frac{D}{w} + 0.05 \quad \text{(Equation 6-2)}$$

Where:
- $D$ = depth from the bottom of the facility to the maximum seasonally high groundwater table or nearest impervious layer, whichever is less (ft)
- $w$ = width of the facility (ft)

Note that adjusted infiltration rate ($k_{\text{design}}$) 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, $V_{\text{design}}$, is equal to $V_{\text{wq}}$. If the bioretention area is designed without underdrains where site conditions allow for infiltration, the volume for design, $V_{\text{design}}$, is the greater of $V_{\text{reduction}}$ and $V_{\text{wq}}$. $V_{\text{design}}$ 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.

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


Where:
- $V_{\text{design}}$ = design volume of runoff to be infiltrated (ft³)
- $k_{\text{design}}$ = 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.

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>¾ inch</td>
<td>100</td>
</tr>
<tr>
<td>½ inch</td>
<td>30-60</td>
</tr>
<tr>
<td>US No. 8</td>
<td>20-50</td>
</tr>
<tr>
<td>US No. 50</td>
<td>3-12</td>
</tr>
<tr>
<td>US No. 200</td>
<td>0-1</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Geotextile Property</th>
<th>Value</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezoidal Tear (lbs)</td>
<td>40 (min)</td>
<td>ASTM D4533</td>
</tr>
<tr>
<td>Permeability (cm/sec)</td>
<td>0.2 (min)</td>
<td>ASTM D4491</td>
</tr>
<tr>
<td>AOS (sieve size)</td>
<td>#60 - #70 (min)</td>
<td>ASTM D4751</td>
</tr>
<tr>
<td>Ultraviolet resistance</td>
<td>70% or greater</td>
<td>ASTM D4355</td>
</tr>
</tbody>
</table>

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.
Chapter 6: Stormwater Runoff BMP Options

Bioretention

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:

<table>
<thead>
<tr>
<th>Particle Size (ASTM D422)</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>#4</td>
<td>100</td>
</tr>
<tr>
<td>#6</td>
<td>88-100</td>
</tr>
</tbody>
</table>
4. Compost shall be free of stones, stumps, roots or other similar objects larger than \( \frac{3}{4} \) inches; have a particle size of 98% passing through \( \frac{3}{4}" \) 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:

<table>
<thead>
<tr>
<th>Particle Size (ASTM D422, D1140)</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot;</td>
<td>98</td>
</tr>
<tr>
<td>Sand (0.05 - 2.0 mm)</td>
<td>50-75</td>
</tr>
<tr>
<td>Silt (0.002 - 0.05 mm)</td>
<td>15-40</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt; 5</td>
</tr>
</tbody>
</table>

- 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%

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:

<table>
<thead>
<tr>
<th>Item</th>
<th>Criteria</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected pH</td>
<td>5.5 – 7.5</td>
<td>ASTM D4972</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Minimum 32 ppm</td>
<td>*</td>
</tr>
<tr>
<td>Phosphorus (Phosphate - P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt;)</td>
<td>Not to exceed 69 ppm</td>
<td>*</td>
</tr>
<tr>
<td>Potassium (K&lt;sub&gt;2&lt;/sub&gt;O)</td>
<td>Minimum 78 ppm</td>
<td>*</td>
</tr>
<tr>
<td>Soluble Salts</td>
<td>Not to exceed 500 ppm</td>
<td>*</td>
</tr>
</tbody>
</table>

* 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:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Minimum Percent Passing By Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 10</td>
<td>100</td>
</tr>
<tr>
<td>No. 20</td>
<td>98</td>
</tr>
<tr>
<td>No. 100</td>
<td>50</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Caliper (in)</th>
<th>Height (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2 to 2-1/2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

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

Plan View
(Not to Scale)

Section A-A'
(Not to Scale)

Roadway Tributary Area - Plan View
(Not to Scale)

NOTES
1. OVERFLOW DEVICE: OPTION 1 - VERTICAL RISER, OPTION 2 - PEA GRAVEL CURTAIN DRAIN, OPTION 3 - FLOW SPREADER.
2. PERFORATED PIPE UNDERDRAIN SYSTEM (AS NEEDED). WHERE SOIL CONDITIONS ALLOW, OMIT THE UNDERDRAIN AND INSTALL AN APPROPRIATELY SIZED GRAVEL DRAINAGE LAYER (TYPICALLY A WASHED ST STONE) BENEATH THE PLANTING MEDIA FOR ENHANCED INFILTRATION.
3. OPTIONAL GEOTEXTILE FABRIC OR CHOKE STONE LAYER.
4. 2’ MIN PLANTING MIX; 3’ PREFERRED.
5. VEGETATION; SEE APPENDIX G.
6. 10” MAX PONDING DEPTH.
7. OPTIONAL VEGETATION BUFFER / PRETREATMENT (I.E. FILTER STRIP OR SWALE).
8. PEA GRAVEL, DIAPHRAGM MAY BE USED IN LIEU OF SLOTTED WHEEL STOP.
9. SLOTTED WHEEL STOP / CURB CUTS MAY BE USED IN LIEU OF GRAVEL DIAPHRAGM, BUT ENERGY DISSIPATION MUST BE CONSIDERED.
6.6.1.5 Operations and Maintenance

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

<table>
<thead>
<tr>
<th>Inspection and Maintenance Activities Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Routine Maintenance</strong></td>
</tr>
<tr>
<td>• Repair small eroded areas and ruts by filling with gravel. Overseed bare areas to reestablish vegetation</td>
</tr>
<tr>
<td>• Remove trash and debris and rake surface soils to mitigate ponding</td>
</tr>
<tr>
<td>• Remove accumulated fine sediments, dead leaves, and trash to restore surface permeability</td>
</tr>
<tr>
<td>• Remove any evidence of visual contamination from floatables such as oil and grease</td>
</tr>
<tr>
<td>• Eradicate weeds and prune back excess plant growth that interferes with facility operation. Remove non-native vegetation and replace with native species</td>
</tr>
<tr>
<td>• Remove sediment and debris accumulation near inlet and outlet structures to alleviate clogging</td>
</tr>
<tr>
<td>• Clean and reset flow spreaders (if present) as needed to restore original function</td>
</tr>
<tr>
<td>• Mow routinely to maintain ideal grass height and to suppress weeds</td>
</tr>
<tr>
<td>• Periodically observe function under wet weather conditions</td>
</tr>
<tr>
<td><strong>Major Maintenance</strong></td>
</tr>
<tr>
<td>• Repair structural damage to flow control structures including inlet, outlet, and overflow structures</td>
</tr>
<tr>
<td>• Clean out under-drain, if present, to alleviate ponding. Replace media if ponding or loss of infiltrative capacity persists and re-vegetate</td>
</tr>
<tr>
<td>• Re-grade and re-vegetate to repair damage from severe erosion/scour channelization and to restore sheet flow</td>
</tr>
<tr>
<td>• Photographs taken before and after major maintenance is encouraged</td>
</tr>
</tbody>
</table>
Table 6-8: Routine Maintenance - Bioretention

<table>
<thead>
<tr>
<th>Defect or Problem</th>
<th>Condition When Maintenance is Needed</th>
<th>Results Expected When Maintenance Is Performed</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erosion</td>
<td>Splash pads or spreader incorrectly placed; eroded or scoured areas due to flow channelization, or higher flows.</td>
<td>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.</td>
<td>Annually prior to wet season. After major storm events (&gt;0.75 in/24 hrs) if spot checks of some basins indicate widespread damage/maintenance needs</td>
</tr>
<tr>
<td>Standing Water</td>
<td>When water stands in the basin between storms and does not drain freely (with 36-48 hours after storm event).</td>
<td>Water drains completely from basin as designed and surface is clear of trash and debris. Underdrains (if installed) are cleared.</td>
<td></td>
</tr>
<tr>
<td>Loss of surface permeability</td>
<td>Accumulation of fine sediments, dead leaves, trash and other debris on surface</td>
<td>Surface permeability restored. Surface layer removed and replaced with fresh mulch.</td>
<td></td>
</tr>
<tr>
<td>Visual contaminants and pollution</td>
<td>Any visual evidence of oil, gasoline, contaminants or other pollutants.</td>
<td>No visual contaminants or pollutants present.</td>
<td></td>
</tr>
<tr>
<td>Vegetation</td>
<td>Weeds, excessive plant growth, plants interfering with basin operation, plants diseased or dying</td>
<td>Basin tidy, plants healthy and pruned. Any plants that interfere with function are removed. Invasive or non-acclimated plants replaced.</td>
<td>Monthly (or as dictated by agreement between County and landscape contractor)</td>
</tr>
<tr>
<td>Inlet/Overflow</td>
<td>Inlet/outlet areas clogged with sediment and/or debris.</td>
<td>Material removed so that there is no clogging or blockage of the inlet or overflow area.</td>
<td></td>
</tr>
<tr>
<td>Trash and debris</td>
<td>Any trash and debris which exceed 5 cubic feet per 1,000 square feet (one standard garbage can).</td>
<td>Trash and debris removed and facility looks well kept.</td>
<td></td>
</tr>
</tbody>
</table>
### Table 6-9: Major Maintenance - Bioretention

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

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

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 conveyances and detention
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 Applicability, Performance, and Limitations

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, $V_{\text{reduction}}$. 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, $V_{\text{reduction}}$, by eliminating underdrains and providing a gravel drainage layer beneath the vegetated swale. Vegetated swales 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 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

<table>
<thead>
<tr>
<th>Storm Water Runoff BMP</th>
<th>Volume Mitigation (% of inflow)</th>
<th>Treatment Effectiveness for Pollutants of Concern(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetated Swale Filter</td>
<td><img src="image" alt="Effectiveness" /></td>
<td>Trash: <img src="image" alt="Effectiveness" />, Nutrients: <img src="image" alt="Effectiveness" />, Bacteria: <img src="image" alt="Effectiveness" />, Metals: <img src="image" alt="Effectiveness" />, Sediment: <img src="image" alt="Effectiveness" />, Organics: <img src="image" alt="Effectiveness" /></td>
</tr>
</tbody>
</table>

\(\text{Volume/Treatment Effectiveness: } \bigcirc = \text{Very High}, \bigotimes = \text{High}, \bigtriangleup = \text{Moderate}, \bigtriangledown = \text{Low}, \bigcirclearrowright = \text{Very Low}\)

\(1\) 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

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

\(1\) 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

<table>
<thead>
<tr>
<th>Coastal Bluff Area</th>
<th>Hillside Design District</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>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 online.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Unit</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water quality design flow rate, $Q_{wq}$</td>
<td>cfs</td>
<td>See Section 6.2 and Appendix C for calculating $Q_{wq}$.</td>
</tr>
<tr>
<td>Volume reduction requirement, $V_{reduction}$</td>
<td>ft³</td>
<td>See Section 6.2 and Appendix C for calculating $V_{reduction}$.</td>
</tr>
<tr>
<td>Swale Geometry</td>
<td>-</td>
<td>Trapezoidal</td>
</tr>
<tr>
<td>Minimum bottom width</td>
<td>feet</td>
<td>2</td>
</tr>
<tr>
<td>Maximum bottom width</td>
<td>feet</td>
<td>10; if greater than 10 must use swale dividers; with dividers, max is 16</td>
</tr>
<tr>
<td>Minimum length</td>
<td>feet</td>
<td>100 or at least 10 minute residence (contact) time</td>
</tr>
<tr>
<td>Maximum channel side slope</td>
<td>H:V</td>
<td>• 2:1 for total swale depth &lt; 1 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 3:1 for total swale depth &gt; 1 ft or for mowed grass swales</td>
</tr>
<tr>
<td>Minimum slope in flow direction</td>
<td>%</td>
<td>1 (provide underdrains for slopes between 1 and 1.5 that have poorly drained soils – hydrologic soil group “C” or “D”. )</td>
</tr>
<tr>
<td>Maximum slope in flow direction</td>
<td>%</td>
<td>6.0 (provide check dams for slopes &gt; 6.0)</td>
</tr>
<tr>
<td>Maximum flow velocity</td>
<td>ft/sec</td>
<td>1.0 (water quality treatment); 3.0 (flood conveyance)</td>
</tr>
<tr>
<td>Maximum depth of flow for water</td>
<td>inches</td>
<td>4 for infrequently mowed vegetated swales; 2 for frequently</td>
</tr>
</tbody>
</table>
### Chapter 6: Stormwater Runoff BMP Options

#### Vegetated Swale Filter

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

**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.
**Chapter 6: Stormwater Runoff BMP Options**

**Vegetated Swale**

**Filter**

**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, $V_{\text{reduction}}$, 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 $Q_{wq}$:

$$Q_{wq} = \frac{1.49}{n} A R^2 b^1 s^2$$ \hspace{1cm} (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:

$$AR^2 b^3 = \left(\frac{Q_{wq}}{n}\right) (b^3 s^2)$$ \hspace{1cm} (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:

$$A = (b + zd)d$$ \hspace{1cm} (Equation 6-6)

$$R = \frac{A}{P}$$ \hspace{1cm} (Equation 6-7)

$$P = b + 2d(1 + z^2)^{0.5}$$ \hspace{1cm} (Equation 6-8)
Chapter 6: Stormwater Runoff BMP Options

Vegetated Swale Filter

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:

$$K_T = \left(\frac{Q_{wq}}{(b^3)(s^2)}\right)^{\frac{1}{8}}$$

(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:

\[
V_{\text{wq}} = \frac{Q_{\text{wq}}}{A_{\text{wq}}}
\]  
(Equation 6-10)

Where:
- \(V_{\text{wq}}\) = design flow velocity (fps)
- \(A_{\text{wq}} = \text{bd} + Zd^2\) = cross-sectional area (ft²) 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):

\[
L = 600V_{\text{wq}}
\]  
(Equation 6-11)

Where:
- \(L\) = swale length (ft)
- \(V_{\text{wq}}\) = 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.
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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:

\[ A_{\text{top}} = (b_i + b_{\text{slope}}) L_i \]  \hspace{1cm} \text{(Equation 6-12)}

Where:
\begin{itemize}
  \item \( A_{\text{top}} \) = top area (ft\(^2\)) at the design treatment depth
  \item \( b_i \) = bottom width (ft) calculated in Step 2
  \item \( b_{\text{slope}} \) = 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, \( b_{\text{slope}} = 2 \) feet)
  \item \( L_i \) = initial length (ft) calculated in Step 4.
\end{itemize}

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

\[ L_f = \frac{A_{\text{top}}}{(b_f + b_{\text{slope}})} \]  \hspace{1cm} \text{(Equation 6-13)}

Where:
\begin{itemize}
  \item \( L_f \) = reduced swale length (ft)
  \item \( b_f \) = increased bottom width (ft)
\end{itemize}

**Step 5.3:** Recalculate \( V_{\text{wq}} \) according to Step 3 using the revised cross-sectional area \( A_{\text{wq}} \) 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 \( Q_{\text{wq}} \)**

Vegetated swales may be designed as flow-through channels (on-line) that convey flows higher than the water quality design flow rate, \( Q_{\text{wq}} \), 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:

<table>
<thead>
<tr>
<th>Particle Size</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>24&quot;</td>
<td>100</td>
</tr>
<tr>
<td>15&quot;</td>
<td>75</td>
</tr>
<tr>
<td>9&quot;</td>
<td>50</td>
</tr>
<tr>
<td>4&quot;</td>
<td>10</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>¾ inch</td>
<td>100</td>
</tr>
<tr>
<td>¼ inch</td>
<td>30-60</td>
</tr>
<tr>
<td>US No. 8</td>
<td>20-50</td>
</tr>
<tr>
<td>US No. 50</td>
<td>3-12</td>
</tr>
<tr>
<td>US No. 200</td>
<td>0-1</td>
</tr>
</tbody>
</table>
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).

<table>
<thead>
<tr>
<th>Geotextile Property</th>
<th>Value</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezoidal Tear (lbs)</td>
<td>40 (min)</td>
<td>ASTM D4533</td>
</tr>
<tr>
<td>Permeability (cm/sec)</td>
<td>0.2 (min)</td>
<td>ASTM D4491</td>
</tr>
<tr>
<td>AOS (sieve size)</td>
<td>#60 - #70 (min)</td>
<td>ASTM D4751</td>
</tr>
<tr>
<td>Ultraviolet resistance</td>
<td>70% or greater</td>
<td>ASTM D4355</td>
</tr>
</tbody>
</table>

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 indicators (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

NOTES:

1. VEGETATED SIDE SLOPES AT 2H:1V MAXIMUM SLOPE FOR FLOW DEPTH < 1'; MOVING TURF SLOPES AT 3H:1V MAXIMUM.
2. GRASS HEIGHT SHALL BE 4" - 6" HIGH.
3. SWALE CONTAINMENT BARRIER Sponsored Bottom Widths > 10'; Minimum Required Bottom Width is 2" Excluding Width of Flow Channel with Divider IS 16".
4. DEPTH OF FLOW FOR WATER QUALITY TREATMENT MUST NOT EXCEED TWO-THIRDS OF THE GRASS HEIGHT AND NOT GREATER THAN 4" (INFREQUENTLY MOVED) OR 2" (FREQUENTLY MOVED).
5. 6" PERFORATED UNDERDRAIN IN 2" DEEP COARSE AGGREGATE BED CONNECTED TO STORMWATER CONVEYANCE SYSTEM, REQUIRED FOR SLOPES > 1.5% OR AS NEEDED.
6. INLET PIPE WITH INLET PROTECTION FOR DISSIPATING ENERGY INTO THE SWALE.
7. IF NO UNDERDRAIN (PERFORATED PIPE IN GRAVEL BED) AND IF SOIL CONDITIONS REQUIRE LOW FLOW DRAIN (SHALLOW DEPRESSION ON BOTTOM OF SWALE) SHALL EXTEND ENTIRE LENGTH OF SWALE AND SHALL HAVE A DEPTH OF 6" MINIMUM AND WIDTH NO MORE THAN 5% SWALE BOTTOM WIDTH, ANCHOR PLATE FLOW SPREADER IF USED, SHALL HAVE V-NOTCHES SPACED AT 8" TO 10" ON CENTER OR HOLES TO ALLOW PREFERENTIAL EXIT OF LOW FLOWS. SEE FIGURE 6-4 FOR MORE DETAIL.
8. INSTALL CHECK DAMS OR GRADE CONTROL STRUCTURES FOR SLOPES > 5% AT 50' MAXIMUM SPACING TO ACHIEVE A MAXIMUM EFFECTIVE LONGITUDINAL SLOPE OF 6%. FLOW SPREADERS SHALL BE PROVIDED AT INLET AND AT THE BASE OF EACH CHECK DAM. SEE FIGURE 6-6.
9. INSTALL ENERGY DISSIPATOR AT THE INLET OF VEGETATED SWALE.
10. SWALE LENGTH SHALL BE 100' OR LENGTH REQUIRED TO PROVIDE 10 MINUTES RESIDENCE TIME, WHICH EVER IS GREATER.
11. INSTALL APPROPRIATE OUTLET STRUCTURE. IF SOIL CONDITIONS REQUIRE, ACCOMMODATE A LOW FLOW CHANNEL AND/OR UNDERDRAIN.
12. AMEND SOILS WITH 2" OF COMPOST TILLED INTO 6" OF NATIVE SOIL UNLESS NATIVE SOIL ORGANIC CONTENT > 10%.
Figure 6-6: Flow Spreader and Check Dam Schematics

Inlet Flow Spreader Detail
(Not to Scale)

Check Dam and Flow Spreader Detail
(Not to Scale)

V-Notched Flow Spreader Detail
(Not to Scale)

NOTES:

1. TOP SURFACE OF FLOW SPREADER SHALL BE LEVEL AND SHALL PROJECT 2" MINIMUM ABOVE GROUND. V-MATCHES AT 6 TO 10 INCHES ON CENTER AND 1 TO 4 INCHES DEEP SHALL BE ACCEPTABLE.

2. FLOW SPREADER ANCHOR POSTS SHALL BE 4-INCH SQUARE CONCRETE, TUBULAR STEEL OR OTHER MATERIAL RESISTANT TO DECAY.

3. FLOW SPREADER PLATES SHALL HAVE A ROW OF HORIZONTAL PERFORATIONS AT THE BASE OF THE PLATE TO PREVENT PONDBING FOR LONG DURATIONS.

4. CHECK DAM SHALL BE NO HIGHER THAN 12", CHECK DAM SPACING SHALL BE NO GREATER THAN 50 FEET APART.
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.
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- 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**

<table>
<thead>
<tr>
<th>Inspection and Maintenance Activities Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Routine Maintenance</strong></td>
</tr>
<tr>
<td>• Remove excess sediment as needed</td>
</tr>
<tr>
<td>• Trash and debris removal</td>
</tr>
<tr>
<td>• Cleaning of underdrain (where applicable) and/or unclogging outlet to eliminate standing water</td>
</tr>
<tr>
<td>• Clean and reset flow spreaders as needed to restore original function</td>
</tr>
<tr>
<td>• Restore sunlight access to shaded regions. Remove overhanging tree branches as needed to prevent excessive shading.</td>
</tr>
<tr>
<td>• Remove any evidence of visual contamination from floatables such as oil and grease</td>
</tr>
<tr>
<td>• Mow routinely to maintain ideal grass height and to suppress weeds</td>
</tr>
<tr>
<td>• Replace non-native vegetation with native species</td>
</tr>
<tr>
<td>• Remove sediment and debris accumulation near inlet and outlet structures</td>
</tr>
<tr>
<td>• Stabilize/repair minor erosion and scouring with gravel</td>
</tr>
<tr>
<td>• Photographs taken before and after maintenance is encouraged</td>
</tr>
<tr>
<td><strong>Major Maintenance</strong></td>
</tr>
<tr>
<td>• Re-grade swale bottom and reseed to mitigate ponding of water between storms or excessive erosion and scouring</td>
</tr>
<tr>
<td>• Install or replace low flow channel using pea gravel media to better convey nuisance flows</td>
</tr>
<tr>
<td>• Re-vegetate bare exposed portions of the swale to restore vegetation to original level of coverage</td>
</tr>
<tr>
<td>• De-thatch grass to remove accumulated sediment and aerate compacted areas to promote infiltration</td>
</tr>
</tbody>
</table>
### Table 6-15: Routine Maintenance Standards - Vegetated Swale Filters

<table>
<thead>
<tr>
<th>Defect or Problem</th>
<th>Condition When Maintenance is Needed</th>
<th>Results Expected and Maintenance to be Performed</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment Accumulation</td>
<td>Sediment depth exceeds 2 inches or covers vegetation.</td>
<td>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.</td>
<td>Annually prior to wet season, After major storm events (&gt;0.75 in/24 hrs) if spot checks of some basins indicate widespread damage/maintenance needs</td>
</tr>
<tr>
<td>Trash and Debris Accumulation</td>
<td>Any trash and debris which exceed 5 cubic feet per 1,000 square feet (one standard garbage can).</td>
<td>Trash and debris removed from swale.</td>
<td></td>
</tr>
<tr>
<td>Standing Water</td>
<td>When water stands in the swale between storms and does not drain freely.</td>
<td>There shall be no areas of standing water once inflow has ceased. Outlet structures and underdrain (if installed) shall drain freely.</td>
<td></td>
</tr>
<tr>
<td>Flow Spreader</td>
<td>Flow spreader uneven or clogged so that flows are not uniformly distributed through entire swale width.</td>
<td>Spreader leveled and cleaned such that flows are distributed evenly over entire swale width.</td>
<td></td>
</tr>
<tr>
<td>Excessive Shading</td>
<td>Vegetation growth is poor because sunlight does not reach swale.</td>
<td>Over-hanging limbs and brushy vegetation on side slopes are trimmed back.</td>
<td></td>
</tr>
<tr>
<td>Erosion/Scouring</td>
<td>Eroded or scoured swale bottom due to flow channelization or higher flows.</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>Visual contaminants and pollution</td>
<td>Any visual evidence of oil, gasoline, contaminants or other pollutants.</td>
<td>No visual contaminants or pollutants present.</td>
<td></td>
</tr>
</tbody>
</table>
### Table 6-16: Major Maintenance Standards - Vegetated Swale Filters

<table>
<thead>
<tr>
<th>Defect or Problem</th>
<th>Condition When Maintenance is Needed</th>
<th>Results Expected and Maintenance to be Performed</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation length</td>
<td>When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.</td>
<td>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.</td>
<td>Monthly (or as dictated by agreement between County and landscape contractor)</td>
</tr>
<tr>
<td>Inlet/Outlet blockage</td>
<td>Inlet/outlet areas clogged with sediment and/or debris.</td>
<td>Material removed so that there is no clogging or blockage in the inlet and outlet area.</td>
<td></td>
</tr>
<tr>
<td>Low flow channel overflow</td>
<td>Nuisance flows are ponding, swale is continually wet.</td>
<td>Low flow channel media is renewed to adequately convey nuisance flows.</td>
<td></td>
</tr>
<tr>
<td>Standing Water</td>
<td>When water stands in the swale between storms and does not drain freely.</td>
<td>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.</td>
<td>Annual – preferably at end of wet season or as needed (infrequent)</td>
</tr>
<tr>
<td>Erosion/Scouring</td>
<td>Eroded or scoured swale bottom due to flow channelization, or higher flows.</td>
<td>No erosion or scouring in swale bottom. If bare areas greater than 12 inches wide exist, re-grade, and re-seed.</td>
<td>After major storm events (&gt;0.75 in/24 hrs) if spot checks of some basins indicate widespread damage/maintenance needs</td>
</tr>
<tr>
<td>Constant Baseflow</td>
<td>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.</td>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>
### Vegetated Swale Filter

<table>
<thead>
<tr>
<th>Defect or Problem</th>
<th>Condition When Maintenance is Needed</th>
<th>Results Expected and Maintenance to be Performed</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor Vegetation Coverage</td>
<td>When grass is sparse or bare or eroded patches occur in more than 10% of the swale bottom.</td>
<td>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.</td>
<td>Semi annual – at beginning and end of wet season</td>
</tr>
</tbody>
</table>
6.6.3 Vegetated Filter Strip

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 impervious surfaces
- May not be suitable for industrial sites
- Requires sheet flow across vegetated area

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

Photo Credit: New Jersey Storm Water BMP Manual

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, \( V_{\text{reduction}} \), 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

<table>
<thead>
<tr>
<th>Storm Water Runoff BMP</th>
<th>Volume Mitigation (% of inflow)</th>
<th>Treatment Effectiveness for Pollutants of Concern $^1$</th>
</tr>
</thead>
</table>

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

<table>
<thead>
<tr>
<th>BMP</th>
<th>Tributary Area (Acres; Sq.Ft.)$^1$</th>
<th>Site Slope (%)</th>
<th>Depth to Seasonally High Groundwater Table (ft)</th>
<th>Hydrologic Soil Group</th>
<th>Horizontal Setback from Drinking Water Wells (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetated Filter Strip</td>
<td>&lt; 2 Acres; 87,120 Sq.Ft.</td>
<td>&lt; 5 site slope; 2 to 6 longitudinal slope of strip $^2$</td>
<td>&gt; 2</td>
<td>Any</td>
<td>N/A</td>
</tr>
</tbody>
</table>

$^1$ 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**

<table>
<thead>
<tr>
<th>Coastal Bluff Area</th>
<th>Hillside Design District</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>

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.
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Vegetated Filter Strip

- 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

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Unit</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water quality design flow rate, $Q_{wq}$</td>
<td>cfs</td>
<td>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, $Q_{wq}$.</td>
</tr>
<tr>
<td>Minimum design flow depth</td>
<td>inches</td>
<td>1</td>
</tr>
<tr>
<td>Design residence time</td>
<td>minutes</td>
<td>10</td>
</tr>
<tr>
<td>Design flow velocity</td>
<td>ft/sec</td>
<td>&lt; 1 ft/sec</td>
</tr>
<tr>
<td>Minimum width (perpendicular to flow direction)</td>
<td>feet</td>
<td>Equal to width of tributary area</td>
</tr>
<tr>
<td>Minimum length in flow direction</td>
<td>feet</td>
<td>15 (25 preferred); if sized for pretreatment only, filter strip can be a minimum of 4.</td>
</tr>
<tr>
<td>Maximum length in flow direction</td>
<td>feet</td>
<td>150</td>
</tr>
<tr>
<td>Maximum slope in flow direction</td>
<td>%</td>
<td>6</td>
</tr>
</tbody>
</table>
### Table 6-59

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Unit</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum slope in flow direction</td>
<td>%</td>
<td>2</td>
</tr>
<tr>
<td>Maximum lateral slope</td>
<td>%</td>
<td>4</td>
</tr>
<tr>
<td>Vegetation</td>
<td>-</td>
<td>Turf grass (irrigated) or approved equal</td>
</tr>
<tr>
<td>Minimum grass height</td>
<td>inches</td>
<td>2</td>
</tr>
<tr>
<td>Maximum grass height</td>
<td>inches</td>
<td>4 (typical) or as required to prevent shading</td>
</tr>
<tr>
<td>Elevation of flow spreader</td>
<td>inches</td>
<td>&gt; 1 inch below the pavement surface</td>
</tr>
</tbody>
</table>

### 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, \( Q_{\text{wq}} \), 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:

\[
d = \left[ \frac{Q_{\text{wq}} n_{\text{wq}}}{1.49 w s^{0.5}} \right]^{0.6}
\]

(Equation 6-14)

Where:
- \( d \) = design flow depth (ft)
- \( Q_{\text{wq}} \) = 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
- \( n_{\text{wq}} \) = 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:

\[
v_{\text{wq}} = \frac{Q_{\text{wq}}}{d w}
\]

(Equation 6-15)

Where:
- \( v_{\text{wq}} \) = water quality design flow velocity (ft/sec)
- \( Q_{\text{wq}} \) = 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:

\[
L = 600 v_{\text{wq}}
\]

(Equation 6-16)

Where:
- \( L \) = swale length (ft)
- \( v_{\text{wq}} \) = 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%.
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

<table>
<thead>
<tr>
<th>Inspection and Maintenance Activities Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Routine Maintenance</strong></td>
</tr>
<tr>
<td>• Remove excess sediment as needed</td>
</tr>
<tr>
<td>• Stabilize/repair minor erosion and scouring with crushed gravel</td>
</tr>
<tr>
<td>• Remove trash and debris</td>
</tr>
<tr>
<td>• Remove any evidence of visual contamination from floatables such as oil and grease</td>
</tr>
<tr>
<td>• Mow routinely to maintain ideal grass height and to suppress weeds</td>
</tr>
<tr>
<td>• Irrigate as necessary to maintain healthy grass cover</td>
</tr>
<tr>
<td>• Remove non-native vegetation and re-vegetate with native species</td>
</tr>
<tr>
<td>• Photographs taken before and after maintenance is encouraged</td>
</tr>
<tr>
<td><strong>Major Maintenance</strong></td>
</tr>
<tr>
<td>• Regrade and revegetate to repair damage from severe erosion/scour channelization and to restore sheet flow</td>
</tr>
<tr>
<td>• Clean and reset flow spreaders as needed to restore original function</td>
</tr>
</tbody>
</table>
### Table 6-22: Routine Maintenance - Vegetated Filter Strips

<table>
<thead>
<tr>
<th>Defect</th>
<th>Conditions When Maintenance Is Needed</th>
<th>Results Expected When Maintenance Is Performed</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment Accumulation</td>
<td>Sediment depth exceeds 2 inches or covers vegetation.</td>
<td>Sediment deposits removed and surface re-leveled in order to maintain sheet flow over the filter strip.</td>
<td>Semi-annually, prior to wet season and after the wet season</td>
</tr>
<tr>
<td>Erosion/Scouring</td>
<td>Eroded or scoured areas due to flow channelization, or higher flows.</td>
<td>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.</td>
<td>After major storm events (&gt;0.75 in/24 hrs) if spot checks indicate widespread damage/maintenance needs</td>
</tr>
<tr>
<td>Flow spreader clogged/uneven</td>
<td>Flow spreader uneven or clogged so that flows are not uniformly distributed through entire filter width.</td>
<td>Spreader leveled and cleaned so that flows are spread evenly over entire filter width.</td>
<td></td>
</tr>
<tr>
<td>Visual contaminants and pollution</td>
<td>Any visual evidence of oil, gasoline, contaminants or other pollutants.</td>
<td>No visual contaminants or pollutants present.</td>
<td></td>
</tr>
<tr>
<td>Aesthetics</td>
<td>Minor vegetation removal and thinning. Mowing berms and surroundings</td>
<td>Facility is well kept.</td>
<td>Semi-annually (or as dictated by agreement between County and landscape contractor)</td>
</tr>
<tr>
<td>Vegetation length, nuisance weeds</td>
<td>When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.</td>
<td>Grass mowed, nuisance vegetation controlled, such that flow is not impeded. Grass mowed to a height between 2-4 inches and clippings removed.</td>
<td></td>
</tr>
<tr>
<td>Trash and Debris Accumulation</td>
<td>Trash and debris accumulated on the filter strip.</td>
<td>Trash and debris removed from filter strip and flow spreading devices.</td>
<td>Litter removal and mowing frequency is dependent on site conditions and desired aesthetics and shall be done at a frequency to meet those objectives</td>
</tr>
<tr>
<td>Noxious Weeds</td>
<td>Any evidence of noxious weeds.</td>
<td>All noxious weeds eradicated and future establishment controlled with use of Integrated Pest Management (IPM) techniques, if applicable. See <a href="http://www.ipm.ucdavis.edu">http://www.ipm.ucdavis.edu</a> for more information.</td>
<td></td>
</tr>
</tbody>
</table>
### Table 6-23: Major Maintenance - Vegetated Filter Strip

<table>
<thead>
<tr>
<th>Defect</th>
<th>Conditions When Maintenance Is Needed</th>
<th>Results Expected When Maintenance Is Performed</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erosion/Scouring</td>
<td>Bare spots greater than 12 inches</td>
<td>No erosion visible. Large, bare areas greater than 12 inches wide re-graded and re-seeded.</td>
<td>As needed</td>
</tr>
</tbody>
</table>
6.6.4 Sand Filter

![Sand Filter Image](image)

**Figure 6-9: Volleyball Court Sand Filter**

### 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

**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

**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
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 not 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

<table>
<thead>
<tr>
<th>Storm Water Runoff BMP</th>
<th>Volume Mitigation (% of inflow)</th>
<th>Treatment Effectiveness for Pollutants of Concern¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Trash</td>
</tr>
<tr>
<td>Sand Filter</td>
<td></td>
<td>◀ Very High ▶ High □ Moderate ○ Low ▼ Very Low</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>BMP</th>
<th>Tributary Area (Acres)¹</th>
<th>Site Slope (%)</th>
<th>Depth to Seasonally High Groundwater Table (ft)</th>
<th>Hydrologic Soil Group</th>
<th>Horizontal Setback from Drinking Water Wells (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Filter</td>
<td>&lt; 10</td>
<td>&lt; 15²</td>
<td>&gt; 2 with underdrains; &gt; 5 without underdrains</td>
<td>Any</td>
<td>100³</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Coastal Bluff Area</th>
<th>Hillside Design District</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>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.</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Unit</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water quality design volume, $V_{wq}$</td>
<td>ft³</td>
<td>See Section 6.2.3 and Appendix C for calculating the water quality design volume, $V_{wq}$</td>
</tr>
<tr>
<td>Length to width ratio $L:W$</td>
<td>1.5:1</td>
<td></td>
</tr>
<tr>
<td>Filter bed depth</td>
<td>inches</td>
<td>24; 36 preferred</td>
</tr>
<tr>
<td>Max ponding depth above filter bed</td>
<td>feet</td>
<td>6</td>
</tr>
<tr>
<td>Hydraulic conductivity of sand, $k$</td>
<td>in/hr</td>
<td>1 (equal to 2 ft/day)</td>
</tr>
<tr>
<td>Underdrains</td>
<td>-</td>
<td>6 inch minimum diameter; 0.5% minimum slope</td>
</tr>
</tbody>
</table>

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.

**Background**

Sand filter design is based on Darcy’s law:

\[
Q_{wq} = k i A
\]  
(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:

\[
i = \frac{h + l}{l}
\]  
(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:
Chapter 6: Stormwater Runoff BMP Options

Sand Filter

7/16/2013

(Sand Filter

\[ Q = k_i A \quad \text{and} \quad Q = vA \quad \text{So}, \quad vA = k_i A \quad \text{or:} \]
\[ v = k_i \]  

(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):

\[
A_{sf} = \frac{V_{wq} RL}{k_{\text{design}} t (h + L)}
\]  

(Equation 6-20)

Where:

- \( A_{sf} \) = surface area of the sand filter bed (\( \text{ft}^2 \))
- \( V_{wq} \) = water quality design volume (\( \text{ft}^3 \))
- \( R \) = routing adjustment factor (use \( R = 0.7 \))
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.

<table>
<thead>
<tr>
<th>U.S. Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 inch</td>
<td>100</td>
</tr>
<tr>
<td>U.S. No. 4</td>
<td>95 to 100</td>
</tr>
<tr>
<td>U.S. No. 8</td>
<td>80 to 100</td>
</tr>
<tr>
<td>U.S. No. 16</td>
<td>50 to 85</td>
</tr>
</tbody>
</table>

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 watertight 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.
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Sand Filter

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.

<table>
<thead>
<tr>
<th>Geotextile Property</th>
<th>Value</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezoidal Tear (lbs)</td>
<td>40 (min)</td>
<td>ASTM D4533</td>
</tr>
<tr>
<td>Permeability (cm/sec)</td>
<td>0.2 (min)</td>
<td>ASTM D4491</td>
</tr>
<tr>
<td>AOS (sieve size)</td>
<td>#60 - #70 (min)</td>
<td>ASTM D4751</td>
</tr>
<tr>
<td>Ultraviolet resistance</td>
<td>70% or greater</td>
<td>ASTM D4355</td>
</tr>
</tbody>
</table>

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 [link], or the California Invasive Plant Council website at [link].

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.
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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 Construction Considerations**

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 18’ 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 AGGREGATE 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 EXCEEDS 2’.

11. GRAVEL SHALL HAVE A DIAMETER AT LEAST 2 TIMES THE SIZE OF THE OPENINGS INTO THE UNDERDRAIN PIPE.
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

<table>
<thead>
<tr>
<th>Inspection and Maintenance Activities Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine Maintenance</td>
</tr>
<tr>
<td>• Remove trash and debris</td>
</tr>
<tr>
<td>• Repair and re-seed erosion near inlet</td>
</tr>
<tr>
<td>• Remove any evidence of visual contamination from floatables such as oil and grease</td>
</tr>
<tr>
<td>• Clean under-drain and outlet piping to alleviate ponding and restore infiltrative capacity if needed</td>
</tr>
<tr>
<td>• Clean and reset flow spreaders as needed to maintain even distribution of low flows</td>
</tr>
<tr>
<td>• Remove minor sediment accumulation, debris, and obstructions near inlet and outlet structures as needed</td>
</tr>
<tr>
<td>• Mow, weed, and trim routinely(where applicable) to maintain ideal grass height and to suppress weeds</td>
</tr>
<tr>
<td>Major Maintenance</td>
</tr>
<tr>
<td>• 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</td>
</tr>
<tr>
<td>• Reset settled piping, add fill material to maintain original pipe flow line elevations</td>
</tr>
<tr>
<td>• Repair structural damage to flow control structures including inlet, outlet, and overflow structures</td>
</tr>
</tbody>
</table>
### Table 6-29: Routine Maintenance - Sand Filters

<table>
<thead>
<tr>
<th>Defect</th>
<th>Conditions When Maintenance Is Needed</th>
<th>Results Expected When Maintenance Is Performed</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trash &amp; Debris</td>
<td>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.</td>
<td>Trash and debris cleared from site.</td>
<td>Annually prior to wet season</td>
</tr>
<tr>
<td>Inlet erosion</td>
<td>Visible evident of erosion occurring near flow spreader outlets.</td>
<td>Eroded areas repaired/reseeded.</td>
<td>After major storm events (&gt;0.75 inches/24 hrs) if spot checks indicate widespread damage/maintenance needs</td>
</tr>
<tr>
<td>Slow drain time</td>
<td>Standing water long after storm has passed (after 24 to 48 hours) and/or flow through the overflow pipes occurs frequently.</td>
<td>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.</td>
<td>Litter removal is dependent on site conditions and desired aesthetics and shall be done at a frequency to meet those objectives</td>
</tr>
<tr>
<td>Concentrated Flow</td>
<td>Flow spreader uneven or clogged so that flows are not uniformly distributed across the sand filter.</td>
<td>Level the spreader and clean so that flows are spread evenly over the sand filter bed.</td>
<td></td>
</tr>
<tr>
<td>Appearance of poisonous, noxious or nuisance vegetation</td>
<td>Excessive grass and weed growth. Noxious weeds, woody vegetation establishing. Turf growing over rock filter</td>
<td>Mowing, weeding and trimming to restore function and prevent noxious and nuisance plants from establishing</td>
<td>Monthly (or as dictated by agreement between County and landscape contractor)</td>
</tr>
</tbody>
</table>
### Table 6-30: Major Maintenance – Sand Filters

<table>
<thead>
<tr>
<th>Defect</th>
<th>Conditions When Maintenance Is Needed</th>
<th>Results Expected When Maintenance Is Performed</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing Water</td>
<td>Standing water long after storm has passed (after 24 to 48 hours), and/or flow through the overflow pipes occurs frequently.</td>
<td>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.</td>
<td>As needed</td>
</tr>
<tr>
<td>Tear in Filter Fabric</td>
<td>When there is a visible tear or rip in the filter fabric allowing water to bypass the fabric.</td>
<td>Filter fabric repaired and/or replaced.</td>
<td>As needed</td>
</tr>
<tr>
<td>Pipe Settlement</td>
<td>If piping has visibly settled more than 1 inch.</td>
<td>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.</td>
<td>As needed</td>
</tr>
</tbody>
</table>