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T-X Sand Filters

Insert image Sand Filter, indicate SCM components discussed below on conceptual rendering

Figure SF-1. Sand Filter Components

Description

A sand filter treats runoff by filtration and also provides infiltration when unlined systems are used. A sand filter consists of a surcharge zone underlain by a sand bed, often with an underdrain system. During a storm, runoff collects in the surcharge zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually releases the runoff that is filtered through the sand bed and discharges the runoff to a nearby channel, swale, or storm drain. When suitable, a partial or full infiltration section can be used to infiltrate some or all of the runoff from the water quality design event. The *Filtration and Infiltration Systems* section of this chapter provides guidance and criteria for selecting and designing an appropriate subsurface section for a Sand Filter.

Photograph SF-1. This sand filter, constructed on two sides of a parking garage, is accessible for maintenance, yet screened from public view by a landscape buffer.

MS4 Permit Applicability (Dependent on design and level of treatment)	
Meets Runoff Reduction Standard	Yes
Meets WQCV Capture Standard	Yes
Meets Pollutant Removal Standard	Yes
Typical Effectiveness for Targeted Pollutants	
Sediment/Solids	High
Nutrients	High
Total Metals	High
Bacteria	Medium
Common Applications	
Step 1: Runoff Reduction	Yes
Pre-treatment (in Treatment Train)	Yes
WQCV + Flood Control	Yes
Cost	
Life-Cycle Costs	Medium

A sand filter is similar to bioretention in terms of filtration and infiltration treatment mechanisms but differs in that it is not specifically designed for vegetative growth. The absence of vegetation in a sand filter allows for active maintenance of the surface of the filter (i.e., raking to loosen the surface layer or to remove accumulated sediments). For this reason, sand filter criteria allow for a larger contributing area and greater depth of storage than bioretention but will also require more frequent maintenance at the surface of the filter to ensure adequate infiltration. A sand filter can be designed to include the EURV and 100-year flood storage volume above the WQCV, released through an outlet structure. Sand filters can be placed in a vault. However, these types of installations are more difficult to inspect and maintain and should only be used if surface treatment is infeasible.

SCM Components

The primary components of a sand filter include inlet(s), energy dissipation and forebay(s), the surcharge volume, filter material, an underdrain (for no- and partial-infiltration sections), and an outlet structure. The *SCM Inflows* section of this chapter provides guidance and criteria on inlets, energy dissipation, and forebays. The *Site Assessment and Infiltration* section of this chapter provides guidance and criteria for underdrains. The primary outlet for the WQCV is typically an underdrain or infiltration into the underlying soil. See the *SCM Outflows* section of this chapter for design of outlets for the WQCV and larger flood events.

Component	Intent
Inlet	Allows stormwater to enter the SCM.
Forebay & Energy Dissipation	Facilitates removal of trash and coarse sediments and minimizes potential for erosion of sand filter surface.
Surcharge Volume	Provides temporary storage volume needed for attenuation of flows.
Filter Material	Removes pollutants in runoff by filtration through porous media (sand).
Underdrain with orifice release	Collects and slowly releases the WQCV over 12 hours to reduce erosion in the receiving stream and enhance treatment by increasing contact time with the media.
Outlet Structure	Conveys stormwater flows that exceed the design volume.

Site Considerations

Sand filters require a stable watershed. When the watershed includes phased construction, sparsely vegetated areas, or steep slopes in sandy soils, consider another SCM or provide pretreatment before runoff from these areas reach the sand filter.

See the *Site Assessment and Infiltration Section* part of this chapter to determine the section of the sand filter based on site-specific conditions.

Sand filters are often used in industrial settings, where pollutants may be present that warrant use of lined system to prevent subsurface pollutant mobilization.

Community Values

Sand filters are highly functional SCMs that are well suited for industrial and large-scale commercial land uses that have generally lower aesthetic expectations. With an exposed sand bed and lack of vegetation, a sand filter is not the best SCM option for highly visible sites such as boutique commercial or mixed-use development, where aesthetics are very important to business owners and property managers. Sand filters are also not generally ideal options for low-density residential or park and open space-type sites, where a more naturalistic aesthetic is generally expected. However, if properly screened with shrubs or other site elements (e.g., site walls, raised planters, etc.), a sand filter can be made very inconspicuous and may be successfully integrated into almost any type of land use. When located in a visible area, frequent inspection and maintenance is critical to their public acceptance because an unmaintained sand filter can become an unattractive weed patch with sediment and trash deposits.

While successfully integrating a sand filter into certain types of sites may be aesthetically challenging, their straightforward design and function provides some distinct advantages over other SCMs that require vegetation, including water conservation and a simplified maintenance regime. If creatively located and designed and well maintained, sand filters can be an appropriate and effective stormwater quality treatment solution for a wide variety of sites.

Maintenance

Periodic maintenance for sand filters includes removing sediment, scarifying the filter surface, and removal and/or replacement of the top layer of the media. More detailed maintenance recommendations for sand filters are provided in Chapter 6 of this manual. During design, the following should be considered to ensure ease of maintenance over the long-term:

- Provide forebays for inlets to remove coarse sediments and trash in a manner that can be easily accessed for maintenance.
- Provide energy dissipation to minimize erosion of the filter bed.
- Do not put a filter sock on the underdrain. This is not necessary and can cause the SCM to clog, resulting in ponded water for extended periods.
- Install cleanouts to enable camera inspection immediately following construction to ensure the underdrain pipe was not crushed during construction. Cleanouts also facilitate maintenance over the life of the facility. Consider locating cleanouts in the side slopes of the basin and above the depth of ponding to prevent short circuiting of flow through the cleanouts to the underdrain.
- Provide vegetated side slopes to pre-treat runoff by filtering (straining). This will reduce the frequency of maintenance.
- If a sand filter is located in an underground vault, design the vault in a way that allows for routine scarification of the filter surface and eventual media replacement. Multiple access manholes are typically required, and vaults must be designed with adequate clearance for access by equipment and maintenance personnel (an underground sand filter is a confined space). In some installations, grates can be used instead of solid covers, allowing for easier inspection and maintenance.

Photograph SF-2. Underground sand filter at Denver Botanic Gardens has a grated top, which enables inspection and maintenance.

Design Procedures and Criteria

The following steps outline the design procedure and criteria for a sand filter:

Photograph SF-3. Sand filter with incorporation of minor event flood attenuation provides water quality and detention for a substation.

1. **Subsurface Exploration and Determination of a No-Infiltration, Partial Infiltration or Full Infiltration Section.** See the *Site Assessment* and *Filtration and Infiltration Systems* sections of this chapter to determine the most appropriate section design for the sand filter based on site conditions.

2. **Design Storage Volume**: Provide a storage volume above the sand bed of the basin equal to the WQCV based on a 12-hour drain time:
   - Determine the imperviousness of the watershed.
   - Calculate the required storage volume, accounting for Step 1 runoff-reduction SCMs in the contributing watershed. Determine the required WQCV or EURV (watershed inches of runoff) using Figure 3-2 located in Chapter 3 of this manual (for WQCV) or equations provided in the Storage Chapter of Volume 2 (for EURV).
   - Calculate the design volume (surcharge volume above the permanent pool) as follows:

   $$V = \left[\frac{\mathrm{WQCV}}{12}\right] A \qquad \text{Equation SF-1}$$

   Where:

   V = design volume (ft^3)

   A = watershed area tributary to the sand filter (ft^2)

3. **Sand Filter Geometry:** Use equation SF-2 to calculate the minimum filter area, which is the flat surface of the sand filter. Sediment will deposit on the filter area of the sand filter. Therefore, if the filter area is too small, the filter may clog prematurely. If clogging of the filter is of particular concern, increasing the filter area will decrease the frequency of maintenance. Equation SF-2 provides the minimum filter area allowing for some of the volume to be stored beyond the area of the filter. **Note that the total volume must also equal or exceed the design volume.**

   $$A_F = 0.0125 \cdot A \cdot I \qquad \text{Equation SF-2}$$

Where:

A_F = minimum filter area (flat surface area) (ft^2)

A = area tributary to the sand filter (ft^2)

I = imperviousness of area tributary to the sand filter (percent expressed as a decimal)

4. **Side Slopes:** The side slopes of the basin should be stable and maintainable. For vegetated side slopes, a 4:1 (horizontal: vertical) minimum slope is recommended. Use vertical walls where side slopes are steeper than 3:1.
5. **Filter Material**: Provide, at a minimum, an 18-inch layer of CDOT Class B or C filter material (see Table SF-1). Maintain a flat surface on the top of the sand bed.

Table SF-1. Gradation specifications for CDOT Class B or C filter material
(Source: CDOT Table 703-7)

	CDOT Class B Filter Material	CDOT Class C Filter Material
Sieve Size	**Mass Percent Passing Square Mesh Sieves**	
37.5 mm (1.5")	100	-
19.0 mm (0.75")	-	100
4.75 mm (No.4)	20-60	60-100
1.18 um (No. 16)	10-30	-
300 um (No. 50)	0-10	10-30
150 um (No. 100)	-	0-10
75 um (No. 200)	0-3	0-3

6. **Inlets**: Use inflow features that create sheet flow or shallow flow conditions to evenly distribute flow. Provide energy dissipation and a forebay at all locations where concentrated flows enter the sand filter. See the *SCM Inflow Features* section of this chapter for additional guidance. The MHFD-Detention workbook performs calculations for outlet sizing, including the orifice control for the underdrain and outlet controls for larger runoff events.
7. **Outlet:** Slope the underdrain into a larger outlet structure and use an orifice plate to drain the WQCV over approximately 12 hours. The *SCM Outflow Features* section of this chapter includes conceptual details for the underdrain and orifice outlet to release the WQCV as well as conceptual details for outlets that incorporate detention of larger events via full spectrum detention. Provide a spillway for larger events that will convey overflows to the receiving drainage system without adversely affecting adjacent structures or infrastructure. The MHFD-Detention workbook performs calculations for

outlet sizing, including the orifice control for the underdrain and outlet controls for larger runoff events.

Construction Considerations

Proper construction of sand filters involves careful attention to material specifications and construction details. For a successful project:

- Protect area from excessive sediment loading during construction. The portion of the site draining to the sand filter must be stabilized before allowing flow into the sand filter.
- When using an impermeable liner, ensure enough slack in the liner to allow for backfill, compaction, and settling without tearing the liner as described in the *Filtration and Infiltration Systems* section of this chapter.
- Avoid application of herbicides for weed control within the sand filter and areas draining directly into the sand filter (e.g. embankments).