4.9 Stormwater Filtering Systems

Introduction

Stormwater filtering systems are practices that capture and temporarily store the design storm volume and pass it through a filter bed of sand media. Filtered runoff may be collected and returned to the conveyance system or allowed to partially infiltrate into the soil.

Stormwater filters are a useful practice to treat stormwater runoff from small, highly impervious sites (see Key Considerations). Stormwater filters capture, temporarily store, and treat stormwater runoff by passing it through an engineered filter media, collecting the filtered water in an underdrain, and then returning it back to the storm drainage system. The filter consists of two chambers: the first is devoted to settling, and the second serves as a filter bed consisting of a sand filter media.

Stormwater filters are a versatile option because they consume very little surface land and have few site restrictions. They provide moderate pollutant removal performance at small sites where space is limited. However, filters have no retention capability, so designers should consider using up-gradient retention practices, which have the effect of decreasing the design storm volume and size of the filtering practices. Filtering practices are also suitable to provide special treatment at designated stormwater hotspots.

Typically, filtering systems should not be designed to provide stormwater detention of larger storm events, but can be in some circumstances. Filtering practices are generally combined with separate facilities to provide this type of control. However, the three-chamber underground sand filter can be modified by expanding the first or settling chamber, or adding an extra chamber between the filter chamber and the clear well chamber to handle the detention volume, which is subsequently discharged at a pre-determined rate through an orifice and weir combination.

Figure 4.9-1. Perimeter Sand Filter (Photo: CWP)

Although several design variants exist, the perimeter Sand Filter is discussed in this section, as it is well adapted to the flat topography and (often) high water table typical in the coastal plain.

Perimeter sand filters (Figures 4.9-1 and 4.9-2) are enclosed stormwater management practices that are typically located just below grade in a trench along the perimeter of parking lot, driveway or other impervious surface. Perimeter sand filters consist of a pretreatment forebay and a filter bed chamber. Stormwater runoff is conveyed into a perimeter sand filter through grate inlets located directly above the system.

KEY CONSIDERATIONS: STORMWATER FILTERING SYSTEMS

DESIGN CRITERIA:

- The drainage area cannot exceed 2 acres.
- Must drain completely within 72 hours of the end of a rainfall event.
- A maximum ponding depth of 12 inches is recommended to help prevent the formation of nuisance ponding conditions.
- Requires at least 2 feet of head.

BENEFITS:

- Achieves moderate to high removal of many of the pollutants of concern typically contained in post-construction stormwater runoff.
- Filtrations systems are ideal for intercepting and treating stormwater runoff from small, highly impervious areas, including stormwater hotspots.

LIMITATIONS:

- Construction and maintenance costs are relatively high.
- Cannot "receive" stormwater runoff that contains high sediment loads.

SITE APPLICABILITY:

- Suburban Use
- Urban Use
- Construction Cost: High
- Maintenance: High
- Area Required: Low

STORMWATER MANAGEMENT PRACTICE PERFORMANCE:

Runoff Reduction Credit Approach
(applies to Shellfish Bed, SMS4, and infiltration credit approaches)

- 0% credit for runoff reduction

Coastal Zone Credit Approach

- 100% credit for storage volume of practice

Statewide Water Quality Requirement Credit Approach

- 1" of runoff must be managed

Pollutant Removal[1]
90%- Total Suspended Solids
65% - Total Phosphorus
45% - Total Nitrogen
50% - Metals
80% - Pathogens

[1] expected annual pollutant load removal

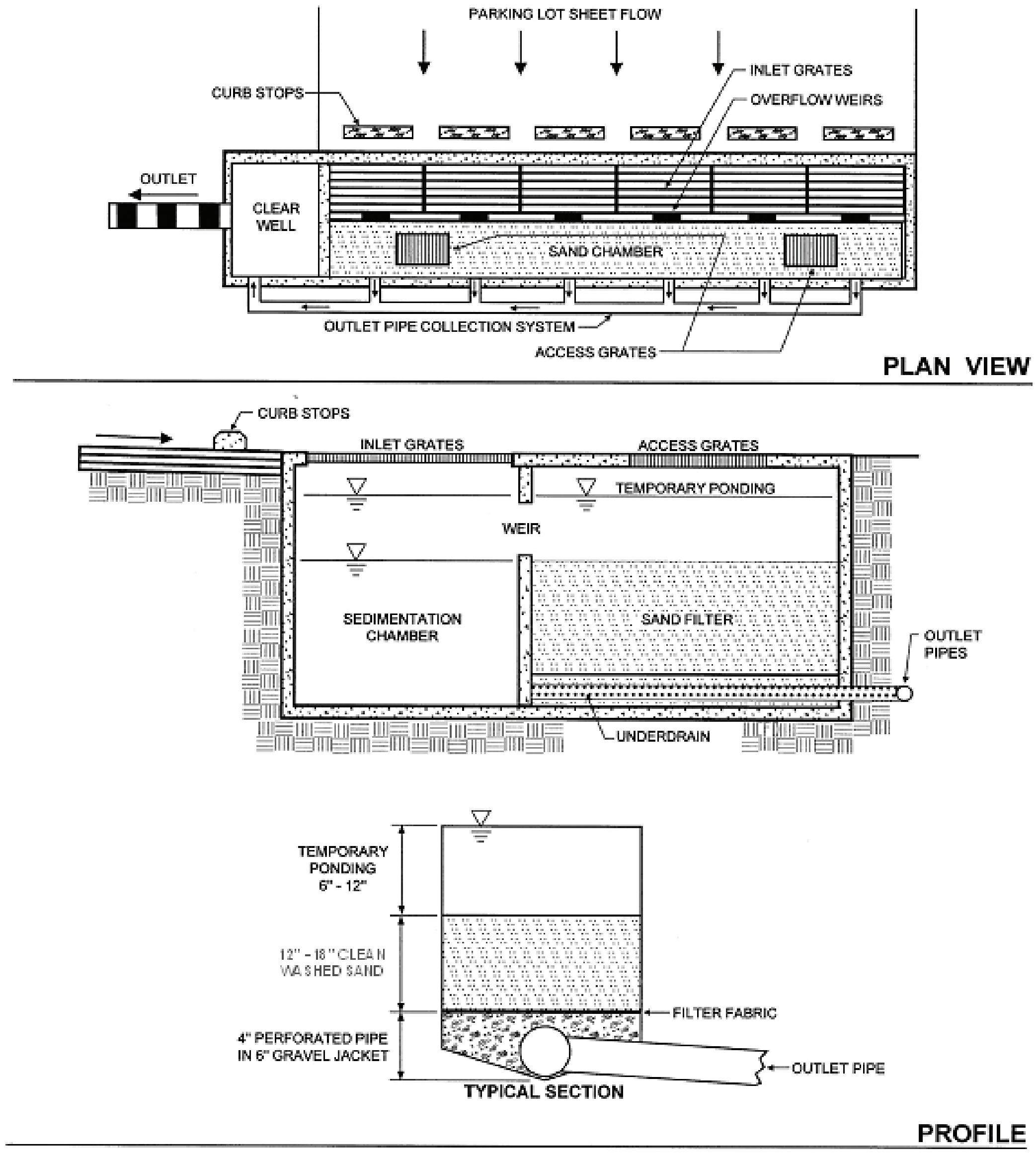

Figure 4.9-2. Perimeter Sand Filter Detail. Note: Material specifications are indicated in Table 4.9-1.

Filtering Feasibility Criteria

Stormwater filters can be applied to most types of urban land. They are not always cost-effective, given their high unit cost and small area served; however, there are situations where they clearly may be the best option for stormwater treatment (e.g., hotspot runoff treatment, small parking lots, ultra-urban areas, etc.). The following criteria apply to filtering practices:

Available Hydraulic Head. The principal design constraint for stormwater filters is available hydraulic head, which is defined as the vertical distance between the top elevation of the filter and the bottom elevation of the existing storm drain system that receives its discharge. Typically, a minimum of 2 feet of head is required for perimeter sand filters.

Depth to Water Table and Bedrock. The designer must assure a standard separation distance of at least 0.5 feet between the seasonally high groundwater table and/or bedrock layer and the bottom invert of the filtering practice.

Contributing Drainage Area. Perimeter sand filters should only be used to treat runoff from sites smaller than 2 acres, with nearly 100% impervious cover.

Space Required. This practice consumes almost no surface area, except for necessary manholes and surface grates.

Land Use. Filtration practices are particularly well suited to treat runoff from stormwater hotspots and smaller parking lots. Other applications include redevelopment of commercial sites or when existing parking lots are renovated or expanded. Filtration practices can work on most commercial, industrial, institutional, or municipal sites and can be located underground if surface area is not available.

Floodplains. Filtration practices should be constructed outside the limits of the mapped 100-year floodplain, unless a waiver is obtained from the local authority.

Site Topography. Filters shall not be located on slopes greater than 6 percent.

Facility Access. All filtering systems shall be located in areas where they are accessible for inspection and for maintenance (by vacuum trucks).

Soils. Soil conditions do not constrain the use of filters. At least one soil boring should be taken within the footprint of the proposed filtering practice to establish the water table and evaluate soil suitability. A geotechnical investigation should be conducted for underground practices such as the perimeter sand filter.

Location Factors. Maintenance requirements for underground sand filters can be significant. Filters may be considered for high density residential areas, but should be maintained by a contractor through a community association.

Setbacks. Filters should be set back at least 10 feet from the property line, and the bottom of the practice should be separated from groundwater by at least 0.5 feet.

Economic Considerations. Perimeter sand filters are expensive relative to other treatment practices, but may be the only option to treat small hotspot drainage areas.

Filtering Conveyance Criteria

Perimeter sand filters are designed as off-line systems so that all flows enter the filter storage chamber until it reaches capacity, at which point larger flows are then diverted or bypassed around the filter to an outlet chamber and are not treated. Runoff from larger storm events must be bypassed using an overflow structure or a flow splitter. Claytor and Schueler (1996) and ARC (2001) provide design guidance for flow splitters for filtering practices.

Stormwater filters should be designed to drain or dewater within 72 hours after a storm event to reduce the potential for nuisance conditions.

Filtering Pretreatment Criteria

Adequate pretreatment is needed to prevent premature filter clogging and ensure filter longevity. Perimeter sand filters are typically designed with a wet pretreatment chamber that is parallel to the filter.

- ✧ Sedimentation chambers are typically used for pretreatment to capture coarse sediment particles before they reach the filter bed.
- ✧ The chamber should be sized to accommodate at least 25 percent of the total design storm volume (inclusive).
- ✧ Sediment chambers should be designed as level spreaders such that inflows to the filter bed have near zero velocity and spread runoff evenly across the bed.

Filtering Design Criteria

Detention time. All filter systems should be designed to drain the design storm volume from the filter chamber within 72 hours after each rainfall event.

Structural Requirements. If a filter will be located underground or experience traffic loads, a licensed structural engineer must certify the structural integrity of the design.

Geometry. Filters are gravity flow systems that normally require ponding above the filter bed. The perimeter sand filter is designed to require minimal hydraulic head, but needs between 6 and 12” of ponding above the filter bed. The design should allow sufficient hydraulic head to include ponding, the filter bed, and the underdrain pipe below the filter.

Type of Filter Media. The normal filter media consists of clean, washed AASHTO M-6/ASTM C-33 medium aggregate concrete sand with individual grains between 0.02 and 0.04 inches in diameter.

Depth of Filter Media. The depth of the filter media plays a role in how quickly stormwater moves through the filter bed and how well it removes pollutants. The recommended filter bed depth is 18 inches. An absolute minimum filter bed depth of 12 inches above underdrains is required; however, designers should note that specifying the minimum depth of 12 inches will incur a more intensive maintenance schedule, possibly resulting in greater costs.

Underdrain and Liner. Stormwater filters are normally designed with an impermeable liner and underdrain system that meet the specification criteria provided in Table 4.9-1.

Underdrain Stone. The underdrain should be covered by a minimum 6-inch gravel layer consisting of clean, washed No. 57 stone.

Maintenance Reduction Features. The following maintenance issues should be addressed during filter design to reduce future maintenance problems:

- **Observation Wells and Cleanouts.** Non-structural and surface sand filters must include an observation well consisting of a 6-inch diameter non-perforated PVC pipe fitted with a lockable cap. It should be installed flush with the ground surface to facilitate periodic inspection and maintenance. In most cases, a cleanout pipe will be tied into the end of all underdrain pipe runs. The portion of the cleanout pipe/observation well in the underdrain layer should be perforated. At least one cleanout pipe must be provided for every 2000 square feet of filter surface area.
- **Access.** Good maintenance access is needed to allow crews to perform regular inspections and maintenance activities. "Sufficient access" is operationally defined as the ability to get a vacuum truck or similar equipment close enough to the sedimentation chamber and filter to enable cleanouts. Direct maintenance access shall be provided to the pretreatment area and the filter bed. For underground structures, sufficient headroom for maintenance should be provided. A minimum head space of 5 feet above the filter is recommended for maintenance of the structure. However, if 5 feet headroom is not available, manhole access must be installed.
- **Manhole Access (for Underground Filters).** Underground Filters must be provided by manholes at least 30 inches in diameter, along with steps to the areas where maintenance will occur.
- **Visibility.** Stormwater filters should be clearly visible at the site so inspectors and maintenance crews can find them easily. Adequate signs or markings must be provided at manhole access points for Underground Filters.
- **Confined Space Issues.** Underground Filters are often classified as a confined space. Consequently, special OSHA rules apply, and training may be needed to protect the workers that access them. These procedures often involve training about confined space entry, venting, and the use of gas probes.

Filter Material Specifications. The basic material specifications for filtering practices that utilize sand as a filter media are outlined in Table 4.9-1.

Table 4.9-1 Filtering Practice Material Specifications	
Material	**Specification**
Surface Cover	Use clean, washed No. 57 stone on top of the sand layer.
Sand	Use clean AASHTO M-6/ASTM C-33 medium aggregate concrete sand with a particle size range of 0.02 to 0.04 inch in diameter.
Geotextile/Filter Fabric	Use an appropriate geotextile fabric that meets AASHTO M-288 Class 2, latest edition, requirements.
Underdrain/Perforated Pipe	Use 4- or 6-inch perforated schedule 40 PVC pipe, with ⅜-inch perfora-tions at 6 inches on center.
Underdrain Stone	Use #57 stone or the ASTM equivalent (1 inch maximum).
Impermeable Liner	Where appropriate, use a thirty mil (minimum) PVC Geomembrane.

Filter Sizing. Filtering devices are sized to accommodate a specified design storm volume (typically the WQV). The volume to be treated by the device is a function of the storage depth above the filter and the surface area of the filter. The storage volume is the volume of ponding above the filter. For a given design volume, Equation 4.9-1 below is used to determine the required filter surface area.

Equation 4.9-1. Minimum Filter Surface Area for Filtering Practices

$$SA_{filter} = \frac{DesignVolume \times d_f}{k \times (h_{avg} + d_f) \times t_f}$$

where:

SA_{filter}	=	area of the filter surface (ft^2)
$DesignVolume$	=	design storm volume, typically the WQV (ft^3)
d_f	=	filter media depth (thickness) (ft), with a minimum of 1 ft
k	=	coefficient of permeability (ft/day), 3.5 ft/day for partially clogged sand
h_{avg}	=	average height of water above the filter bed (ft)
t_f	=	Allowable drawdown time (1.67 days)

The coefficient of permeability (ft/day) is intended to reflect the worst case situation (i.e., the condition of the sand media at the point in its operational life where it is in need of replacement or maintenance). Filtering practices are therefore sized to function within the desired constraints at the end of the media's operational life cycle.

The filter treatment system must be designed to hold at least 25 percent of the design storm volume in temporary ponding prior to filtration (Equation 4.9-2). This volume takes into account the varying filtration rate of the water through the media, as a function of a gradually declining hydraulic head.

Equation 4.9-2 Required Ponding Volume for Filtering Practices

$$V_{ponding} = 0.25 \times DesignVolume$$

where:

$V_{ponding}$ = storage volume required prior to filtration (ft^3)

The total storage volume for the practice (*Sv*) can be determined using Equation 4.9-3 below.

Equation 4.9-3 Storage Volume for Filtering Practices

$$Sv = 4.0 \times V_{ponding}$$

In the LID Compliance Calculator spreadsheet, filtering practices are not assigned any runoff reduction credit. For projects in the Coastal Zone, the Sv for filtering practices is given a 100% credit toward the storage requirement. For the statewide water quality requirements, filtering practices are credited in a similar manner as a pond without a permanent pool, and at least 1 inch of runoff must be treated.

Filtering Landscaping Criteria

No landscaping is necessary for perimeter sand filters.

Filtering Construction Sequence

Erosion and Sediment Control. No runoff shall be allowed to enter the filter system prior to completion of all construction activities, including revegetation and final site stabilization. Construction runoff shall be treated in separate sedimentation basins and routed to bypass the filter system. Should construction runoff enter the filter system prior to final site stabilization, all contaminated materials must be removed and replaced with new, clean filter materials before a regulatory inspector approves its completion. The approved erosion and sediment control plans shall include specific measures to provide for the protection of the filter system before the final stabilization of the site.

Filter Installation. The following is the typical construction sequence to properly install a structural sand filter. This sequence can be modified to reflect different filter designs, site conditions, and the size, complexity, and configuration of the proposed filtering application.

> **Step 1:** Stabilize Drainage Area. Filtering practices should only be constructed after the contributing drainage area to the facility is completely stabilized, so sediment from the CDA does not flow into and clog the filter. If the proposed filtering area is used as a sediment trap or basin during the construction phase, the construction notes should clearly specify that, after site construction is complete, the sediment control facility will be dewatered, dredged, and regraded to design dimensions for the post-construction filter.

> **Step 2:** Install E&S Controls for the Filtering Practice. Stormwater should be diverted around filtering practices as they are being constructed. This is usually not difficult to ac-

complish for off-line filtering practices. It is extremely important to keep runoff and eroded sediments away from the filter throughout the construction process. Silt fence or other sediment controls should be installed around the perimeter of the filter, and erosion control fabric may be needed during construction on exposed side-slopes with gradients exceeding 4H:1V. Exposed soils in the vicinity of the filtering practice should be rapidly stabilized by hydro-seed, sod, mulch, or other method.

Step 3: Assemble Construction Materials on-site. Make sure they meet design specifications and prepare any staging areas.

Step 4: Clear and Strip the project area to the desired subgrade.

Step 5: Excavate/Grade until the appropriate elevation and desired contours are achieved for the bottom and side slopes of the filtering practice.

Step 6: Install the Filter Structure and check all design elevations (i.e., concrete vaults for surface, underground, and perimeter sand filters). Upon completion of the filter structure shell, inlets and outlets must be temporarily plugged and the structure filled with water to the brim to demonstrate water tightness. Maximum allowable leakage is 5 percent of the water volume in a 24-hour period. If the structure fails the test, repairs must be performed to make the structure watertight before any sand is placed into it.

Step 7: Install the gravel, underdrains, and choker layer of the filter.

Step 8: Spread Sand Across the Filter Bed in 1-foot lifts up to the design elevation. Backhoes or other equipment can deliver the sand from outside the filter structure. Sand should be manually raked. Clean water is then added until the sedimentation chamber and filter bed are completely full. The facility is then allowed to drain, hydraulically compacting the sand layers. After 48 hours of drying, refill the structure to the final top elevation of the filter bed.

Step 9: Stabilize Exposed Soils on the perimeter of the structure with permanent seeding, as appropriate.

Step 10: Conduct the final construction inspection. Multiple construction inspections by a qualified professional are critical to ensure that stormwater filters are properly built. Inspections are recommended during the following stages of construction:

- ✧ Initial site preparation, including installation/Erosion and Sediment (E&S) controls
- ✧ Excavation/grading to design dimensions and elevations
- ✧ Installation of the filter structure, including the water tightness test
- ✧ Installation of the underdrain and filter bed
- ✧ Final inspection after a rainfall event to ensure that it drains properly and all pipe connections are watertight. Develop a punch list for facility acceptance.

Filtering Maintenance Criteria

Maintenance of filters is required and involves several routine tasks, which are outlined in Table 4.9-2 below. A cleanup should be scheduled at least once a year to remove trash and floatables that accumulate in the pretreatment cells and filter bed. Frequent sediment cleanouts in the dry and wet sedimentation chambers are recommended every 1 to 3 years to maintain the function and performance of the filter. If the filter treats runoff from a stormwater hotspot, crews may need to test the filter bed media before disposing of the media and trapped pollutants. Petroleum hydrocarbon contaminated sand or filter cloth must be disposed of in compliance with state and local disposal requirements. Testing is not needed if the filter does not receive runoff from a designated stormwater hotspot, in which case the media can be safely disposed of in a landfill.

Table 4.9-2 Typical Annual Maintenance Activities for Filtering Practices

Frequency	Maintenance Tasks
2 times per year (may be more or less frequently depending on land use)	♦ Check to see if sediment accumulation in the sedimentation chamber has exceeded 6 inches. If so, schedule a cleanout.
Annually	♦ Conduct inspection and cleanup. ♦ Dig a small test pit in the filter bed to determine whether the first 3 inches of sand are visibly discolored and need replacement. ♦ Check to see if inlets and flow splitters are clear of debris and are operating properly. ♦ Check concrete structures and outlets for any evidence of spalling, joint failure, leakage, corrosion, etc. ♦ Ensure that the filter bed is level and remove trash and debris from the filter bed. Sand or gravel covers should be raked to a depth of 3 inches.
Every 5 years	♦ Replace top sand layer. ♦ Till or aerate surface to improve infiltration/grass cover.
As needed	♦ Remove blockages and obstructions from inflows. Trash shall be removed regularly to ensure the inflow capacity of the BMP is preserved. ♦ Stabilize contributing drainage area and side-slopes to prevent erosion.
Upon failure	♦ Corrective maintenance is required any time the sedimentation basin and sediment trap do not draw down completely after 72 hours (i.e., no standing water is allowed).

Regular inspections by a qualified professional are critical to schedule sediment removal operations, replace filter media, and relieve any surface clogging. Frequent inspections are especially needed for underground and perimeter filters, since they are out of sight and can be easily forgotten. Depending on the level of traffic or the particular land use, a filter system may either become clogged within a few months of normal rainfall or could possibly last several years with only routine maintenance. Maintenance inspections should be conducted within 24 hours following a storm that exceeds ½-inch of rainfall, to evaluate the condition and performance of the filtering practice. Note: Without regular maintenance, reconditioning sand filters can be very expensive.

An example maintenance checklist for filtering practices is included in *Appendix F*.

Stormwater Filtering Systems References and Additional Resources

1. Atlanta Regional Commission (ARC). 2001. Georgia Stormwater Management Manual, First Edition. Available online at: http://www.georgiastormwater.com
2. Claytor, R. and T. Schueler. 1996. Design of Stormwater Filtering Systems. Chesapeake Research Consortium and the Center for Watershed Protection. Ellicott City, MD. http://www.sciencetime.org/ConstructedClimates/wp-content/uploads/2013/01/ClaytorSchueler1996.pdf
3. Hirschman, D., Collins, K., and T. Schueler. 2008. Technical Memorandum: The Runoff Reduction Method. Center for Watershed Protection and Chesapeake Stormwater Network. Ellicott City, MD.
4. Schueler, T., D. Hirschman, M. Novotney, and J. Zielinski. 2007. Urban Stormwater Retrofit Practices, Version 1.0, Urban Subwatershed Restoration Manual No. 3.