New Jersey Stormwater Best Management Practices Manual

February 2004

CHAPTER 9.9

Standard for Sand Filters

Definition

A sand filter consists of a forebay and underdrained sand bed. It can be configured as either a surface or subsurface facility. Runoff entering the sand filter is conveyed first through the forebay, which removes trash, debris, and coarse sediment, and then through the sand bed to an outlet pipe. Sand filters use solids settling, filtering, and adsorption processes to reduce pollutant concentrations in stormwater. The adopted TSS removal rate for sand filters is 80 percent.

Purpose

Sand filters are normally used to remove relatively large amounts of sediments, metals, hydrocarbons, and floatables from stormwater runoff.

Conditions Where Practice Applies

Sand filters are normally used in highly impervious areas with relatively high TSS, heavy metal, and hydrocarbon loadings such as roads, driveways, drive-up lanes, parking lots, and urban areas. However, due to their relatively high sediment removal capabilities, sand filters are not generally recommended in pervious drainage areas where high coarse sediment loads and organic material such as leaves can quickly clog the sand bed. Where such loadings cannot be avoided, pretreatment is recommended. Since sand filters can be located underground, they can also be used in areas with limited surface space.

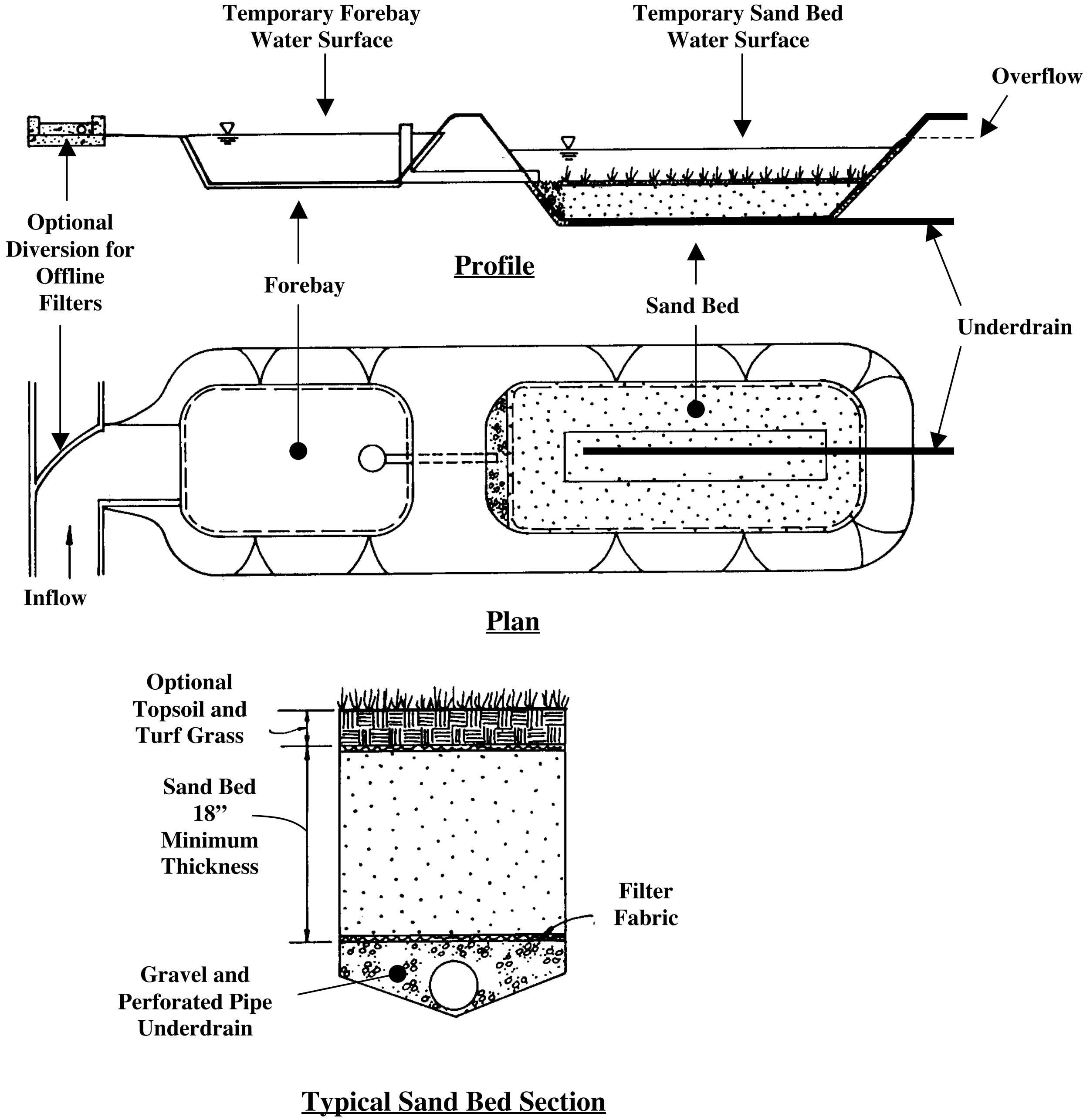
A sand filter must have a maintenance plan and, if privately owned, should be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Design Criteria

In general, all sand filters consist of four basic components or zones: 1) Forebay Zone, 2) Sand Bed Zone, 3) Sand Bed Underdrain, and 4) Overflow. These and other typical sand filter components are shown in Figures 9.9-1, 2, and 3. These figures depict, respectively, a surface, subsurface, and perimeter sand filter, which are the three sand filter types discussed in this manual.

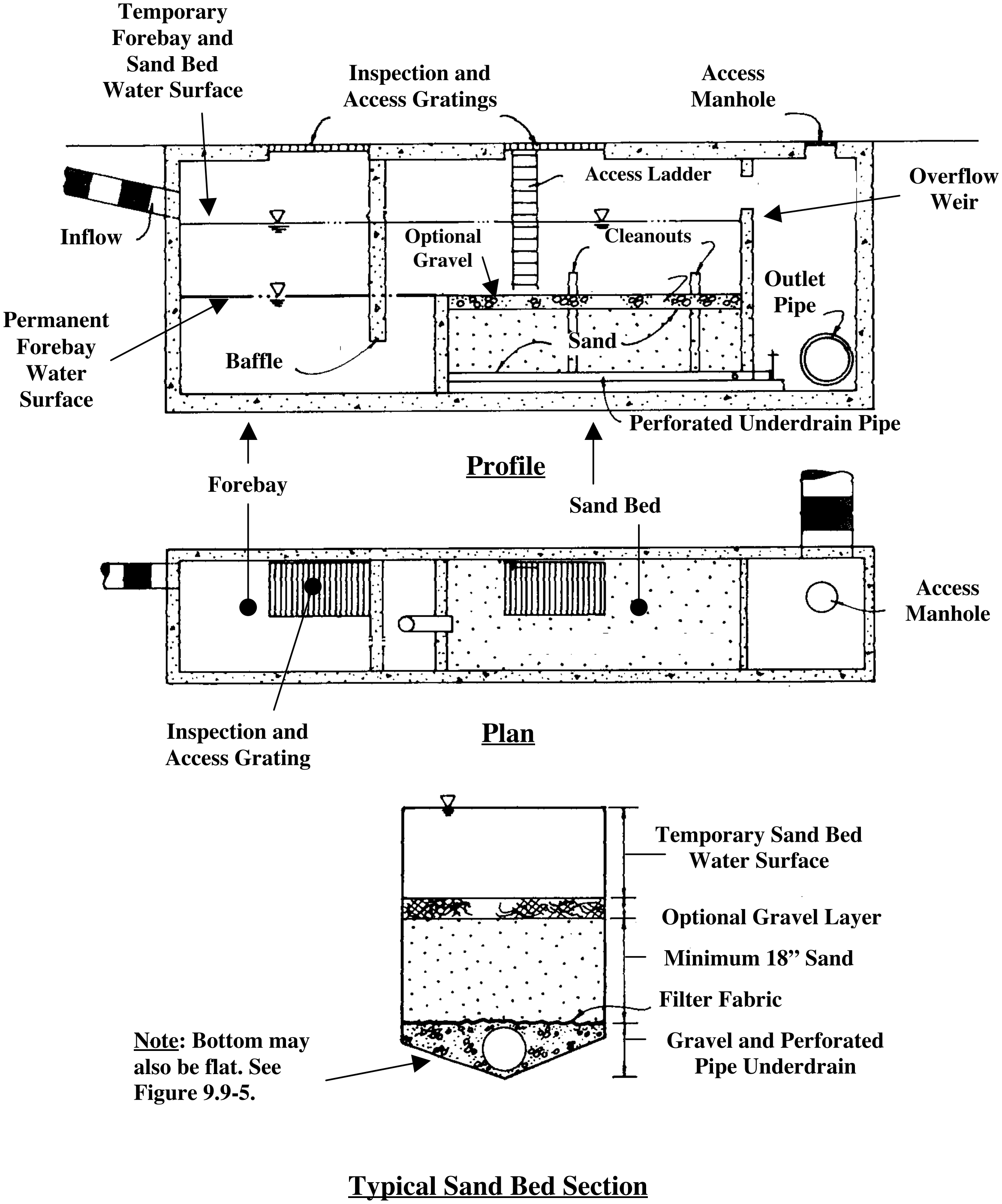
The basic design parameters for all three of these sand filter types are the surface areas and the temporary storage volumes in their forebay and sand bed zones and the thickness and infiltration rate of their sand beds. There must be sufficient total temporary storage volume within the forebay and sand bed zones (including the sand bed itself) to contain the design runoff volume and direct it thought the sand bed without overflow. The thickness of the sand bed must provide adequate pollutant removal, while the bed's permeability or infiltration rate must be sufficient to drain the stored runoff within 72 hours. In addition, the capacity of the sand bed underdrain must allow the sand bed to drain freely, while the overflow must safely convey the runoff from storms greater than the design storm. Details of these and other design parameters are presented below.

Figure 9.9-1: Typical Surface Sand Filter Components



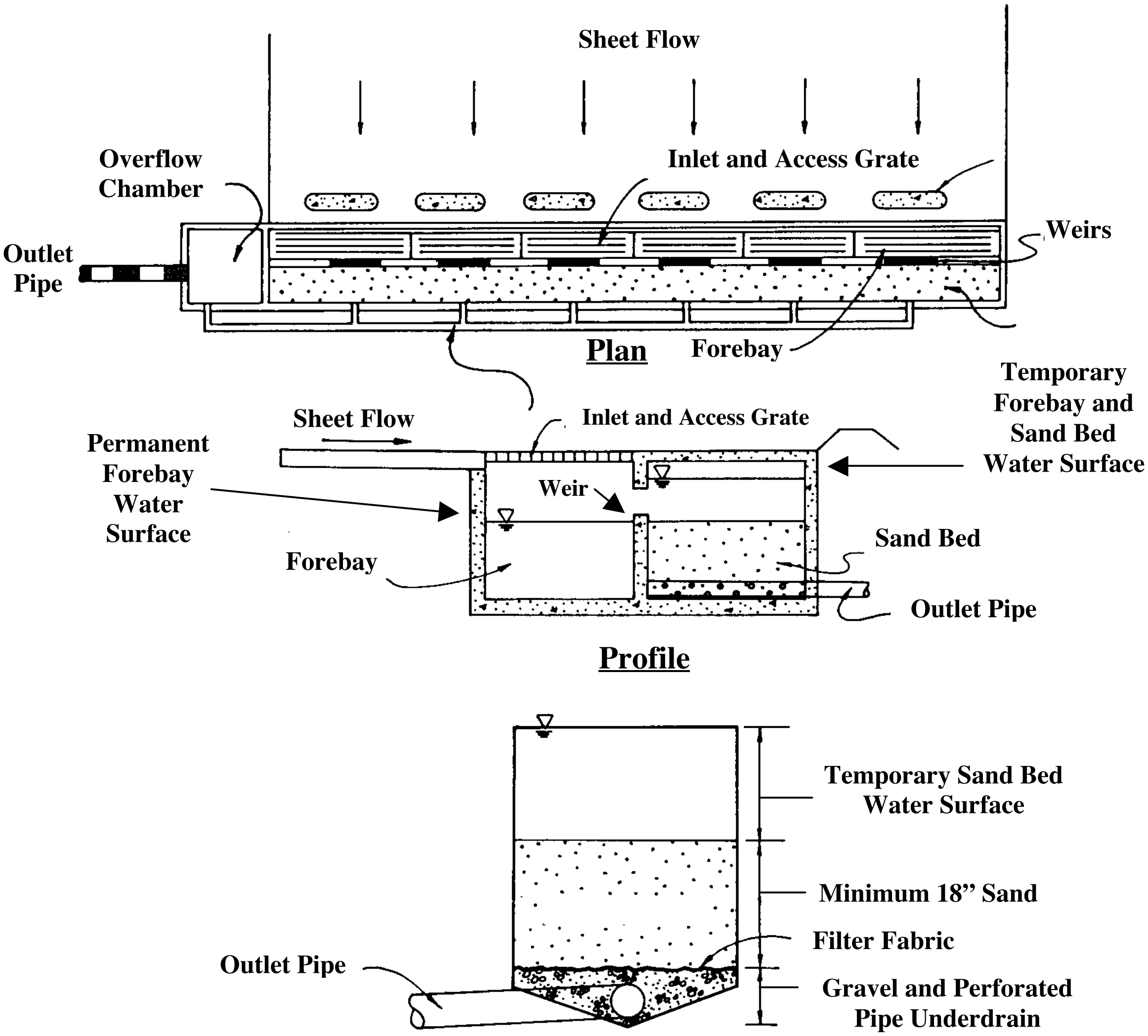
Source: Adapted from Claytor and Schueler, 1996.

Figure 9.9-2: Typical Subsurface Sand Filter Components



Source: Adapted from Claytor and Schueler, 1996.

Figure 9.9-3: Typical Perimeter Sand Filter Components



Plan

Profile

Typical Sand Bed Section

Note: Bottom may also be flat.
See Figure 9.9-5.

Source: Adapted from Claytor and Schueler, 1996.

A. Storage Volume and Duration

Sand filters must be designed to treat the runoff volume generated by the stormwater quality design storm. Techniques to compute this volume are discussed in *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. The maximum time required to fully drain the stormwater quality design storm runoff volume is 72 hours. As shown in Table 9.9-1, a design drain time of 36 hours must be used when designing the sand bed.

B. Component Dimensions, Areas, and Volumes

The required volumes, areas, and dimensions of the various sand filter components are shown in Table 9.9-1. Several of these parameters are depicted in Figure 9.9-4.

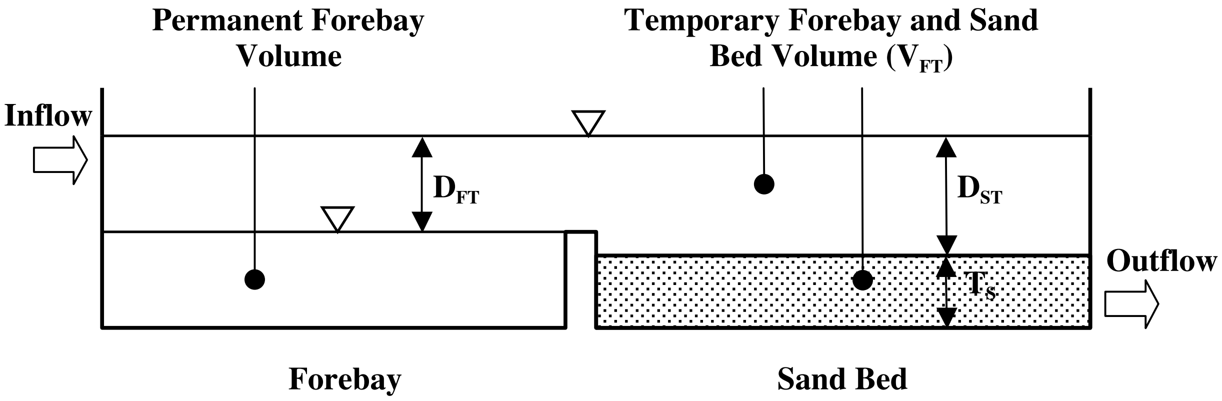
Table 9.9-1: Typical Sand Filter Design Parameters

#	Parameter Description	Parameter	Parameter Value		
			Surface Filter	Subsurface Filter	Perimeter Filter
1	Total Temporary Volume in Forebay and Sand Bed Zones[1]	V_{QS}	Stormwater Quality Design Storm Runoff Volume	Stormwater Quality Design Storm Runoff Volume	Stormwater Quality Design Storm Runoff Volume
2	Approximate Temporary Sand Bed Volume[2]	V_{ST}	$(0.5)(V_{QS})$	$(0.5)(V_{QS})$	$(0.5)(V_{QS})$
3	Minimum Sand Bed Thickness	TH_S	18 Inches	18 Inches	18 Inches
4	Sand Bed Design Porosity	n	0.3	0.3	0.3
5	Sand Bed Design Permeability	k	4 Feet per Day	4 Feet per Day	4 Feet per Day
6	Sand Bed Design Drain Time	T_D	1.5 Days	1.5 Days	1.5 Days
7	Minimum Sand Bed Surface Area	A_S	See Equation 9.9-1	See Equation 9.9-1	See Equation 9.9-1
8	Approximate Temporary Forebay Volume[3]	V_{FT}	$(0.5)(V_{QS})$	$(0.5)(V_{QS})$	$(0.5)(V_{QS})$
9	Minimum Forebay Surface Area	A_F	$(0.05)(V_{QS})$	$(0.05)(V_{QS})$	$(0.05)(V_{QS})$
10	Minimum Temporary Forebay Depth	D_{FT}	2 Feet	N/A	N/A
11	Minimum Permanent Forebay Depth	D_{FP}	N/A[4]	2 Feet	2 Feet
12	Overall Minimum Length to Width Ratio	L/W	2	2	N/A

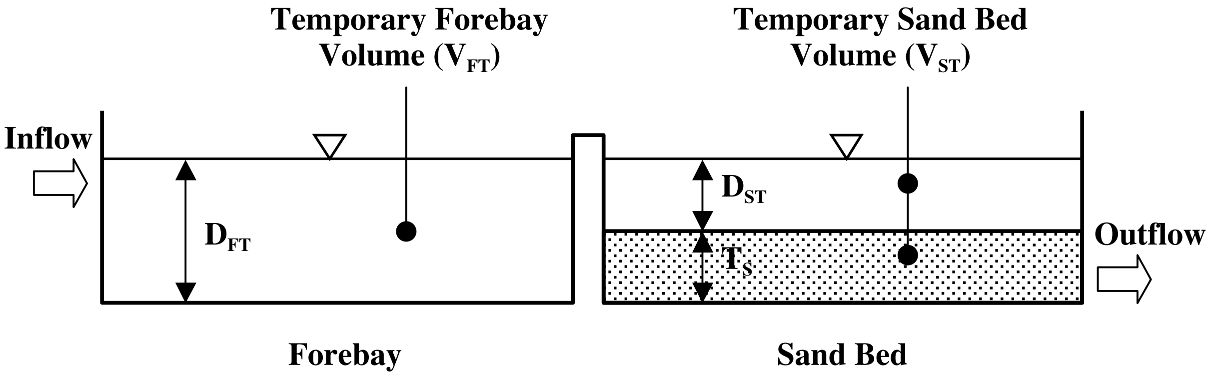
Notes:

1. Includes temporary storage volume in sand, but excludes storage volume in forebay permanent pool.
2. Includes temporary storage volume in sand.
3. Excludes storage volume in forebay permanent pool.
4. Forebay in surface sand filter typically does not have permanent pool.

Figure 9.9-4: Sand Filter Schematics



Schematic for Subsurface and Perimeter Sand Filters



Schematic for Surface Sand Filters

Source: Adapted from Claytor and Schueler, 1996.

C. General Design Procedure

Due to the number of design parameters, the design of a sand filter is generally a trial and error process to some degree. Utilizing the design parameters in Table 9.9-1 and the sand filter schematics shown in Figure 9.9-4, the general design procedure for sand filters is as follows:

1. Determine the runoff volume (V_{QS}) and peak discharge rate (Q_{QDS}) to the sand filter for the stormwater quality design storm. From Line 1 in Table 9.9-1, the total temporary storage volume in the sand filter's forebay and sand bed zones (including the storage volume within the sand bed, but excluding any permanent forebay storage volume) must equal V_{QS}.
2. Determine the approximate required volumes of the sand filter's forebay and sand bed zones. As shown on Lines 2 and 8 in Table 9.9-1, these volumes should each be approximately equal to one half of the stormwater quality design storm runoff volume (V_{QS}).
3. Estimate the maximum temporary depths in the sand bed (D_{ST}) and forebay (D_{FT}) zones for the stormwater quality design storm. This estimate should be based on an analysis of site conditions, including the difference between the invert elevation of the downstream conveyance system and the maximum ground elevation at the filter site. Analysis of this elevation difference should include consideration for the minimum sand bed thickness (T_{HS}) on Line 3 and either the minimum temporary forebay depth (D_{FT}) for surface filters on Line 10 or the permanent forebay depth (D_{FP}) for subsurface and perimeter filters on Line 11 of Table 9.9-1. As shown in Figure 9.9-4, the maximum temporary depth in the sand bed zone (D_{ST}) is measured from the top of the sand bed, while the maximum temporary forebay depth (D_{FT}) is measured from any permanent forebay water surface.
4. Compute the minimum forebay surface area (A_F). As shown on Line 9 of Table 9.9-1, this minimum area is $(0.05)(V_{QS})$. It should be noted that the 0.05 multiplier in the equation has the units of area per volume or L^2/L^3. As such, the equation yields square feet of forebay area from cubic feet of stormwater quality design storm runoff volume.
5. From the maximum temporary depth in the forebay (D_{FT}) from Step 3 and the minimum forebay area (A_F) from Step 4, compute the total temporary storage volume in the forebay (V_{FT}). Compare this volume with the approximate required forebay volume computed in Step 2. Adjust the maximum temporary forebay depth (D_{FT}) and/or forebay area (A_F) as necessary to achieve a total temporary forebay storage volume (V_{FT}) as close as practical to the required forebay volume from Step 2. While adjusting the forebay surface area (A_F) by varying its length and width, remember that the forebay will be located immediately adjacent to the sand bed zone and that the recommended minimum overall length to width ratio of these combined zones in surface and subsurface filters is two to one.
6. As shown on Line 7 of Table 9.9-1, compute the minimum sand bed surface area (A_S) using the following equation:

$$A_S = (V_{QS})(TH_S) \ / \ [(k)(D_{ST}/2 + TH_S)(T_D)] \qquad \text{(Equation 9.9-1)}$$

Where:

A_S = Minimum Sand Bed Surface Area (in square feet)
V_{QS} = Runoff Volume from the Stormwater Quality Design Storm (in cubic feet)
TH_S = Thickness of Sand in Sand Bed (in feet)
k = Sand Bed Design Permeability (in feet per day)
D_{ST} = Maximum Temporary Sand Bed Depth (in feet)
T_D = Sand Bed Drain Time (in days)

As shown in Table 9.9-1, the following parameter design values for Equation 9.9-1 are recommended:

Minimum Sand Thickness in Sand Bed (TH_S) = 18 inches
Sand Bed Design Permeability (k) = 4 feet per day
Sand Bed Design Drain Time = 1.5 days

7. Compute the total temporary storage volume in the sand bed zone (V_{ST}) from the following equation:

$$V_{ST} = (A_S)(D_{ST}) + (A_S)(TH_S)(n) \qquad \text{(Equation 9.9-2)}$$

Where:

V_{ST} = Temporary Sand Bed Storage Volume (in cubic feet)
A_S = Sand Bed Surface Area (in square feet)
D_{ST} = Maximum Temporary Sand Bed Depth (in feet)
TH_S = Thickness of Sand in Sand Bed (in feet)
n = Sand Bed Design Porosity

As shown in Table 9.9-1, the following parameter design values for Equation 9.9-2 are recommended:

Minimum Sand Thickness in Sand Bed (TH_S) = 18 inches
Sand Bed Design Porosity (n) = 0.3

8. Compare the total temporary sand bed storage volume (V_{ST}) with the approximate required sand bed zone volume computed in Step 2. As shown on Line 2 of Table 9.9-1, this temporary sand bed storage volume should be approximately one half of the stormwater quality design storm runoff volume (V_{QS}). In addition, add the total temporary sand bed volume (V_{ST}) to the total temporary forebay storage volume (V_{FT}) to determine the total temporary storage volume in the sand filter. As shown on Line 1 of Table 9.9-1, this total temporary storage volume must equal the stormwater quality design storm runoff volume (V_{QS}). Adjust the maximum temporary sand bed depth (D_{ST}) and/or sand bed area (A_S) as necessary to achieve a total temporary sand bed storage volume (V_{ST}) as close as practical to the required sand bed volume from Step 2 and a total filter volume equal to V_{QS}. Once again, while adjusting the sand bed surface area (A_S) by varying its length and width, remember that the sand bed will be located immediately adjacent to the forebay and that the recommended minimum overall length to width ratio of these combined zones in surface and subsurface filters is two to one.

D. Filter Bed Sand

The sand used in the sand bed must meet the specifications for clean medium aggregate concrete sand in accordance with AASHTO M-6 or ASTM C-33. This must be certified by a professional engineer licensed in the State of New Jersey.

E. Gravel Layer and Underdrain

The gravel layer serves as bedding material for the underdrain pipes. It must have sufficient thickness to provide a minimum of 2 inches of gravel above and below the pipes. It should consist of 0.5” to 1.5” clean broken stone or pea gravel (AASHTO M-43).

The underdrain piping must be rigid Schedule 40 PVC pipe in accordance with AASHTO M278. Perforated underdrain piping should have a minimum of 3/8-inch diameter perforations at 6-inch centers with four perforations per annular row. The portion of drain piping beneath the sand bed must be perforated. All remaining underdrain piping, including cleanouts, must be nonperforated. All joints must be secure and watertight. Cleanouts must be located at the upstream and downstream ends of the perforated section of the underdrain and extend to or above the surface of the sand bed. Additional cleanouts should be installed as needed.

The underdrain piping must connect to a downstream storm sewer manhole, catch basin, channel, swale, or ground surface at a location that is not subject to blockage by debris or sediment and is readily accessible for inspection and maintenance. Blind connections to downstream storm sewers are prohibited. To ensure proper system operation, the gravel layer and perforated underdrain piping must have infiltration rates at least twice as fast as the design infiltration rate of the sand bed.

Additional details of typical sand filter underdrains are shown in Figure 9.9-5.

F. Overflows

All sand filters must be able to safely convey overflows to downstream drainage systems. The capacity of the overflow must be consistent with the remainder of the site's drainage system and sufficient to provide safe, stable discharge of stormwater in the event of an overflow. Sand filters that are classified as dams under the NJDEP Dam Safety Standards at N.J.A.C. 7:20 must also meet the overflow requirements of these Standards. Overflow capacity can be provided by a hydraulic structure such as a weir or orifice, or a surface feature such as a swale or open channel, as filter location and site conditions allow.

G. Tailwater

The hydraulic design of the underdrain and overflow systems, as well as any stormwater quantity control outlets, must consider any significant tailwater effects of downstream waterways or facilities. This includes instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood elevation of a receiving stream.

H. On-line and Off-line Systems

In general, most sand filters are constructed off-line. In off-line sand filters, most or all of the runoff from storms larger than the stormwater quality design storm bypass the filter through an upstream diversion. This not only reduces the size of the required filter overflow, but also reduces the filter's long-term pollutant loading and associated maintenance and the threat of erosion and scour caused by larger storm inflows. However, sand filters may also be constructed on-line. On-line filters receive upstream runoff from all storms, providing runoff treatment for the stormwater quality design storm and conveying the runoff from larger storms through an overflow. Multi-purpose on-line filters also store and attenuate these larger storms to provide runoff quantity control. In such filters, the invert of the lowest stormwater quantity control outlet is set at or above the maximum stormwater quality design storm water surface.

Maintenance

Effective sand filter performance requires regular and effective maintenance. *Chapter 8: Maintenance and Retrofit of Stormwater Management Practices* provides information and requirements for preparing a maintenance plan for stormwater management facilities, including sand filters. Specific maintenance requirements for sand filters are presented below. These requirements must be included in the filter's maintenance plan.

A. General Maintenance

All sand filter components expected to receive and/or trap debris and sediment must be inspected for clogging and excessive debris and sediment accumulation at least four times annually as well as after every storm exceeding 1 inch of rainfall. Such components may include inlets and diversion structures, forebays, sand beds, and overflows.

Sediment removal should take place when all runoff has drained from the sand bed and the sand is reasonably dry. In addition, runoff should be drained or pumped from forebays with permanent pools before removing sediment. Disposal of debris, trash, sediment, and other waste material should be done at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations.

B. Vegetated Areas

In surface sand filters with turf grass bottom surfaces, mowing and/or trimming of vegetation must be performed on a regular schedule based on specific site conditions. Grass should be mowed at least once a month during the growing season. Vegetated areas must also be inspected at least annually for erosion and scour. The filter bottom must be inspected for unwanted underbrush and tree growth at least once a year.

When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed during both the growing and non-growing season at least twice annually. If vegetation has greater than 50 percent damage, the area should be reestablished in accordance with the original specifications and the inspection requirements presented above.

All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health must not compromise the intended purpose of the sand filter. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

C. Structural Components

All structural components must be inspected for cracking, subsidence, spalling, erosion, and deterioration at least annually.

D. Other Maintenance Criteria

The maintenance plan must indicate the approximate time it would normally take to drain the maximum design storm runoff volume below the top of the filter's sand bed. This normal drain or drawdown time should then be used to evaluate the filter's actual performance. If significant increases or decreases in the normal drain time are observed, the filter's sand bed, underdrain system, and tailwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements and maintain the proper functioning of the filter.

The sand bed should be inspected at least twice annually. The infiltration rate of the sand bed material may also be retested. If the water fails to infiltrate 72 hours after the end of the stormwater quality design storm, corrective measures must be taken.

Considerations

A. Forebay and Sand Bed Drains

Wherever possible in subsurface and perimeter filters, a drain and valve should be provided in the forebay to permit draining of all standing water and facilitate sediment removal. This drain and valve can be connected to the sand bed underdrain system.

B. Drainage Area Stabilization

No runoff should enter the filter's sand bed until the upstream drainage area is completely stabilized and site construction is completed.

C. Watertight Construction

Underground sand filters should always be constructed completely watertight, especially if treating runoff from "hotspots" or over extremely sensitive groundwater areas.

D. Pretreatment

As with all other best management practices, pretreatment can extend the functional life and increase the pollutant removal capability of a sand filter. Pretreatment can reduce incoming velocities and capture coarser sediments, which will extend the life of the system. This is usually accomplished through such means as a vegetative filters and/or a manufactured treatment device. Information on vegetative filters and manufactured treatment devices is presented in Chapters 9.10 and 9.6, respectively.

As shown in Figures 9.9-1, 9.9-2, and 9.9-3, forebays at the inflow points to sand filters can capture coarse sediments, trash, and debris, which can simplify and reduce the frequency of filter maintenance. A forebay should be sized in accordance with Table 9.9-1 to hold the sediment volume expected between clean-outs.

References

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