

Appendix

F

**Additional Design and Construction
Requirements for Sand Filter Systems**

F.1 Design Requirements

In addition to the requirements detailed in Chapter 3, the following information should be provided for underground sand filter design:

- Delineate the drainage area to show the downstream storm sewer system or stream and the extent of the underground facility.
- Show 100-year ponding and/or safe overflow pathways.
- Provide structural details of the underground detention system.
- Provide a profile of entire system with inverts, pipe size, pipe type, slopes, and hydraulic grade line (HGL) through the facility.
- Provide cross section(s) and a plan view.
- Provide water tight joints at all pipe connections.
- The underground detention structure should be composed of reinforced concrete. Other materials may be used for storm water management detention when the reviewing authority has approved their application.
- All structural information for non-standard structures or modified structures along with H-20 loading information must be provided for approvals.
- Anti-flotation analysis is required to check for buoyancy problems in high water table areas.
- Anchors should be designed to counter the pipe and structure buoyancy by at least a 1.2 factor of safety.

F.2 Design Details and Specifications

This section discusses design details and specifications for:

- vertical sand filters
- surface sand filters - sedimentation basin
- surface sand filters - sand filtration basins

Vertical Sand Filter - Filter Layer

Figure F.1 is a typical cross-section of the filter chamber.

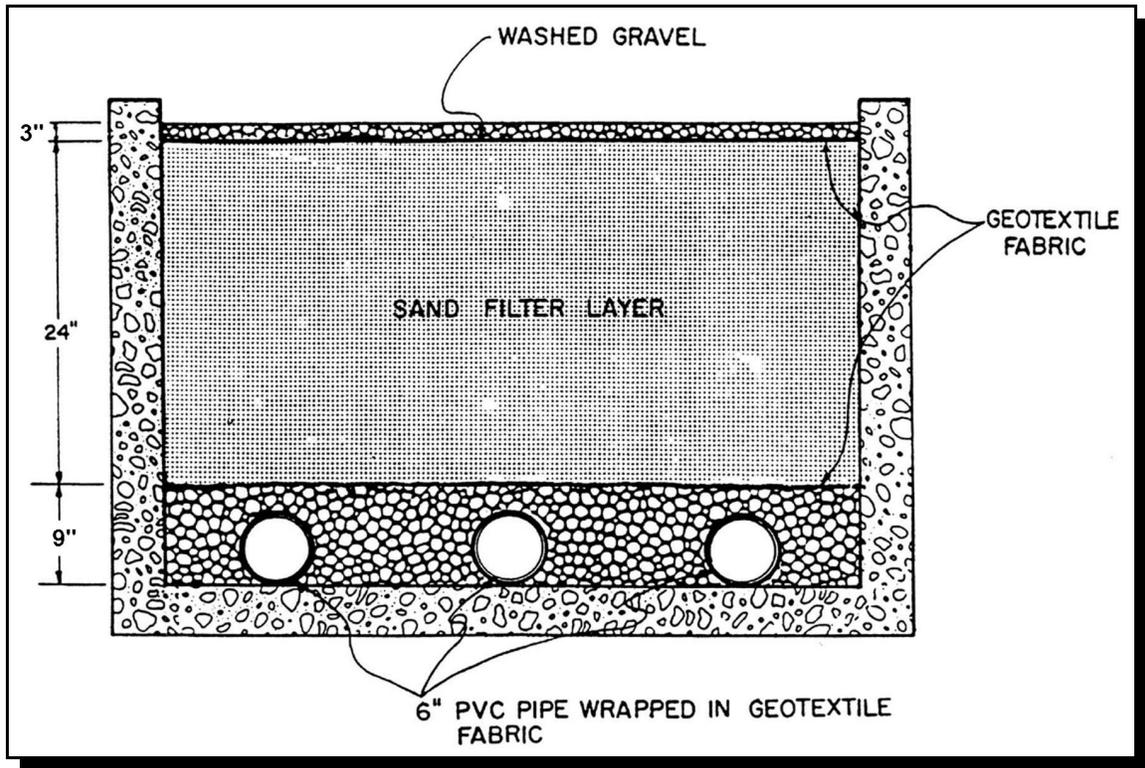


Figure F.1 Typical Cross-Section of the Filter Chamber
(Source: City of Austin, 1988)

Upper Filter Layer

The washed gravel or aggregate layer at the top of the filter may be 1" to 3" thick and should be D.C. #57 gravel.

Geotextile Fabric

The geotextile fabric below the top gravel layer and below the sand should be Woven Monofilament Geotextile 104F with the specifications listed in Table F.1.

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Table F.1 Specifications for the Woven Monofilament Geotextile 104F

Property	Test Method	Units	Value	104F
Mechanical				
Grab Tensile MD/XD	ASTM D-4632	lbs	Typical	400/275
			MARV	370/250
Grab Elongation MD/XD	ASTM D-4632	%	Typical	26/26
			MARV	24/24
Puncture Strength	ASTM D-4833	lbs	Typical	150
			MARV	120
Mullen Burst	ASTM D-3786	psi	Typical	520
			MARV	480
Trapezoidal Tear MD/XD	ASTM D-4533	lbs	Typical	120/85
			MARV	100/70
Hydraulic				
Percent Open Area (POA)	$\frac{\text{Opening Area}}{\text{Total Area}} * 100$	%	Typical	5
			MARV	4
Apparent Opening Size (AOS)	ASTM D-4751	US Sieve	Typical	70-100
			MARV	70
Permittivity	ASTM D-4491	sec	Typical	0.40
			MARV	0.28
Permeability	ASTM D-4491	cm/sec	Typical	0.015
			MARV	0.010
Water Flow Rate	ASTM D-4491	gpm/ft ²	Typical	26
			MARV	18
Physical				
Weight	ASTM D-5261	oz/yd ²	Typical	6.3
			MARV	5.9
Thickness	ASTM D-5199	mils	Typical	15
			MARV	13
Endurance				
UV Resistance	ASTM D-4355	% Retained @ 500 hours	MARV	90
Packaging				
Roll Width	Measured	in	Typical	72/144
Roll Length	Measured	in	Typical	300
Roll Weight	Calculated	lbs	Typical	108/192
Area	Calculated	yd ²	Typical	200/400
Notes:				
<ul style="list-style-type: none"> ■ “MARV” indicated minimum average roll value calculated as the typical minus two standard deviations. Statistically, it yields a 97.7% degree of confidence that any sample taken during quality assurance testing will exceed the value reported. ■ “MD” indicates the machine/warp/roll direction. ■ “XD” indicates the cross-machine/fill/across the roll direction. 				

The fabric roll should be cut with sufficient dimensions to cover the entire wetted perimeter of the

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filter area with a 6" minimum overlap.

Sand Filter Layer

The sand filter layer should be 18" to 24" deep. ASTM C33 concrete sand is recommended, but sand with similar specifications may be used.

Bottom Gravel Layer

The bottom gravel layer surrounding the collector (perforated) pipes should be 0.5" to 2" diameter gravel and provide at least 3" of cover over the top of the drainage pipes. No gravel is required under the pipes. The gravel and the sand layer above must be separated by a layer of geotextile fabric that meets the specifications listed in Table F.1.

Underdrain Piping

The underdrain piping consists of three 6" perforated pipes, an appropriate number of 4" pipes, and should be reinforced to withstand the load of the overburden. Perforations should be 3/8". All piping should be to schedule 40 polyvinyl chloride or greater strength.

The minimum grade of piping should be 1/8 inch per foot or 1% of the slope. Access should be provided for cleaning all underdrain piping. Clean-outs for each pipe shall extend to the maximum surface elevation of the structure and be flush with the top slab of the structure.

Each pipe should be carefully wrapped with geotextile fabric that meets the stipulated specifications before placement in the filter.

Surface Sand Filter - Sedimentation Basin

The sedimentation basin consists of an inlet structure, outlet structure, and basin liner. The sedimentation basin design should maximize the distance from where the heavier sediment is deposited near the inlet to where the outlet structure is located. This will improve basin performance and reduce future maintenance requirements.

Inlet Structure

The inlet structure should be designed to capture the first flush and convey the peak flow of a 15-year storm through the basin. The water quality shall be discharged uniformly as sheet flow into the sedimentation basin in order to achieve the relatively quiescent state. Sediments having higher specific gravity will tend to settle down near the inlet structure. For this reason, the drop inlet is recommended in order to facilitate future sediment removal and maintenance (Figure F.2).

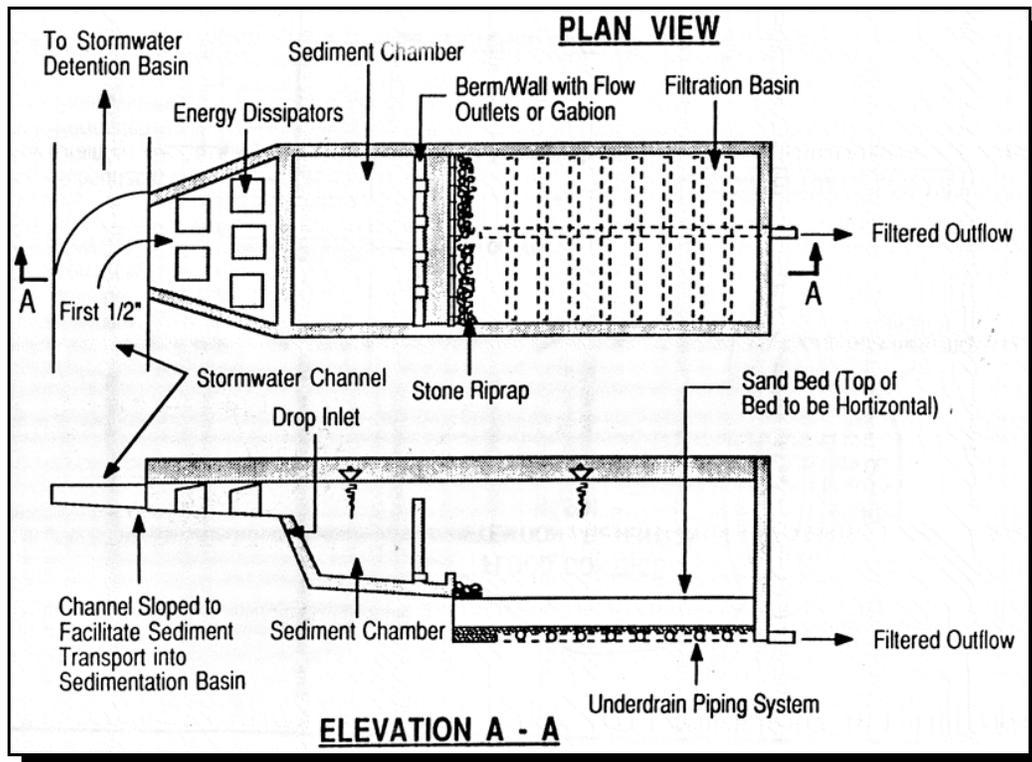


Figure F.2 Conceptual Partial Sedimentation Filtration System

Outlet Structure

The outlet structure conveys the water from the sedimentation basin to the filtration basin. The outlet structure should be designed to provide for a minimum dewatering time of 24 hours for full-sediment basin design or discharge flow evenly to the filtration basin for partial sediment basin design. A perforated pipe or equivalent is the recommended outlet structure. The 24 hours dewatering time should be achieved by installing a throttle plate or other flow control device at the end of the riser pipe. The perforated riser pipe should be selected from Table F.2.

Table F.2 Selection of Perforated Riser Pipes

Riser Pipe Nominal Diameter (inches)	Vertical Spacing Between Rows (inches)	Number of Perforations Per Row	Diameter of Perforations (inches)
6	2.5	9	1
8	2.5	12	1
10	2.5	16	1

Source: City of Austin

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For the partial sedimentation basin design, the outlet structure should be a berm or wall with multiple outlet ports or gabion so as to discharge the flow evenly to the filtration basin. Rock gabions should be constructed using 6" to 12" diameter rocks. The berm/wall/gabion height should not exceed 6 feet and high flow should be allowed to overtop the structure (weir flow). Outlet ports should not be located along the vertical center axis of the berm/wall so as to induce flow-spreading. The outflow side should incorporate features to prevent scouring of the sand bed (e.g., concrete, splash pad or rip rap) (Figure F.3).

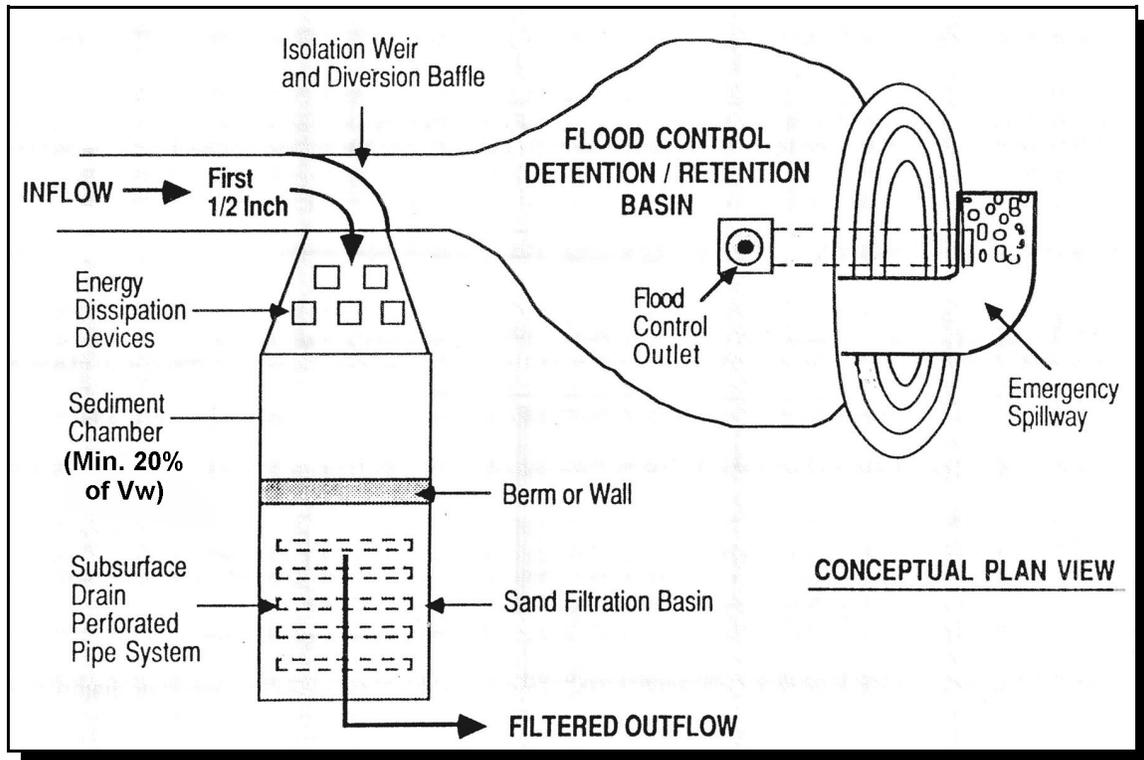


Figure F.3 Conceptual Partial Sedimentation with Filtration System
Source: City of Austin, 1988

A trash rack should be provided for the outlet. Openings in the rack should not exceed $1/3$ the diameter of the vertical riser pipe. The rack should be made of durable material, resistant to rust and ultraviolet rays. For the bottom rows of perforations, it is recommended that geotextile fabric be wrapped over the pipe's bottom rows and that a layer of 1" to 2" of gravel be placed around the pipe.

Basin Liner

Impermeable liners may be either clay, concrete or geomembrane. If geomembrane is used, suitable geotextile fabric should be placed below and on the top of the geomembrane for puncture protection. Clay liners should meet the specifications outlined in Table F.3.

Table F.3 Clay Liner Specifications

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	cm/sec	1×10^{-6}
Plasticity Index of Clay	ASTM D-423 & D-424	cm/sec	Not < 15
Liquid Limit of Clay	ASTM D-2216	cm/sec	Not < 30
Clay Part. Passing	ASTM D-422	cm/sec	Not < 30
Clay Compaction	ASTM D-2216	cm/sec	95% of Standard Proctor Density

Source: City of Austin

The clay liner should have a minimum thickness of 12".

If a geomembrane liner is used it should have a minimum thickness of 30 mils and be ultraviolet resistant. The geotextile fabric (for protection of geomembrane) should meet specifications outlined in Table F.1.

Basin Geometry

The shape of the sedimentation basin and the flow regime within this basin will influence how effectively the basin volume is utilized in the sedimentation process. The length to width ratio of the basin should be 2:1 or greater. Inlet and outlet structures should be located at extreme ends of the basin in order to maximize particle settling opportunities.

Short circuiting (i.e., flow reaching the outlet structure before it passes through the sedimentation basin volume) flow should be avoided. Dead storage areas (areas within the basin which are bypassed by the flow regime and are, therefore, ineffective in the settling process) should be minimized (Figure F.4). Baffles may be used to mitigate short circuiting and/or dead storage problems (Figures F.5).

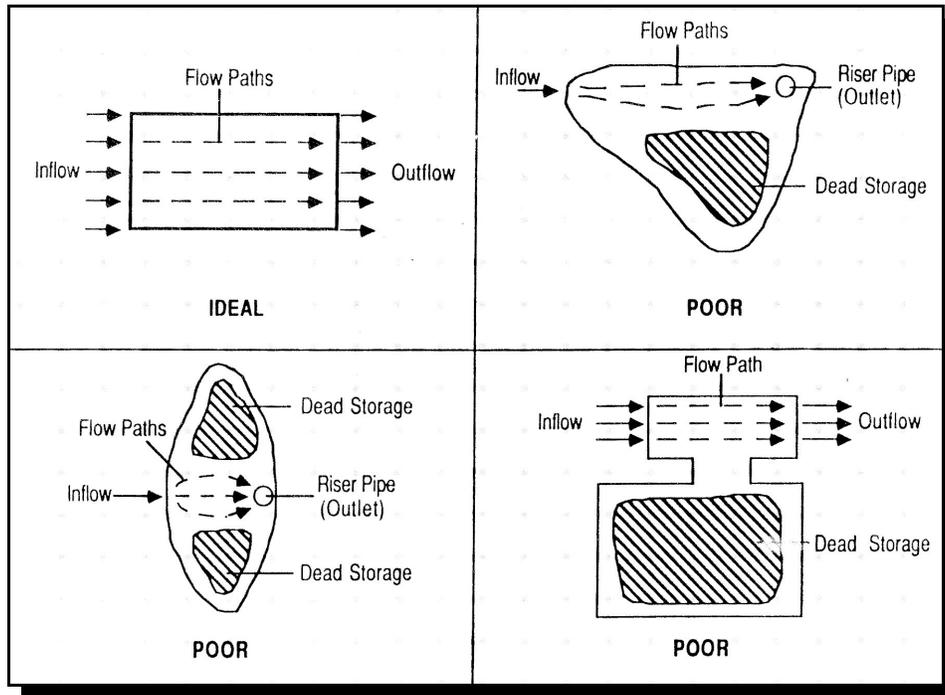


Figure F.4 Sedimentation Basin Configurations
Source: City of Austin, 1988

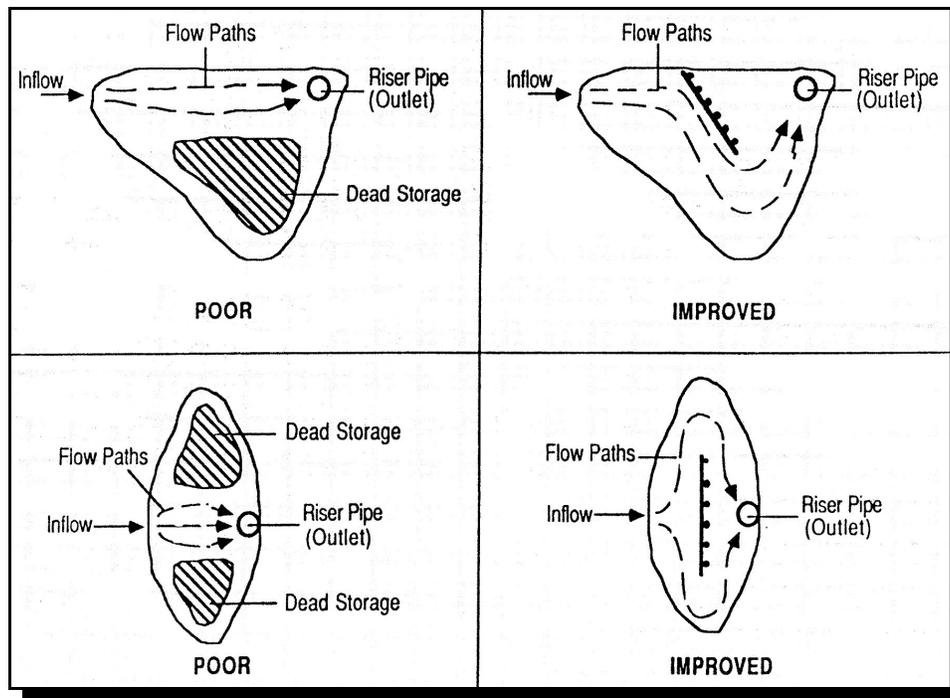


Figure F.5 Sedimentation Basin Baffles
Source: City of Austin, 1988

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Sediment Trap (Optional)

A sediment trap is a storage area which captures sediment and removes it from the basin flow regime. In so doing the sediment trap inhibits resuspension of solids during subsequent runoff events, improving long-term removal efficiency. The trap also maintains adequate volume to hold the water quality volume which would otherwise be partially lost due to sediment build-up. Sediment traps may reduce maintenance requirements by reducing the frequency of sediment removal. It is recommended that the sediment trap volume be equal to 10% of the sedimentation basin volume.

Water collected in the sediment trap should be conveyed to the filtration basin in order to prevent standing water conditions from occurring. All water collected in the sediment trap should drain out within 60 hours. The invert of the drain pipe should be above the surface of the sand bed filtration basin. The minimum grading of the piping to the filtration basin should be 0.25 inch per foot (2% slope). Access for clearing the sediment trap drain system is necessary. Figure F.6 illustrates the sediment trap details.

Surface Sand Filters – Sand Filtration Basin

The sand bed filtration basin consists of the inlet structure, sand bed, underdrain piping and basin liner.

Inlet Structure

The inlet structure should spread the flow uniformly across the surface of the filter media. Flow spreaders, weir or multiple orifice openings are recommended (Figure F.7).

Sand Bed

The sand bed may be a choice of one of the following four configurations:

1. Sand Bed with Full Bottom Gravel Layer (Figure F.8) - The top layer is to be a minimum of 18" of ASTM C-33 Concrete Sand; smaller sand size is acceptable. Under the sand should be at least 9" of 0.5" to 2" diameter gravel and a subsurface drainage system. The sand and gravel must be separated by a layer of geotextile fabric that meets the specification list in Table F.1.
2. Sand Bed - Trench Design (Figure F.8) - The top layer should be 12" to 18" of ASTM C-33 Concrete Sand. Laterals should be placed in trenches with a covering of 0.5" to 2" gravel and geotextile fabric. The laterals should be underlain by a layer of drainage matting. The geotextile fabric is needed to prevent the filter media from infiltrating into the lateral piping. The drainage matting is needed to provide for adequate vertical and horizontal hydraulic conductivity to the laterals, and should meet the specifications in Table F.4. The geotextile fabric should meet the specifications in Table F.1.

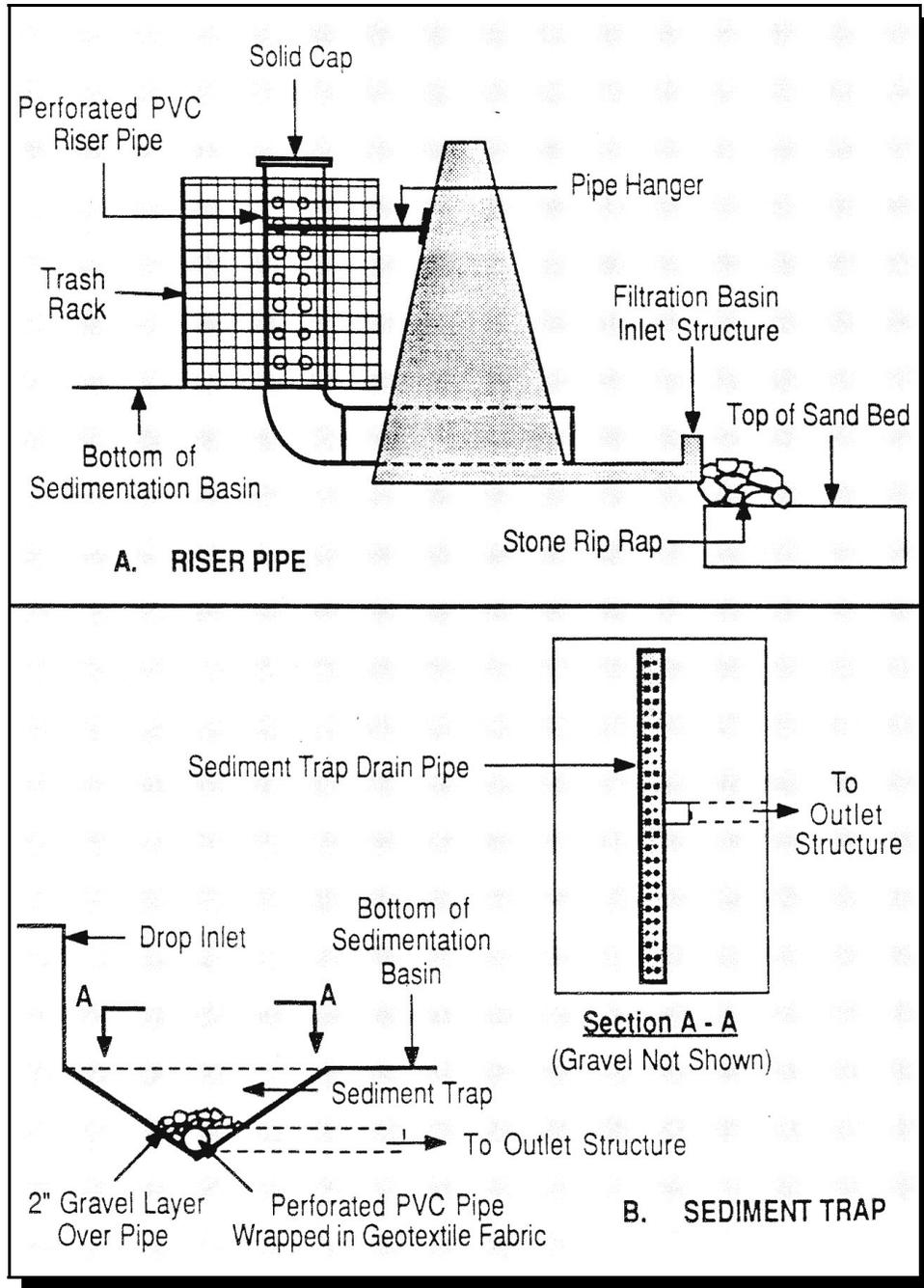


Figure F.6 Example Riser Pipe and Sediment Trap Details
Source: City of Austin, 1988

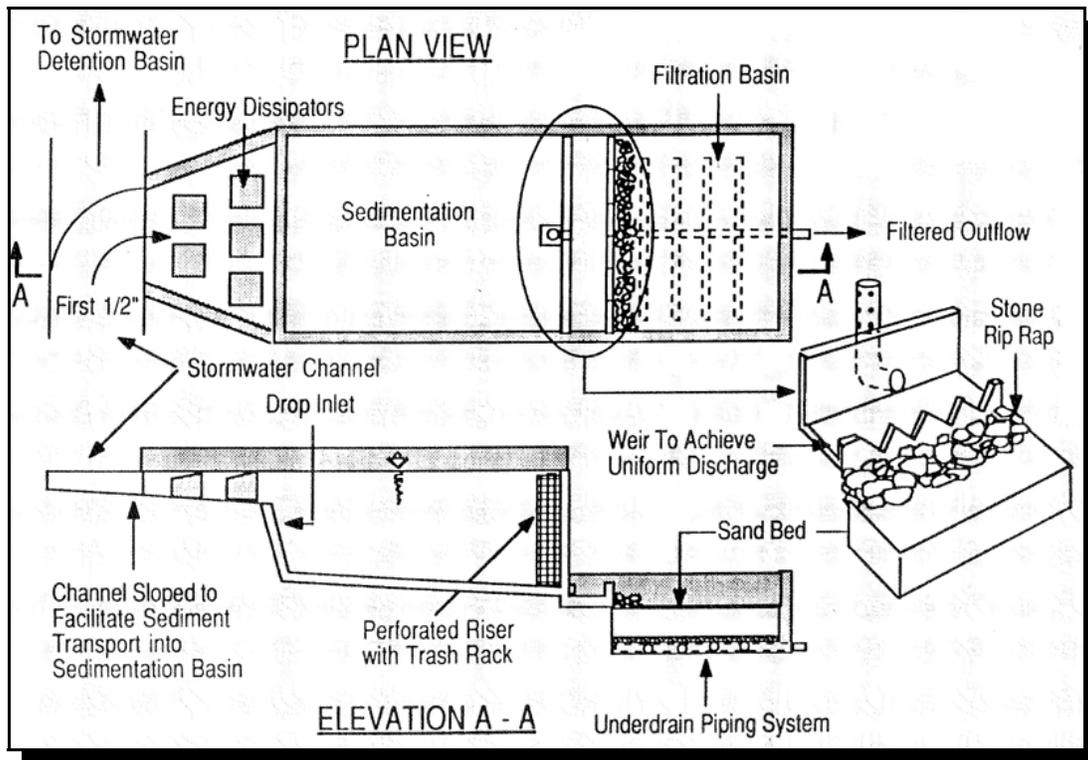


Figure F.7 Conceptual Full Sedimentation Filtration System

3. Sand Bed with Full Top and Bottom Gravel Layers (Figure F.9) - The top gravel layer is to be a minimum of 1" of D.C. #57 gravel. Under the top gravel layer should be minimum 12" of ASTM C-33 Concrete Sand. Beneath the sand shall be 8" of D.C. #57 gravel with a subsurface drainage system. The sand and gravel must be separated by a layer of geotextile fabric meeting the specifications list in Table F.1.

4. Sand Bed with Full Top Peat and Bottom Gravel Layers (Figure F.10) - The upper peat layer must be a minimum of 12" thick. In order to eliminate the possibility of saturating the peat bed, a 1.0 inch per hour infiltration rate is required to limit the maximum surface ponding by using a customblend hemic/fibric mixture or one that is recommended by a soil scientist or engineer. Approximately 1.5" of Ag-Lime calcitic limestone must be mixed into the top 4 to 6" of peat. The minimum 4" layer of 50%-50% peat and sand mixture must be placed immediately under the peat layer. This is to allow for uniform flow of water through the bed. A geotextile fabric should be placed under the 24" vertical thickness sand layer to separate sand from the bottom gravel layer. Other design elements should be the same as for the surface sand filter.

Table F.4 Drainage Matting Specifications

Property	Test Method	Unit	Specification
Material	Non-woven geotextile fabric		
Unit Weight		oz/yd ²	20
Flow Rate (fabric)		gpm/ft ²	180 min.
Permeability	ASTM D-2434	cm/sec	12.4 x 10 ⁻²
Grab Strength (fabric)	ASTM D-1682	lb	Dry Lg.90 Dry Wd: 7 Wet Lg.95 Wet Wd:7
Puncture Strength (fabric)	COE CV-02215	lb	42 minimum
Mullen Burst Strength	ASTM D-1117	psi	140 minimum
Equivalent Opening Size	U.S. Standard Sieve	No.	100 (70-120)
Flow Rate (drainage core)	Drexel University	gpm / ft width	14

Source: City of Austin

Underdrain Piping

The underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes. The piping should be reinforced to withstand the weight of the overburden. The internal diameters of the lateral branch pipes should be 4" or greater and perforations should be 3/8". All PVC pipe is to be schedule 40 or greater strength. A maximum spacing of ten feet between laterals is recommended. Lesser spacings are acceptable.

The minimum pipe slope should be 1/8 inch per foot or 1% slope. All pipes must provide clean-out caps for future maintenance.

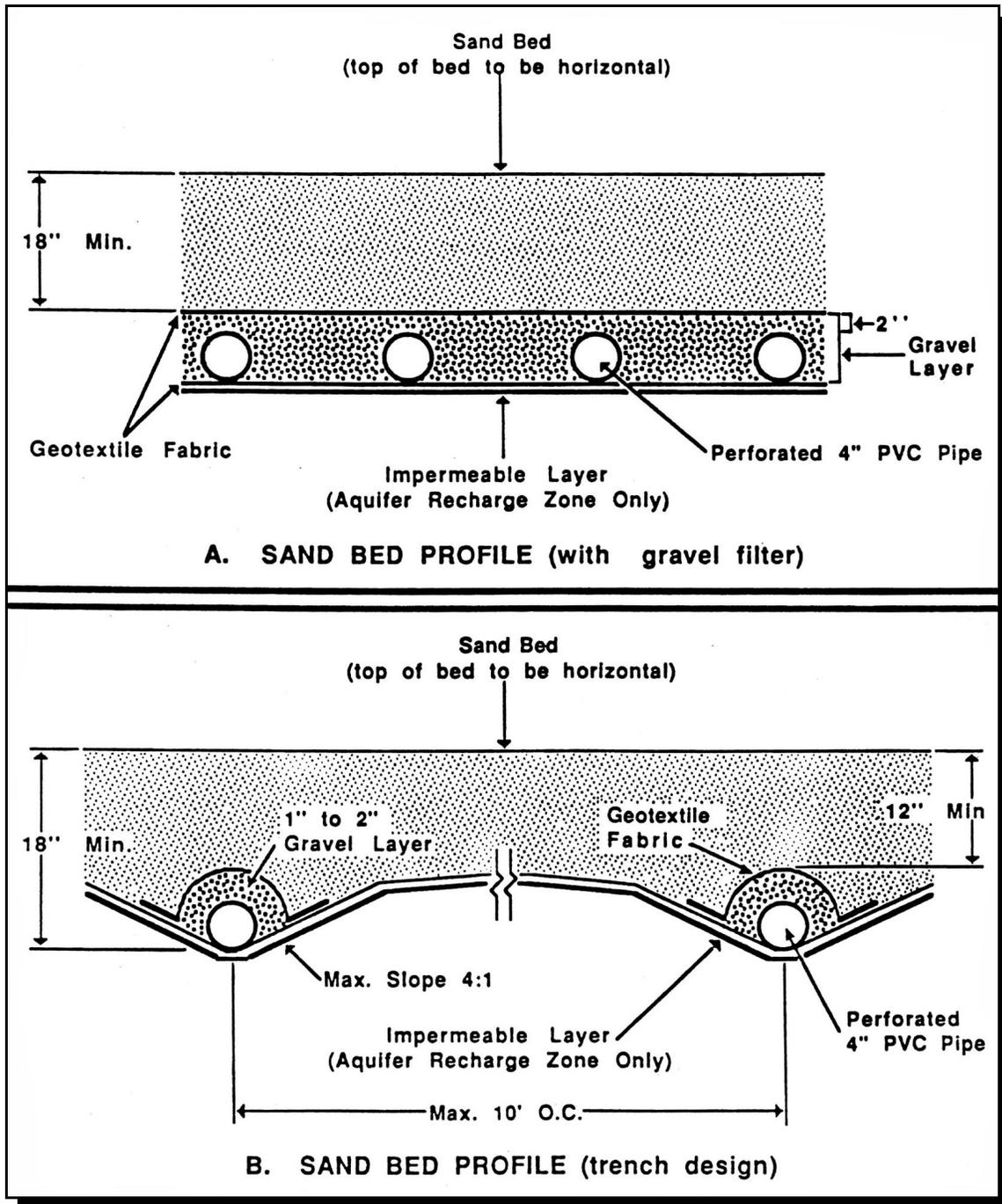


Figure F.8 Sand Bed Filtration Configurations
 Source: City of Austin, 1988

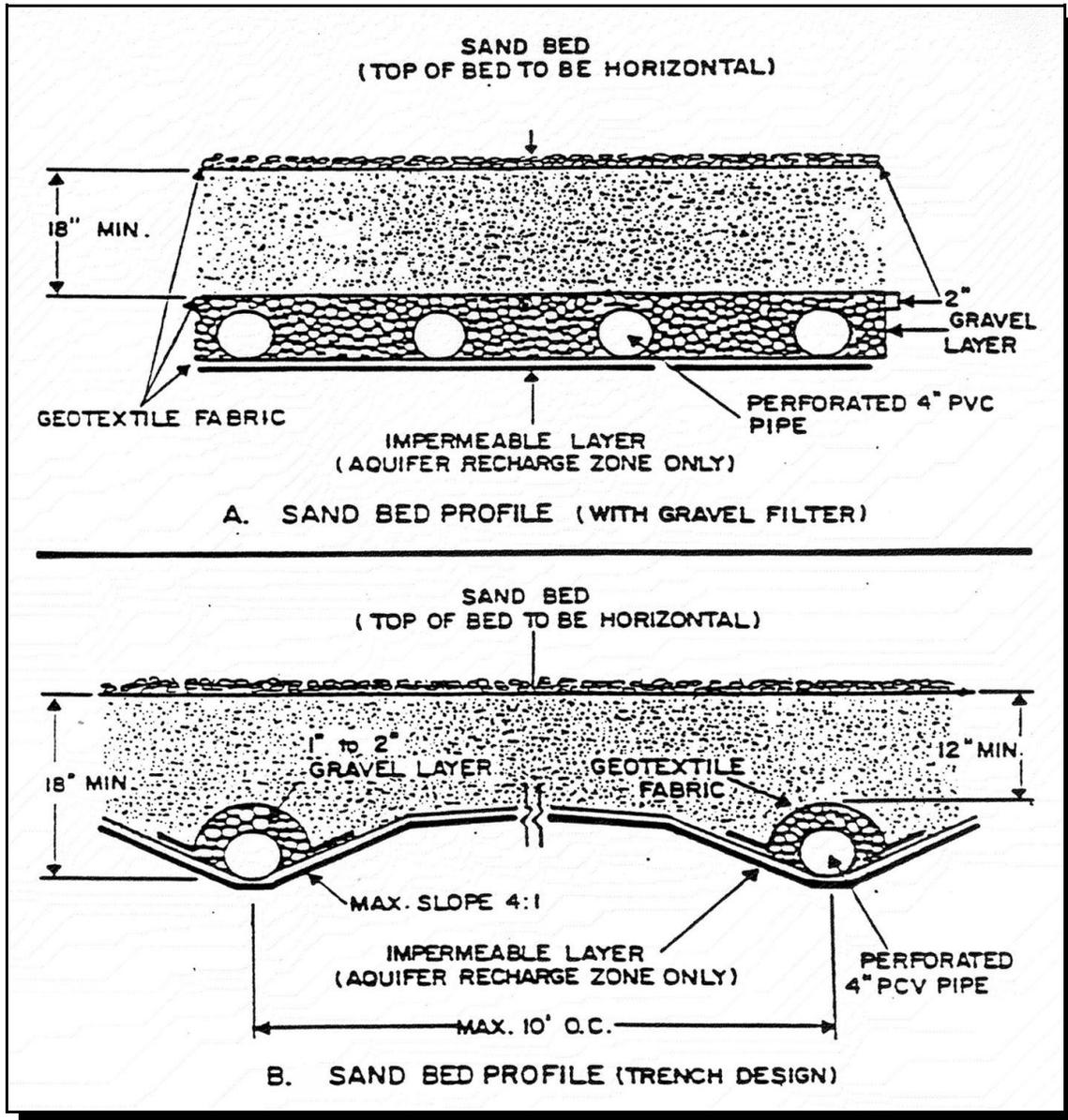


Figure F.9 Sand Bed Filtration Configurations with Top Gravel Layer
 Source: District of Columbia

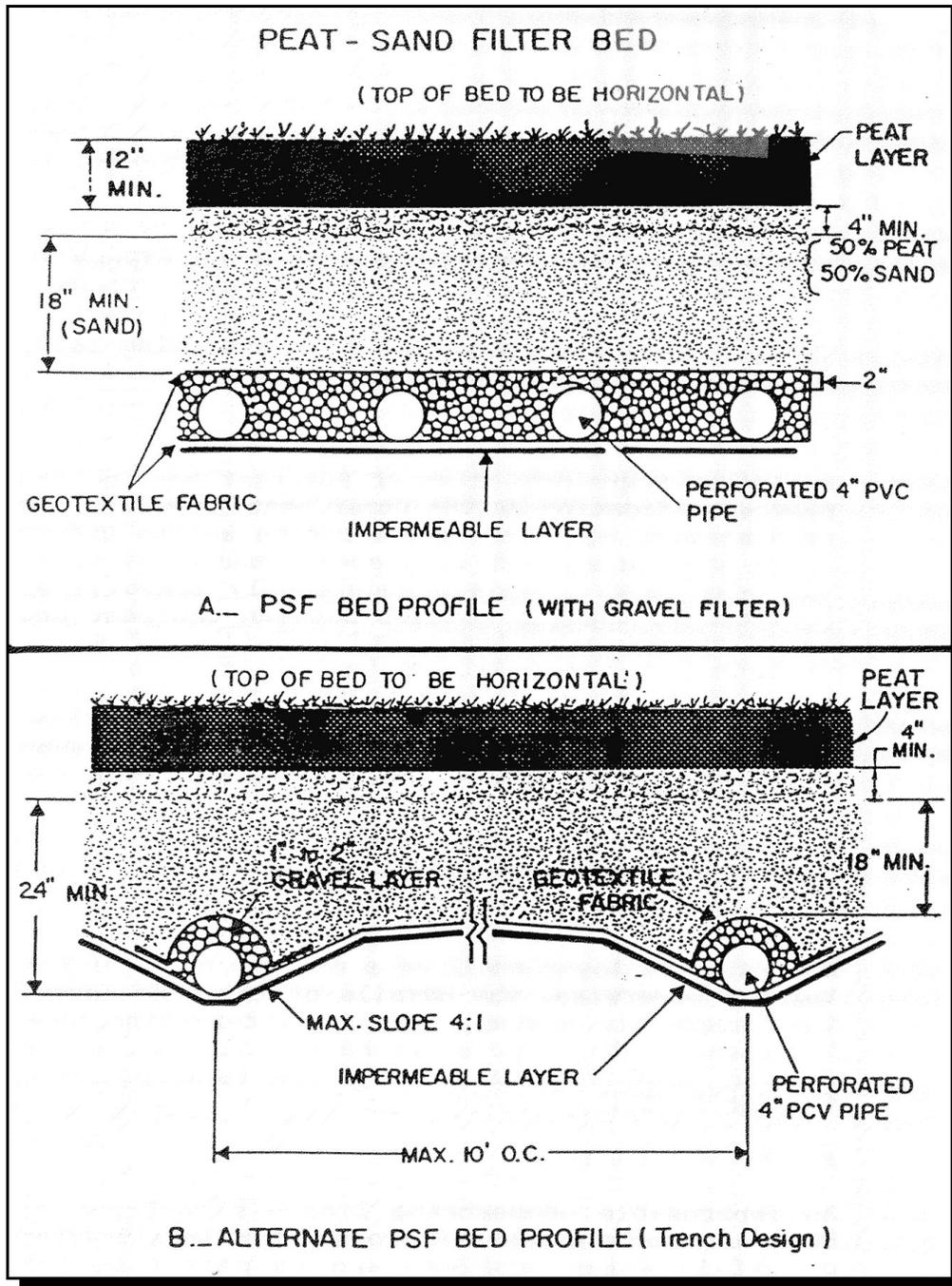


Figure F.10 Peat - Sand Filter Bed Configuration
Source: City of Alexandria, 1992

F.3 Construction Requirements

This section discusses construction requirements for:

- One-Chamber Underground Sand Filters
- Three-Chamber Underground Sand Filters
- Vertical Sand Filters
- Perimeter Sand Filters
- Surface Sand Filters
- Roof Downspout Filtration Systems

1-Chamber Underground SF, 3-Chamber Underground SF, Vertical SF

- The sand filter may be either cast-in-place or precast. In the District of Columbia, precast structures require advance approval. Cast-in-place should be as per Section 02720.01 to 02726.06 of the District of Columbia Public Works Water and Sewer Specification and Detailed Drawings in Office Manual.
- The approved erosion and sediment control plans should include specific measures to provide for the protection of the filter system before the final stabilization of the site.
- Excavation for the sand filter and connecting pipes should include removal of all materials and objects encountered in the excavation; disposal of excavated material as specified in the approved erosion and sediment control plans, maintenance and subsequent removal of any sheeting, shoring and bracing; dewatering and precautions, and work necessary to prevent damage to adjacent properties resulting from this excavation.
- Access manholes and steps to the filtration system should conform to District of Columbia DPW standards.
- After completion of the sand filter shell, a leak test should be performed to verify water tightness before the filter layers are installed.
- All filter materials in the second chamber should be placed according to construction and materials standards and specifications, as specified on an approved construction plan.
- No runoff should be allowed to enter the sand filter system prior to completion of all construction activities, including revegetation and final site stabilization. Construction runoff should 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 it's completion.

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- The water level in the filter chamber should be monitored by the design engineer after the first storm event, before the project is certified as been completed. If the dewatering time of the filter chamber takes longer than 24 hours, the top gravel layer and filter fabric underneath, must be replaced with a more rapid draining fabric and clean gravel. The structure should then be checked again to ensure a detention time that is less than 24 hours.

Perimeter Sand Filters

- Erosion and sediment control measures must be established to prevent any inflow of storm water into the perimeter sand filter system until construction on site is completed and the entire drainage area have been stabilized with vegetated cover.
- The inverts of the notches, multiple orifices or weirs separating the sedimentation chamber from the filter chamber must be constructed completely level to achieve uniform sheet flow to the filter chamber.
- Inflow grates or slotted curbs may conform to the grade of the completed pavement as long as the filters, notches, multiple orifices, and weirs connecting the sedimentation chamber area are completely level .
- The minimum slope of the underdrain pipe should be 0.5%.
- If precast concrete lids are used, lifting rings or threaded sockets must be provided to allow for easy removal with lifting equipment.
- The facility must not be placed in service until all soil surfaces in the drainage area have been finally stabilized with vegetation cover.

Surface Sand Filters

- Provisions must be made for access to the basin for maintenance purposes. A maintenance vehicle access ramp is necessary. The slope of the ramp should not exceed 4:1.
- The design should minimize susceptibility to vandalism by use of strong materials for exposed piping and accessories.
- Side slopes for earthen embankments structures should not exceed 3:1 to facilitate mowing.
- The temporary erosion and sedimentation control plan must be configured to permit construction of the pond while maintaining erosion and sedimentation control.
- No runoff is to enter the sand filtration basin prior to completion of construction and site

stabilization.

Roof Downspout Filtration Systems

- Erosion and sediment control measures must be configured to prevent any flow of storm water into the RDF system until construction on site is complete and all soil surfaces on the drainage watershed have been stabilized with vegetation.
- During excavation of the trench to design dimensions, the excavated materials must be placed away from the excavation in a downstream area to prevent redeposition during subsequent runoff events. Large tree roots should be trimmed flush with the sides to protect the filter fabric and geomembrane during its installation.
- There should be no voids between the filter fabric geomembrane. If boulders or similar obstacles are removed from the excavation sides, the void should be filled with natural soils before the filter layers are installed.
- The collector gravel, sand and crushed stone aggregate should be placed in the trench using a backhoe or front-end loader with a drop height near the bottom on the RDF system. Aggregate should not be dumped into the trench by a truck.
- Before the sand is placed, the RDF System must be lined with filter fabric. The fabric must be wrapped around the sand layer with at least 6" of overlap. After the aggregate is placed on the top of the sand layer, the filter fabric should be wrapped around the top with at least 6" overlap.
- The reservoir stone should be clean, washed crushed aggregate and should be placed in loose lifts of about 12" and light compacted with plate compactors. Compaction assure fabric conformity to the sides and should reduce the potential for clogging and settlement problems.
- There should be no mixing of clean aggregate with natural or fill soils. All contaminated aggregate should be removed and replaced with clean aggregate.
- The RDF should not be placed in service until all soil surfaces in the drainage watershed have been stabilized with vegetated cover.
- An Inspection well shall be installed up to the final grade with a cap.