WISCONSIN DEPARTMENT OF NATURAL RESOURCES

TECHNICAL STANDARD

STORM WATER SAND FILTER SYSTEM

1012

DEFINITION

A storm water sand filter system collects and filters runoff through a multi-stage treatment system that consists of energy dissipation and forebay for pretreatment, a pretreatment sedimentation basin, and a sand filter bed. The sand filter bed media may be enhanced with additives to control dissolved phosphorus, metals, pathogens, and other pollutants.

PURPOSE

The purpose of this system is to treat pollutants in urban storm water runoff. Enhancing the sand filter bed media with additives allows the storm water sand filter system to better address other pollutants such as nutrients, organic contaminants, and certain soluble pollutants. This system may be part of a larger storm water system that addresses other storm water management requirements.

CONDITIONS WHERE PRACTICE APPLIES

This standard applies to sites treating urban storm water runoff pollution. The practice can be scaled to contributory drainage basin areas typically up to 50 acres, provided adequate drawdown times can be maintained. For drainage areas smaller than two acres, Technical Standard 1004, Bioretention for Infiltration, may be more suitable.

This standard does not apply to locations with continuous flows due to high groundwater, sump pumps, or other permitted discharges.

Application of this standard may attenuate peak flows; however, it is not intended to address flood control. Modifications to the peak flow criteria or additional analysis of potential flooding issues may be needed or required by local authorities. In areas with high groundwater or where runoff comes from source areas listed under s. NR 151.124(3)(a), Wis. Adm. Code, or areas listed under s. NR 151.124(4)(a), Wis. Adm. Code, the use of this practice may present an increased risk for groundwater contamination necessitating the use of a liner and an underdrain, or other design considerations.

If the practice receives construction site runoff or runoff from agricultural areas, additional design considerations and additional operation and maintenance provisions are required to prevent filter media clogging.

CRITERIA

This standard contains requirements to design storm water sand filter systems for the purposes of pollutant removal. This technical standard does not address all possible runoff quantity and peak flow control considerations or provide structural design guidance related to storm water sand filter elements.

General Criteria

Storm water sand filter systems may be used independently or in series with other storm water practices.

Laws and Regulations. Comply with all applicable federal, tribal, state, and local laws, rules, regulations, or permit requirements. This standard does not contain the text of federal, tribal, state, or local laws or regulations. Requirements specific to peak flow control, runoff volume control, minimum pipe sizes, drainage easements, offsets from property lines, and separation from structures are examples of common local regulations that may be applicable to this practice.

Site Criteria

Meet the following site criteria when locating a storm water sand filter system including Identification of potential site constraints, such as buildings, potable wells, karst geology, lot boundaries, site topography, drainage patterns, and existing or proposed public rights-of-way, easements, as well as other environmental and regulatory items of concern.

(1) Limit the drainage area of the system to 50 acres, unless modeling demonstrates adequate drawdown times can be maintained.

(2) Provide at least the minimum separation distance from community water supply systems in accordance with s. NR 811.12(5)(d), Wis. Adm. Code and from private and non-community water supply wells in accordance with s. NR 812.08, Wis. Adm. Code.

(3) Do not locate the practice such that overflow from the practice could flood existing or proposed structures during design storm events. Local regulations may dictate design standards to protect structures or other property.

(4) Locate the sand filter system so there is no hydraulic connection with structure foundations, pavement foundations, and provide a minimum of 50 feet private onsite wastewater treatment systems (POWTS) dispersal cells, or other wastewater disposal systems.

(5) Locate the sand filter system where there is sufficient difference in elevation between the inlet and outlet elevations to operate by gravity flow. Design flow from upstream conveyance/treatment system to allow for *total system* drawdown within a maximum of twenty-four (24) hours from the end of a single precipitation event to avoid anaerobic conditions. Shorter drawdown times may be required to meet the performance standards of any additives employed in the sand filter.

(6) Do not locate in floodplains or where tailwater effects are likely to prevent drying of the filter media between storms.

(7) Provide a stable overland flow path from the pond's emergency spillway.

(8) Locate the pond where there is adequate access for maintenance.

(9) Route storm water flows through the forebay and sedimentation basin prior to entering the sand filter bed.

(10) If the sand filter system also has infiltration through the bottom of either the sedimentation basin or the sand filter bed, then evaluate the site in accordance with the WDNR Technical Standard 1002 Site Evaluation for Storm Water Infiltration and meet the site requirements of that standard.

Design Criteria – General

The storm water sand filter system consists of three main design elements: a forebay with energy dissipation for pretreatment, a sedimentation basin, and a sand filter bed. To receive credit toward meeting ch. NR 151, Wis. Adm. Code, performance standards or pollutant allocations contained in U.S. EPA approved Total Maximum Daily Loads (TMDLs), design and construct the storm water sand filter system to contain all three main design elements. For specified design storms, refer to local regulatory requirements or the most current version of NOAA Atlas 14, or its successor, to obtain precipitation frequency data.

Forebay and Energy Dissipation. Locate forebays at the inlet locations to settle out larger sediment particles, capture trash and other floating debris. Design the forebay and energy dissipation to intercept and reduce peak flow and reduce velocity to 2 feet per second for the 10-year, 24-hour storm.

Examples of energy dissipators include riprap, baffled aprons, and turf reinforcement mats. Certain types of basins (e.g., settling, stilling, impact) can also function as energy dissipators. Base the technique selection on the hydraulic forces from the concentrated flows entering the forebay, promoting uniform flow into the sedimentation basin.

Use flow spreaders, such as stone weepers or porous stone gabions, as shown in Figure 1A, to convey flow to the sedimentation basin, as shown in Figure 1B.

Sedimentation Basin. The sedimentation basin is downstream of the forebay and energy dissipator. The sedimentation basin consists of a settling area, and an outlet structure. The sedimentation basin is typically vegetated and dry; however, a permanent pool may be used with additional design requirements. Refer to WDNR Technical Standard 1011 Vegetated Dry Detention Pond or WDNR Technical Standard 1001 Wet Detention Pond for additional design criteria and guidance for dry and wet sedimentation basins.

(1) Design the sedimentation basin to settle 20-micron particles (approximately 30% TSS for NURP particle size distribution) and a surface drawdown time of 24 hours from the end of a single precipitation event.

(2) Maximize the sedimentation basin flow path with a minimum length to width ratio of 2:1 from inlet to outlet to minimize short circuiting. Maintain an adequate slope to drain water from the inlet to the outlet but limit slopes to prevent erosion.

(3) Design the bottom of the sedimentation basin and outlet to the sand filter to be at least two (2) inches higher than the top of the sand filter bed to prevent excessive tailwater effects that might prolong drawdown times

(4) Stabilize earthen berms with slopes no steeper than 3:1 (horizontal:vertical) and ensure berms are compatible with the expected vegetation and maintenance requirements. Use flatter side slopes where feasible for slope stability, to reduce erosion potential, and for maintenance. If steeper slopes are required, alternative side slope configurations including retaining walls or concrete walls may be used. Design any retaining walls and concrete walls to be stable under anticipated conditions.

(5) Design the emergency spillway to safely pass the 100-year, 24-hour storm.

Sand Filter Bed. The sand filter bed consists of an inlet structure, sand bed with optional media additives, underdrain pipe(s), and a liner (where needed) to protect groundwater.

(1) Grade the top surface of the sand filter bed to be level.

(2) Design the sand filter bed as shown in Figure 3 and as follows:

- Use a minimum 18-inch-thick layer of 0.02 to 0.04-inch diameter sand that corresponds with ASTM C-33 concrete sand, and a *uniformity coefficient* (UC) of five (5) or less.
- Under the sand, place a layer of one-half (0.5) to one and one-half (1.5) inch diameter clear stone, free of fines, that provides three (3) inches to five (5) inches of cover over the top and 2 inches below the underdrain lateral pipes.
- Separate the sand and stone layers with Type DF Schedule A or B geotextile fabric as specified in the WisDOT Standard Specifications. Failure to use high flow fabric will result in clogging and failure of the sand filter.

(3) Size the sand filter bed so full drawdown of the sand filter bed occurs within 24 hours from the end of a single precipitation event to help maintain aerobic conditions in the filter bed between storm events. Do not subject sand filter beds to continuous flows. Such situations could lead to anaerobic conditions that would support the export of some previously captured pollutants from the filter.

(4) Underdrain Piping. Use rigid schedule 40 polyvinyl chloride (PVC) underdrain piping consisting of a perforated main collector pipe(s) and perforated lateral branch pipes. Use lateral branch pipes with wye connections with internal diameter of six (6) inches or greater and three-eighths (3/8)

inch perforations, spaced no more than 6 inches apart. Space the lateral branch pipes no more than ten (10) feet between laterals and five (5) feet from the edge of the sand filter bed. Lesser spacings are acceptable.

Use a minimum underdrain pipe grade of 0.5 % and ensure adequate flow to prevent clogging/sedimentation.

Design cleanout ports for cleaning all underdrain piping using a vertical riser with a removable PVC cap. Install cleanouts every fifty (50) feet or less, at collector drain lines and at every bend.

To reduce damage to cleanouts due to maintenance equipment, vandalism, and mowing, minimize or avoid exposed piping and set the top of the cleanout flush with the top of the sand bed. Locate at least one lateral to be accessible for cleaning when the pond is full. The full pond cleanout should extend above the water quality elevation and/or be located outside of the water quality volume ponding area. Ensure upper end of any lateral is vented to prevent air lock.

Ensure non-erosive discharge from the underdrain pipe. Route pipes to ensure a safe flow path into a *stable* drainage system. Design the sand filter outlet to prevent backflow into the system, using flap gates or other backflow preventers, if necessary. Verify that backwater effect is sufficiently short to achieve necessary drawdown time. Design an emergency overflow for the sand filter if the hydraulics would allow overtopping of the sand filter berm.

Design Criteria – Additional Components

Flow Structure Between Sedimentation Basin and Sand Filter Bed.

The flow structure may be a stone weeper, gabion, or a concrete wall. A concrete wall may be applicable where space constraints require. Design the flow structure to evenly distribute flow to the sand filter bed.

Design may include a flow splitter to safely bypass storm events that are not intended to flow through the sand filter bed to prevent sand filter bed media erosion. Include an emergency spillway designed to safely pass peak flows produced by the 100-year, 24-hour storm event around the sand filter and without damage to the spillway.

Do not exceed six (6) feet in height for the stone weeper, gabion, or concrete wall. Do not allow high flows to overtop the structure (weir flow).

Stone weeper: Design the stone weeper with a boulder core that has stones of nine (9) to eleven (11) inches in diameter. Face the upgradient side of the weeper with three (3) inch diameter clear stone. Depress the center of the weeper to create an overflow to prevent eroding the edges at the soil interface. Design the stone weeper with a minimum bottom width of three (3) feet, underlain with geotextile fabric. Extend the weeper at least 6 inches below grade to prevent undercutting.

Gabions: Fill gabion baskets with three (3) to six (6) inch clear stone with no finer stone particles. Design the gabion with a minimum bottom width of three (3) feet, underlain with geotextile fabric to protect from undercutting. Anchor gabions into the walls of the sedimentation basin laterally and the ground vertically by weight. Wrap buried portions with twelve (12) ounce non-woven fabric. Use wire baskets and ensure that gates are securely wired shut. Tie or stack the baskets to act as a unit to minimize overturning or displacement. Extend the gabions to at least 6 inches below grade to prevent undercutting.

Concrete wall: If a concrete wall separates the sedimentation basin and sand filter bed, use an outlet structure with riser pipes spaced along the length of the wall and flowing to a splash pad and level spreader as shown in Figure 2. In this configuration, perforate all riser pipes and use a minimum of schedule forty (40) PVC or equivalent. Select the perforated riser pipe configuration from Table 1.

Table 1 Configuration of Perforated Riser Pipes			
Riser Pipe Dia. (inches)	**Vertical Spacing Between Rows (Center to center in inches)**	**Number of Perforations per Row**	**Diameter of Perforations (inches)**
6	4	4	1
8	4	6	1
10	4	8	1

Source: City of Austin, TX Environmental Criteria Manual.

Cover the riser pipes with a trash rack made of galvanized welded wire, fabric-sized to prevent clogging of riser pipe openings.

Design trash racks to be removable to facilitate access and maintenance. Support the trash rack with galvanized or rust-proof posts set into a four (4) inch thick reinforced concrete base that is square, with the length of each side being three (3) feet plus the diameter of the riser pipe with the riser centered on the base.

Extend the height of the trash rack above the maximum water surface elevation and have a removable galvanized welded wire lid. If the top of the riser pipe is more than three (3) feet high from the base, use removable galvanized cross bracing for the riser and trash rack. Place a cone of two (2) to three (3) inch diameter clear stone around the pipe to enhance settling.

If the riser discharge pipe is to extend through a concrete wall, use a sleeve in the wall and apply a waterproof sealant to prevent leaks around the sleeve.

Incorporate features on the outflow side to prevent erosion of the sand filter bed media (e.g., concrete splash pad or stone) and a rock flow spreader or equivalent to ensure even distribution onto the sand filter bed. Size the rocks appropriately to prevent scour and erosion.

Liner. In areas with high groundwater, *karst geology*[1], or when runoff comes from sources listed under s. NR 151.124(3)(a), Wis. Adm. Code or areas listed under s. NR 151.124(4)(a), Wis. Adm. Code, use of this practice may present an increased risk for groundwater contamination, necessitating the use of a geomembrane liner or clay liner. Refer to Technical Standard 1001 Wet Detention Pond for selection of the type of liner and design criteria. If a liner is used, provide a narrative that describes the liner design and construction methods.

Vegetation.

Sedimentation Basin: Refer to Technical Standards 1011 Vegetated Dry Storm Water Pond or 1001 Wet Detention Basin for vegetation requirements for the sedimentation basin.

Provide site-specific planting information with project plans and specifications to establish dense vegetation. Use a landscaping firm, landscape architect, contractor, or agronomist with knowledge and experience in planting and maintaining the selected vegetation.

Select vegetation that is tolerant of soil conditions, road salt, periods of inundation, potential dry periods, and variable soil moisture conditions.

Sand Filter: Avoid the establishment vegetation in the sand filter where the sand filter is being used to meet nutrient reduction goals.

Modeling and Sizing. Use pollutant loading models such as WinSLAMM, P8, or equivalent methodology to evaluate the overall efficiency of the sand filter, including the addition of enhanced filter media, in

[1] Words in the standard that are shown in italics are described in the Glossary section. The words are italicized the first time they are used in the text.

reducing total suspended solids (TSS), phosphorus, and other pollutants. Additional modeling may be needed to evaluate flow rates and velocities to ensure a stable design and prevent erosion and scour.

When designing the storm water sand filter, use these preliminary sizing equations to provide a starting point for the final required sizing:

Equation 1: $SA = \frac{WQV}{(2.33*H)+7}$

Equation 2: $WQV = DA * q$

Where:

SA = minimum surface area of the sand filter in square feet assuming a drawdown time of 24 hours from the end of a single precipitation event.

WQV = water quality volume in cubic feet.

H = maximum ponding depth in the basin in feet. The assumed maximum ponding depth of the sand filter bed should be at least one (1) foot less than the maximum ponding depth in the sedimentation basin, to account for tailwater effects, unless demonstrated otherwise through an engineering analysis.

DA = drainage area in square feet contributing runoff to the device.

q = calculated runoff depth in feet for 2-year, 24-hour design storm.

Design the volume above the sand filter bed to be roughly equal to 20 percent of the calculated WQV to account for backwater effects resulting from partially clogged sand filter media.

Flow routing calculations start at the elevation of the flow structure between the sedimentation basin and sand filter.

Note: The above equations are for estimation purposes only. Equation 1 assumes a coefficient of permeability (k) for the filter media of 3.5 feet per day for the filter media, or 1.75 inch per hour and assumes a drawdown time of 24 hours from the end of a single precipitation event. No infiltration into native soil is presumed to occur. The designer may substitute the WQV calculated in Equation 2 with other calculation methods or modeled values.

Construction. When possible, construct the storm water sand filter bed element of the storm water sand filter system off-line until the contributory watershed is stabilized. Where the sand filter bed cannot be constructed off-line, use the following approaches:

(1) Construct and stabilize the forebay and sedimentation basin areas early in the construction process. These portions of the storm water sand filter can serve as a temporary sedimentation basin (see Technical Standard 1064) or as a temporary sediment trap (see Technical Standard 1063). Keep the sand filter bed element of the system offline until the contributory watershed area is stabilized.

(2) Once the contributory area is stabilized, remove trapped sediment from the forebay and sedimentation basin. Complete final grading and any required soil enhancements or compaction mitigation to create the necessary soil conditions for the selected vegetation. See Technical Standard 1053 Channel Erosion Mat, Technical Standard 1059 Seeding for Construction Site Erosion Control, and other applicable construction technical standards for stabilizing the sedimentation basin.

(3) Once the sedimentation basin is *stabilized*, bring the sand filter bed online. If the sand filter bed was brought online prior to stabilization of either the sedimentation basin or contributory watershed area, replace the sand filter media. Check the geotextile fabric and stone layer for sediment intrusion and replace if necessary.

(4) Sand depths referenced in this standard represent final compacted depths. Account for settlement and consolidation effects. Construct the final top surface of the sand filter bed to be horizontal, flat.

Enhanced Sand Filter Bed Media

The sand filter bed media may be enhanced with additives to provide better trapping of pollutants than can be accomplished with a sand media alone. The additives may be uniformly mixed with the sand or layered within the sand filter media. Refer to the tech note for use of additives and specific design criteria.

The term “additives" describes products that are either water-applied or land-applied to perform some water treatment purpose. Additives may come in a variety of chemical formulations, including chemical salts, polymers, acids and bases, metals, and organic chemicals and materials. Additives may cause undesirable and unintended impacts if they are discharged directly to the environment. Use additives on the previously reviewed additive list or obtain written approval from DNR in accordance with s. NR 106.10, Wis. Adm. Code. Submit dosage information, safety data sheets, and toxicological data as requested by the DNR for each product or media mix for which approval is sought.

The use of some additives may require a filtration layer thicker than the eighteen (18) inches shown in Figure 3 and may require a drawdown time longer or shorter than 24 hours from the end of a single precipitation event. Modify the design of the storm water sand filter accordingly, to meet these requirements.

OPERATION AND MAINTENANCE

Develop an operation and maintenance plan that is consistent with the purposes of this practice, its intended life, safety requirements, and the criteria for its design. Include the following aspects in the operation and maintenance plan:

(1) Identify the responsible party for operation, maintenance and documentation of the plan.

(2) Identify maintenance access for the storm water sand filter components.

(3) Reduce or eliminate the use of chloride de-icers within the contributing drainage area as chloride de-icers can negatively impact the pollutant removal efficiency for metals and nutrients, and cause destabilization of captured fines (clays and silts), resulting in loss of treatment effectiveness and the release of previously sequestered pollutants.

(4) For a dry sedimentation basin, remove sediment once accumulation is visible, if the sediment smothers vegetation, or if standing water exists for 24 hours after a runoff event. Include details in the operation and maintenance plan on inspecting sediment depths, frequency of accumulated sediment removal, and disposal locations for accumulated sediment (ch. NR 528, Wis. Adm. Code).

(5) Identify inlet and outlet maintenance.

(6) Inspect at least annually to detect and remedy nuisance weeds, woody growth, trash, and other debris. Repair erosion.

(7) Identify steps to maintain native vegetation species, including removal of undesirable species.

(8) Avoid the use of pesticides and fertilizers within the system.

(9) If a liner is used, identify how the liner will be protected from damage during sediment removal.

(10) Identify corrective maintenance of the filter media to include removal and replacement of the top layers of sand and/or stone that have become clogged. An integral part of sand filter bed known as the “schmutzdecke” or “filter cake”, a thin layer at the top of the sand which contains particulates and biota and serves as the main functioning membrane of the sand filtration basin. Most of the water quality function of a sand filtration basin is carried out in the schmutzdecke

layer which is generally the top 3 inches.

Tilling or breaking up of the schmutzdecke layer is not adequate as it will exacerbate clogging issues deeper into the system. Sand filter systems may also require the periodic removal of vegetative growth.

When evaluating the condition of the filter media consider:

a. If sand filter bed is completely covered with a schmutzdecke but there is no observable standing water, then the system is presumed to be functioning properly.

b. If the sand filter bed is holding water beyond 72 hours after a precipitation event has ended, remove the schmutzdecke layer until clean sand is observed, to potentially full removal of the filter media. Given preferential flow paths, this may not be a uniform depth across the filter media.

c. For filter media whose functionality is in question, a percolation test, coring sample test, and/or sensor may be employed to evaluate drawdown time and functionality and determine if filter media replacement is needed. Keep a record of the dewatering times for all sand filters to determine if maintenance is necessary.

(11) Remove accumulated debris and vegetation from the sand filter bed and the rest of the system every 6 months or as necessary to keep the filter clean.

(12) Dispose of waste, trash, debris, captured sediment, and spent filter media properly.

(13) Remove accumulated debris every 6 months, or as necessary to keep the sedimentation basin functioning. Repair eroded areas and re-established missing vegetation as soon as conditions allow and implement erosion control practices as needed.

CONSIDERATIONS

The following considerations are intended to enhance the use of this practice, or to address special cases that may arise in the implementation of storm water sand filters:

(1) Use of deep-rooted vegetation, excluding trees, and native vegetation may provide better aesthetics, enhanced infiltration, and sediment retention.

(2) Use flatter side slopes to improve safety while mowing or use vegetation requiring limited or no mowing.

(3) Basins with outlet control structure orifices smaller than 6-inches in diameter will need additional maintenance and/or clogging protection.

(4) If gabion wire baskets are used, consider PVC coated or stainless-steel wire baskets to avoid zinc leaching from galvanized elements.

(5) An anaerobic condition in the bottom of the filter may address nitrogen removal. This is typically accomplished by using a bend in the outlet pipe to create a saturated zone at the bottom of the system. This can only be accomplished if the system has a liner at the bottom. Keep any media used to capture phosphorus, metals, and organics above the resulting saturated zone to prevent the release of phosphorus from the media due to anaerobic conditions and to maintain the integrity of the media.

(6) To protect groundwater, if site information indicates that compliance with a preventive action limit (in accordance with ch. NR 140, Wis. Adm. Code) is not achievable, modify the storm water sand filter to prevent infiltration to the maximum extent practicable. This can be best accomplished through use of a synthetic liner and underdrain system.

(7) If a concrete wall is used between the sedimentation basin and sand filter, consider placing a weir in the concrete wall to avoid potential issues associated with ice formation to improve winter performance.

PLANS AND SPECIFICATIONS

Prepare plans and specifications in accordance with the criteria of this standard and describe the requirements for applying the practice to achieve its intended use. Specify the materials, construction processes, locations, size and elevations of all components of the practice to allow for certification of construction upon completion. Include the *seasonally high groundwater elevation* on a to-scale profile or cross-section view of the filtration device and the storm sewer system connected to it.

REFERENCES

Schueler, T.R., Kumble, P.A. and Heraty, M.A., *A Current Assessment of Urban Best Management Practices*. Metropolitan Washington Council of Governments, 1992.

City of Austin, Texas, *Environmental Criteria Manual*, Section 1 Water Quality Management, 1.6.0 Design Guidelines for Water Quality Controls, May 15, 2023 (https://library.municode.com/TX/Austin/codes/environmental_criteria_manual?nodeId=S1WAQUMA_1.6.0DEGUWAQUCO_1.6.5DEGUSEFISY) accessed 11/12/2024).

WDNR, Additive website, https://dnr.wisconsin.gov/topic/Wastewater/Additives.html.

WDNR, Native plants website, https://dnr.wisconsin.gov/topic/endangeredresources/nativeplants.

WDNR, The Water Quality Review Procedures for Additives, Edition #3, December 2, 2022, https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=208572214.

Wisconsin Department of Transportation, Standard Specifications for Highway and Structure Construction, https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/rdwy/stndspec.aspx.

GLOSSARY

Karst geology: An area or surficial geologic feature subject to bedrock dissolution so that it is likely to provide a conduit to groundwater. May include caves, enlarged fractures, mine features, exposed bedrock surfaces, sinkholes, springs, seeps, swallets, fracture trace (linear feature, including stream segment, vegetative trend and soil tonal alignment), Karst pond (closed depression in a karst area containing standing water) or Karst fen (marsh formed by plants overgrowing a karst lake or seepage area).

NURP: NURP stands for Nationwide Urban Runoff Program and in this document refers to the NURP particle size distribution.

Seasonally high groundwater elevation: The higher of either the elevation to which the soil is saturated as observed as a free water surface in an unlined hole, or the elevation to which the soil has been seasonally or periodically saturated as indicated by soil color patterns throughout the soil profile.

Stable/Stabilized: A uniform perennial, vegetative cover with a density of at least 70% vegetative cover (for unpaved areas and areas not covered by permanent structures or that employ equivalent permanent stabilization measures), with less than 10% cover by ch. NR 40, Wis. Adm. Code, regulated invasive species.

Total system: The system from the inlet of the forebay to the outlet from the sand filter.

Uniformity Coefficient (UC): A ratio calculated as the size opening that will just pass 60% of the sand (d60 value) divided by the size opening that will just pass 10% of the sand sample (d10 value).

Figures 1A and 1B
Typical Sand Filter Configuration using Stone Berm / Gabion

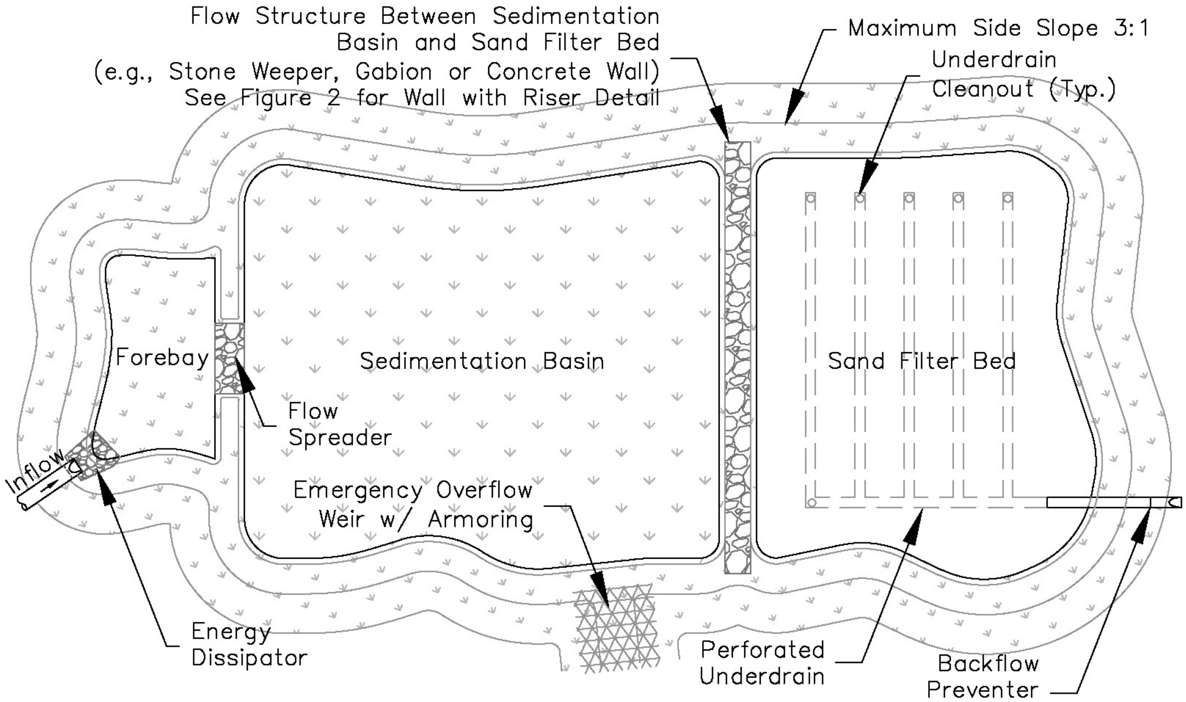

FIGURE 1A

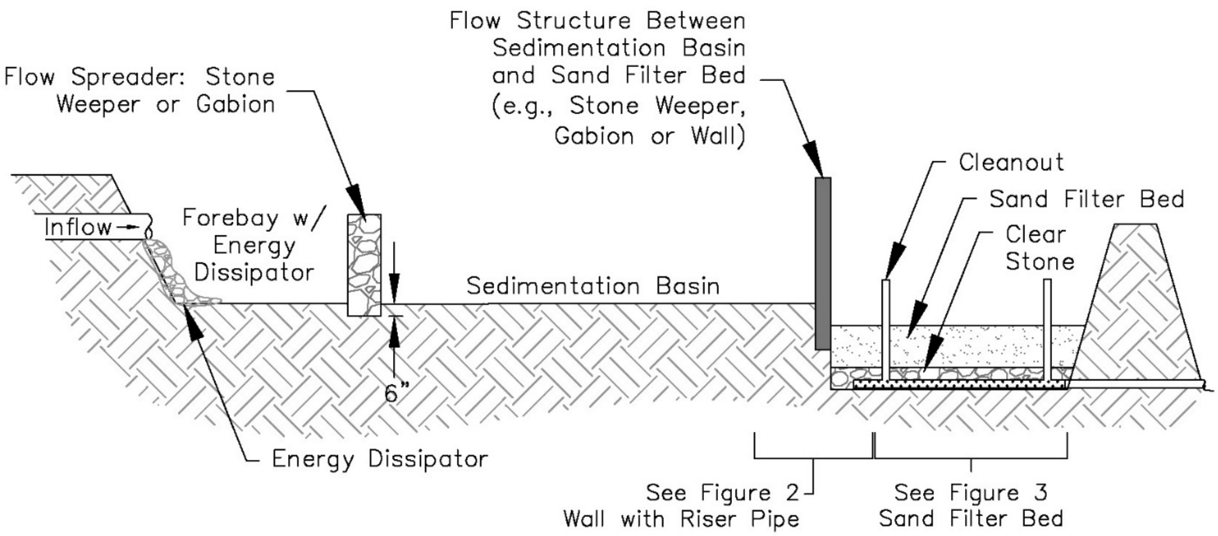

FIGURE 1B

Figure 2
Typical Flow Structure Wall with Riser Pipe

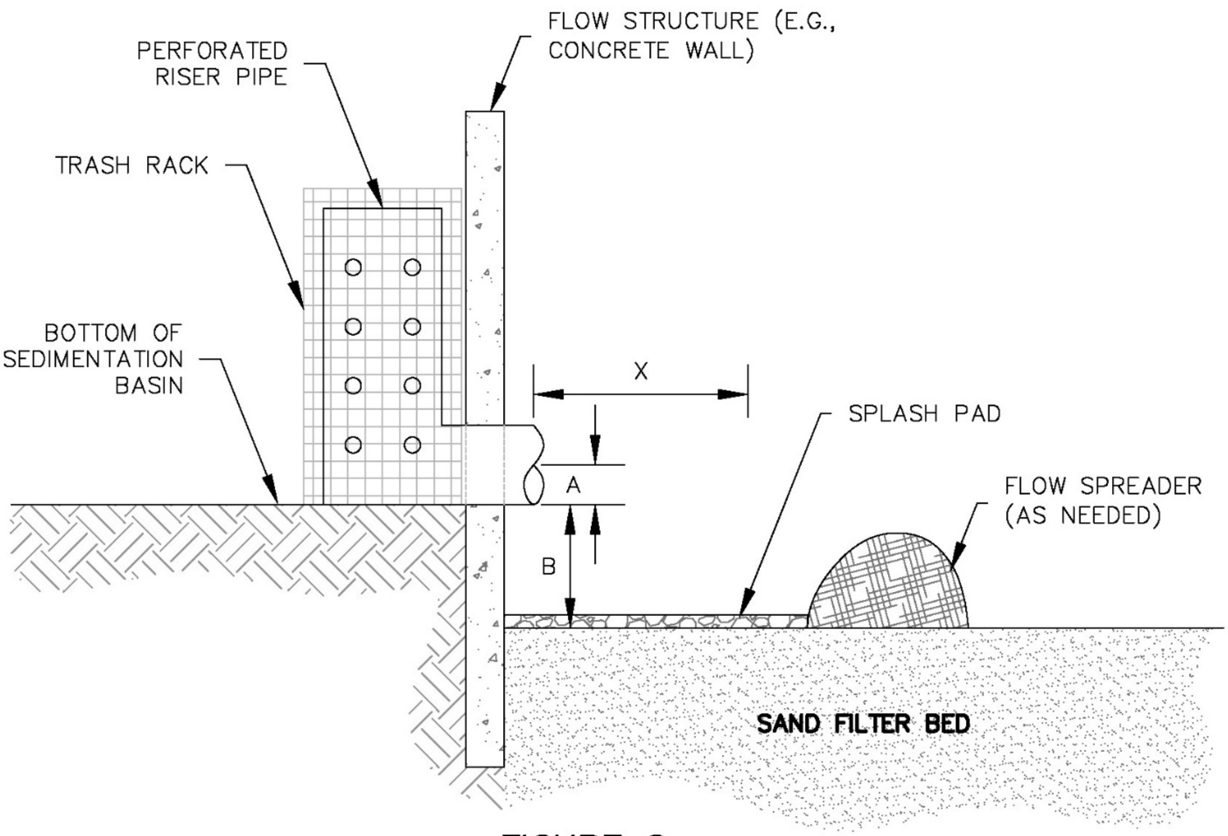

FIGURE 2

Source: City of Austin

To determine **X**, the maximum pipe discharge travel distance in feet, first calculate that maximum discharge (**Q**) from the pipe in cubic feet per second using the orifice equation. Next calculate the maximum discharge velocity (v) in cubic feet per second. Also calculate "fall time" for flow trajectory using the equation below:

$$t = \sqrt{\frac{2*(B+A)}{g}}$$

Where time (t) is in seconds and:

B = height in feet

A = pipe radius including thickness + any gap between riser pipe and sedimentation basin bottom (ft)

g = gravitational acceleration = 32.2 ft/sec/sec^2

$$X \geq 1 + v*t \text{ (ft)}$$

Note one (1) foot is added for margin of safety.

Figure 3
Sand Filter Bed

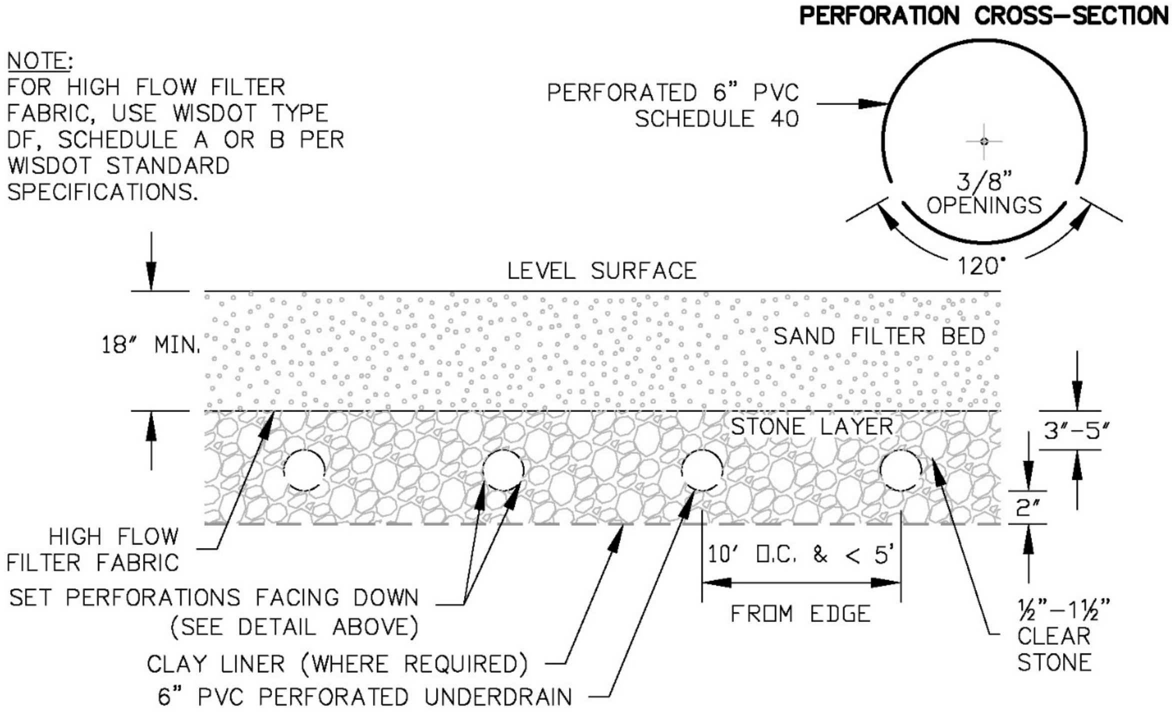

FIGURE 3