WQ-06 SAND FILTER

1.0 Sand Filter

1.1 Description

Sand Filters remove pollutants through sedimentation and filtration within the sand. The primary components of Sand Filters include; a pretreatment/sedimentation chamber or basin, a sand filter chamber, a flow spreader, an outlet chamber, and underdrain piping. Runoff first enters the sedimentation chamber where the runoff velocity is reduced to allow larger pollutant particles to drop out. When the stormwater exits the sedimentation chamber, it is spread evenly over the sand filter bed where it flows downward through the sand filter. As the stormwater runoff flows through the sand filter, the filtration media traps and absorbs pollutants. Sand Filters are beneficial when land space is scarce or expensive because they can be designed to be placed underground.

Use Sand Filters to treat drainage areas of 1 to 2 acres. Sand Filters are typically used to address the spatial constraints of highly developed urban areas where the drainage areas are highly impervious. The implementation of several Sand Filters on the site prevents the entire site from being untreated if one of the Sand Filters facilities becomes clogged and requires maintenance.

Sand Filters are adaptable, and have minimum site constraints. They can be used in areas with fine soils, low infiltration rates, and limited space.

Use Sand Filters on sites where the drainage area to the facility will remain well stabilized after the construction phase to prevent excess sediment and debris from permanently clogging the filter. Identify any disturbed areas within the Sand Filter watershed and immediately stabilize to prevent the filter from clogging.

Sand Filters are most effective when designed as off-line BMPs and are intended primarily for water quality control, not quantity control. A diversion structure, such as a flow splitter or weir is provided to route the first flush or water quality volume of runoff into the Sand Filter, while directing the remainder of runoff to a water quantity control BMP.

The cost of underground concrete Sand Filters is high in relation to other water quality BMPs, and the maintenance burden for the owner is substantial. However, because this BMP can be placed underground, the costs may be offset by the saving of land space.

The most widely known type of underground sand filtration facility is the DC (District of Columbia) Sand Filter developed by Mr. Hung V. Truong of the D.C. Environmental Regulation Administration. This type of Sand Filter is for use in ultra-urban settings where the drainage area is 1 acre or less. The DC sand filter consists of the following three chambers:

- A wet sedimentation chamber,
- A sand filtration chamber, and
- An outlet chamber.

1.2 Design and Sizing Requirements

1.2.1 Basic Design Guidelines

The following list includes general design guidelines for Sand Filter installations:

- When feasible use a flow splitter at the inflow structure that is capable of isolating the water quality volume and bypassing larger storm events.

- Pretreat the runoff discharging to the Sand Filter to remove debris, large particulates, and oils. Typically, use a small sediment chamber to allow sediment particles to settle and accumulate prior to entering the Sand Filter. Alternate types of pretreatment device depend on specific site conditions and the pollutants present in a given watershed.
- Size the Sand Filter to completely empty or drain the water quality volume in 24 hours or less.
- Provide a structurally sound foundation capable of supporting loads while the Sand Filter is operating at maximum capacity.

1.2.2 Sand Filter Area

The entire Sand Filter is designed to hold 75 percent of the water quality volume of 1.0-inch of runoff from the entire drainage area. The volume may be allocated to the filter chamber and the pretreatment (wet pool) chamber. The justification of providing only 75 percent of the total runoff volume is that sand is a relatively permeable material and the filter bed is continually filtering water during the duration of the storm event. It is estimated that the median rainstorm event will last longer than six hours for the first 1-inch of runoff to occur.

The required surface area for a Sand Filter is calculated from the following equation:

$$A_f = \frac{dA\left[\ln(H_1 + d) - \ln(H_2 + d)\right]}{kT - d\left[\ln(H_2 + d) - \ln(d)\right]}$$

Where:

Af	=	Surface area of the Sand Filter in feet^2
d	=	Depth of filter material in feet (1.5-ft. minimum)
A	=	Total surface area in feet^2 (equal to Sand Filter area + sediment chamber area)
H_1	=	Maximum water depth above filter bed in feet ([5-feet)
H_2	=	Height of invert of sediment chamber outlet above top of Sand Filter bed in feet
k	=	Coefficient of permeability for sand in feet/day (typical value is 3.5-feet/day)
T	=	Time for water quality volume to filter through the bed in days ([1-day)
ln	=	Natural logarithm

If the area of the Sand Filter is limited due to site constraints, the previous equation may be rearranged to solve for d, H_1, H_2, or T.

At a minimum, the sediment chamber of the Sand Filter has a surface area equal to the surface area of the Sand Filter bed.

1.2.3 Pretreatment or Wet Sedimentation Chamber Requirements

The efficiency of the pretreatment chamber to remove suspended solids is based on the surface loading rate (outflow divided by chamber surface area) and is relatively independent on depth. Inlet structures such as a flow spreaders or weirs are used to minimize turbulence and to spread the flow evenly across the surface of the Sand Filter. The length to width ratio of the pretreatment chamber is 2:1 with a depth varying from 2 to 6 feet. The pretreatment chamber is sized to hold 50% of the water quality volume and slowly release it over a period of several hours allowing coarse sediments to settle out and prevent clogging of the sand filter.

1.2.4 Sand Filter Chamber Requirements

The sand bed in the sand filtration chamber has a minimum depth of 18-inches and the top surface is completely level. Use clean ASTM-33 medium concrete sand.

For underground Sand Filter facilities, provide a 5-foot minimum between the top of the sand bed and the bottom of the concrete slab to provide clearance for maintenance. Place a de-watering valve just above the sand bed layer to drain the facility in situation where the Sand Filter becomes clogged and requires maintenance.

Make provisions to distribute the flow from the sedimentation chamber uniformly across the Sand Filter chamber. The underground DC Sand Filter uses overflow weirs along the width of the Sand Filter to accomplish this. When flow from the sedimentation chamber outlets by pipe flow, incorporate a flow distribution chamber.

1.2.5 Underdrain System Requirements

Use an under drain system to collect runoff that has percolated through the Sand Filter. Use 6 inch perforated schedule 40 PVC piping placed in an 8 to 10 inch deep gravel jacket. Place a Type C nonwoven geotextile filter fabric layer between the sand and the gravel. Use 0.75- 1.5 inch drain rocks or gravel backfill under the filter fabric. To ensure adequate drainage, slope the bottom chamber towards the underdrain pipes spaced ten (10) feet apart along the filter bed. The underdrain system may discharge to the main storm sewer system or may outfall to an outlet chamber. Provide cleanout wells with caps or junction boxes at both ends of any underdrain collector pipe. Extend cleanout wells to the surface of the Sand Filter.

1.2.6 Overflow

Sand Filters are more efficient when they are placed off-line and when runoff volumes greater than the 1-inch water quality volume are diverted when possible. A by-pass structure can be used to direct flow away from the Sand Filter once the water quality volume has been exceeded.

If it is beneficial to the site drainage patterns, Sand Filters may be placed on-line. Place an overflow structure in the sediment chamber designed to pass the 10-year 24-hour storm at a minimum. Place the overflow from the sediment chamber as far upstream of the sand filtration bed as possible to prevent the initial water quality volume from being flushed out.

1.2.7 Accessibility and Site Requirements

High ground water can damage underground structures or affect the performance of filter underdrain systems. Ensure a minimum 2 feet of clearance is provided between the seasonal high groundwater level and the bottom of the Sand Filter. Provide access to each of the three chambers using access doors, or manholes.

1.3 Installation

The following steps provide support for typical Sand Filter installations.

1. Excavate the Sand Filter area.
   - Set digger at least 4-ft from pegged position of Sand Filter to prevent slumping when excavating.
   - Excavate areas for chambers and incoming inlet and outlet pipes to levels shown on construction plans, allowing for foundation fill.
   - Where depth exceeds 3-ft or soil is unstable, batter or shore side slopes.
   - Stockpile excavated material away from site.
   - Check material at base of excavation is firm and stable, and if not, consult engineer.
   - Erect safety fencing around hole.
2. Dig Foundations
   - Place and compact base course to prevent chamber movement.

- Apply concrete blinding layer. Unstable soils may require reinforcing mesh and increased concrete strength and depth.
- Check levels match construction plans and finished surface is level.

3. Install Chambers
    - Ensure lifting machinery is certified to lift units
    - Ensure prefabricated units have ladders, underdrain and inlet and outlet holes.
    - Cut holes for inlet and outlet before pre-fabricated chambers are lifted into position.
    - Clear and control area of all traffic and people during lifting.
    - Ensure chambers are in position as shown in construction plans with outlets at correct ends.
    - Apply waterproof sealant to all vertical, wall and floor joints, risers and connection pipes.
4. Check Water Tightness
    - In general this involves plugging all chamber outlets, filling both chambers with water, and then measuring water loss after 24 hours. Greater than 5% loss of water volume shows leakages that will require sealing before continuing construction.
5. Connect Components
    - When watertight, connect inlet and outlet pipes, and if specified, construct inlet and sediment tank weirs. Plug inlet and outlets during construction.
    - Fit dewatering valve at finished level of filter material, draining to outlet.
    - For units not prefabricated: install ladders as specified, and lay perforated underdrain wrapped in geotextile into position shown on construction plans, connected to outlet.
6. Install Filter Material
    - Carefully backfill underdrain, avoiding filling, crushing or damaging pipe.
    - Carefully place specified filter material in filtration chamber as detailed on construction plans.
    - DO NOT compact material.
7. Review Elevations
    - Check all elevations of Sand Filter components and ensure levels match construction plans.

1.4 Inspection and Maintenance

- Inspect Sand Filters at least once per month, and after any large storm events to check for damage.
- Maintain Sand Filters as needed to remove visible surface sediment accumulation, trash, debris, and leaf litter to prevent the filter from clogging prematurely.
- Remove sediment from the forebay/sedimentation chamber when it accumulates to a depth of more than 6 inches.
- Check any structures (outlets, flow diversions, embankments, etc.) at least annually for damage or degradation.
- Perform inspection activities as shown in Table 1. Repair any problems identified immediately.

Table 1 – Maintenance for Sand Filters

BMP Element:	Potential Problems:	How to Remediate the Problem:
Entire BMP	Trash/debris is present.	Remove the trash/debris.
Adjacent pavement (if applicable)	Sediment is present on the pavement surface	Sweep or vacuum the sediment as soon as possible.
Perimeter of sand filter	Areas of bare soil and/or erosive gullies have formed.	Regrade soil if necessary to remove the gully, and then plant a ground cover and water until it is established. Provide lime and a one-time fertilizer application.
	Vegetation is too short or too long.	Maintain vegetation at an appropriate height.
Flow diversion structure	The structure is clogged.	Unclog the conveyance and dispose of any sediment offsite.
	The structure is damaged.	Make any necessary repairs or replace if damage is too large for repair.
Pretreatment area	Sediment has accumulated to a depth of greater than six inches.	Search for the source of the sediment and remedy the problem if possible. Remove the sediment and stabilize or dispose of it in a location where it will not cause impacts to streams or the BMP.
	Erosion has occurred.	Provide additional erosion protection such as reinforced turf matting or riprap if needed to prevent future erosion problems.
	Weeds are present.	Remove the weeds, preferably by hand. If a pesticide is used, wipe it on the plants rather than spraying.
Filter bed and underdrain collection system	Water is ponding on the surface for more than 24 hours after a storm.	Check to see if the collector system is clogged and flush if necessary. If water still ponds, remove the top few inches of filter bed media and replace. If water still ponds, then consult an expert.
Outlet device	Clogging has occurred.	Clean out the outlet device. Dispose of the sediment offsite.
	The outlet device is damaged.	Repair or replace the outlet device.

1.5 IDEAL Modeling

The County's preferred method of demonstrating compliance with its water quality standard is to use the IDEAL model. To facilitate use of this model, the table below shows how to represent this BMP and BMPs similar to this one in the IDEAL model. It lists the parameters needed to successfully run the model and the parameters that affect the trapping efficiency of the BMP.

Table 2: IDEAL Modeling Guide

Sand Filter Modeling in IDEAL		
What to Model as in IDEAL	Sand Filter	
Similar BMPs	Sand Filtration Facilities	
	Perimeter/ Surface Sand Filters	
Specifications Needed for IDEAL	If the settling device is specified: - Sediment basin shape, size, and dimensions - If a rockfill check dam is being utilized: check dam dimensions - If a low flow orifice is being utilized: orifice dimensions - If an emergency spillway is being utilized with the settling device: type, shape, and dimensions of the spillway	
	Filter shape, dimensions, and material	
	Material saturated hydraulic conductivity, porosity, and representative diameter	
	If an emergency spillway is being utilized, the type, shape, and dimensions of the spillway	
	Direct loading of bacteria that will be entering the cell	
Parameters that Drive Performance	**Feature**	**How Value Affects Sediment Trapping Efficiency (TE)**
	Hydraulic Conductivity	Increasing hydraulic conductivity increases TE
	Area of Filter	Increasing area increases TE
	Settling Device Orifice Diameter	Increasing diameter increases TE
	Settling Device Depth	Increasing depth increases TE
	Settling Device Area	Increasing area increases TE

1.6 References

Auckland Regional Council. Sand Filter Construction Guide.

NCDENR Stormwater BMP Manual, Chapter 12 Bioretention, Chapter Revised 07-24-09