United States Environmental Protection Agency | Office of Water Washington, D.C. | EPA 832-F-99-007 September 1999

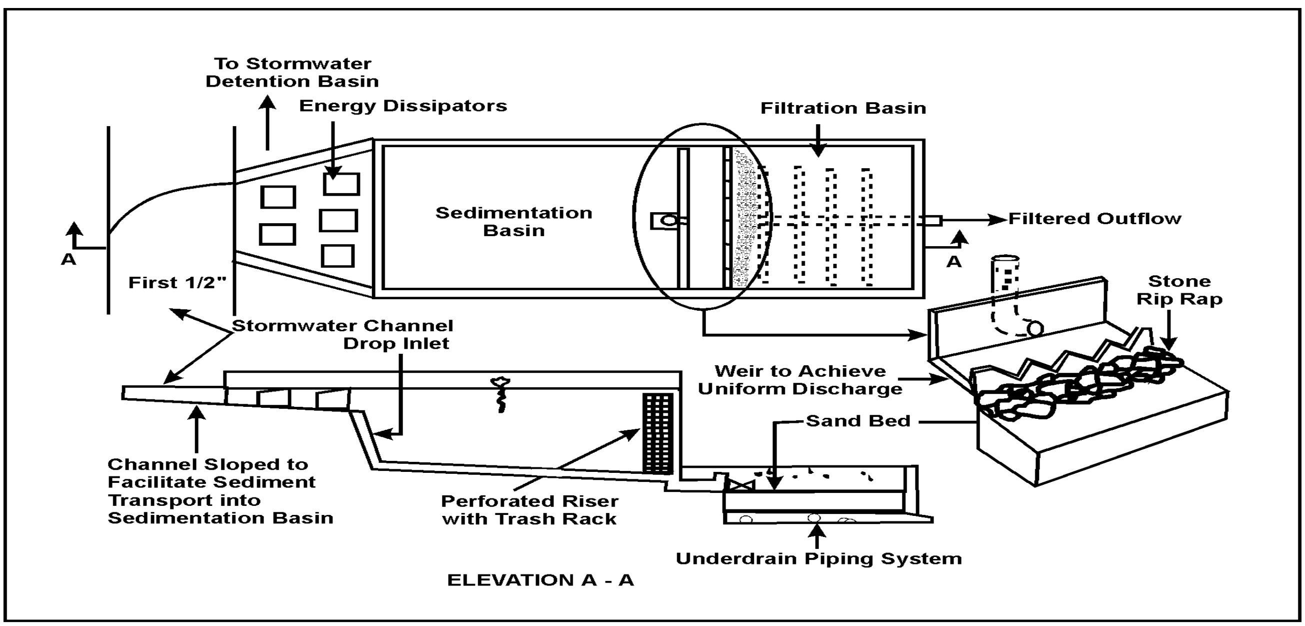
Storm Water Technology Fact Sheet
Sand Filters

DESCRIPTION

Sand filters have proven effective in removing several common pollutants from storm water runoff. Sand filters generally control storm water quality, providing very limited flow rate control.

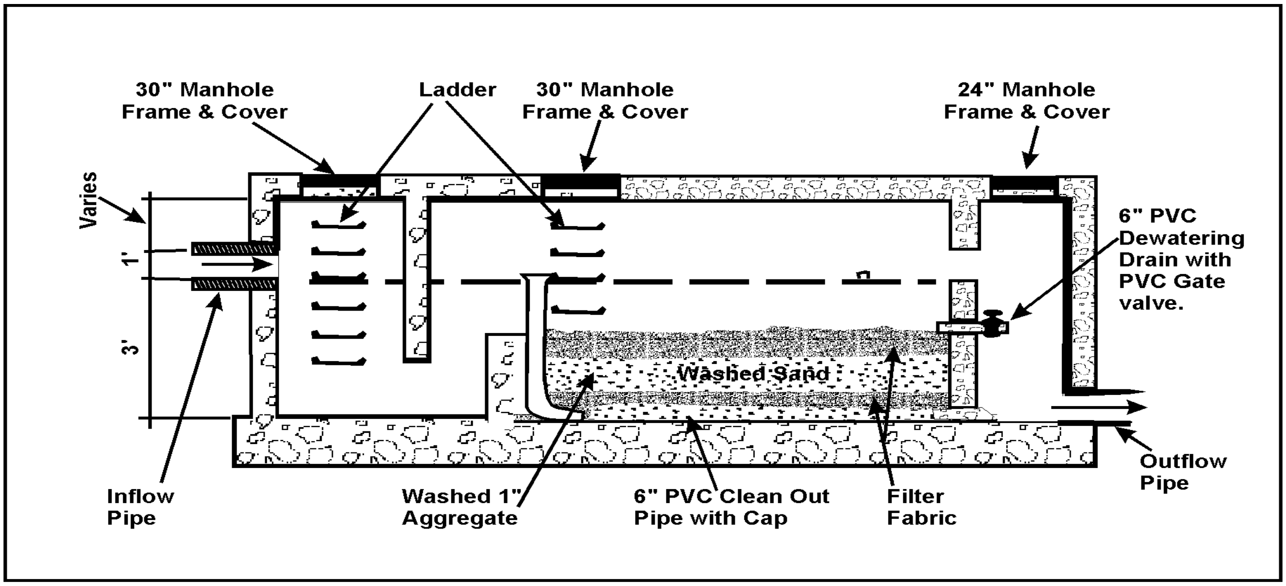
A typical sand filter system consists of two or three chambers or basins. The first is the sedimentation chamber, which removes floatables and heavy sediments. The second is the filtration chamber, which removes additional pollutants by filtering the runoff through a sand bed. The third is the discharge chamber. The treated filtrate normally is then discharged through an underdrain system either to a storm drainage system or directly to surface waters. Sand filters take up little space and can be used on highly developed sites and sites with steep slopes. They can be added to retrofit existing sites. Sand filters are able to achieve high removal efficiencies for sediment, biochemical oxygen demand (BOD), and fecal coliform bacteria. Total metal removal, however, is moderate, and nutrient removal is often low.

There are three main sand filter designs currently in common use: the Austin sand filter (Figure 1); the Washington, D.C., sand filter (Figure 2); and the



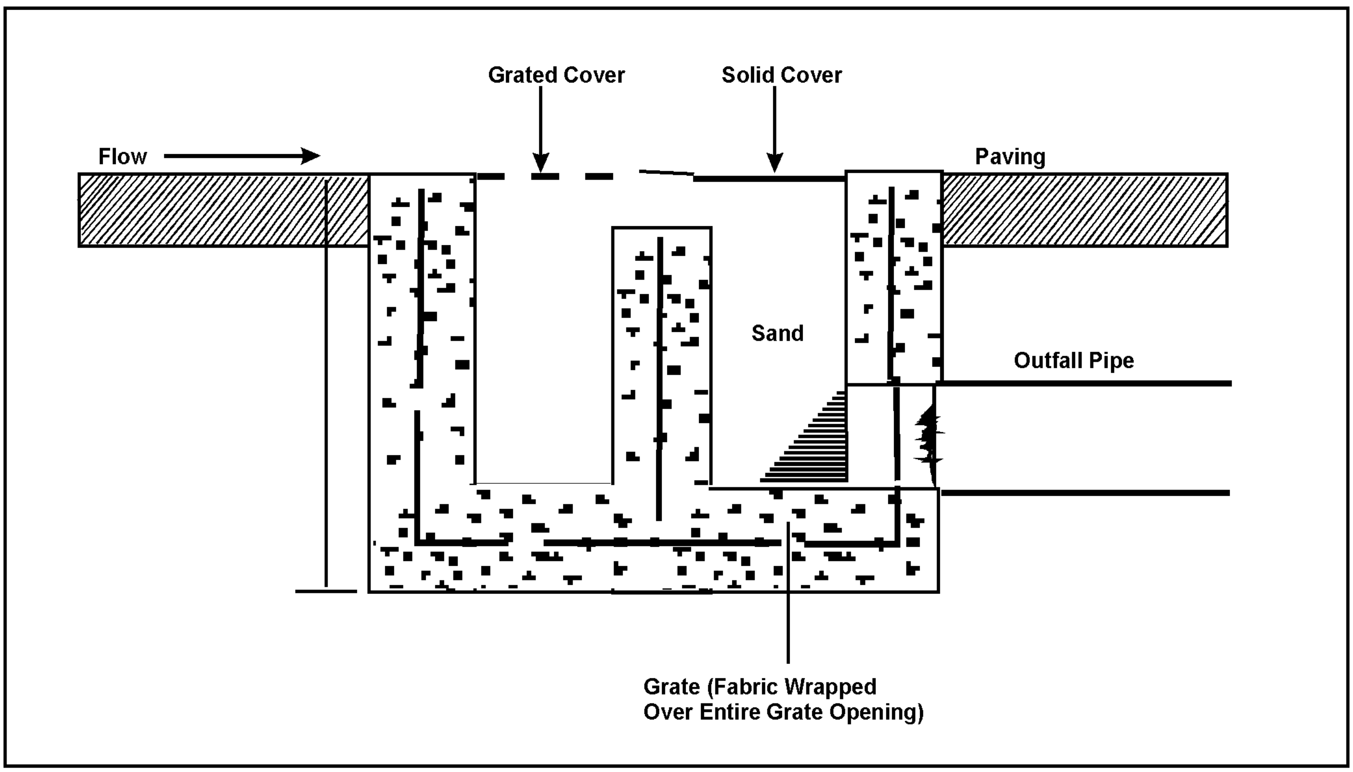
Source: Schueler, 1992.

FIGURE 1 TYPICAL AUSTIN SAND FILTER DESIGN



Source: Troung, 1989.

FIGURE 2 TYPICAL WASHINGTON, D.C. SAND FILTER DESIGN



Source: Shaver, 1991.

FIGURE 3 TYPICAL DELAWARE SAND FILTER DESIGN

Delaware sand filter (Figure 3). The primary differences among these designs are location (i.e., above or below ground), the drainage area served, their filter surface areas, their land requirements, and the quantity of runoff they treat.

Modifications that may improve sand filter design and performance are being tested. One modification is the addition of a peat layer in the filtration chamber. The addition of peat to the sand filter may increase microbial growth within the sand filter and improve metals and nutrient removal rates.

APPLICABILITY

Sand filters are intended primarily for water quality enhancement. In general, sand filters are preferred over infiltration practices, such as infiltration trenches, when contamination of groundwater with conventional pollutants - BOD, suspended solids, and fecal coliform - is of concern. This usually occurs in areas where underlying soils alone cannot treat runoff adequately - or ground water tables are high. In most cases, sand filters can be constructed with impermeable basin or chamber bottoms, which help to collect, treat, and release runoff to a storm drainage system or directly to surface water with no contact between contaminated runoff and groundwater.

The selection of a sand filter design depends largely on the drainage area's characteristics. For example, the Washington, D.C., and Delaware sand filter systems are well suited for highly impervious areas where land available for structural controls is limited, since both are installed underground. They are often used to treat runoff from parking lots, driveways, loading docks, service stations, garages, airport runways/taxiways, and storage yards. The Austin sand filtration system is more suited for large drainage areas that have both impervious and pervious surfaces. This system is located at grade and is often used at transportation facilities, in large parking areas, and in commercial developments.

In general, all three types of sand filters can be used as alternatives for water quality inlets. They are more frequently used to treat runoff contaminated with oil and grease from drainage areas with heavy vehicle usage. In regions where evaporation exceeds rainfall and a wet pond would be unlikely to maintain the required permanent pool, the Austin sand filtration system can be used.

ADVANTAGES AND DISADVANTAGES

Sand filters can be highly effective storm water best management practices (BMPs). All three types of sand filters achieve high removal rates for sediment, BOD, and fecal coliform bacteria. The filter media is periodically removed from the filter unit, thus also permanently removing trapped contaminants. Waste media from the filters does not appear to be toxic and is environmentally safe for landfill disposal. If they are designed with an impermeable basin liner, sand filters can also reduce the potential for groundwater contamination. Finally sand filters also generally require less land than other BMPs, such as ponds or wetlands.

The size and characteristics of the drainage area, as well as the pollutant loading, will greatly influence the effectiveness of the sand filter system. For example, sand filters may be of limited value in some applications because of they are designed to handle runoff from relatively small drainage areas and they have low nutrient removal and metal removal capabilities. In these cases, other BMPs, such as wet ponds, may be less costly and/or more effective. The system also requires routine maintenance to prevent sediment from clogging the filter. In some cases, filter media may need to be replaced 3 to 5 years. Lastly, sand filters generally do not control storm water flow, and consequently, they do not prevent downstream stream bank and channel erosion.

Climatic conditions may also limit the filter's performance. For example, it is not yet known how well sand filters will operate in colder climates or in freezing conditions.

DESIGN CRITERIA

Typically the Austin sand filter system is designed to handle runoff from drainage areas up to 20 hectares (50 acres). The collected runoff is first diverted to the sedimentation basin, where heavy sediments and floatables are removed. There are two designs for the sedimentation basin: the full sedimentation system, as shown in Figure 1; and a partial sedimentation system, where only the initial flow is diverted. Both systems are located off-line and are designed to collect and treat the first 1.3 centimeters (0.5 inches) of runoff. The partial system has the capacity to hold only a portion (at least 20 percent) of the first flush volume in the sedimentation basin, whereas the full system captures and holds the entire flow volume.

Equations used to determine the sedimentation basin surface areas (As) in square and meters acres are shown in Table 1.

TABLE 1 SURFACE AREA EQUATION FOR AUSTIN SAND FILTER SYSTEM

Partial Sedimentation	Full Sedimentation
As=(AD)(H)/(1/Ds-1/10)	As=(AD)(H)/10
Af=(AD)(H)/10	Af=(AD)(H)/18

Note: Designed to collect and treat 0.5 inches of runoff.
Ds (feet)=depth of the sedimentation basin.
H (feet)=depth of rainfall, 0.042ft (0.5 in).
AD(acres)=impervious and pervious areas that provide contributing drainage.

Source: Galli, 1990.

Flow is conveyed from the sedimentation basin, through a perforated riser, a gabion wall, or a berm, to the filtration basin. The filtration basin consists of a 45-centimeter (18-inch) layer of sand particles 0.05 to 0.10 centimeters (0.02 to 0.04 inches) in diameter that may be underlain by a gravel layer. Equations used to determine the surface areas (Af) in acres are also shown in Table 1. The filtrate is discharged from the filtration basin through underdrain piping 10 to 15 centimeters (4 to 6 inches) in diameter with 1-centimeter (0.4 inch) perforations. Filter fabric is placed around the underdrain piping to prevent sand and other particulates from being discharged.

Typically, the Washington, D.C., sand filter system is designed to handle runoff from completely impervious drainage areas of 0.4 hectares (1 acre) or less. The system, as shown in Figure 2, consists of three underground chambers: a sedimentation chamber, a filtration chamber, and a discharge chamber. The sand filter system is designed to accept the first 1.3 centimeters (0.5 inches) of runoff. Coarse sediments and floatables are removed from the runoff within the sedimentation chamber. Runoff is discharged from the sedimentation chamber through a submerged weir, into the filtration chamber, which consists of a combination of sand and gravel layers totaling 1 meter (3 feet) in depth with underdrain piping wrapped in filter fabric. The underdrain system collects the filtered water and discharges it to the third chamber, where the water is collected and discharged to a storm water channel or sewer system. An overflow weir is located between the second and third chambers to bypass excess flow. The Washington, D.C., sand filter is often constructed on-line, but can be constructed off-line. When the system is off-line, the overflow between the second and third chambers is not included.

The Delaware sand filter, shown in Figure 3, is similar to the Washington, D.C., sand filter in that both utilize underground concrete vaults. However, the Delaware sand filter has only two chambers: a sedimentation chamber and a filtration chamber. A 2.5-centimeter (1 inch) design storm was selected for sizing the sedimentation basin because it is representative of large storm events: in Delaware, 92 percent of all storms are less than 2.5 centimeters (1 inch) in depth. Runoff enters the sedimentation chamber through a grated cover and then overflows into the filtration chamber, which contains a sand layer 45 centimeters (18 inches) in depth. Gravel is not normally used in the filtration chamber although the filter can be modified to include it. Typical systems are designed to handle runoff from drainage areas of 2 hectares (5 acres) or less. A major advantage of the Delaware sand filter is its shallow structure depth of only 76 centimeters (30 inches), which reduces construction and maintenance costs.

Proper design and maintenance are also critical factors in maintaining the operating life of any filter system. The life of the filter media may be increased by a number of methods, including:

- Stabilizing the drainage area so that sediment loadings in the runoff are minimized.
- Providing adequate storm water detention times to enhance sedimentation and filtration.
- Inspecting and maintaining the sand filter frequently enough to ensure proper operation.

PERFORMANCE

Sand filters are currently in use in Delaware, Maryland, Florida, Texas, Virginia, and Washington, D.C. Studies on the systems' pollutant removal efficiencies are currently being performed in Washington, D.C., and Austin, TX. Additional evaluations are needed to evaluate alternative sand filter designs and media. Sand filters remove particulates in both the sedimentation and the filtration chambers. The City of Austin has estimated their systems' pollutant removal efficiencies based on preliminary findings of their storm water monitoring program (Austin, 1988). The estimates shown in Table 2 are average values for various sand filters serving drainage areas of several different sizes. As shown in Table 2, no removal of nitrate was observed. No other dissolved pollutants were monitored. Additional monitoring is currently being performed by the City of Austin to supplement the preliminary estimates.

TABLE 2 TYPICAL POLLUTANT REMOVAL EFFICIENCY

Pollutant	Percent Removal
Fecal Coliform	76
Biochemical Oxygen Demand (BOD)	70
Total Suspended Solids (TSS)	70
Total Organic Carbon (TOC)	48
Total Nitrogen (TN)	21
Total Kjeldahl Nitrogen (TKN)	46
Nitrate as Nitrogen (NO_3-N)	0
Total Phosphorus (TP)	33
Iron (Fe)	45
Lead (Pb)	45
Zinc (Zn)	45

Source: Galli, 1990

OPERATION AND MAINTENANCE

All filter system designs must provide adequate access to the filter for inspection and maintenance. The sand filters should be inspected after all storm events to verify that they are working as intended. Since the Washington, D.C., and Austin sand filter systems can be deep, they may be designated as confined spaces and require compliance with confined space entry safety procedures.

Typically, sand filters begin to experience clogging problems within 3 to 5 years (NVPDC, 1992). Accumulated trash, paper and debris should be removed from the sand filters every 6 months or as necessary to keep the filter clean. A record should be kept of the dewatering times for all sand filters to determine if maintenance is necessary. Corrective maintenance of the filtration chamber includes removal and replacement of the top layers of sand, gravel and/or filter fabric that has become clogged. The removed media may usually be disposed in a landfill. The City of Austin tests their waste media before disposal. Results thus far indicate that the waste media is not toxic and can be safely landfilled (Schueler, 1992). Sand filter systems may also require the periodic removal of vegetative growth.

COSTS

The construction cost for an Austin sand filtration system is approximately $18,500 (1997 dollars) for a 0.4 hectare- (1 acre-) drainage area. The cost per hectare decreases with increasing drainage area. The cost for precast Washington, D.C. sand filters, with drainage areas of less than 0.4 hectares (1 acre), ranges between $6,600 and $11,000 (1997 dollars). This is considerably less than the cost for the same size cast-in-place system. Costs for the Delaware sand filter are similar to that of the D.C. system, with the exception of the lower excavation costs due to the Delaware filters' shallowness.

Annual costs for maintaining sand filter systems average about 5 percent of the initial construction cost (Schueler, 1992). Media is replaced as needed. Currently the sand is being replaced in the D.C. filter systems about every 2 years. The cost to replace the gravel layer, filter fabric and top portion of the sand for D.C. sand filters is approximately

$1,700 (1997 dollars). Improvements in Washington, D.C.'s maintenance procedures may extend the life of the filter media and reduce the overall maintenance costs.

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