Article 108

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Field Evaluation of a Stormwater Sand Filter

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Sand and other media filters are gaining popularity in the United States as stormwater quality treatment practices. A study conducted recently by Denver, Colorado's Urban Drainage and Flood Control District ("the District") investigated the causes of low hydraulic performance of such stormwater filters and the effects on constituent removal. While there is extensive literature on the ability of sand filters to remove pollutants, very little has been reported on long-term hydraulic performance and the myriad of problems stemming from partially or fully clogged filtering practices. Stormwater filters have been widely used in more humid climates recently (Delaware, Virginia, Washington, D.C.) with some degree of success (see article 105), but have yet to be tested in more arid or colder climates. How well do they perform under these more severe conditions?

To help answer this question in a field test, the District, in cooperation with the City of Lakewood, Colorado, constructed and installed an underground sand filter to manage a two-acre, mostly impervious, catchment. Figure 1 shows a perspective of this installation. It consisted of a sedimentation chamber with overflow pipes designed to skim off floatable debris and a sand filter chamber. The sand filter layer was 12 inches in depth and was underlain by a 12-inch gravel layer with underdrain pipes. Flows were measured using a V-notch weir. Discrete flow samples were taken at the inlet, just upstream of the filter and at the filter's outlet pipe. All samples were flow-weight composited to obtain accurate event mean concentrations for each storm. The filter was designed to operate off-line during larger storms, meaning that flow volumes larger than the design treatment capture volume bypassed the filter itself.

Performance Assessed

The water quality performance characteristics of the District's test sand filter were found to be comparable to those reported in the literature, especially for total suspended solids (EPA, 1983; Veenhuis, 1989; City of Austin, 1990). However, this was true only for the

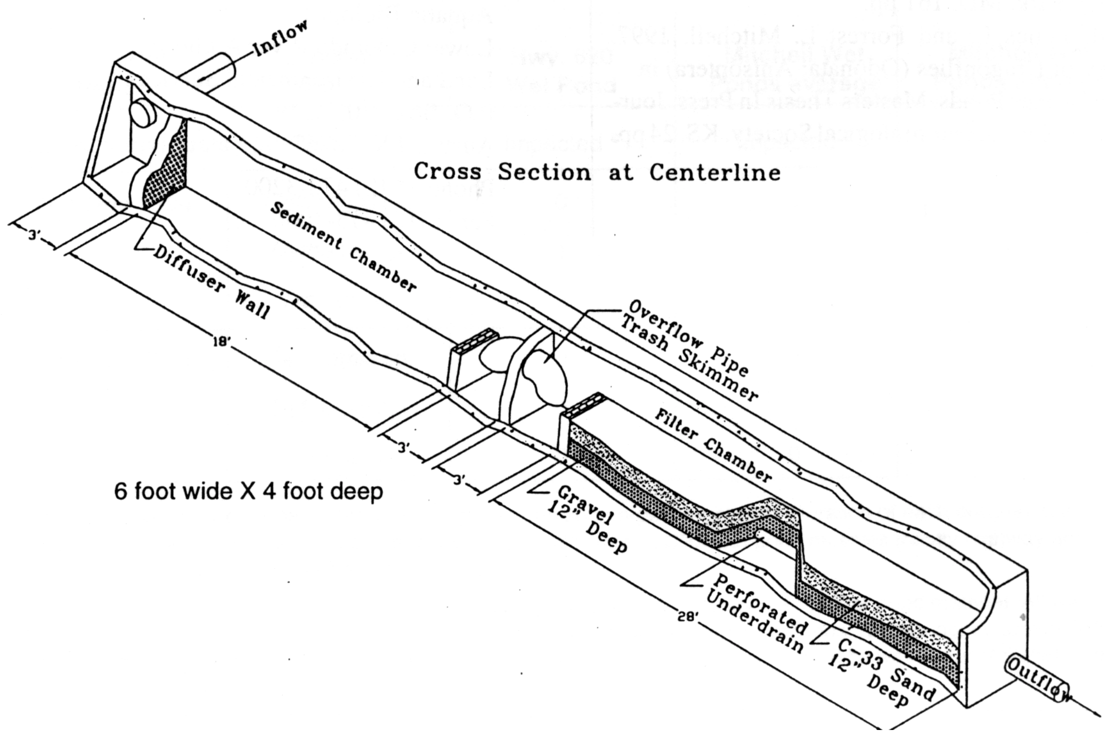

Figure 1: Schematic of Underground Sand Filter Tested in Lakewood, Colorado

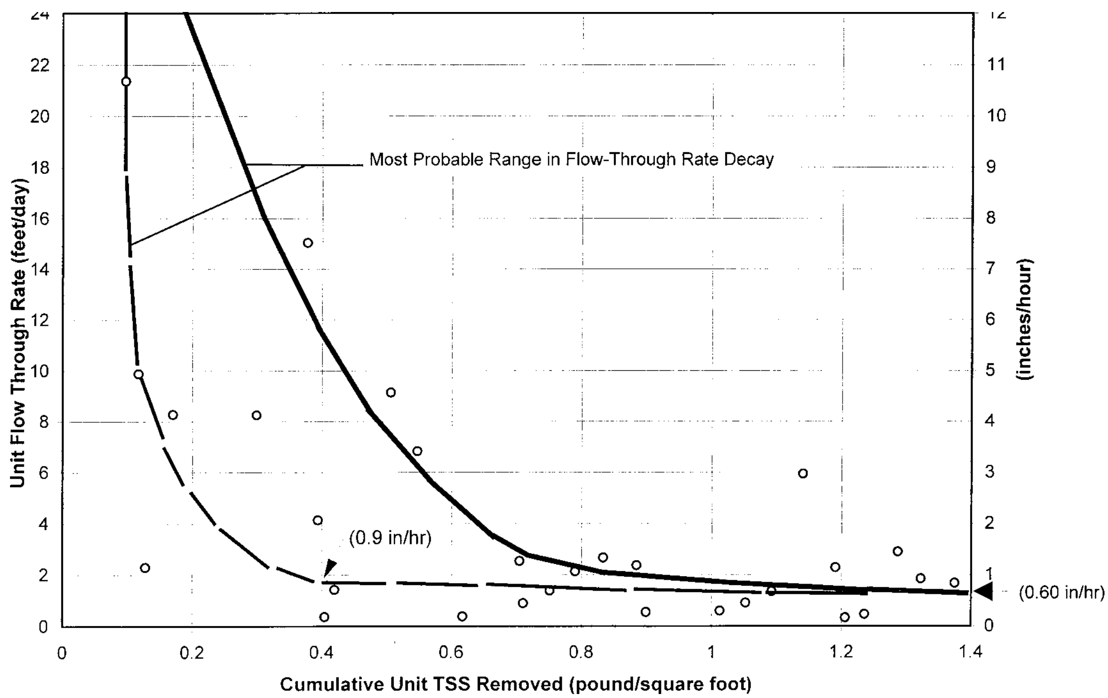

Figure 2: Flow Through Rate Vs. Cumulative Unit TSS Removed (1995 Season)

fraction of the runoff that actually flowed through the filter. This is not true for all of the runoff that bypassed the filter. As the filter accumulated sediment on its surface, it lost hydraulic conductivity. Figure 2 shows how rapidly the test filter's unit hydraulic flow-through rate (inches per hour) degrades as the TSS load accumulates on each square foot of the filter's surface.

In the Denver field test, immediately after the filter was installed, its flow-through rate was in excess of 24 feet per day. This rapidly diminished to less than 1.8 feet per day after 0.4 to 0.5 pounds of sediment per square foot of filter area had accumulated on its surface (i.e., 0.4 lb./sq.ft. of sediments accumulation is roughly equivalent to a 1/16 inch deep layer). A final flow-through rate of 1.2 feet per day was reached after few storms were processed through the filter.

During design, it was expected that at least 70% of all runoff events would be processed through the filter in total, and that some bypass would occur for the other 30% of the larger runoff events. What actually happened during the 1995 summer season was that over 50% of all runoff events exceeded the combined capacity of the filter and the upstream surcharge volume. Because of the large number of flow bypasses, less than 45% of the total TSS measured in the 1995 runoff was removed. This compares to the 85% TSS removal rates reported in the literature.

Although flow bypasses were anticipated, the rate at which the filter clogged and lost hydraulic conductivity was a surprise. If these findings can be extrapolated to other installations, three design and operation criteria emerge: (1) provide an aggressive maintenance program to keep such filters operating as designed, (2) size filter beds larger than most current designs recommend, and (3) install an adequate stormwater capture volume or detention basin upstream of the filter to balance the flow through rate with the population of storms for which the filter is being designed (Urbonas and Ruzzo, 1986; City of Austin, 1988). These concerns have significant economic and operational consequences and all need to be addressed whenever sand or other media filters are being selected.

Comparison to an East Coast Application

Warren Bell and his colleagues (1996) prepared an extensive report on the performance of sand filters in Alexandria, Virginia, that also recorded some bypass flows around filters. This research, however, did not address the fraction of total annual runoff that bypassed the filter. Bell's group primarily field tested the Delaware filter that was originally proposed by Shaver and Baldwin (1991). Bell's findings suggested a longer period for reduced hydraulic performance than was found in the District's test facility, although Bell's data were insufficient to judge if the clogging rates were similar. It is not surprising that the Delaware filters did not clog as rapidly as the Lakewood test site because the inflow concentrations were quite different; the stormwater entering the Delaware test sites had much lower average event mean concentration of TSS than were found at the Lakewood site (i.e., 60 mg/l vs. 400 mg/l).

The Delaware filter was also larger in proportion to the tributary impervious area and had a larger storage volume above the filter, compared to the Lakewood facility. This suggests that adequately sized filters—those sized with maintenance frequency, appropriate upstream detention volume, and average annual runoff and TSS concentrations in mind—can perform well for longer periods than observed at the Lakewood site.

Lessons Learned

Filters can be popular stormwater practices where land area is at a premium, but they need regular maintenance to keep working effectively. Media filters, once clogged, will drain at very slow rates (i.e., falling head of approximately 1.2 feet per day) and stormwater will either pond upstream of the filter or bypass it.

To prevent this problem, it is necessary to properly size a filter for the expected maintenance cycle so that it matches both the average annual runoff volume and the average annual TSS runoff concentration. In order for the filter to keep working throughout the design event without backing up flow when it is partially clogged, the designer has to provide sufficient stormwater capture detention volume upstream of the device to match the filter’s clogged flow-through rate. As stated above, it is the capture and treatment percentage of all runoff events that is the real measure of stormwater practice performance, not just the removal efficiency for those storms that do not bypass a facility.

When a media filter is located within an underground vault, it is out of sight and out of mind. Such installations are far less likely to receive needed maintenance than more visible surface facilities. Unless regular inspection programs are in place, there is nothing to insure that the filter will continue to operate properly. A strongly implied lesson learned from the Lakewood field test is that undersized filters can seal, and, as a result, fail to process through as much volume or runoff as expected.

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