

Enhanced Biofilter Treatment of Urban Stormwater by Optimizing the Residence Time in the Media

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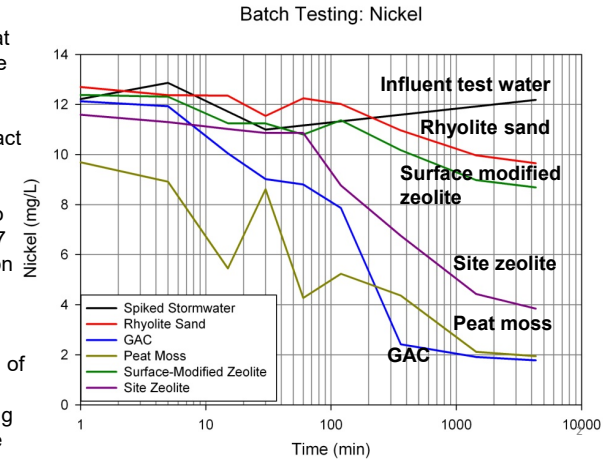
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Batch Testing Results: Contact Time

Minimal filtered metal removal observed for all media except peat when contact time <10 minutes.

The optimal contact times for filtered metals removal ranged from 10 to 1,000 minutes (17 hrs), depending on the metal and the media type.

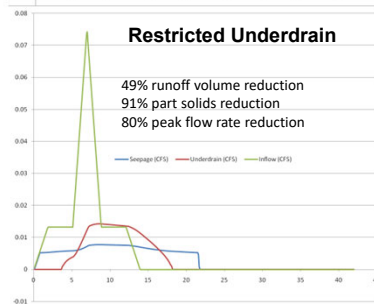
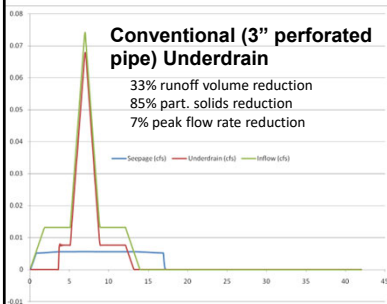
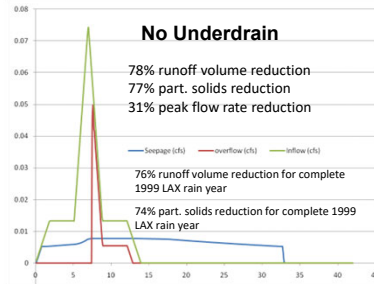
However too long of a contact time increased leaching losses from some media.



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Underdrain Effects on Water Balance

0.75 inch rain with complex inflow hydrograph from 1 acre of pavement. 2.2% of paved area is biofilter surface, with natural loam soil (0.5 in/hr infiltr. rate) and 2 ft. of modified fill soil for water treatment and to protect groundwater.



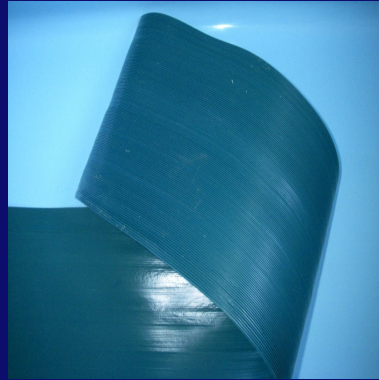
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- Outlet control can be more consistent in providing desired resident time for pollutant control.
- However, most outlet controls (underdrains) are difficult to size to obtain long residence times.
- Perforated pipe underdrains short-circuit natural infiltration, resulting in decreased performance (less runoff volume and peak flow rate reductions).
- Orifice outlet controls that allow long residence times usually are very small and clog easily.
- We are studying a foundation drain material (SmartDrain™) that can be applied to biofiltration devices and provide another option for outlet control.

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SmartDrain™ (<http://www.smartdrain.com/>)

- SmartDrain™ operates under laminar flow conditions (Reynolds number of 100 to 600); low sediment carrying capacity and reduced clogging potential.
- SmartDrain™ has 132 micro channels in an 8 inch wide strip; results in very small discharge rates.



Close-up photograph of SmartDrain™ material showing the microchannels on the underside of the 8 inch wide strip.

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Variables affecting the drainage characteristics of the underdrain material

A pilot-scale biofilter was used to test the variables affecting the drainage characteristics of the underdrain material:

- Length
- Slope
- Hydraulic head
- Type of sand media



A fiberglass trough 10 ft long and 2 x 2 ft in cross section used as the pilot-scale biofilter

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Experimental procedure

- The SmartDrain™ was installed on top of a 4" layer of the drainage sand, and another 4" layer of the sand was placed on top of the SmartDrain™.
- Flow rate measurements were manually taken from the effluent of the biofilter at 25 to 30 minute intervals until the water was completely drained from the trough.



SmartDrain™ installation in the drainage sand (it was unrolled before placement of the cover sand).

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Experimental procedure Cont.

- During the tests, the trough was initially filled with water to a maximum head of 22 inches above the center of the pipe and then allowed to drain, resulting in head vs. discharge data.
- A hydraulic jack and blocks were used to change the slope of the tank.



test for effect of length and slope on the drainage characteristics of SmartDrain™ material

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Experimental procedure Cont.

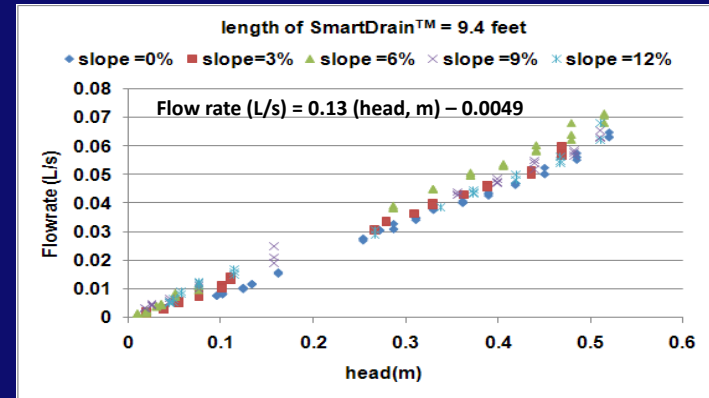
- The flows were measured by timing how long it took to fill a 0.5 L graduated cylinder.
- Five replicates for each of five different lengths of the SmartDrain™ (9.4ft, 7.1ft, 5.1ft, 3.1ft, and 1.1ft) and three to five slopes were examined to study the variables affecting the drainage characteristics of the material.



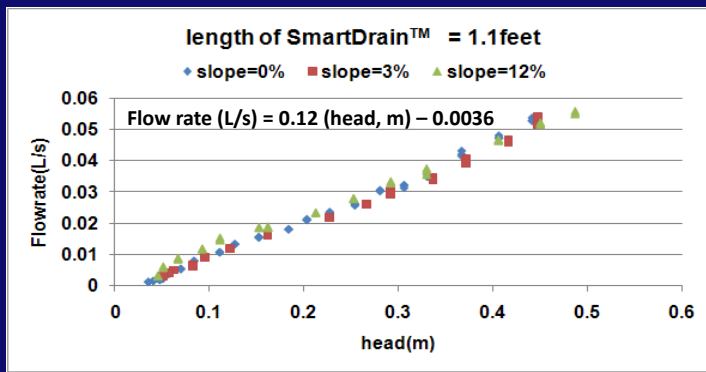
Flow rate measurement from effluent of the biofilter

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Slope tests on the SmartDrain™ material.



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Slope of the SmartDrain™ material had no significant effect on the stage-discharge relationship, whereas only a small effect of length of the SmartDrain™ material on the discharge was observed (operates similar to a series of very small orifices).

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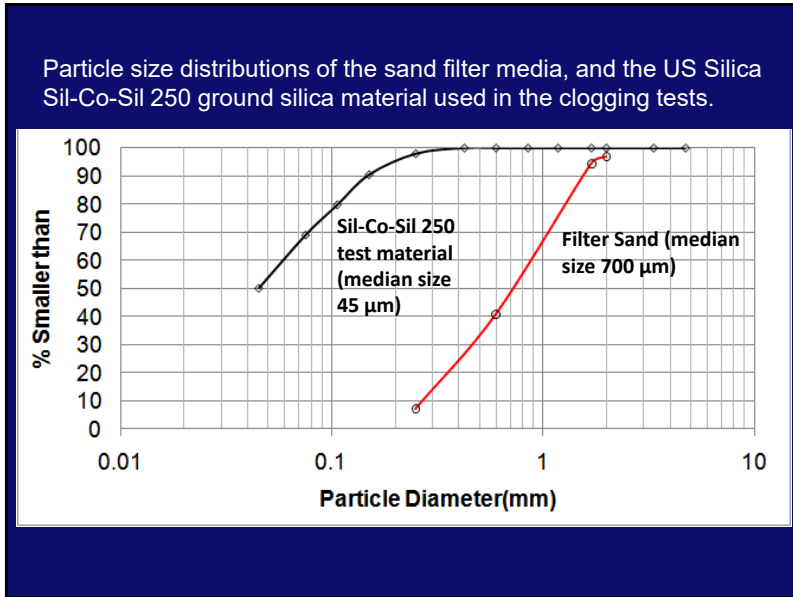
Examining the clogging potential of the SmartDrain™.

- A Formica-lined plywood box was used to verify the head vs. discharge relationships for deeper water and used for the clogging tests.
- The SmartDrain™ was installed on top of a 4" layer of the drainage sand, and another 4" layer of the sand was placed on top of the SmartDrain™.
- The box was filled with tap water to produce a maximum head of 4ft above the filter.
- Sil-Co-Sil 250 was mixed with the test water to provide a concentration of 1g/L (1,000 mg/L).

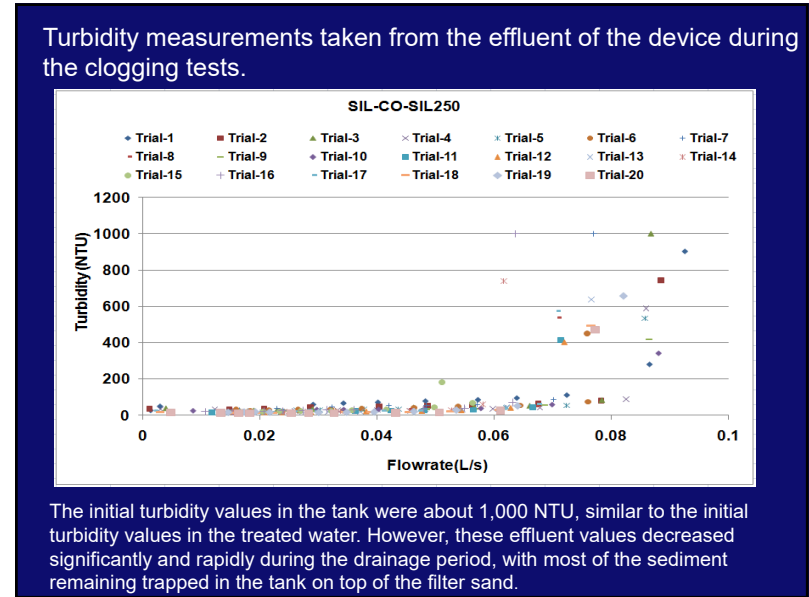


Formica-lined plywood box 3ft by 2.8ft. in cross sectional area and 4ft tall.

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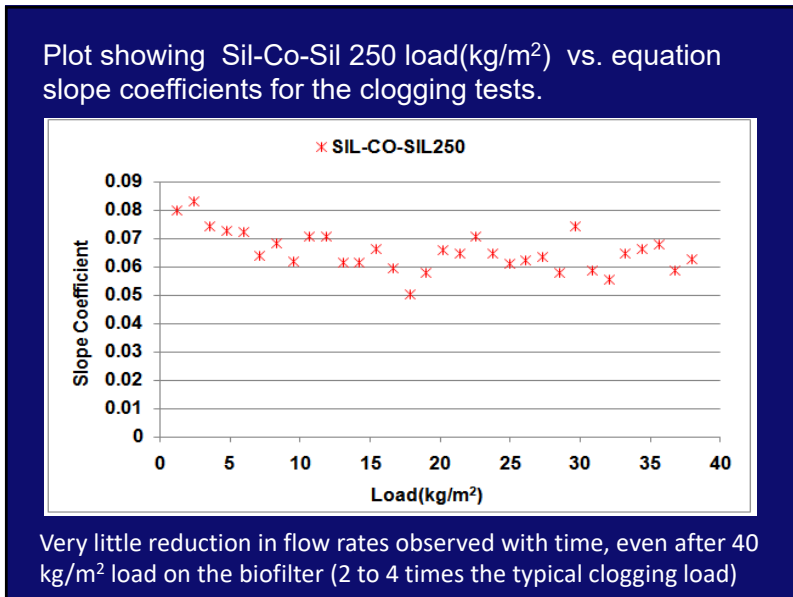


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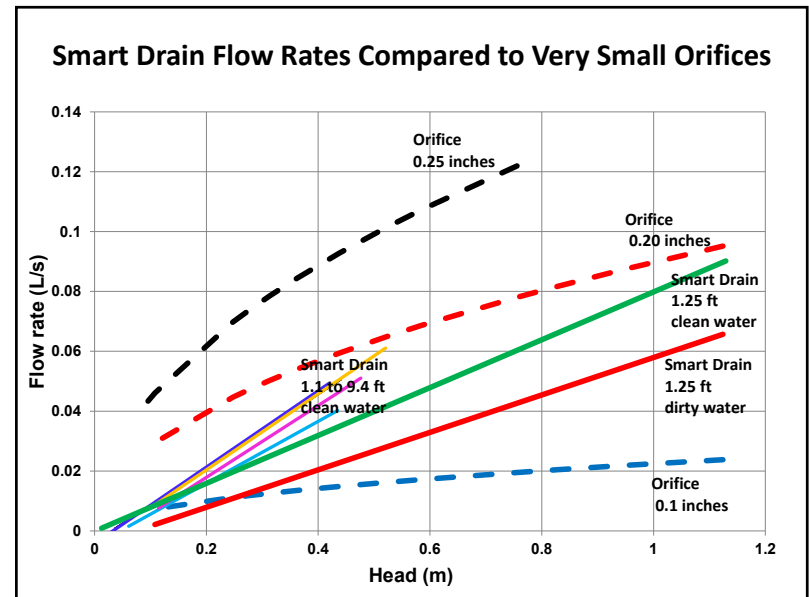
The initial turbidity values in the tank were about 1,000 NTU, similar to the initial turbidity values in the treated water. However, these effluent values decreased significantly and rapidly during the drainage period, with most of the sediment remaining trapped in the tank on top of the filter sand.

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Very little reduction in flow rates observed with time, even after 40 kg/m² load on the biofilter (2 to 4 times the typical clogging load)

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Biofilter Underdrain Options and Water Balance

- The sandy-silt loam soil results in extended surface ponding, requiring an underdrain (736 hours of rain per year; 44,500 ft³/acre discharged to biofilters per year).
- Conventional underdrain (3 inch perforated pipe) reduces ponding, but also decreases infiltration opportunities and decreases contact time with media.
- SmartDrain™ also reduces ponding time, while providing additional infiltration and increased media contact time.

Annual runoff (ft³/acre/year) and percentage fate:

	Surface ponding (hrs/year)	Infiltration volume	Surface discharge	Subsurface (filtered) discharge	Surface discharge reduction (%)
No underdrain	1,480	31,700 (72%)	12,800 (28%)	0 (0%)	72%
Typical 3 inch underdrain	530	17,200 (39%)	4,400 (10%)	22,900 (51%)	38%
SmartDrain™	1,080	26,300 (59%)	10,500 (23%)	7,800 (18%)	58%

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Biofouling Testing of SmartDrain™ Material

- The Formica-lined plywood box was also used to verify the head vs. discharge relationships for the biofouling tests.
- The SmartDrain™ was installed on top of a 4" layer of the drainage sand, and another 4" layer of the sand was placed on top of the SmartDrain™.
- The box was filled with tap water and left open to the sun for several weeks to promote the growth of algae. Two different species of algae were added to the test water.
- All-purpose liquid fertilizer was used to increase the growth of algae in the biofilter device.



growth of algae in the biofilter device

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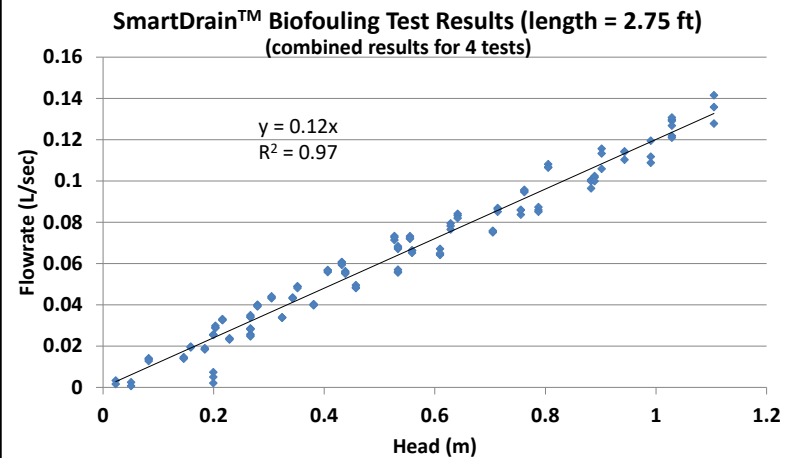
Biofouling Tests of SmartDrain™ Material

Turbidity values in the tank after several weeks ranged from 6 to 39 NTU, whereas effluent values were reduced to 4 to 7 NTU during the drainage tests.



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Stage-discharge relationships for the biofouling tests were very similar to the Sil-Co-Sil clogging test results.



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Conclusions

- The slope of the SmartDrain™ material had no significant effect on the stage-discharge relationship, while the length had only a small effect on the discharge rate.
- Effluent turbidity (NTU) measurements decreased rapidly with time, indicating significant retention of silt in the test biofilter.
- Clogging and biofouling of the SmartDrain™ material was minimal during extended tests.
- Our tests indicate that the SmartDrain™ material provides an additional option for biofilters, having minimal clogging potential while also providing very low discharge rates which encourage infiltration and allow extended media contact periods, compared to typical underdrains.