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Laboratory and Field Studies of Soil Characteristics of Proposed Stormwater Bioinfiltration Sites

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Stormwater Symposium 2012, Baltimore, Maryland.

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Introduction

- The performance of bioinfiltration facilities and other infiltration devices can be affected by factors such as texture, structure and degree of compaction of the media used during construction and the underlying soils.
- Large borehole infiltration tests were conducted in the Tuscaloosa area to compare with small surface infiltration measurements.
- Controlled laboratory column tests were also conducted to examine the effects of different compaction levels on the infiltration rates through the soil media obtained from the surface and subsurface of bioinfiltration test sites, along with benefits associated with mixing sand with the media mixture.

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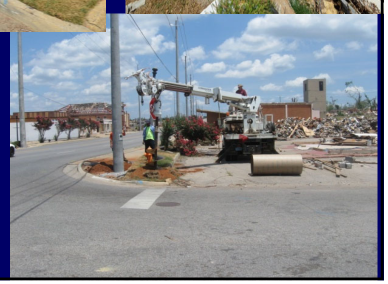
Soil media characteristics of proposed stormwater bioinfiltration construction sites

Laboratory and field-scale studies were conducted to provide information of the existing soil in areas which were severely affected by the April 27, 2011 tornado that devastated the city of Tuscaloosa, AL, and are undergoing reconstruction.



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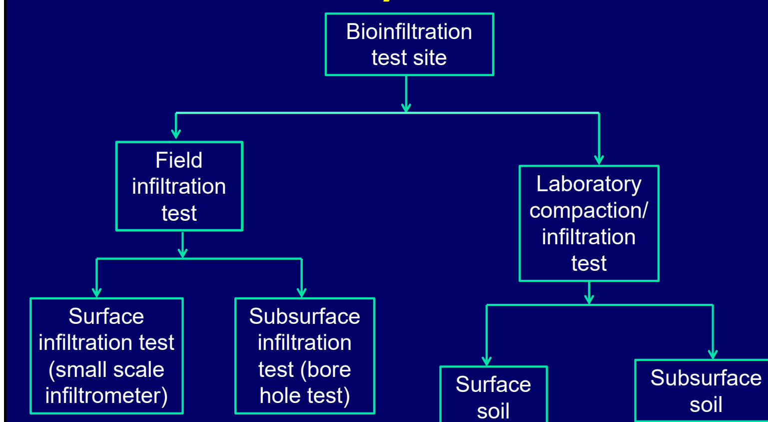
Stormwater bioinfiltration site studies comparing borehole with laboratory results



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Field surface and subsurface infiltration tests

- Surface double-ring infiltration tests and large bore hole infiltration measurements were conducted to determine the surface and subsurface infiltration characteristics.
- Controlled laboratory column tests were also conducted on surface and subsurface soil samples under the three different compaction conditions.

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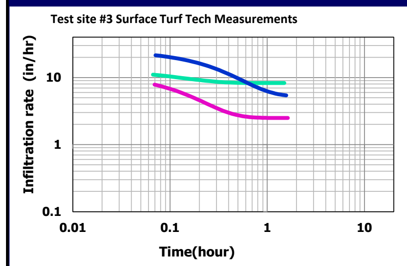

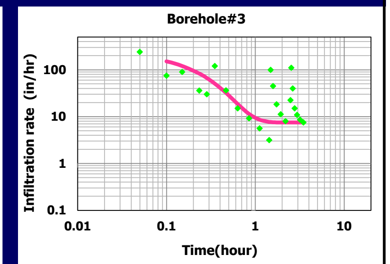

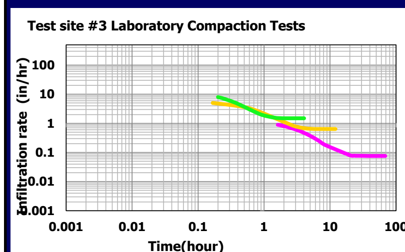

Test methods resulted in varying results; in this case, the soil at the bottom of the borehole was not compacted and had higher infiltration rates than the compacted surface soil.

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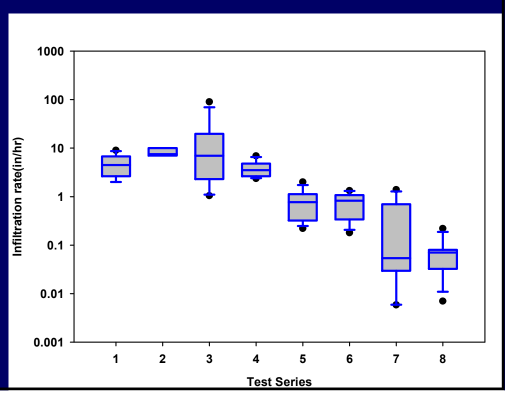
Summary of surface, subsurface, and laboratory infiltration data for the proposed bioinfiltration sites

Box and whisker plots comparing saturated soil infiltration rates (in/hr). Test series descriptions (12 replicates in each test series except for the borehole tests which only included 3 observations):

1. Turf-Tec small double ring infiltrometer (compacted surface soils)
2. Pilot-scale borehole infiltration tests (uncompacted subsurface soils)
3. Surface soil composite sample with hand compaction
4. Subsurface soil composite sample with hand compaction
5. Surface soil composite sample with standard proctor compaction
6. Subsurface soil composite sample with standard proctor compaction
7. Surface soil composite sample with modified proctor compaction
8. Subsurface soil composite sample with modified proctor compaction



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Summary of *in-situ* surface soil density measurements at the proposed bioinfiltration sites

	Horton's parameter			
Location	f_o(in/hr) mean	f_c(in/hr) mean	k(1/min) mean	Dry density (g/cc)
Test site #1	10	4	0.15	1.88
Test site #2	7.2	4	0.12	1.66
Test site #3	16.5	5.3	0.10	1.61
Test site #4	24	7	0.06	1.66

General relationship of soil bulk density to root growth on soil texture (USDA Natural Resources Conservation Service)

Soil Texture	Ideal bulk densities for plant growth (g/cm^3)	Bulk densities that restrict toot growth (g/cm^3)
Sandy	<1.60	>1.80
Silty	<1.40	>1.65
Clayey	<1.10	>1.47

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Laboratory column tests

- The effects of different compaction levels on infiltration rates using soil samples obtained from the surface and subsurface of the proposed bioinfiltration sites were examined with column tests.

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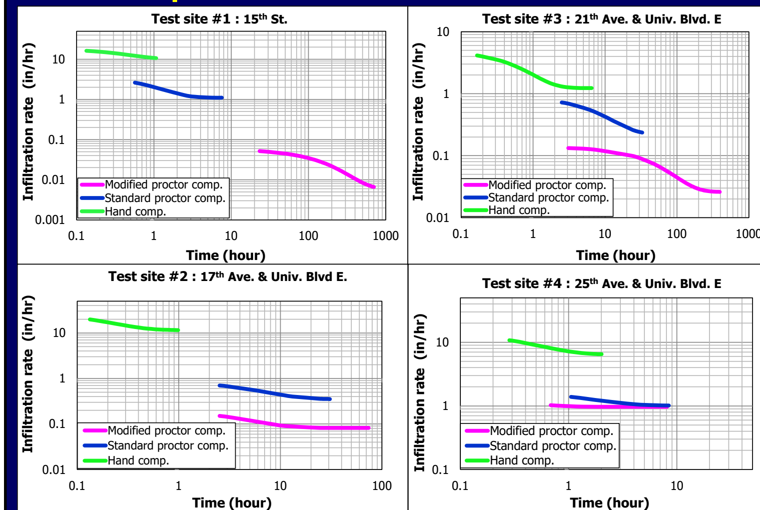
Summary of lab surface soil infiltration test data fitted to Horton's equation.



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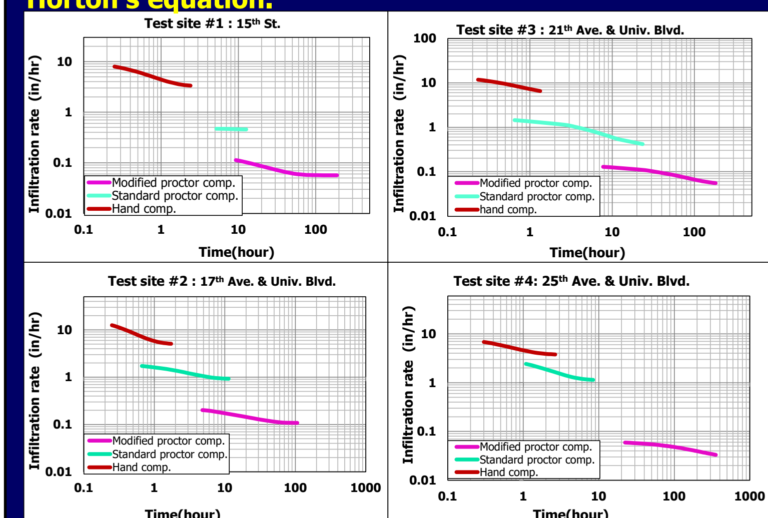
Summary of lab subsurface soil infiltration data fitted to Horton's equation.



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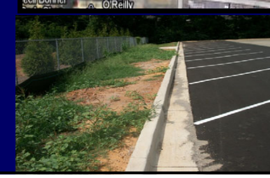
Field and laboratory studies at existing poorly-functioning biofilter

- The biofilter facility is located in Shelby Park, adjacent to The Univ. of Alabama rental car parking lot from which it receives flow.
- The biofilter is about 300 ft long and 30 ft wide (0.21 acres) and is about 11% of the paved and roofed source area.



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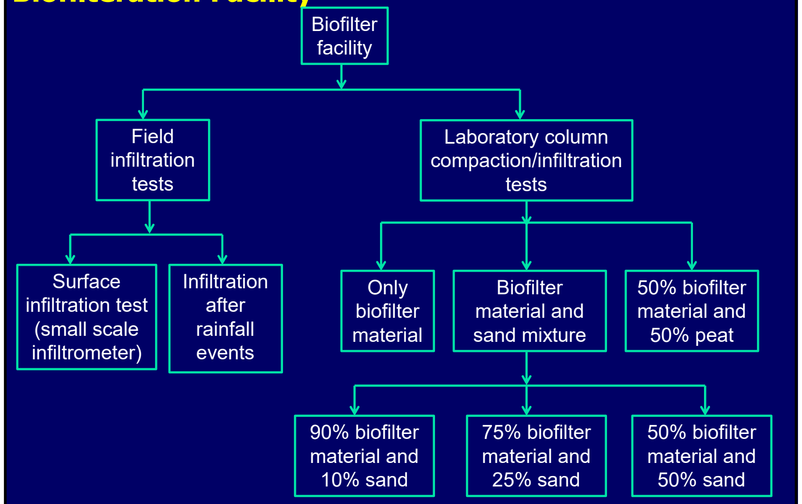
Field and Lab Infiltration Study of Poorly Functioning Biofilteration Facility



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Field infiltration tests

- Four clusters of three Turf-Tec infiltrometer tests were conducted along the biofilter to examine variations along the biofilter length.
- The biofilter media was classified as sandy clay loam, with 20% clay and 80% sand (3% organic matter content).

Very little “bio” in this biofilter, indicating compacted media having adverse affects on plant growth.

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In-situ density measurements of biofilter media

- A small hole about 6 in. deep and 6 in. wide was hand dug and the soil brought to the lab for analyses.
- Sand was then poured into the hole from a graduated cylinder to measure the volume of the excavation.
- The moisture, mass, texture, and the density of the excavated media were determined.

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Summary of *in-situ* soil density measurements

Shelby Park biofilter media characteristics (sandy clay loam)

Test locations	Median size D_{50} (mm)	Uniformity coefficient (C_u)	Bulk density (g/cm³)
1	3	37.5	2.18
2	0.5	17	2.32
3	0.32	5.56	1.8
4	0.73	n/a	2.05

General relationship of soil bulk density to root growth on soil texture (USDA Natural Resources Conservation Service)

Soil Texture	Ideal bulk densities for plant growth (g/cm³)	Bulk densities that restrict toot growth (g/cm³)
Sandy	<1.60	>1.80
Silty	<1.40	>1.65
Clayey	<1.10	>1.47

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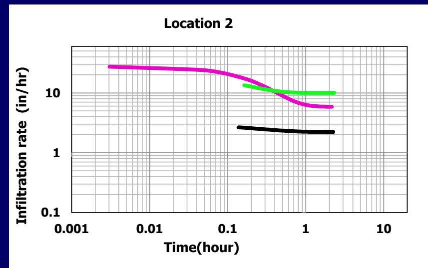
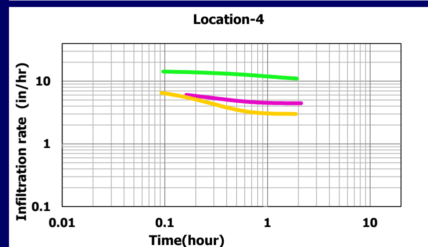
Field infiltration test results

- The average initial infiltration rates during the Turf Tec field tests were about 11 in/hr (280 mm/hr), and ranged from 3 to 28 in/hr (75 to 710 mm/hr).
- The final rates had an average value of about 4.6 in/hr (115 mm/hr), and ranged from 1.5 to 10.5 in/hr (38 to 270 mm/hr), indicating non-compacted surface soils





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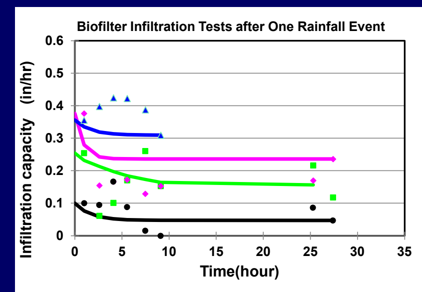
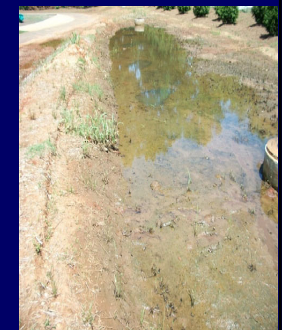
Infiltration after rainfall events

- Extended periods of surface ponding of water was often observed following heavy rains.
- Infiltration rate measurements were manually recorded from ponded areas after five rains





Extended ponding of water in low area of biofilter after rain.

These very low values were about equal to the observed laboratory tests conducted under the most severe compaction conditions (the modified proctor compaction tests).

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Laboratory column tests

- The effects of different compaction levels on infiltration rates, along with benefits associated with adding sand to the media mixture, were examined with column tests

Compaction	f_o (in/hr)	f_c (in/hr)	K (1/min)
Modified Proctor Compaction; density 1.96 g/cc	0.39	0.26	0.001
Standard Proctor Compaction; density 1.66 g/cc	0.99	0.81	0.010
Hand Compaction; density 1.54 g/cc	6.20	4.09	0.0363

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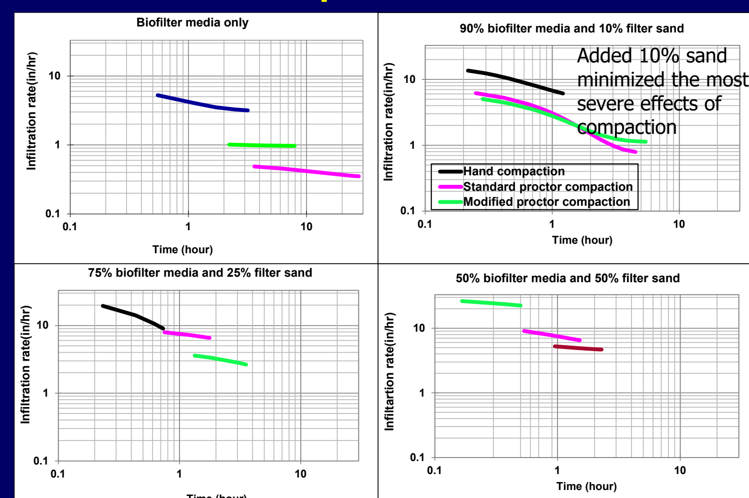
Summary of field and lab. infiltration data fitted to Horton's equation.



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Conclusions

- Small-scale infiltrometers work well if surface characteristics are of the greatest interest. Large-scale (deep) infiltration tests would be appropriate when subsurface conditions are of importance (as in bioinfiltration systems and deep rain gardens).
- Adding sand to a media having large fractions of silt and clay-sized particles helps minimize the detrimental effects of compaction on the infiltration rates.
- Soil compaction has dramatic effects on the infiltration rates; therefore care needs to be taken during stormwater treatment facilities construction to reduce detrimental compaction effects.
- Current tests are focusing on a wide range of sands (with organic amendments) to determine their flow characteristics when used in biofilters.

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