Mesocosm Testing Protocol
for Bioretention Soil Media Testing

1. Introduction

A mesocosm is an experimental tool that integrates relevant structure and functions of existing or proposed site conditions into a controlled laboratory environment. For purposes of this testing protocol, mesocosms are assembled with a specific soil media profile (i.e. gravel, sand, bioretention soil media (BSM), and shredded hardwood mulch) to assess how the soil profile will function in a full scale bioretention facility under varying conditions. These mesocosms can be utilized to mimic field conditions through exposure to multiple falling head filtration tests that include drying periods of various durations between the tests to simulate multiple rain events. It is recommended that replicate tests on multiple mesocosms be conducted simultaneously in order to capture the range of the variability in the media's filtration rate normally encountered in the field.

If facilities are constructed near roadways or other surfaces that may potentially be treated with de-icing road salt (NaCl), at least one testing cycle should include a road salt brine solution. Sodium (Na) is known to disperse organic matter, silts, and clays and slows infiltration rates when introduced to the media intermittently between freshwater flushes. It therefore has the potential to significantly reduce the filtration capacity of the facility (i.e. reduction of up to 90% has been observed in such tests).

This test is a measure of the overall bowl recession rate (i.e. rate at which the ponded water recedes into the soil). Under saturated conditions, this rate will equilibrate and closely approximate the saturated hydraulic conductivity (k_{sat}) of the soil media. As presented, this test is repeatable and reflects what users will observe in the field.

The remainder of this document outlines the procedures that should be followed in order to construct the mesocosm apparatus, perform the tests, and to analyze/summarize the data.

2. Mesocosm Soil Profile

2.1. Typical Soil Media Profile

Below is the standard typical mesocosm soil profile that shall be used for this testing protocol, unless other design specifications are provided. Refer to Section 2.2 if a specific bioretention facility design is to be used.

6” Design ponding depth
3” Shredded hardwood mulch
36” Bioretention soil media (BSM)
6” ASTM C33 coarse sand
2” Washed VDOT #8 choker stone
8” Washed VDOT #57 aggregate
Rebar grate supporting hardware cloth (See Section 3.1 for specifications)

2.2. Site Specific Mesocosm Soil Profile

If a specific bioretention facility design is to be tested, the typical section provided in Section 2.1 should be revised to match. This will require the following design information be obtained in order to ensure the proper elements are tested:

- Bioretention soil media (BSM) design specifications and depth
- Filter fabric type and brand, if any (Note: Sometimes filter fabric is used in lieu of a gap graded sand/gravel filter. In such cases, the fabric is wrapped on the bottom of the column and held in-place with steel band clamps.)
- Sand and aggregate class sizes and depths, if specified beneath the soil media

3. Required Materials for a Single Mesocosm Test

3.1. Apparatus (Refer to Appendix 1)

- Mesocosm stand
- 12" diameter tube (PVC or clear acrylic), minimum length shall accommodate all media layers of bioretention facility, ponding depth, and 4" for installation of rebar grate at base
- 12" rubber Fernco fittings, as necessary
- Rebar grate to support mesh hardware cloth (required to hold media in-place)
    - Rebar grate: 3-12" lengths of #4 rebar at 3.3" on center (o.c) overlaid and welded with 2-12" lengths of #4 rebar at 4.5" o.c. to create a grid
    - Hardware cloth: 23 gage, galvanized wire with 1/4" mesh opening
- Scale
- Duct tape
- 5 gallon bucket
- Contractor trash bag

3.2. Filter Fabric, Aggregates, and Soil Media (per Section 2)

- Gap-graded sand/gravel filter (i.e. choking layer)
  - ASTM C33 coarse sand
  - #8 choker stone
- #57 aggregate
- BSM or individual components of BSM to manually mix (e.g., sand, soil, organics)
- Shredded hardwood mulch
- Other media or filter fabric[1] as prescribed in design specifications.

Note: All materials shall be obtained from proposed supplier.

3.3. Additional Materials

- Road salt (NaCl) brine solution (i.e. if potential exposure to road salt deicing, See Section 5)
- Hose with mist/spray nozzle attachment
- 12" diameter foam circle with string attachment, at least 1" thick
- Stopwatch
- Record keeping materials

4. Apparatus Set-up

4.1. Secure PVC tube(s) in mesocosm stand with a 5-gallon bucket installed underneath to collect water (Appendix 1). A plastic apron, such as a contractor trash bag, may be attached to the bottom of the PVC tube to guide water into the 5-gallon bucket. An alternate method for securing mesocosms may be employed such that it sufficiently secures the tubes and allows water to flow through unimpeded.

4.2. Install rebar grate and hardware mesh at base of PVC tube (Appendix 1). Grate and mesh shall be installed such that aggregate and media remains in-place without impeding flow.

[1] *Filter fabric is not included in the provided 'typical' standard mesocosm profile. Obtain a minimum 2.5'x2.5' sample for each mesocosm if fabric is specified in the design plans. (Note: If the fabric is not appropriately selected for the BSM particle size distribution clogging can occur, which will likely be observed after repeated tests in the facility.)*

4.3. Fill mesocosms from the bottom up with specified depth of aggregates[2] - #57 aggregate and gap-graded sand/aggregate filter (i.e. choking layer).

4.4. Install BSM in 12" lifts with hydraulic compaction of each lift. Use a flat shovel, or comparable, to smooth each layer (i.e. lift) of media prior to installing additional lifts, as described below:

a. Fill the mesocosm with 12 inch depth of BSM for the first lift, and then use a string to lower the 12" diameter foam circle to rest flat on the top of the BSM. Use the hose with the sprinkler nozzle to sufficiently saturate the lift (e.g., water covers the foam pad and water drips from the bottom of the mesocosm)[3].

b. Prior to installing additional lifts, allow water to drain through the media so that there is no standing water on the surface after the foam is removed. Continue to fill the mesocosm with the additional 2-12" lifts, saturating in between.

c. Re-measure soil media depth. If the depth of soil media has been reduced, add additional soil media to regain the 36" BSM depth and hydraulically compact as noted in Section 4.4.a, b.

4.5. Install shredded hardwood mulch (optional).

4.6. After all medias are in-place, attach a scale to the inside wall of the column. A reading of zero on the scale should correspond to the top of the mulch to represent the ponding depth.

[2] *In most bioretention facilities the base layer of aggregate is installed as a water retention basin to store water in the pore spaces between the aggregate that has drained through the facility. Over time water is slowly released through a controlled drain opening or into the natural subsoil layers. Depth of these layers can vary drastically from a few inches to several feet. If aggregate storage is proposed, a minimum depth of 6"shall be used in the mesocosm to mimic the field conditions and limit the mesocosm to a manageable height. Aggregate base layers will not impede flow, or alter overall infiltration rate, thus, not required for this test.*

[3] *The sprinkler head and foam circle act as a dissipater to prevent water from separating the fine particles from the soil media and creating a layering of grain sizes as the water draws down. The hardwood mulch top layer will provide similar protection once installed in the mesocosm and in the actual, full scale facility.*

5. Testing Procedures

The general testing procedure is to fill water to the 6" or as otherwise specified design ponding depth and to measure incremental and overall drawdown of multiple cycles after varying drying times[4]. A saltwater brine solution shall be substituted for a minimum of one cycle if the bioretention facility will be exposed to road salt[5].

The step-by-step procedure is as follows:

5.1. Use a sprinkler head attachment on a hose to gently spray water evenly down into the mesocosm until the water level reaches desired maximum ponding depth.

5.2. Record the time when the 6" ponding depth is obtained. Continue recording incremental time and depth measurements until the ponding depth is zero. Generally, a measurement interval that results in a minimum 0.25" drop in head is sufficient (i.e., if the soil drains 0.25" in 30 minutes, measurements may be taken every 30 minutes or less). Be aware, however, that soil particle interaction may speed or slow the filtration rate without warning.

5.3. Once the water has completely penetrated the soil media surface (i.e., water level is at zero), take a final time measurement.

5.4. Repeat Steps 5.1 through 5.3 to perform the second cycle immediately after the first water cycle is complete.

5.5. After the second cycle, allow the mesocosm apparatus to completely drain of water (either through the base of the apparatus or through the underdrain) and dry for a minimum of 36 hours. Then repeat steps 5.1 through 5.3 for the third water cycle.

[4] *Drying periods between cycles allows the mesocosm apparatus to completely drain of water. This simulates a typical wet/dry cycle that would be seen in a natural environment and confirms if there is a multiple event scenario that may cause performance degradation.*

[5] *Road salt brine shall be prepared by mixing approximately 2.5 kg of road salt into 14 liters of freshwater (i.e. a saturated solution at room temperature).*

5.6. Test cycles shall be performed as follows:

Table 1. Recommended Testing Cycles

Cycle 1 - Freshwater
Cycle 2 - Freshwater
36 hour Drying Period (minimum)
Cycle 3 - Saltwater Brine Solution [1]
Cycle 4 - Freshwater
96 hour Drying Period (minimum)
Cycle 5 - Freshwater
Cycle 6 - Freshwater
36 hour Drying Period (minimum)
Cycle 7 - Freshwater
Cycle 8 - Freshwater

[1] *Potential exposures to road salt (NaCl) from de-icing of roads or other surfaces within the proposed drainage area may affect filtration (See Section 1) and should be tested. If road salt (NaCl) exposure is expected, then a minimum of 1 testing cycle shall use a salt water brine solution. The effect of the brine solution is not immediate, so it should be tested in Cycle 3 to allow sufficient time for it to take effect.*

6. Success Criteria

Mesocosm filtration test results of BSM are considered acceptable when the mean overall infiltration rate for each cycle is between 1 and 8 in/hr. If the rate from any particular cycle is outside this acceptable range, but returns to within the acceptable range during the following cycle or after a drying period and, the overall mean infiltration rate from all cycles is within range, then the BSM shall still be considered acceptable.

7. Results

Results shall be summarized and reported as follows:

- Cycle Data. Data for each wet cycle shall be recorded in the blank Cycle Data Worksheet provided as Appendix 2a. Data will include time, elapsed time, depth, and incremental infiltration rate. Overall infiltration rate shall also be included.

- Mesocosm Test Result Summary. Once all wet/dry cycles are done, the summary table and graph as provided in Appendices 2b and 2c, shall be completed. This summary reports the overall infiltration rate of each cycle, along with BSM composition, media depths and sources, wet cycles (i.e. road salt brine (Na) or freshwater), and length of drying cycles. The accompanying graph shall also be prepared to illustrate any variability. If multiple mesocosms are tested, a report may be compiled using these summary sheets.

- Summary of Multiple Mesocosms. When comparing results from multiple mesocosms, a bar graph with error bars shall be used to illustrate level of variability (Appendix 2d).

8. List of Appendices

Appendix 1. Mesocosm Apparatus
Appendix 2. Blank Forms

Appendix 1. Mesocosm Apparatus

Figure 1. Example mobile mesocosm apparatus for three (3) mesocosm tubes. Five (5) gallon buckets are installed underneath to collect water draining from mesocosms.

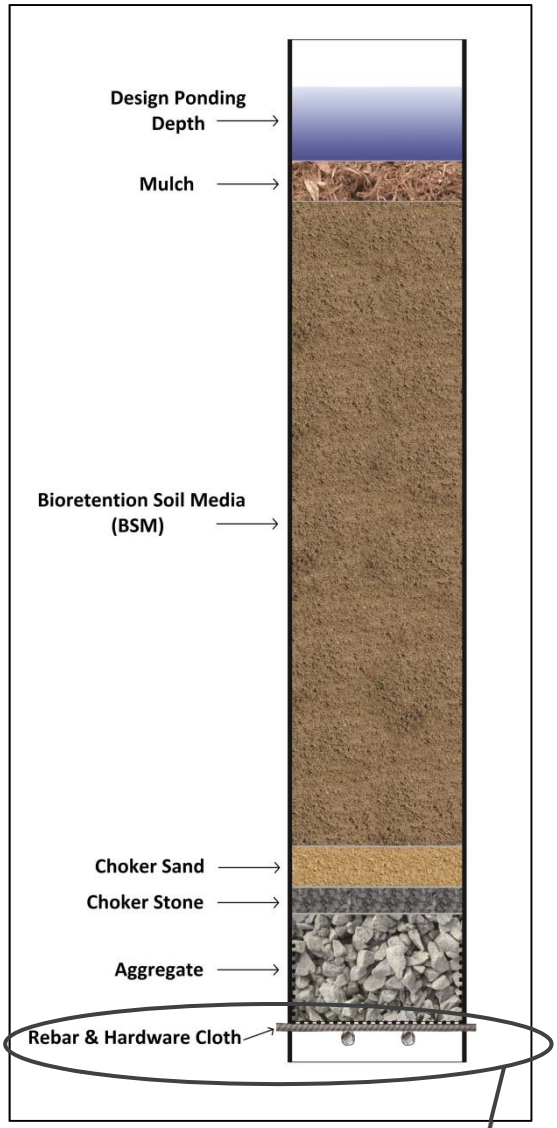

Figure 2. Typical Mesocosm Profile

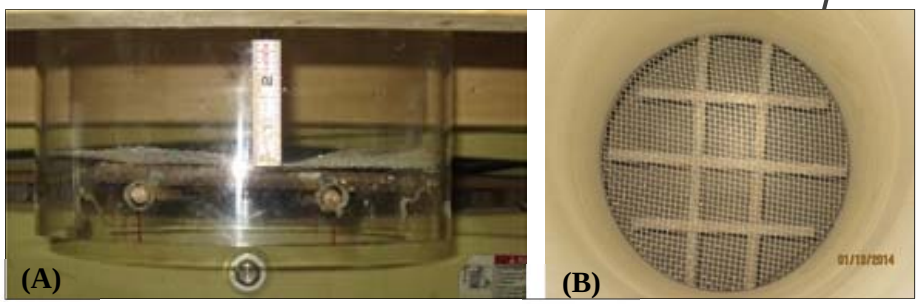

Figure 3. Rebar grate & hardware mesh (A) looking at holes drilled into clear pipe to secure grate (B) view of grate and mesh from top of mesocosm tube.

Appendix 2. Blank Forms

Appendix 2a. Example Cycle Data Worksheet

Date:	mm/dd/yyyy	**Start Time:**	HH:mm
Test Number:	1, 2, 3, etc.	**End Time:**	HH:mm
Performed By:			

Media Source:	Example Company, Inc.
Media Depth (in):	36
Flood Depth (in):	6

Time	Interval Time (hrs)	Elapsed Time (hrs)	Depth (in)	Infiltration Rate (in/hr)
6:19 AM	0	0.00	**6**	
6:34 AM	0.25	0.25	3	--
6:49 AM	0.25	0.50	0.25	11.00
6:52 AM	0.05	0.55	0	5.00

Overall Infiltration Rate (in/hr):	**10.91**
Infiltration Rate Acceptable?	**Yes**

Appendix 2b. Example Mesocosm Test Result Summary

Sample XYZ
Example Test #

Results Summary:

Cycle Number	Date	Overall Infiltration Rate (in/hr):	Infiltration Rate Acceptable?
Cycle 1	2/19/2014	10.9	Yes
Cycle 2	2/19/2014	3.8	Yes
36-hour Drying Period [2]			
Cycle 3	2/21/2014	7.5	Yes
Cycle 4	2/21/2014	4.2	Yes
96-hour Drying Period [2]			
Cycle 5	2/23/2014	5.1	Yes
Cycle 6	2/23/2014	2.4	Yes
36-hour Drying Period [2]			
Cycle 7	2/25/2014	0.9	No
Cycle 8	2/25/2014	1.0	Yes

Minimum Infiltration Rate:
1-2 inches/hour

Soil Media Composition [1]:
X% Sand
X% Topsoil
X% Organic Matter

Fresh Water Cycles
Salt Water [3] Cycles

[1] Media obtained from Example Company on DATE.

[2] Drying periods between cycles were used to allow the mesocosm apparatus to completely drain of water. This simulates a typical wet/dry cycle that would be seen in a natural environment.

[3] Road salt was collected from Example Company (Town, VA) on DATE. Salt was mixed at a concentration of 2.52 kg of road salt into 14 liters of water to make brine solution.

Mesocosm Profile:

Material	Depth	Source
Ponding Depth	6"	Example Company, Inc
Mulch	3"	Example Company, Inc
Soil Media	36"	Example Company, Inc
Coarse Sand	3"	Example Company, Inc
Choker Stone (#8)	2"	Example Company, Inc
Aggregate (#57)	8"	Example Company, Inc

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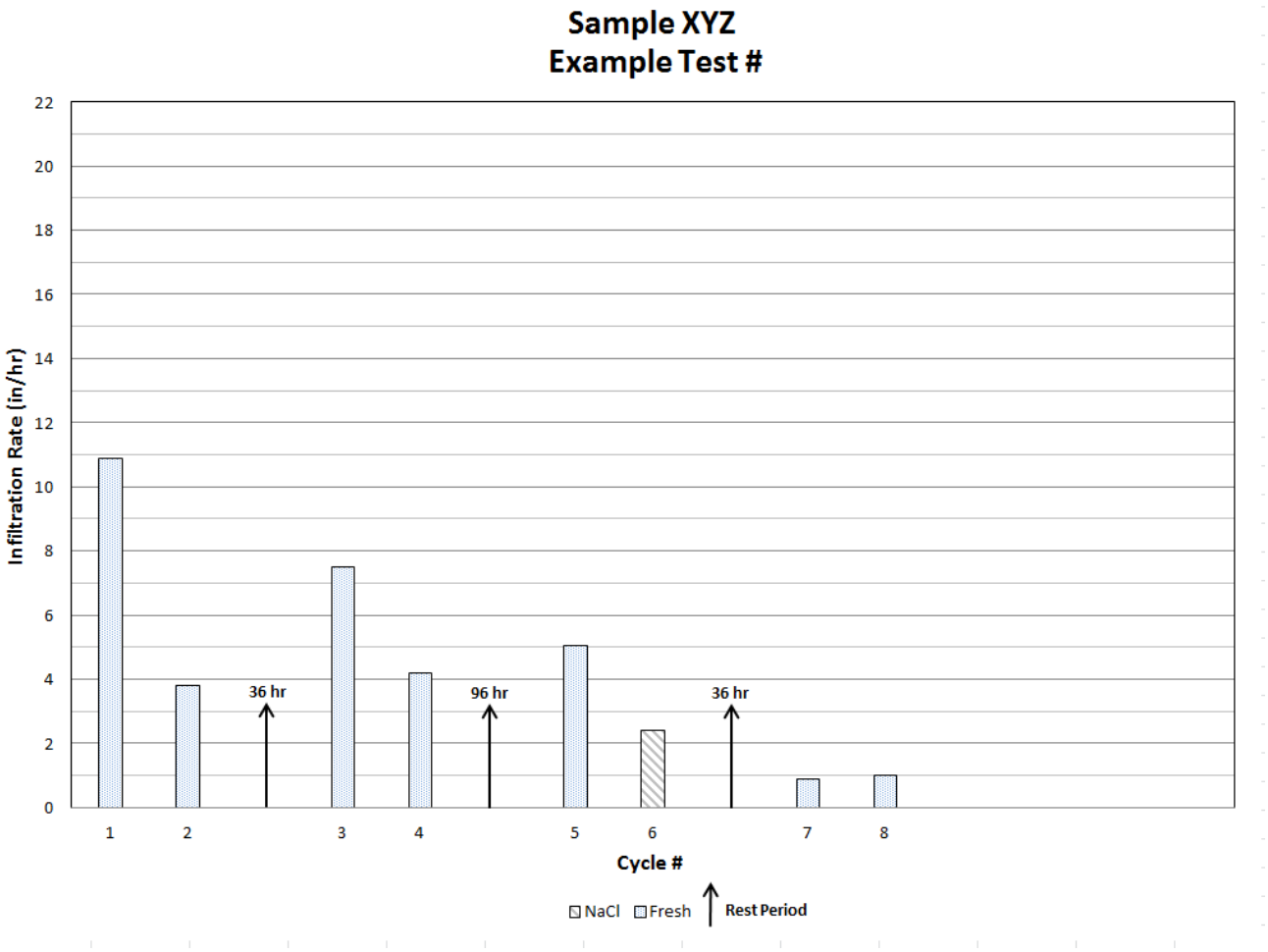
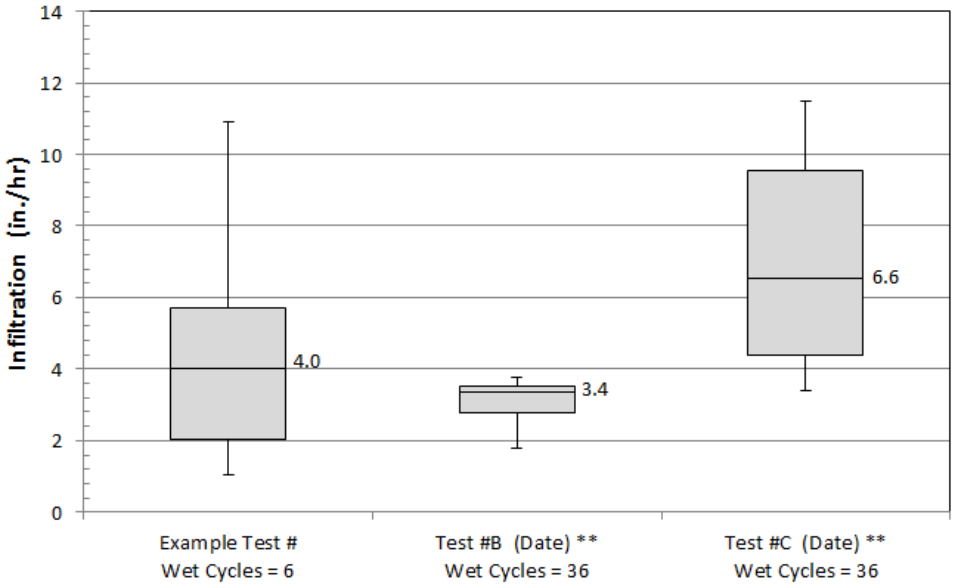
Appendix 2c. Example Mesocosm Test Result Summary Graph



Appendix 2d. Example Overall Summary Graph

Sample XYZ

Overall Summary *



* On the graphs, the gray boxes represent the middle 50% of each data set, as measured by the upper and lower quartiles. The median value is labeled and identified as the thin line in each gray box.

** Refer to the report dated DATE for Test #B and Test #C results. Results are provided herein for comparison only to testing that is presented in this report.

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