Aspect CONSULTING

MEMORANDUM

Project No.: 080080

January 10, 2012

To: Shanti Colwell, Seattle Public Utilities

cc: Claire Gibson, Seattle Public Utilities Materials Laboratory

From:

J. SCOTT KINDRED
STATE OF WASHINGTON
27425
REGISTERED
PROFESSIONAL ENGINEER

1/10/12

J. Scott Kindred, PE
Associate Water Resources Engineer

Re: **Recommended Modification of the ASTM D2434 Procedures for Permeability Testing of Bioretention Soils**

The purpose of this memorandum is to recommend modifications of the City of Seattle's current procedures for testing the permeability of bioretention soils. These modifications are needed to provide more consistent testing results for bioretention soils used in the City's green stormwater infrastructure (GSI) facilities.

Background

Bioretention soils are used in raingardens and other green stormwater infrastructure (GSI) facilities to filter contaminants from stormwater and provide a plant growing media. Specifications for bioretention soil have typically included prescriptive requirements (percent organics, cation exchange capacity, grainsize) and performance requirements (permeability). Experience on past projects has demonstrated that laboratory testing of the same bioretention soil can often provide a wide range of permeability results.

The current permeability testing method, ASTM D2434 Standard Test Method for Permeability of Granular Soils, is more appropriate for mineral aggregate material than soils that contain appreciable organics. Organic soils tend to swell when mixed with water and are sensitive to compaction, which can cause variability in test results. As a result, the City of Seattle has identified a need for changes to the standard permeability testing procedures to provide more consistent and reliable results. Aspect Consulting, LLC (Aspect) was retained to conduct two workshops with local soil testing laboratories, have each of the laboratories conduct permeability testing, and develop recommendations for modifications to the standard permeability testing procedures that would provide more consistent results.

This memorandum summarizes the results of the workshops and soil testing and presents our recommendations for revisions to the standard permeability testing procedures.

Description of Workshops

Five private local laboratories that routinely perform bioretention soil permeability tests were invited to participate in the workshops and testing. These firms were Associated Earth Sciences (AESI), GeoEngineers, GeoTest, HWA Geosciences (HWA), and Shannon & Wilson. Seattle Public Utilities (SPU) and their Materials Laboratory also participated in the process. The first workshop was held with SPU and the laboratories group to determine what issues or concerns they currently have regarding the ASTM standard method, and to discuss proposed modifications that would address those issues. The most significant testing issues identified were: soil compaction, soil swelling, soak time, and permeability testing apparatus.

Based on these discussions, proposed modifications to the permeability procedure were developed and used by the laboratories to test samples of bioretention soil. Following submittal of the testing results using the modified procedure, a second workshop was conducted to report and discuss the permeability testing results and propose additional modifications to the testing procedures.

Characteristics of Tested Bioretention Soil

Following completion of the first workshop, each laboratory was given approximately 5 to 7 gallons of bioretention soil from the same batch provided by Cedar Grove Composting, a local supplier of bioretention soil. Cedar Grove Composting produces this material by mixing a controlled grade of sand aggregate with compost. Cedar Grove Composting has test results on file for the sand aggregate, the compost, and the bioretention soil, which are provided in Appendix A. The sieve analysis results for the sand aggregate are summarized in Table 1 and shown on Figure 1.

Table 1 – Grainsize Distribution of Sand Aggregate Used to Produce Bioretention Soil

Sieve Size	Percent Passing (% by weight)
1 inch	100.0
#4 (0.187 inch)	99.6
#10 (0.0787 inch)	87.6
#40 (0.0165 inch)	34.3
#200 (0.0029 inch)	1.9

Description of Bioretention Soil Testing Procedures

In addition to permeability testing, a number of soil tests were conducted to characterize the soil samples and document the degree of variability between the samples provided to each lab. These tests are listed below:

- Grainsize analysis;
- Moisture content;
- Organic content;
- Soil moisture-density relationship (modified Proctor) test;

- Permeability test.

The first three tests provided information regarding the soil constituents. The Proctor test was necessary to quantify the degree of compaction for the permeability test.

Grainsize Analysis Test

The grainsize analysis is a laboratory method to determine the particle size distribution of soil. The ASTM D422 method consists of placing a soil sample in a stacked column of sieves with screens or mesh sizes from largest (No. 1 sieve) to smallest (e.g. No. 200 sieve). The soil is dried and agitated, usually in a mechanical shaker, to move particles through the sieves. After the soil sample has been agitated, the sample remaining on each sieve is weighed and the percent of the total soil sample that passed through the sieve is reported. As agreed during the first workshop, all grainsize analyses were performed on bioretention soil samples that had been burned to minimize the organic matter remaining in the sample.

Moisture and Organic Content Tests

Moisture content and organic content of the received soil samples was measured using ASTM D2974. Moisture content was measured to document the condition of the soil when it was received by the laboratory. The amount of organic matter in a soil can influence the soil compressibility and compaction, water holding capacity, and permeability. Moisture content is measured by drying the soil at a temperature of 105° C. The weight of the sample before and after drying is measured and the difference represents the moisture content of the sample. Organic content is determined by weighing the dry soil, then burning it at 440° C. The remaining soil is weighed, with the lost weight representing the oxidation of organic matter to inorganic ash. Typical organic content values for bioretention soils are 4 to 10 percent.

Moisture-Density Relationship (Proctor) Test

The ASTM D1557 moisture-density relationship (modified Proctor) method is a laboratory compaction test performed to determine the optimal soil moisture required for the soil to achieve its maximum dry density. It is the most commonly used method in Washington State for determining the relationship between soil moisture and soil density.

The ASTM D1557 Proctor testing method provides procedures for three different methods for determining MDD. Which method should be used depends on the grainsize distribution of the sample. Methods A and B use a 4-inch mold and are intended for fine-grained soils, whereas Method C uses a 6-inch mold and is typically intended for coarser-grained soils. All the laboratories used Method A or B (which only differ regarding what size gravels are removed from the sample before testing) although GeoEngineers and AESI also performed Proctor tests using Method C.

These tests are performed by compacting a soil with known moisture content into the cylindrical mold using a specified procedure to place and compact the sample. Soil is placed in the mold in layers of equal thickness, with each layer receiving a specified number of blows from a standard weighted hammer dropped from a specified height. This procedure is repeated at several different soil moisture contents, and later the dry densities are determined for each test. A compaction curve is plotted showing the graphical relationship between the dry density and the moisture content. The graph is usually in the form of a curve with at least three moisture-density points. The peak of the curve is defined as the MDD and optimal moisture content for compaction of the soil.

Standard Permeability Testing Method

The ASTM D2434 soil permeability rate testing method was developed for granular soils that are free of organics (described as granular soils that occur in natural deposits used for embankments, or pavement base courses). It is not intended for use with soils containing more than 10 percent soil (inorganic) passing the No. 200 sieve. The method allows use of testing equipment between 3 inches and 9 inches in diameter to accommodate the largest grainsize particles in the sample.

In summary, the standard permeability rate testing method is to:

- Select a cylinder size, based on the maximum particle size;
- Place soil into the cylinder based on a specified procedure;
- Tamp the specimen to the desired compaction;
- Apply a vacuum to the sample;
- Add water until a stable head condition is achieved (no appreciable drift in water manometer levels is seen); then
- Run test runs with increasing heads.

For organic soils, swelling of organics in the presence of water can occur and significantly change the permeability of the soil. The standard method does not provide direction on pre-soaking the soils to prevent soil swelling during the test.

Results of the First Workshop

Based on discussions during the first workshop, the workshop group identified a number of modifications to the standard permeability test procedures that were believed to be important to improve the consistency of results. In most instances, these modifications involved more specific procedures that those specified in ASTM D2434 and did not actually involve utilizing procedures that were in conflict with the standard method.

Our recommendations for revisions of the existing test procedures included these items:

1) Apparatus:
    a. 6-inch mold size shall be used for the test.
    b. If using porous stone disks for the testing, the permeability of the stone disk should be measured before and after the soil tests to ensure clogging or decreased permeability has not occurred during testing.
    c. Use the confined testing method, with a 5- to 10-pound force spring.
    d. Use de-aired water.
2) Sample:
    a. Maximum grainsize within the sample shall not be more than ½ inch.
    b. Snip larger organic particles (if present) into ½ inch long pieces.
3) Preparation of Sample:
    a. Moisture content of soil should be at optimum moisture (+ or – 0.5 percent).
    b. Place soil in cylinder via a scoop.

c. Place soil in 1-inch lifts and compact using a 2-inch-diameter round tamper. Pre-weigh how much soil is necessary to fill 1-inch lift at 85% of maximum dry density, then tamp to 1-inch thickness. Once mold is full, verify that density is at 85% of maximum dry density (+ or – 0.5%).
d. Apply vacuum (20 inches Hg) for 15 minutes before inundation.
e. Inundate sample under a vacuum of 20 inches Hg slowly over a period of 60 to 75 minutes.
f. Remove the vacuum slowly over a period of at least 15 seconds.
g. Soak the sample in the mold for 16 to 20 hours before starting test.

4) Procedure:
   a. The permeability test will be conducted over a range of hydraulic heads: 0.5 cm, 1 cm, 1.5 cm, 2 cm, 3 cm, 4 cm, 6 cm, and 8 cm.
   b. Document steady state flow rates for four consecutive measurements before increasing the head.
   c. Repeat the permeability test for 4 consecutive days to determine if results change after repeated cycles. Each day should repeat the same hydraulic heads.
   d. On the last day, measure flow rates at hydraulic head values of 16 cm, 32 cm, and 64 cm (if feasible).

Laboratory Testing Results

The laboratory results for grainsize analysis, moisture and organic content, moisture-density relationship, and permeability are discussed below.

Grainsize Analysis Results

The grainsize analysis results are provided in Appendix B and summarized in Figure 1. As shown on Figure 1, the grainsize analysis results are quite similar for the different laboratories. Note that the percent passing the # 200 sieve ranges from 3.2 percent (GeoTest) to 3.9 percent (Shannon & Wilson). Grainsize results for the sand aggregate provided by Cedar Grove Composting are also shown on the graph. Note that the grainsize analyses performed by the laboratories were performed on samples after the organic burn and likely contain a small percentage of ash. The aggregate sample tested by Cedar Grove Composting contained 1.9 percent passing the #200 sieve, suggesting that the post-burn samples contained on the order of 1 to 2 percent ash.

Moisture Content and Organic Content Results

The moisture content of the received samples and organic content results are provided in Appendix B and are summarized in Table 2 below:

Table 2 – Summary of Test Sample Moisture and Organic Content Results

Laboratory	% Moisture	% Organics
AESI	13.2	3.5
GeoTest	Not Provided	5.4
GeoEngineers	19.3	4.8
HWA	10.1	4.7
Shannon & Wilson	14.0	5.6
SPU	19.5	4.7
Average	*15.3*	*4.8*
Standard Deviation	*3.6*	*0.7*

The moisture content of the received samples ranged from 10.1 percent to 19.5 percent. The organic content ranged from 3.5 percent to 5.6 percent with an average of 4.8 percent. This compares well with the organic content of 4.6 percent provided by Cedar Grove Composting.

Moisture-Density Relationship (Proctor) Results

The Proctor results are provided in Appendix C and summarized below in Table 3. In addition, the actual Proctor curves are shown on Figure 2. Note that most of the laboratories utilized a 4-inch mold (Method A or B) while AESI and GeoEngineers also ran Proctor tests using the 6-inch mold (Method C). The Proctor results range from 108.6 to 113.6 pounds/cubic foot for the 4-inch mold and from 102.6 to 106.8 pounds/cubic foot for the 6-inch mold. The laboratory representatives agreed that based on their experience, this variability in test results for the same soil material is typical.

The 6-inch molds provided a lower maximum dry density and higher optimum moisture content than the 4-inch molds. Permeability is highly dependent on compaction and it is critical that the same proctor method be used to provide more consistent permeability results. Since the permeability test uses a 6-inch mold, our recommended modifications of the permeability procedures specifies that the proctor test be conducted using the 6-inch mold.

Table 3 – Summary of Moisture-Density Relationship (Proctor) Results

	4" Mold		6" Mold	
	Max. Dry Density (pcf)	**Optimum Moisture %**	**Max. Dry Density (pcf)**	**Optimum Moisture %**
AESI	111.5	14.8	102.6	15.3
GeoTest	108.6	16.5	--	--
GeoEngineers	113.6	12.5	106.8	15.9
HWA	109.6	15.3	--	--
Shannon & Wilson	113.0	14.5	--	--
SPU	111.0	15.0	--	--
Average	*111.2*	*14.8*	*104.7*	*15.6*
Standard Deviation	*1.8*	*1.2*	*2.1*	*0.3*

Notes: pcf = pounds/cubic foot

Permeability Testing Results

The permeability testing results are provided in Appendix D and summarized below in Table 4.

Table 4 – Summary of Permeability Results

Laboratory	**Dry Density (pcf)**	**% Compaction**	**Mold Diameter (in.)**	**Day 1 (in./hr)**	**Day 2 (in./hr)**	**Day 3 (in./hr)**	**Day 4 (in./hr)**
AESI	94.8	85.0%	6	3.4	3.8	4.1	4.7
GeoTest	91.5	84.3%	6	10	13	16	21
GeoEngineers (85% of MDD)	96.9	85.3%	6	3.8	3.7	3.7	3.8
GeoEngineers (90% of MDD)	102.6	90.3%	6	1.8			
HWA	93.1	84.9%	6	19	25	23	22
Shannon & Wilson	95.0	84.1%	6	6.2	5.4	5.2	5.5
HWA	93.1	84.9%	4	17	21		
SPU	95.9	86.4%	4	39	39	40	42

Notes: pcf = pounds/cubic foot
in. = inches
hr = hour

Results at 85% compaction for AESI, GeoEngineers, and Shannon & Wilson are relatively consistent, ranging from 3.4 to 6.2 inches/hour for the first day. GeoEngineers test at 90% compaction provided a lower permeability of 1.8 inches/hour. GeoTest and HWA results are significantly higher (10, 17, and 19 inches/hour on the first day). Because their Proctor values were lower than measured by the other laboratories, their permeability tests were performed at a lower

soil density, which is the likely explanation for the higher permeability. The relationship between permeability and compaction (soil density) is shown on Figure 3.

Two labs (HWA and SPU) performed the permeability test using a 4-inch diameter mold. The HWA 4-inch results are similar to their 6-inch results. SPU's permeability results were significantly higher than the other laboratories. SPU used a 4-inch mold and did not have a de-aired water source. The reason for this difference is not known and therefore the permeability rates will be disregarded for the purposes of this study.

Several labs (AESI, GeoTest, HWA, and SPU) observed an increase in permeability from day one to day four. The most likely explanation offered during the workshop is that some fine grained materials washed out of the mold during the test.

Conclusions and Recommendations

In general, testing results indicated that the laboratories received material that was very similar in grainsize distribution, organic content, and maximum dry density. Permeability results for the first day of testing ranged from 1.8 to 19 inches/hour. In general, permeability was inversely proportional to soil density, with a range of 1.8 inches/hour at a dry density of 102.6 pounds/cubic foot to 19 inches/hour at a dry density of 93.1 pounds/cubic foot. Based on these results, controlling soil compaction is probably the most important factor in obtaining consistent permeability results. SPU's permeability results were substantially higher than the other laboratories (39 inches/hour on the first day). The reason for this difference is unknown.

The final recommended testing procedures for permeability of bioretention soil are found in Appendix E. The primary changes to the original permeability testing procedures include the following:

- Obtain the MDD using ASTM D1557 Method C, which utilizes a 6-inch mold. This approach was selected so the Proctor test and permeability test would be conducted in the same size mold.
- When adding water to the sample during the Proctor test, allow the sample to pre-soak for at least 48 hours to allow the organics to fully saturate before compacting the sample. The workshop attendees believed that allowing the organics to fully saturate was important to provide consistent Proctor results.
- Before running the permeability test, allow the sample to pre-soak for at least 48 hours. During the pre-soak, the moisture content should be higher than optimum moisture but less than full saturation (i.e., there should be no free water). This is to address situations where the sample may arrive in the laboratory relatively dry.
- After saturating the sample in the permeability mold, allow it to soak for 24 to 72 hours before running the permeability test. The workshop attendees agreed that this period of time should be sufficient to allow the organics to fully swell.
- Conduct permeability testing over a range of hydraulic gradients between 0.1 and 2. This range was considered typical for field conditions.
- Complete the permeability testing within one day. It was the opinion of the workshop attendees that repeating the test over multiple days was unnecessary.

Limitations

Work for this project was performed and this memorandum prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of City of Seattle. This memorandum does not represent a legal opinion. No other warranty, expressed or implied, is made.

References

ASTM D422 – 63, 2007, Standard Test Method for Particle-Size Analysis of Soils; published by ASTM International, West Conshohocken, Pennsylvania.

ASTM D1557 – 09 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3 (2,700 kN-m/m3)); published by ASTM International, West Conshohocken, Pennsylvania.

ASTM D2434 – 68, 2006 Standard Test Method for Permeability of Granular Soils (Constant Head), published by ASTM International, West Conshohocken, Pennsylvania.

ASTM D2974 - 07a Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils; published by ASTM International, West Conshohocken, Pennsylvania.

Attachments:

Figure 1: Grainsize Distribution Results
Figure 2: Proctor Test Results
Figure 3: Relationship Between Dry Density and Permeability
Appendix A: Characteristics of Sand Aggregate, Compost, and Bioretention Soil Provided by Cedar Grove Composting
Appendix B: Grainsize, Moisture Content, and Organic Content Testing Results
Appendix C: Moisture-Density Relationship (Proctor) Test Results
Appendix D: Permeability Test Results
Appendix E: Recommended Modifications for Permeability Testing of Bioretention Soils

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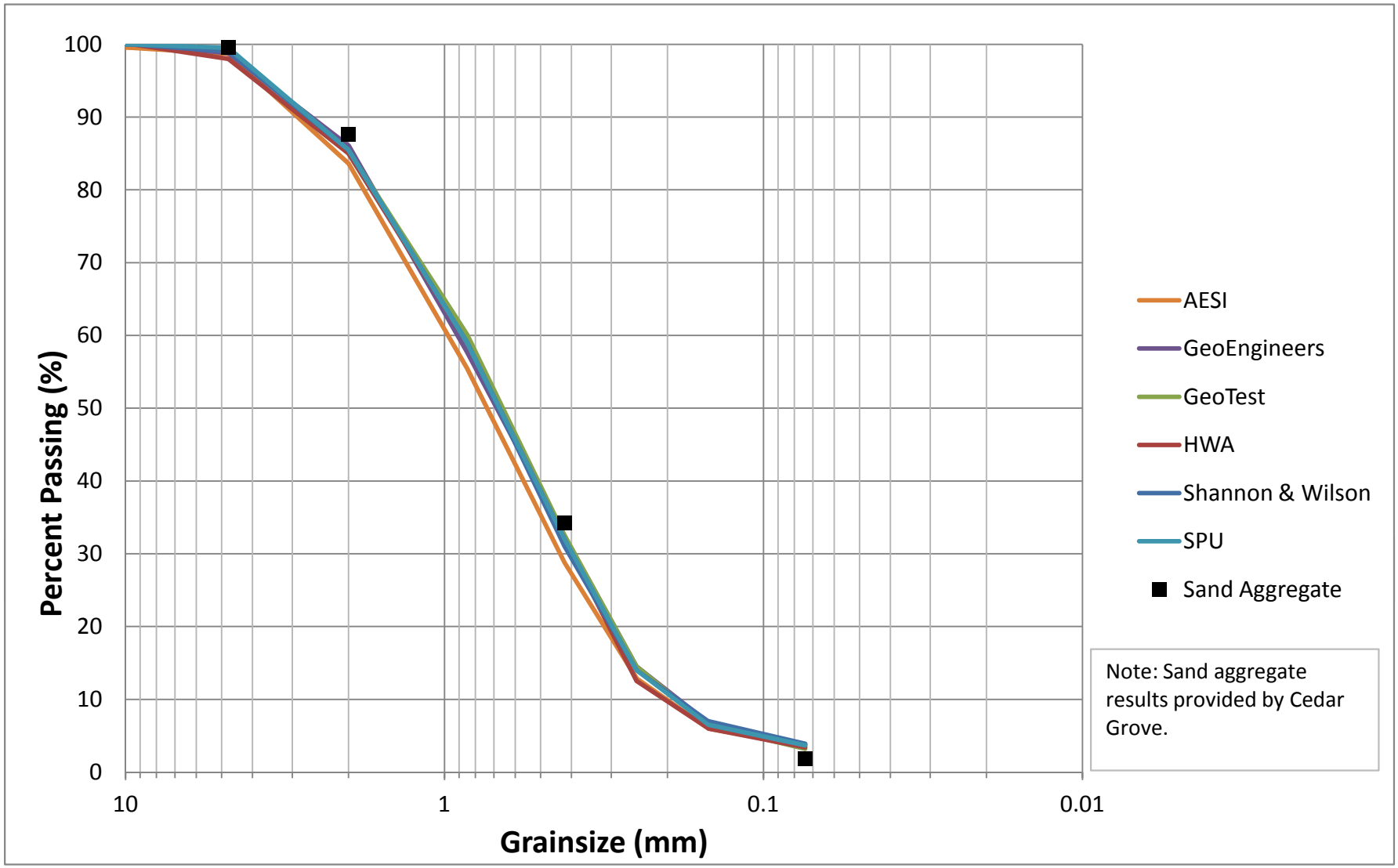

Aspect Consulting
October 19, 2011
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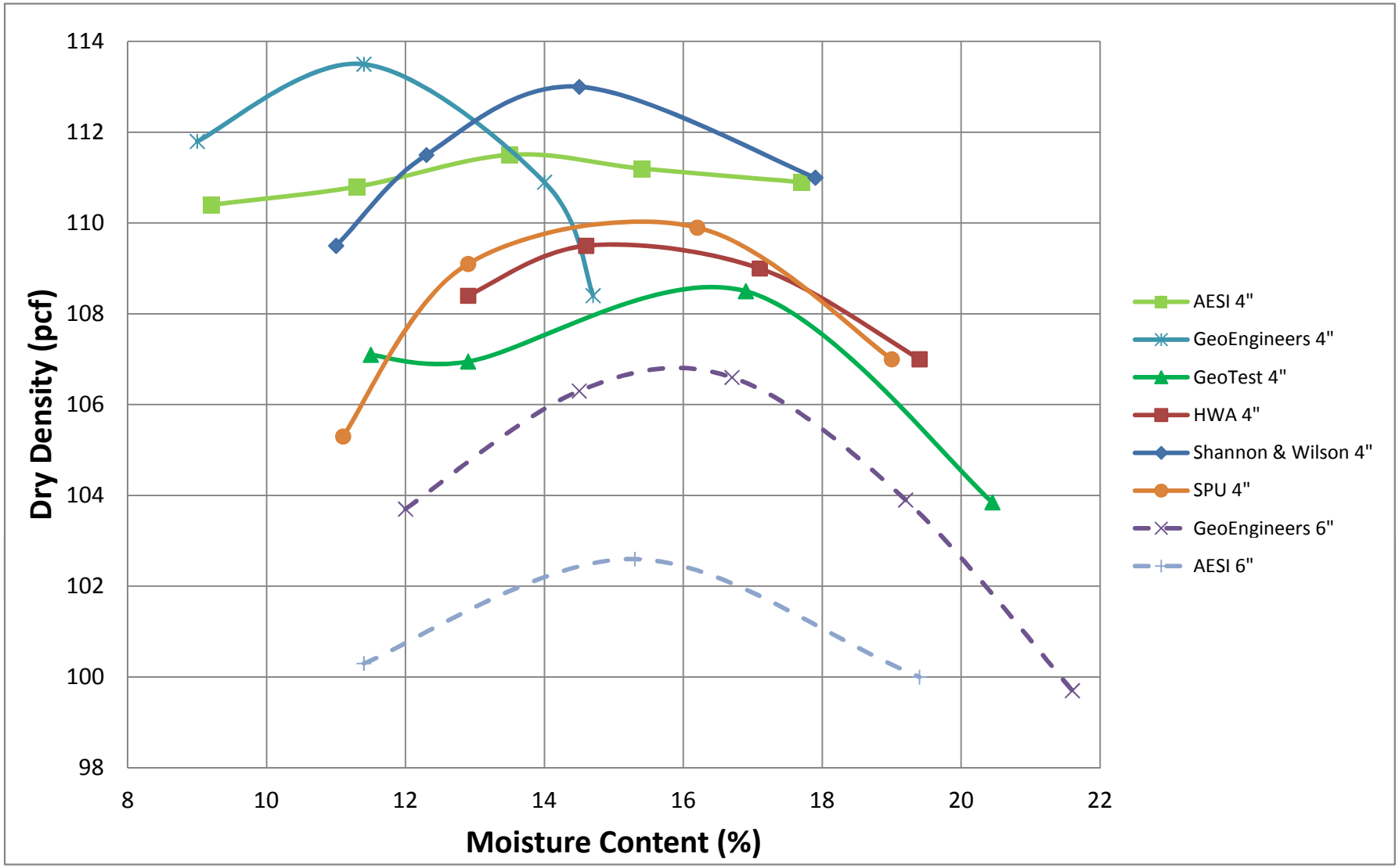
Figure 1
Grainsize Distribution Results
SPU Bioretention Soils, Seattle, WA



Aspect Consulting
October 19, 2011
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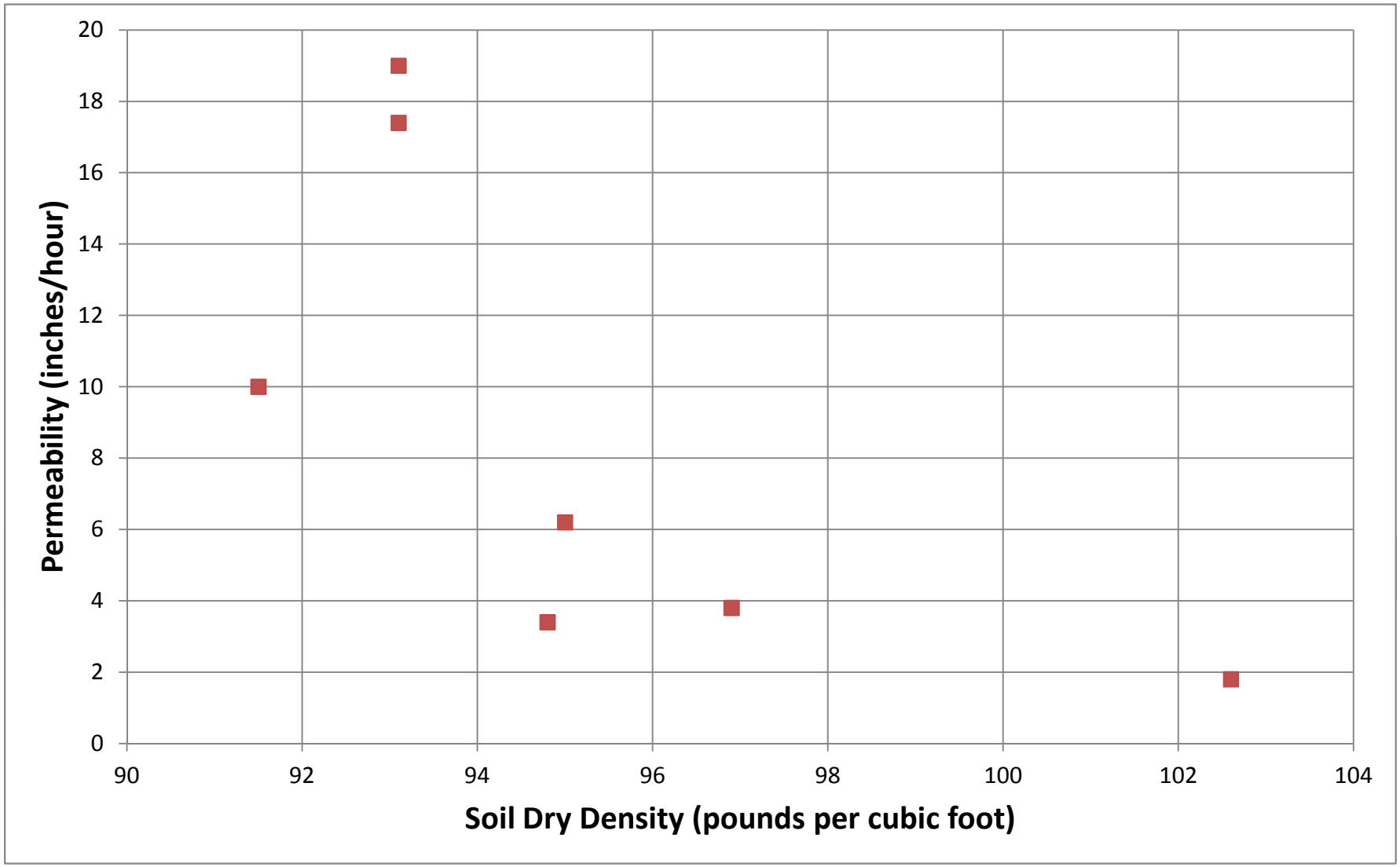
Figure 2
Proctor Test Results
SPU Bioretention Soils, Seattle, WA



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October 19, 2011
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Figure 3
Relationship Between Dry Density and Permeability
SPU Bioretention Soils, Seattle, WA

APPENDIX A

Characteristics of Sand Aggregate, Compost, and Bioretention Soil Provided by Cedar Grove Composting

ANALYTICAL CHEMISTS
and
BACTERIOLOGISTS
Approved by State of California

SOIL CONTROL LAB

42 HANGAR WAY
WATSONVILLE
CALIFORNIA
95076
USA

TEL: 831-724-5422
FAX: 831-724-3188

Account Number:
0040690-2-2192

Cedar Grove Composting
17825 Cedar Grove Rd SE
Maple Valley, WA 98038
Attn: Martin Okoli

Reporting Date:
May 13, 2010

Date Received:	Soil sample received April 27, 2010
Project #/Name:	None / None
Sample Identification:	CNW sand 4-26-10
Matrix:	Soil
Laboratory #:	0040690-1/2

Sieve Size	**Percent Passing (% by weight)**	
1"	100.0	% by wt
#4	99.6	% by wt
#10	87.6	% by wt
#40	34.3	% by wt
#200	1.9	% by wt

*Note: Percent Passing by weight is the same thing as Percent Finer by weight.

Mike Galloway

Cedar Grove Composting
Compost Quality Assurance Program 2011

Cedar Grove Fine Grade Compost For CDC Specification

Cedar Grove Compost is made from 100% locally recycled yard and food trimmings, and clean wood waste. Cedar Grove Compost is made at facilities that are in compliance with Washington Department of Ecology (WDOE) requirements for compost manufacturing and product quality (WAC 173-350-220). In addition, Cedar Grove voluntarily meets the US Composting Council's Seal of Testing Assurance (STA) standards. Results of tests for horticultural values are shown in Chart 1, along with applicable STA standards. Details of WDOE compost quality requirements and Cedar Grove Compost results are in Chart 2. **See notes on page 2.**

Chart 1. Cedar Grove Fine Grade Compost Horticultural Values

	US Composting Council Seal of Testing Assurance Standard	Cedar Grove Fine Compost (2/10/2011)
Moisture content		**47.4%**
Organic Matter	>40%	**49.4%**
Carbon to Nitrogen Ratio		**19**
Conductivity "as received"	<4 mmhos/cm	**2.6 mmhos/cm NOTE 1**
Seedling Emergence	>80%	**100%**
Seedling Vigor	>80%	**100%**
Compost Stability (mg CO-2 C/g OM/day)	<7	**3.4 - "Stable" NOTE 2**
Viable Weed Seeds		**None detected 12/22/10**
Dry weight		**29 lbs / cu. Ft.**
Major Nutrients Total Nitrogen		**1.3%**
Ammonium (NH-4)		**410 mg/kg**
Nitrate (NO-3)		**1.3 mg/kg NOTE 3**
Phosphorous (P_2O_5)		**0.68%**
Potassium (K_2O)		**1.2%**

Chart 2. Compost Quality Requirements - Washington Administrative Code *173-350 Sect. 220*

	WAC 173-350-220 Standard	Cedar Grove Compost (2/10/2011)
Metals	***Parts per million (mg/kg), dry wt.***	
Arsenic	<=20	**8.9**
Cadmium	<=10	**<1.0**
Copper	<=750	**68**
Lead	<=150	**37**
Mercury	<=8	**<1.0**
Molybdenum	<=9	**2.8**
Nickel	<=210	**24**
Selenium	<=18	**<1.0**
Zinc	<=1400	**210**
pH	5-10 (range)	**7.28**
Salmonella (Pathogen indicator)	< 3 MPN / 4 grams of total solids	**Pass**
Sharps	0 percent	**None Detected**
Manufactured Inerts	< 1 percent	**< 0.5 percent**

Chart 3. WDOT Particle Size Specifications by Compost Grade

Sieve size	WDOT "Fine" Compost	Cedar Grove (2/10/2011)
1"	95-100%	**100%**
5/8"	90-100%	**97.4% NOTE 4**
¼"	75-100%	**92%**

US Composting Council
Seal of Testing Assurance

All tests performed by Soil Control Laboratories, Watsonville, CA; using TMECC/STA specified methods.

NOTE 1. "As received" reports conductivity in moist soil. The number reported on the lab report (4.9 mmhos/cm) is a calculation of conductivity of dried material.

NOTE 2. Stability is tested in accordance with TMECC 05.08-B, "Carbon Dioxide Evolution Rate". This laboratory test is a more accurate CO-2 measure than Solvita tests specified.

NOTE 3. The form of nitrogen present is dynamic, changing with exposures to air, temperature, soil life and other factors. WSU Agronomists advise that laboratory characterizations of Nitrate:Ammonia balances are not meaningful for field applications.

NOTE 4. Cedar Grove Compost is screened to 7/16". There is no way to remove the small fraction of material that is 3/16" larger and passes a 5/8" screen.

NOTE 5. Neither WAC 173-350-220 nor the STA program requires testing for Cation Exchange Capacity. We do not conduct regular testing for this parameter. When tests have been conducted, Cedar Grove Compost CEC levels are consistently greater than 20.

Notes and additional information added by Howard Stenn, Cedar Grove Staff Horticulturist, 3/10/2011.

soiltest farm consultants, inc.

2925 Driggs Dr. Moses Lake, WA 98837

Phone: (509) 765-1622 Fax: (509) 765-0314 Web: www.soiltestlab.com

Soil Plant 2009 NAPT Participating Laboratory

PAP-Accredited NAPT 2009

WE PUT QUALITY IN YOUR HANDS!

CEDAR GROVE COMPOSTING
3620 36TH PL NE

Everett, WA 98205

Date Received: 3/18/2011
Grower: CEDAR GROVE
Sampled By:
Field: **BIORETENTION SOIL**
Lab # S2799

Soil Test Results

Phosphorus	Bray	mg/kg	72
Potassium	NH4OAC	mg/kg	558
Boron	DTPA	mg/kg	0.42
Zinc	DTPA	mg/kg	3.9
Manganese	DTPA	mg/kg	36.7
Copper	DTPA	mg/kg	1.1
Iron	DTPA	mg/kg	37
Calcium	NH4OAC	meq/100g	3.4
Magnesium	NH4OAC	meq/100g	1.6
Sodium	NH4OAC	meq/100g	0.46
Buffer pH	SMP		7.4
Lime Req		Tons/Acre	0
CEC		meq/100g	7.1
Total Bases		meq/100g	6.8
Base Saturation		%	96.5
Chloride		mg/kg	
Gypsum Req.		Tons/Acre	

pH 1:1		7.7	$CaCl_2$ pH = 6.5
E. C. 1:1	m.mhos/cm	1.11	
Est Sat Paste E.C.	m.mhos/cm	2.89	
Effervescence			
			Lbs/Acre
Ammonium - N	mg/kg	47.4 @ 12"	152

Depth inches	Cad. Red. Nitrate-N mg/kg	Nitrate-N lbs/acre	Ext Sulfate-S mg/kg	Moisture inches
0 - 12	7.5	24	27	
Totals	7.5	24	27	

Sum of Tested N 175.6 + Est. N 0.0 = 176 lbs/acre N

Texture
Other Tests:

TOTAL N = 0.13%, TOTAL C = 2.24%, C:N RATIO = 17:1,
SAT PASTE Ca = 3.6 meq/L, Mg = 1.5 meq/L, Na = 0.8 meq/L, SAR = 0.57

We make every effort to provide an accurate analysis of your sample. For reasonable cause we will repeat tests, but because of factors beyond our control in sampling procedures and the inherent variability of soil, our liability is limited to the price of the tests. Recommendations are to be used as general guides and should be modified for specific field conditions and situations.

This is your Invoice. S173291 Acct #: 4225 PO #: Reviewed by: Brent Thyssen CPSSc List Price: **$94.40**

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS
400 NORTH 34TH STREET • SUITE 100
P.O. BOX 300303 • SEATTLE, WASHINGTON 98103
206-632-8020 FAX 206-695-6777

PERMEABILITY TEST ON GRANULAR SOIL
CONSTANT HEAD (6" MOLD)
ASTM D 2434

Project: **Cedar Grove BRS**
Job No: 21-1-08824-047
Sample: BRS 1-31-11, Rec'd 1/31/2011
Test By: AKV 2/8/2011
Comp By: AKV 2/9/2011
Check By: JFL 2/9/2011

MC Before Test= 18.5%
Initial Dry Density= 86.0 pcf
Percent Compaction= 80.0%
Final Dry Density= 85.4 pcf
Fines Washout= 9.1 g
Washout= 0.71%

Sample Classification:
Brown, slightly silty SAND; numerous organics (SP-SM)

Remarks:
Specimen compacted by hand with 2" round tamper to target density (80% Modified MDD) based on preliminary water content.

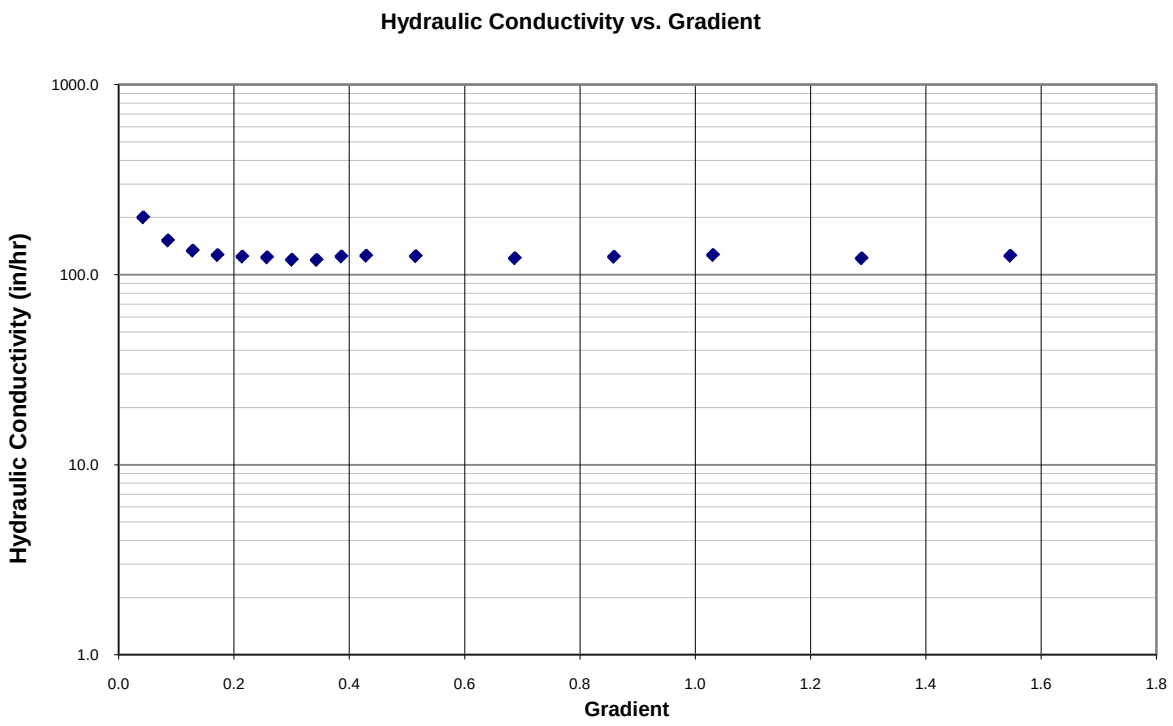
Fines washout occurred largely during first two testing intervals.

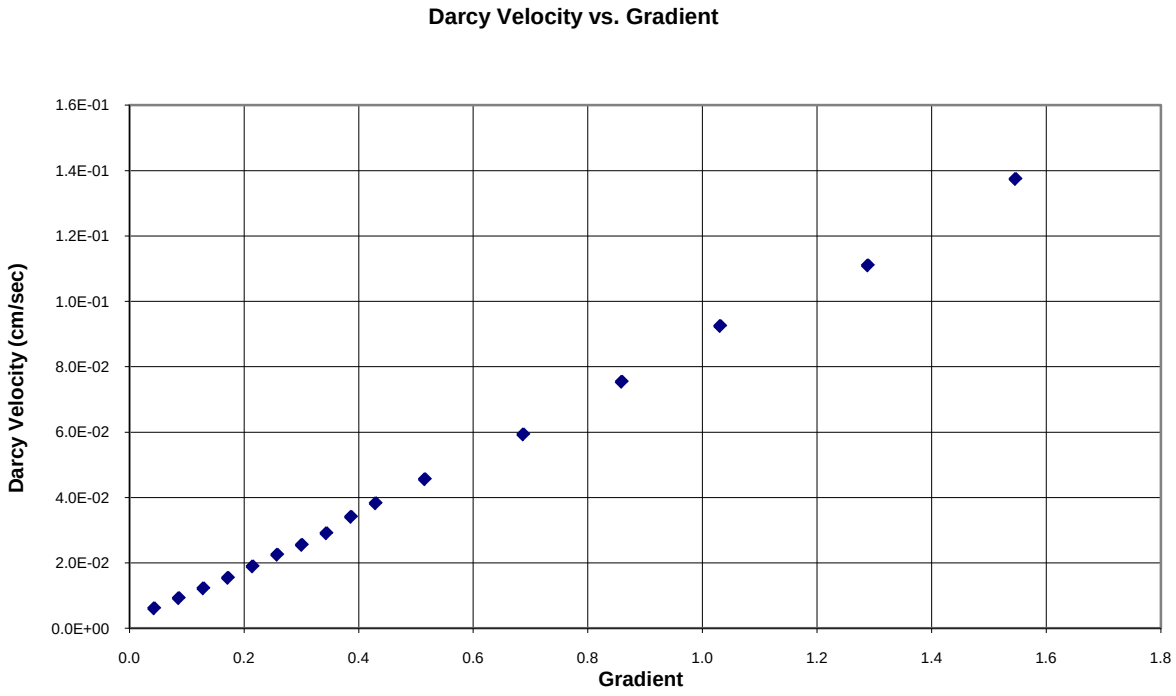
Test No.	Reservoir Level		Δh	H	t	Q			
	h_1 (cm)	h_2 (cm)	(cm)	(cm)	(s)	(cm^3)	I	Q/at	k (in/hr)
1	52.5	47.8	4.7	0.5	774	375.1	0.04	6.1E-03	2.00E+02
2	47.8	42.4	5.4	1.0	588	430.9	0.09	9.2E-03	1.52E+02
3	42.4	38.1	4.3	1.5	353	343.1	0.13	1.2E-02	1.34E+02
4	38.0	33.8	4.2	2.0	273	335.2	0.17	1.5E-02	1.27E+02
5	33.7	28.6	5.1	2.5	270	407.0	0.21	1.9E-02	1.25E+02
6	28.6	22.4	6.2	3.0	276	494.8	0.26	2.2E-02	1.24E+02
7	22.4	15.5	6.9	3.5	271	550.6	0.30	2.5E-02	1.20E+02
8	15.4	7.3	8.1	4.0	279	646.4	0.34	2.9E-02	1.20E+02
9	51.8	42.2	9.6	4.5	282	766.1	0.39	3.4E-02	1.25E+02
10	42.2	31.2	11.0	5.0	288	877.8	0.43	3.8E-02	1.26E+02
11	31.0	18.7	12.3	6.0	270	981.6	0.52	4.6E-02	1.25E+02
12	52.2	36.2	16.0	8.0	270	1276.8	0.69	5.9E-02	1.22E+02
13	36.1	15.9	20.2	10.0	268	1612.0	0.86	7.5E-02	1.24E+02
14	41.6	17.2	24.4	12.0	264	1947.2	1.03	9.2E-02	1.27E+02
15	52.8	36.6	16.2	15.0	146	1292.8	1.29	1.1E-01	1.22E+02
16	36.5	20.7	15.8	18.0	115	1260.9	1.55	1.4E-01	1.26E+02
								Average k	**1.3E+02**

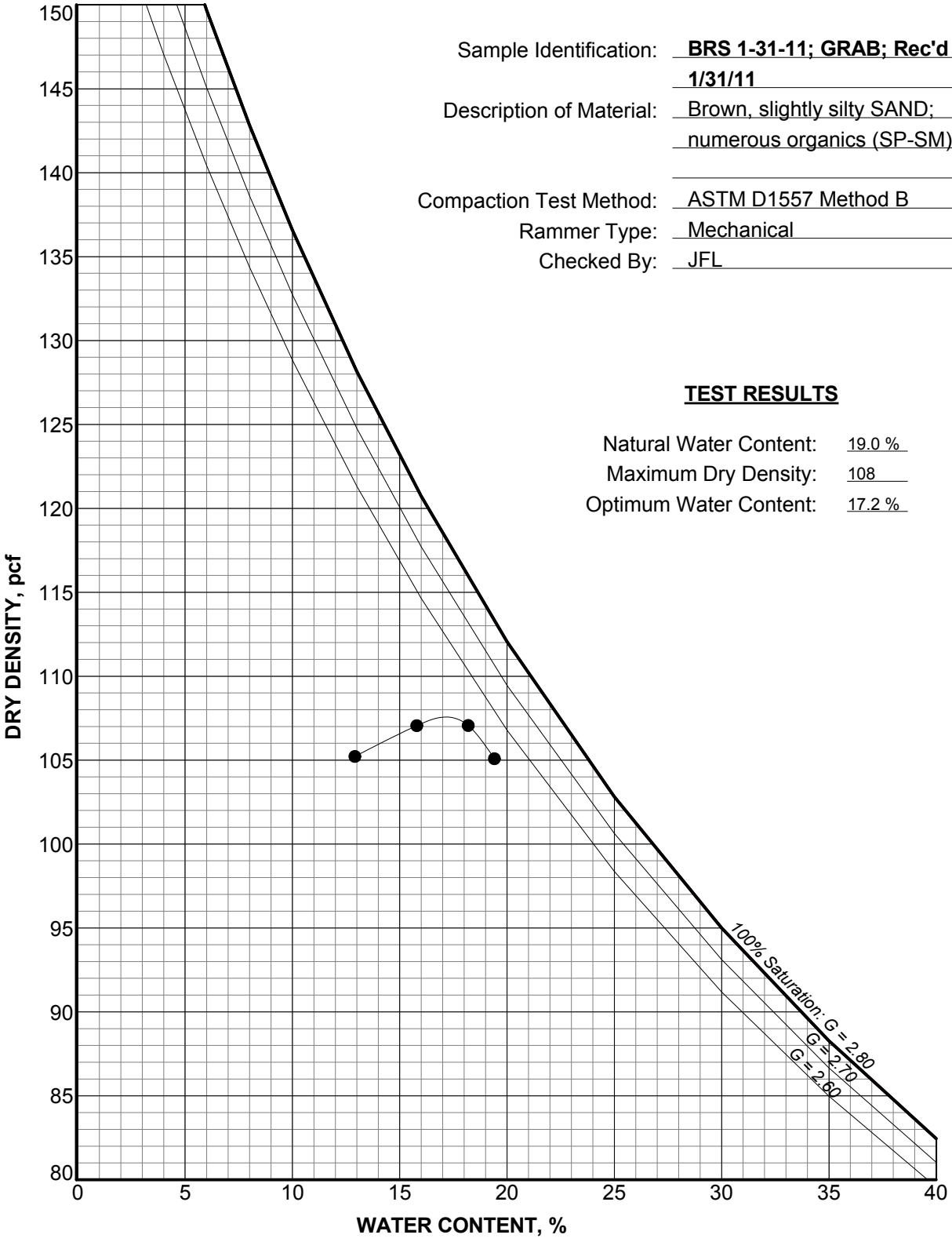
h_1 : Initial reservoir water level
h_2 : Final reservoir water level
Δh : Change in reservoir water level during test
H : Head difference across the specimen
t : Elapsed time for changing water level
Q : Volume of water discharged
I : Hydraulic gradient (Head/Height)
a : Cross-section area of the specimen
k : Hydraulic conductivity of the specimen

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS
400 NORTH 34TH STREET • SUITE 100
P.O. BOX 300303 • SEATTLE, WASHINGTON 98103
206•632•8020 FAX 206•695•6777

Cedar Grove BRS
BRS 1-31-11, Rec'd 1/31/2011
21-1-08824-047
Date Reported: 2/9/2011







Sample Identification: **BRS 1-31-11; GRAB; Rec'd 1/31/11**

Description of Material: Brown, slightly silty SAND; numerous organics (SP-SM)

Compaction Test Method: ASTM D1557 Method B

Rammer Type: Mechanical

Checked By: JFL

TEST RESULTS

Natural Water Content: 19.0 %

Maximum Dry Density: 108

Optimum Water Content: 17.2 %

Cedar Grove Bioretention Soils
Seattle, Washington

MOISTURE-DENSITY TEST

February 2011 21-1-08824-047

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. FINAL

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS
400 NORTH 34TH STREET • SUITE 100
P.O. BOX 300303 • SEATTLE, WA 98103
(206) 632-8020 • FAX: (206) 633-6777

Project Name: Cedar Grove Bioretention
Job Number: 21-1-08824-047
Checked By/On: JFL 2/7/11

Organic Content By Mass
ASTM D2974

Boring	Sample	Depth (ft)	WC Wet + Tare	Oven Dry + Tare	Furnace Dry + Tare	Tare Wt.	WC (%)	Organic (%)
BRS 1-31-11	GRAB (1/2)	0	322.82	292.87	284.76	114.89	---	---
BRS 1-31-11	GRAB (2/2)	0	373.87	338.09	328.28	129.79	---	---
Totals			696.69	630.96	613.04	244.68	17.0	4.6

Am Test Inc.
13600 NE 126TH PL
Suite C
Kirkland, WA 98034
(425) 885-1664

Professional Analytical Services

Feb 4 2011
Shannon & Wilson
400 n. 34th St
Suite 100
Seattle, WA 98103
Attention: Joe Laprade

Dear Joe Laprade:

Enclosed please find the analytical data for your project.

The following is a cross correlation of client and laboratory identifications for your convenience.

CLIENT ID	MATRIX	AMTEST ID	TEST
BRS-1-31-11 Cedar Grove	Soil	11-A001193	CEC-s

Your sample was received on Tuesday, February 1, 2011. At the time of receipt, the sample was logged in and properly maintained prior to the subsequent analysis.

The analytical procedures used at AmTest are well documented and are typically derived from the protocols of the EPA, USDA, FDA or the Army Corps of Engineers.

Following the analytical data you will find the Quality Control (QC) results.

Please note that the detection limits that are listed in the body of the report refer to the Method Detection Limits (MDL's), as opposed to Practical Quantitation Limits (PQL's).

If you should have any questions pertaining to the data package, please feel free to contact me.

Sincerely,

Aaron W. Young
Laboratory Manager

Project #: 21-1-08824-047
PO Number: 21-1-08824-047

BACT = Bacteriological
CONV = Conventionals
TC=Total Coliforms
MET = Metals
ORG = Organics
NUT=Nutrients
DEM=Demand
MIN=Minerals
APC=Aerobic Plate Count

Am Test Inc.
13600 NE 126TH PL
Suite C
Kirkland, WA 98034
(425) 885-1664
www.amtestlab.com

AMTEST LABORATORIES

Professional Analytical Services

ANALYSIS REPORT

Shannon & Wilson
400 n. 34th St
Seattle, WA 98103
Attention: Joe Laprade
Project #: 21-1-08824-047
PO Number: 21-1-08824-047
All results reported on an as received basis.

Date Received: 02/01/11
Date Reported: 2/ 4/11

AMTEST Identification Number **11-A001193**
Client Identification **BRS-1-31-11 Cedar Grove**
Sampling Date

Miscellaneous

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANLST	DATE
Cation Exchange Capacity	43.	meq/100g		0.5	SW-846 9081	HL	02/04/11

Aaron W. Young
Laboratory Manager

ANTEST LABORATORIES

QC Summary for sample number: 11-A001193

DUPLICATES

SAMPLE #	ANALYTE	UNITS	SAMPLE VALUE	DUP VALUE	RPD
11-A001193	Cation Exchange Capacity	meq/100g	43.	36.	18.

STANDARD REFERENCE MATERIALS

ANALYTE	UNITS	TRUE VALUE	MEASURED VALUE	RECOVERY
Cation Exchange Capacity	meq/100g	10.	10.	100. %

BLANKS

ANALYTE	UNITS	RESULT
Cation Exchange Capacity	meq/100g	< 0.5

APPENDIX B

Grainsize, Moisture Content, and Organic Content Testing Results

Associated Earth Sciences, Inc.

Moisture, Ash, and Organic Matter of Peat and Other Organic Soils - ASTM 2974

Date Sampled	Project	Project No.		Soil Description
4/15/2011	Aspect Bio Filtration Soils	KE110139A		Bio Retention Mix
Tested By	**Location**	**EB/EP No.**	**Depth**	
MS	Delivered			

Moisture Content

Sample ID	#1	#2	#3
Wet Weight + Pan	500.70	551.30	718.23
Dry Weight + Pan	447.69	500.00	655.10
Weight of Pan	100.48	101.25	101.00
Weight of Moisture	53.01	51.30	63.13
Dry Weight of Soil	347.21	398.75	554.10
% Moisture	15.27	12.87	11.39

Organic Matter and Ash Content

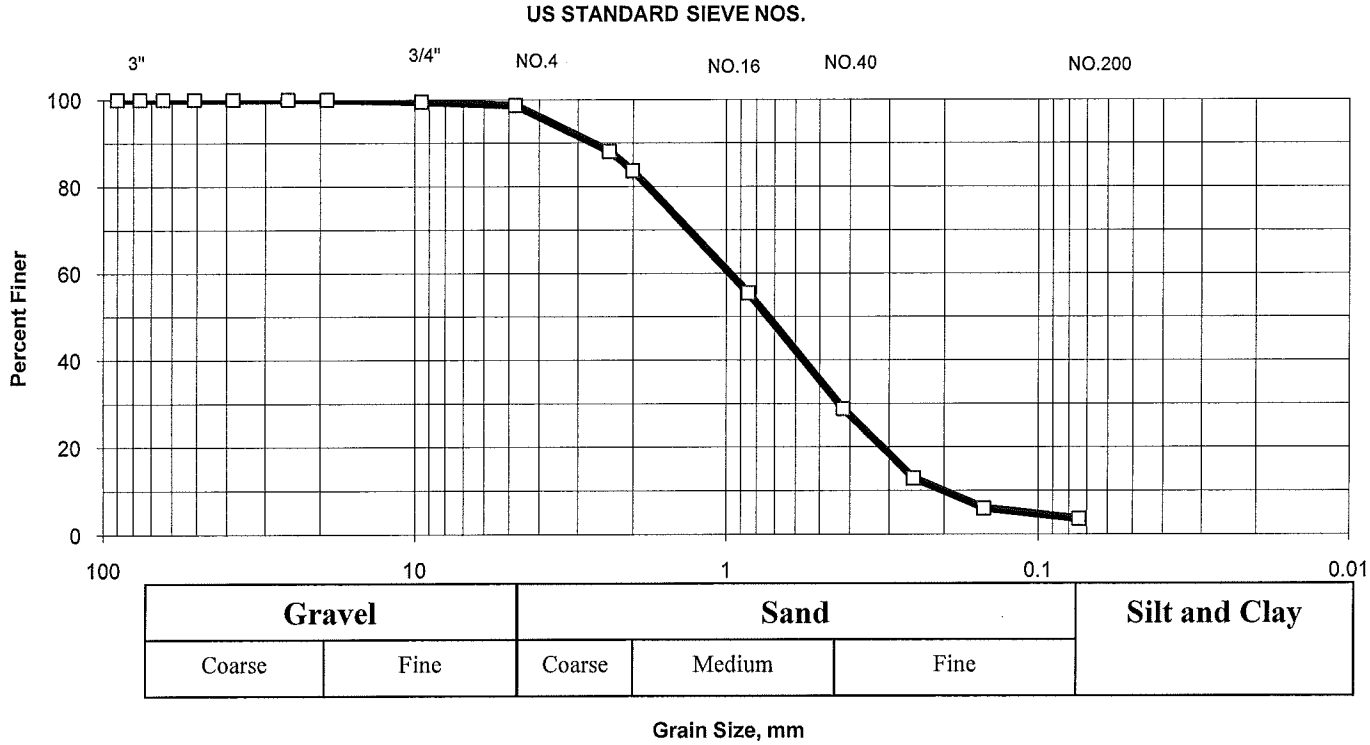
Dry Soil Befor Burn + Pan	686.50	738.20	902.52
Dry Soil After Burn + Pan	672.76	725.09	883.82
Weight of Pan	339.41	339.45	348.42
Wt. Loss Due to Ignition	13.74	13.11	18.70
Actual Wt. Of Soil After Burr	333.35	385.64	535.40
% Organics	3.96	3.29	3.37

GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
4/15/2011	**Aspect Bio Filtration Soil**	KE110139A		**Bio Retention Mix**
Tested By	Location	EB/EP No	Depth	Intended Use / Specification
MS	**Delivered**			

Wt. of moisture wet sample + Tare	725	Total Sample Tare	519.66
Wt. of moisture dry Sample + Tare	725	Total Sample wt + tare	853.1
Wt. of Tare	100.25	Total Sample Wt	333.4
Wt. of moisture Dry Sample	624.75	Total Sample Dry Wt	333.4
Moisture %	0%		

					Specification Requirements	
Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Minimum	Maximum
3.5	90		-	100.00	-	-
3	76.1		-	100.00	-	-
2.5	64		-	100.00	-	-
2	50.8		-	100.00	-	-
1.5	38.1		-	100.00	-	-
1	25.4		-	100.00	-	-
3/4	19		-	100.00	-	-
3/8	9.51	1.62	0.49	99.51	-	-
#4	4.76	4.45	1.33	98.67	-	-
#8	2.38	39.62	11.88	88.12	-	-
#10	2	54.57	16.37	83.63	-	-
#20	0.85	148.55	44.55	55.45	-	-
#40	0.42	237.56	71.25	28.75	-	-
#60	0.25	290.49	87.12	12.88	-	-
#100	0.149	313.5	94.02	5.98	-	-
#200	0.074	321.53	96.43	3.57	-	-



ASSOCIATED EARTH SCIENCES, INC.

911 5th Ave., Suite 100 Kirkland, WA 98033 425-827-7701 FAX 425-827-5424

Sieve Analysis

Project Name: Biosoils Testing Workshop
Project Number: 0129-039-00
Tested By: SAS
Date: 4/19/2011
Exploration No.: Biosoils
Sample No.: BS1
Depth: n/a

Moisture Content (%)	19.3%

moisture content determined during organic content testing (ASTM D-2974)

Sieve Size	Percent Passing (%)
3.0 in. (75.0-mm)	100.0
1.5 in. (38.1-mm)	100.0
3/4 in. (19.0-mm)	100.0
3/8 in. (9.5-mm)	100.0
No. 4 (4.75-mm)	98.8
No. 10 (2.00-mm)	86.1
No. 20 (.850-mm)	57.7
No. 40 (.425-mm)	32.4
No. 60 (.250-mm)	14.5
No. 100 (.150-mm)	6.8
No. 200 (.075-mm)	3.8

Size Fraction	Percent By Weight
Coarse Gravel	
Fine Gravel	1.2
Coarse Sand	12.7
Medium Sand	53.8
Fine Sand	28.6
Fines	3.8
Total	100.0

LL _____
PI _____

D10 0.19
D30 0.40
D60 0.91

Cc 0.93
Cu 4.91

USCS Classification

Group Name poorly graded sand
Symbol (SP)

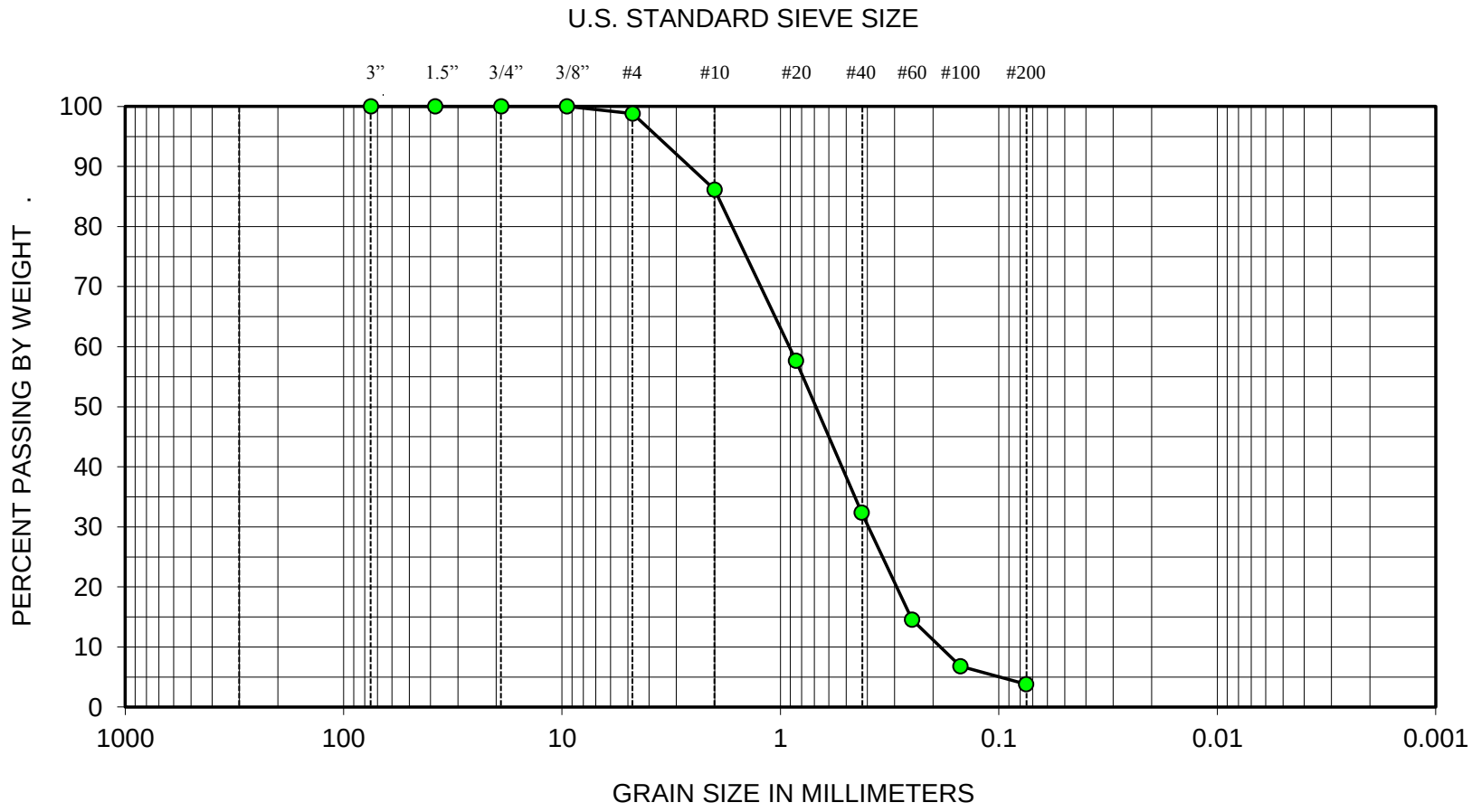
GEOENGINEERS

SIEVE ANALYSIS DATA

FIGURE #-#

0129-039-00 CMK:SAS: sas 04-19-2011 (SIEVE.pptx)

GEOENGINEERS



BOULDERS	COBBLES	GRAVEL		SAND			SILT OR CLAY
		COARSE	FINE	COARSE	MEDIUM	FINE	

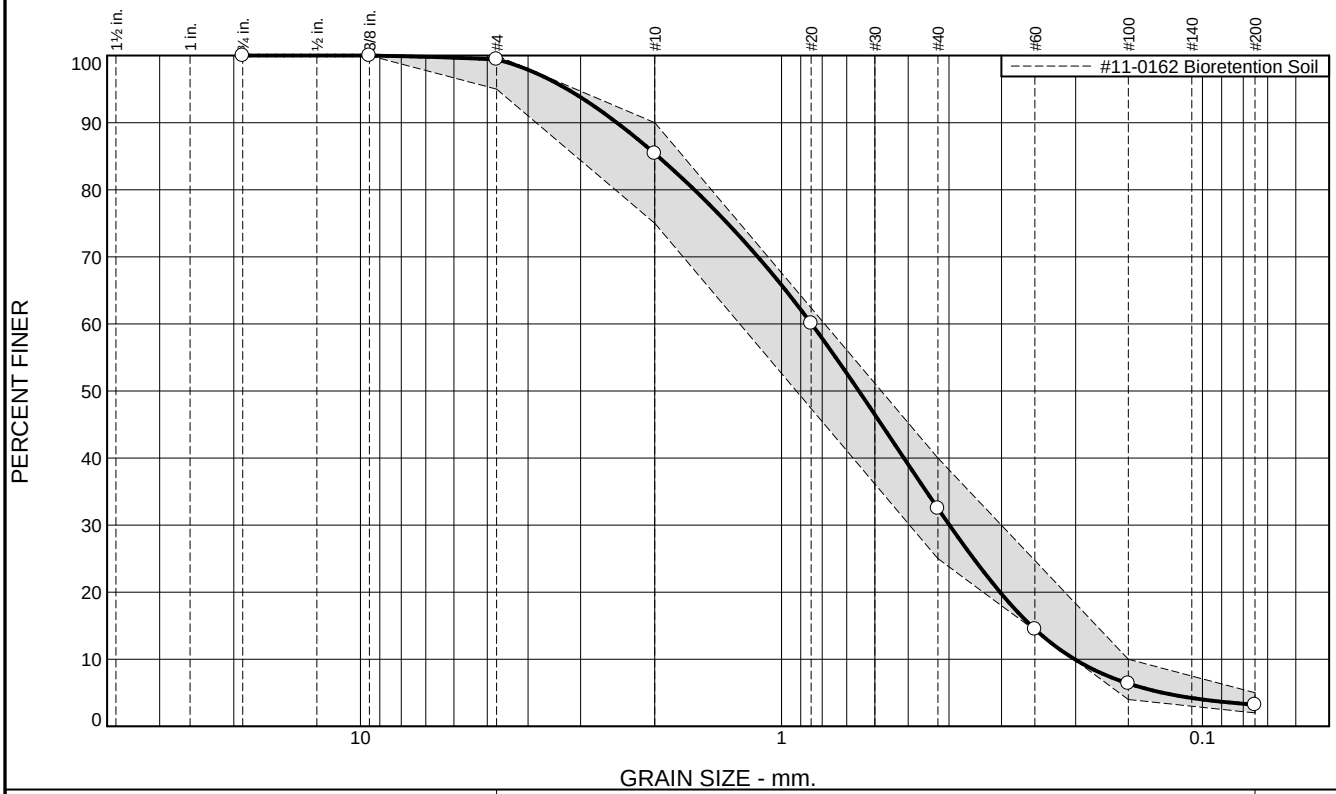
NOTE: Test performed in accordance with ASTM D-422 ***organic matter burned off prior to sieve analysis***

SYMBOL	DESCRIPTION	SAMPLE NUMBER	SOIL CLASSIFICATION
●	Biosoils	BS1	Poorly graded sand (SP) *(organic content = 4.8%; moisture content = 19.3%)*

SIEVE ANALYSIS RESULTS

FIGURE #-#

Sieve Analysis Test Report - ASTM D422



% Gravel		% Sand			% Fines
Coarse	Fine	Coarse	Medium	Fine	Silt
0.0	0.6	14.0	52.9	29.3	3.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4"	100.0		
3/8"	100.0	100.0 - 100.0	
#4	99.4	95.0 - 100.0	
#10	85.4	75.0 - 90.0	
#20	60.1		
#40	32.5	25.0 - 40.0	
#60	14.5		
#100	6.4	4.0 - 10.0	
#200	3.2	2.0 - 5.0	

* #11-0162 Bioretention Soil

Material Description

GeoTest - Bioretention Soil
poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 2.4606 D_{85}= 1.9667 D_{60}= 0.8483
D_{50}= 0.6547 D_{30}= 0.3989 D_{15}= 0.2551
D_{10}= 0.2012 C_u= 4.22 C_c= 0.93

Classification

USCS= SP AASHTO=

Remarks

Organics Content, ASTM D2974(C): 5.4%
(Sieve analysis performed after organics burn)

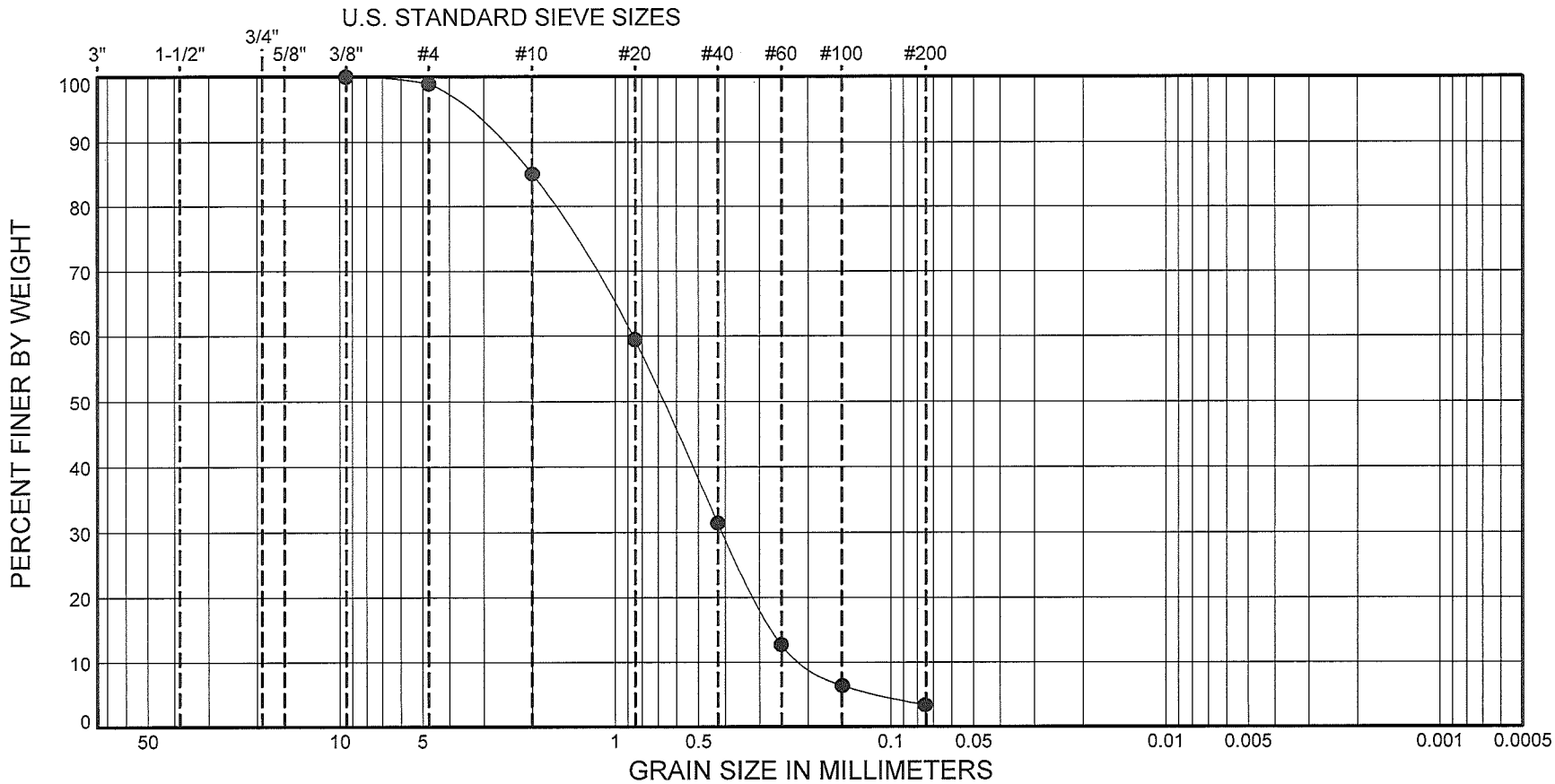
Location: Cedar Grove Composting

Date: 4-14-11

GEOTEST
741 Marine Drive
Bellingham, WA 98225
www.GeoTest-Inc.com

Client: Aspect Consulting
Project: SPU Bioretention Soil Workshop
Project No: 11-0162 **Report** S01

Tested By: BF **Checked By:** GR



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	BS-1			(SP) Very dark brown, poorly graded SAND	10				1.0	95.6	3.4

HWA GEOSCIENCES INC.

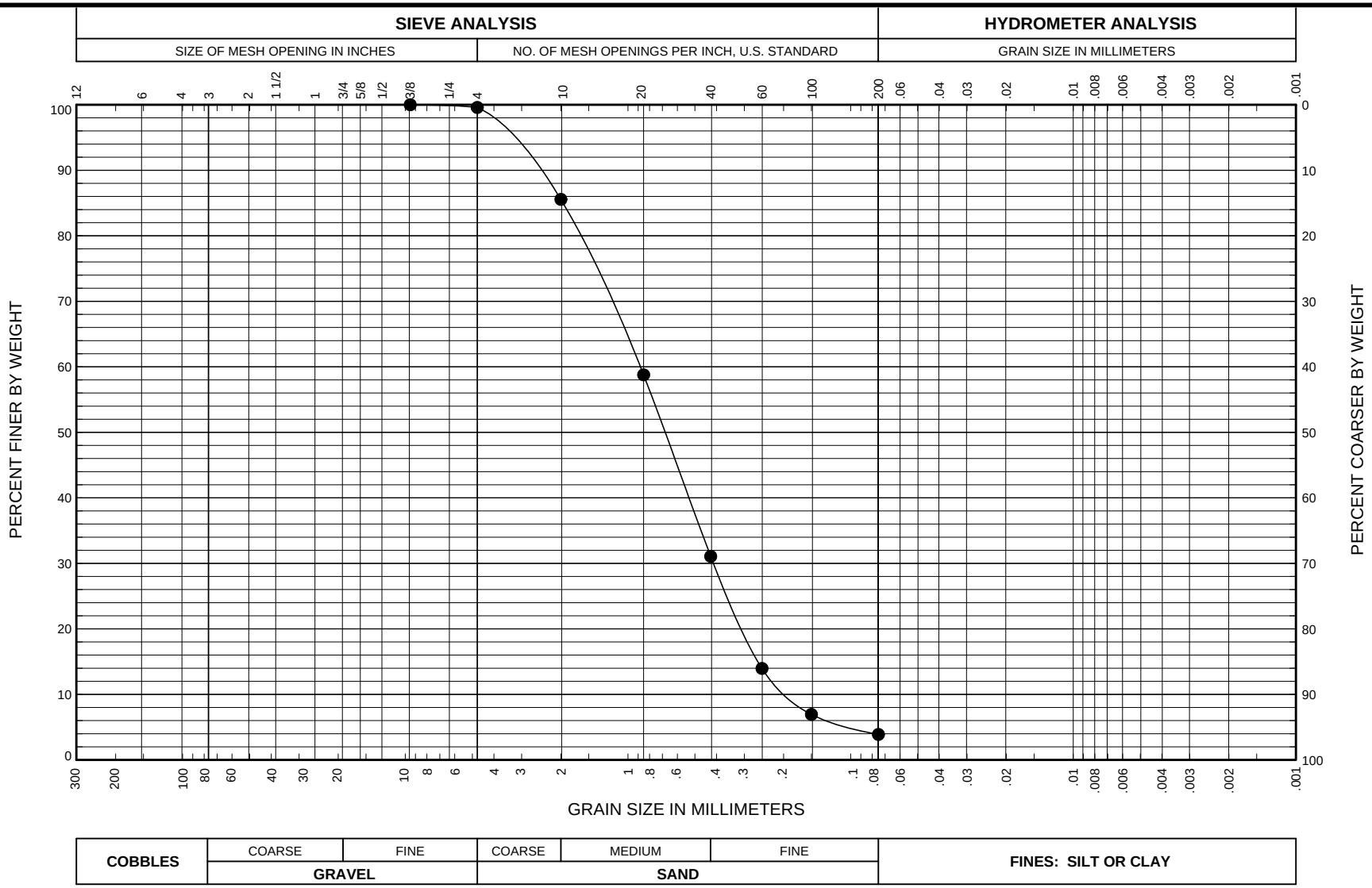
Biosoils Permeability Testing Workshop

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.:

FIGURE: 1

HWAGRSZ 2011-045.GPJ 4/18/11



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	NAT. W.C. %	PASS. #200,%	TEST BY	CKD BY	ASTM STND
● BS-ShanWil*	0.0	SP	Poorly Graded Sand; organic content= 5.6% by mass				14.0	3.9	AKV	JFL	D422

** Grain size analysis performed on specimen after burning for organic content.*

Biosoils Testing Workshop
Seattle, Washington

GRAIN SIZE DISTRIBUTION

April 2011 21-1-63100-004

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. Biosoils

FIG. Biosoils

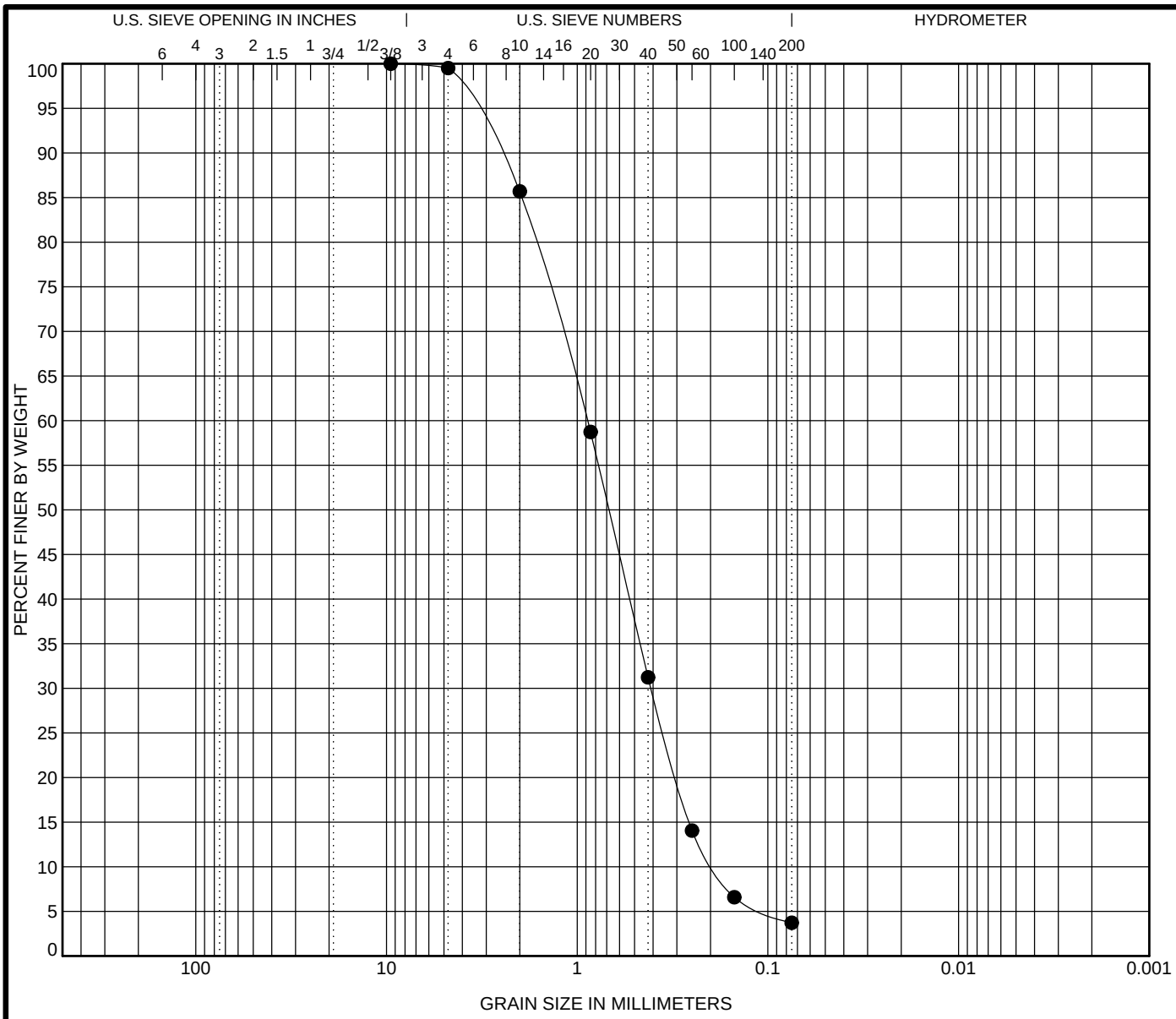
AASHTO GSA MAIN 21-63100-004.GPJ SHAN WIL.GDT 4/18/11

ORGANIC CONTENT

ASTM D2974
METHOD A/C

PROJECT					
Name :	**Biofiltration Workshop Soil**	Tested By :	CAN	Date :	**4/11/2011**
Number :	**Cedar Grove Compost**	Checked By :		Date :	
Comments :	**Using 5 porcelain dishes for test.**				

SAMPLE	Exploration No.										
	Sample No.										
	Depth	ft.									
MOISTURE CONTENT	Tare No.		**V-1**	**V-2**	**V-3**	**V-4**	**V-5**		**SUM**		
	a. Wet Wt. + Tare	g	**305.82**	**319.43**	**307.81**	**308.23**	**303.56**		**1544.85**		
	b. Dry Wt. + Tare	g	**279.45**	**290.25**	**281.05**	**280.38**	**276.77**		**1407.90**		
	c. Tare Weight	g	**131.25**	**131.45**	**125.99**	**128.40**	**131.50**		**648.59**		
	d. Moisture Loss (a-b)	g	**26.37**	**29.18**	**26.76**	**27.85**	**26.79**		**136.95**		
	e. Dry Weight (b-c)	g	**148.20**	**158.80**	**155.06**	**151.98**	**145.27**		**759.31**		
	f. Moist.Cont. (d/e)x100	%	**17.79**	**18.38**	**17.26**	**18.32**	**18.44**		**18.04**		
ORGANIC CONTENT	g. Tare No.		**V-1**	**V-2**	**V-3**	**V-4**	**V-5**		**SUM**		
	h. Dry Wt. + Tare	g	**279.45**	**290.25**	**281.05**	**280.38**	**276.77**		**1407.90**		
	i. Ash Wt. + Tare	g	**272.57**	**282.73**	**274.33**	**272.99**	**269.61**		**1372.23**		
	j. Tare Weight	g	**131.25**	**131.45**	**125.99**	**128.40**	**131.50**		**648.59**		
	k. Organic Loss (h-i)	g	**6.88**	**7.52**	**6.72**	**7.39**	**7.16**		**35.67**		
	l. Dry Weight (h-j)	g	**148.20**	**158.80**	**155.06**	**151.98**	**145.27**		**759.31**		
	m. Ash Weight (i-j)	g	**141.32**	**151.28**	**148.34**	**144.59**	**138.11**		**723.64**		
	n. Ash Cont. (m/l)x100	%	**95.36**	**95.26**	**95.67**	**95.14**	**95.07**		**95.30**		
	o. Org. Cont. (100-n)	%	**4.64**	**4.74**	**4.33**	**4.86**	**4.93**		**4.70**		



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Sample ID	Depth	Classification	LL	PL	PI	Cc	Cu
●	4/11/11;	0.0	POORLY GRADED SAND(SP)				1.0	4.7

	Sample ID	Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	4/11/11;	0.0	9.5	0.88	0.41	0.189	0.5	95.8	3.7	

Seattle Public Utilites
Geotechnical Engineering

GRAIN SIZE DISTRIBUTION (ASTM D422)

SPU GSD Biofiltration Workshop

April 2011 **FIGURE: 1**

US GRAIN SIZE PERMEAMETER TEST.GPJ TEMPL.GDT 4/15/11

APPENDIX C

Moisture-Density Relationship (Proctor) Test Results

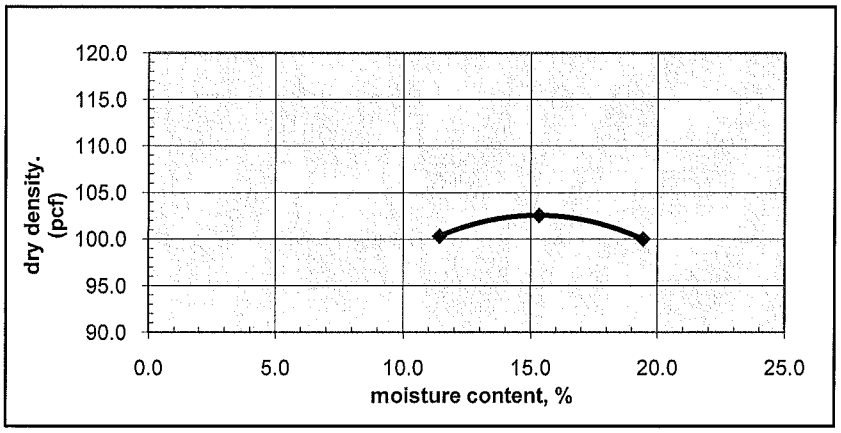
Associated Earth Sciences, Inc.

Proctor Analysis
ASTM D1557, D698

Date Sampled	Project	Project No.		Soil Description
4/15/2011	Aspect Bio Filtration Soil	KE110139A		Bio Retention Mix
Tested By **Collected By**	**Location**	**EB/EP No.**	**Depth**	
MS	Delivered			

Percent passing 3/4" sieve:	100%	ASTM D1557 Method C	Automatic Tamper

A	Mold Number	1	2	3		Remarks
B	Water Added	field	wet	dry		
C	Wt. of Wet Soil + Mold (lb)	20.800	20.885	20.315		
D	Wt. of Mold (lb)	11.995	11.995	11.995		
E	Wt. of Wet Soil (lb)	8.805	8.890	8.320		
F	Wet Density, (pcf)	118.269	119.411	111.754		
G	Wt. of Pan (lb)	0.485	0.495	0.485		
H	Wt. of Wet Soil + Pan (lb)	1.990	1.755	1.950		
J	Wt. of Dry Soil + Pan (lb)	1.790	1.550	1.800		
K	Wt. of Water (lb)	0.200	0.205	0.150		
M	Wt. of Dry Soil (lb)	1.305	1.055	1.315		
N	Moisture Content (%)	15.3	19.4	11.4		
O	Dry Density (pcf)	102.6	100.0	100.3		
Z	For a 6 inch mold: Z = 0.074449		For a 4" mold: Z = 0.0333			



Test Results:	
Optimum Moisture Percentage:	15.3
Maximum Dry Density:	102.6

Correction for oversize: ASTM D4718	
Corrected Moisture Percentage:	N/A
Corrected Maximum Dry Density:	N/A

Assumed Specific Gravity: 2.7

ASSOCIATED EARTH SCIENCES, INC.

911 Fifth Ave., Suite 100 Kirkland, WA 98033 425-827-7701 FAX 425-827-5424

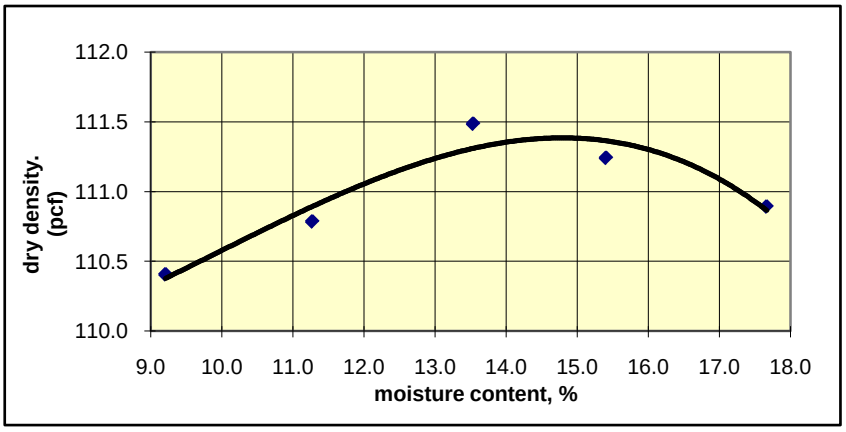
Associated Earth Sciences, Inc.

Proctor Analysis
ASTM D1557, D698
Modified A

Date Sampled	Project	Project No.		Soil Description
5/19/2011	Ceder Grove	KE110139A		
Tested By **Collected By**	**Location**	**EB/EP No.**	**Depth**	
MSP				

Percent passing #4 sieve:	100%	ASTM D1557 Method C	Automatic Tamper

A	Mold Number	1	2	3	4	5	Remarks
B	Water Added	field	wet	wet	wet	wet	
C	Wt. of Wet Soil + Mold (lb)	13.465	13.555	13.665	13.725	13.795	
D	Wt. of Mold (lb)	9.450	9.450	9.450	9.450	9.450	
E	Wt. of Wet Soil (lb)	4.015	4.105	4.215	4.275	4.345	
F	Wet Density, (pcf)	120.571	123.273	126.577	128.378	130.480	
G	Wt. of Pan (lb)	0.500	0.500	0.485	0.035	0.035	
H	Wt. of Wet Soil + Pan (lb)	4.355	3.560	2.540	2.170	2.000	
J	Wt. of Dry Soil + Pan (lb)	4.030	3.250	2.295	1.885	1.705	
K	Wt. of Water (lb)	0.325	0.310	0.245	0.285	0.295	
M	Wt. of Dry Soil (lb)	3.530	2.750	1.810	1.850	1.670	
N	Moisture Content (%)	9.2	11.3	13.5	15.4	17.7	
O	Dry Density (pcf)	110.4	110.8	111.5	111.2	110.9	
Z	For a 6 inch mold: Z = 0.074449 For a 4" mold: Z = 0.0333						



Test Results:	
Optimum Moisture Percentag	14.8
Maximum Dry Density:	111.5

Correction for oversize: ASTM D4718	
Corrected Moisture Percenta	N/A
Corrected Maximum Dry Der	N/A

Assumed Specific Gravity: 2.7

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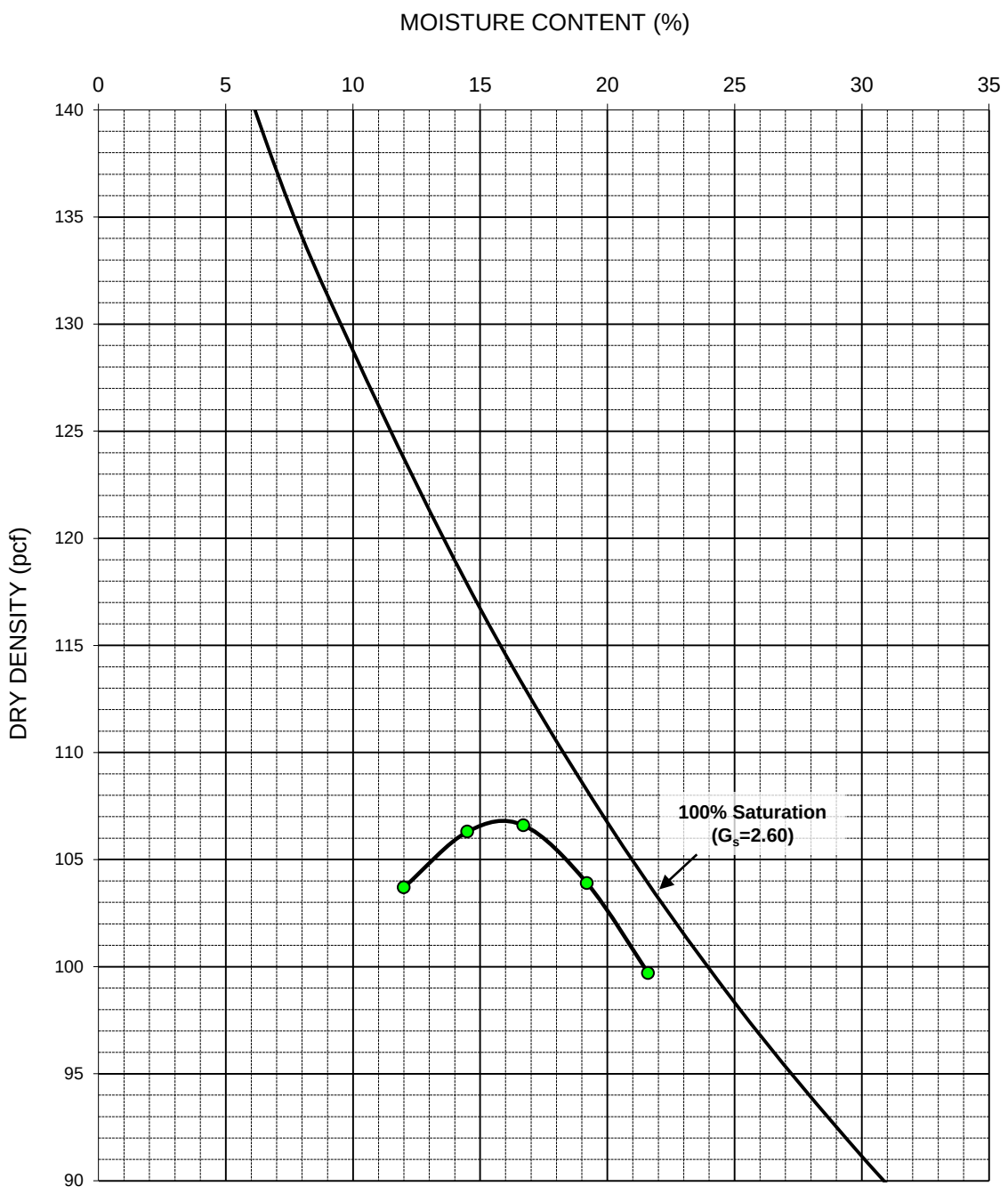


DESCRIPTION	SAMPLE NUMBER	SOIL CLASSIFICATION	OPTIMUM MOISTURE CONTENT	MAXIMUM DRY DENSITY (pcf)
● Biosoils	BS1	Poorly graded sand (SP) *(organic content = 4.8%; moisture content = 19.3%)*	15.9%	106.8

NOTE: Test performed in accordance with ASTM D-1557, Method C

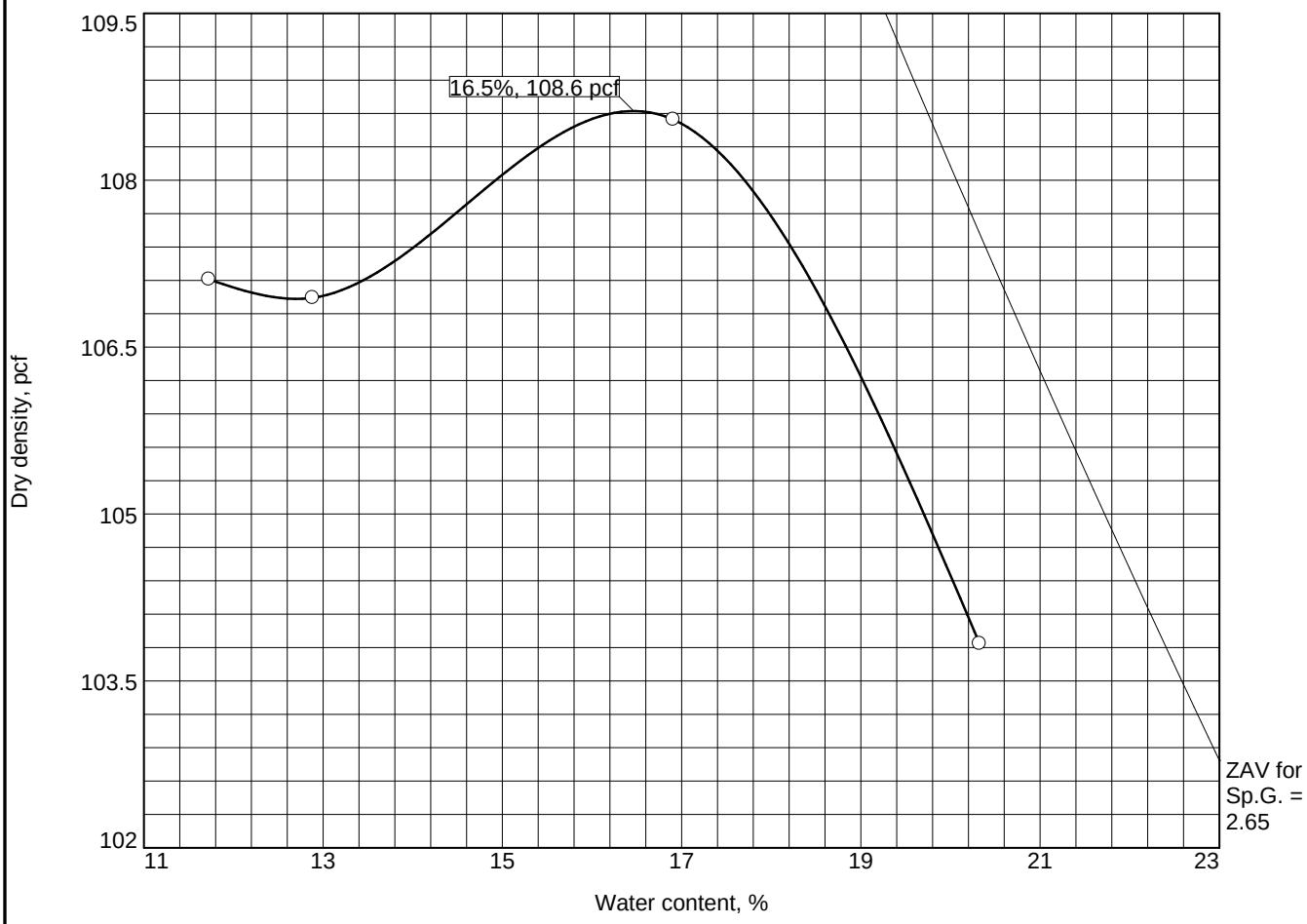
GEOENGINEERS

COMPACTION TEST RESULTS

FIGURE #-#

0129-139-00 CMK:SAS:sas 04-19-11 (PROCTOR.pptx)

Moisture-Density (Proctor) Test Report



Test specification: ASTM D 1557-07 Method A Modified

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > #4	% < No.200
	USCS	AASHTO						
	SP						0.6	3.2

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 108.6 pcf Optimum moisture = 16.5 %	GeoTest - Bioretention Soil poorly graded sand

Project No. 11-0162 **Client:** Aspect Consulting

Project: SPU Bioretention Soil Workshop

Date: 4-14-11

○ **Location:** Cedar Grove Composting

Remarks:
SPG: assumed

GEOTEST 741 Marine Drive Bellingham, WA 98225 www.GeoTest-Inc.com

Report S01

Tested By: BF **Checked By:** GR

LABORATORY COMPACTION CHARACTERISTICS OF SOIL

HWA GEOSCIENCES INC.

CLIENT: *Aspect Counseling*

PROJECT: *Biosoils Permeability Testing Workshop* **SAMPLE ID:** *BS-1*

PROJECT NO: *2011-045-23* Sampled By: *Client* Tested By: *JH*

Date Sampled: *N/A* Date Received: *4/6/2011* Date Tested: *4/15/2011*

MATERIAL TYPE OR DESCRIPTION:
Very dark brown, poorly graded SAND with organic material

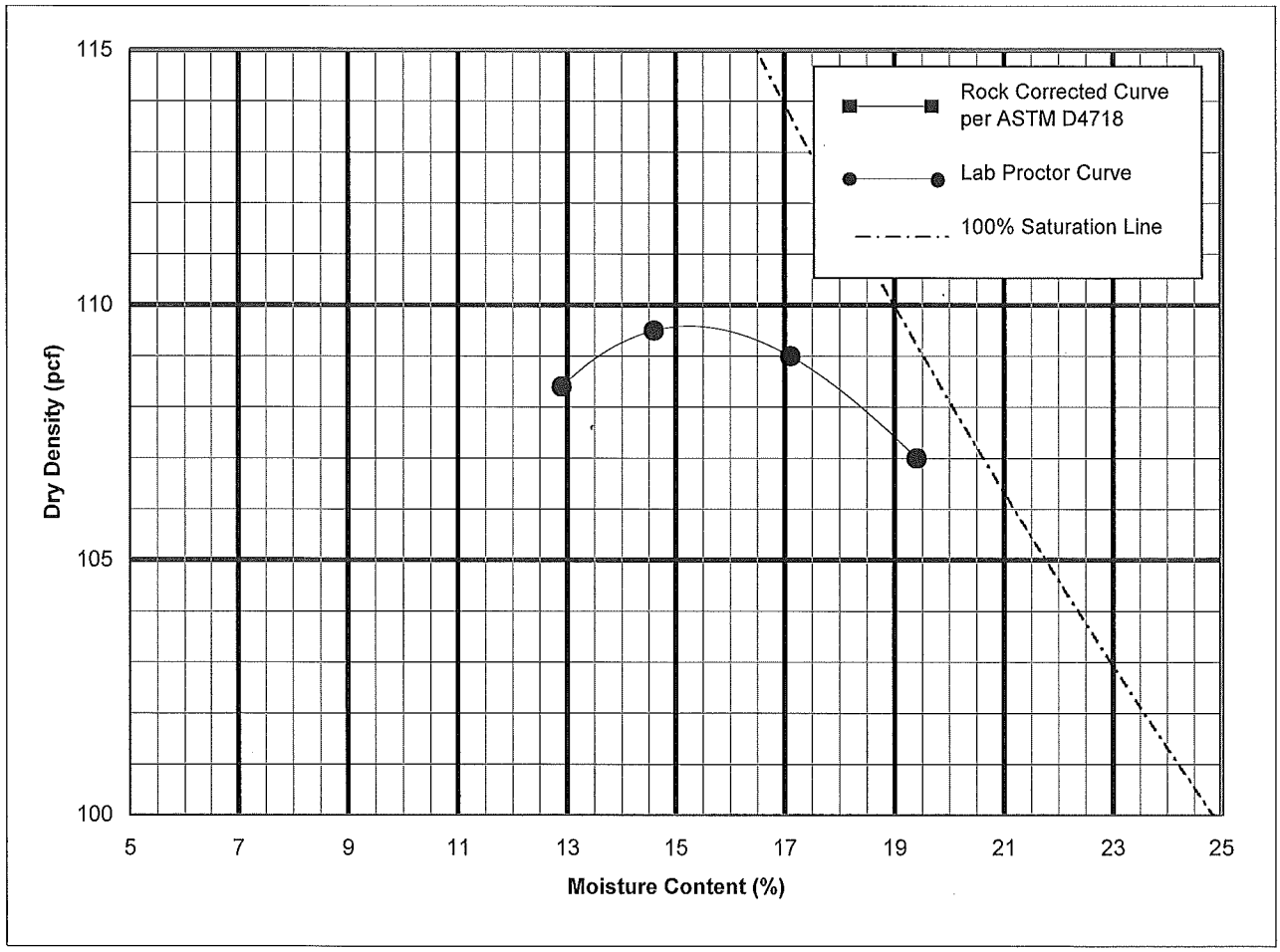
MATERIAL SOURCE, SAMPLE LOCATION AND DEPTH:

Designation: [ ] ASTM D 698 [X] ASTM D 1557 Natural Moisture Content: *10.1* %

Method: [ ] A [X] B [ ] C Oversize: *0* % retained on: *3/8* in.

Preparation: [ ] Dry [X] Moist Rammer: [X] Auto [ ] Manual Assumed S.G.: *2.65*

Test Data					
Dry Density (pcf)	108.4	109.5	109.0	107.0	
Moisture Content (%)	12.9	14.6	17.1	19.4	



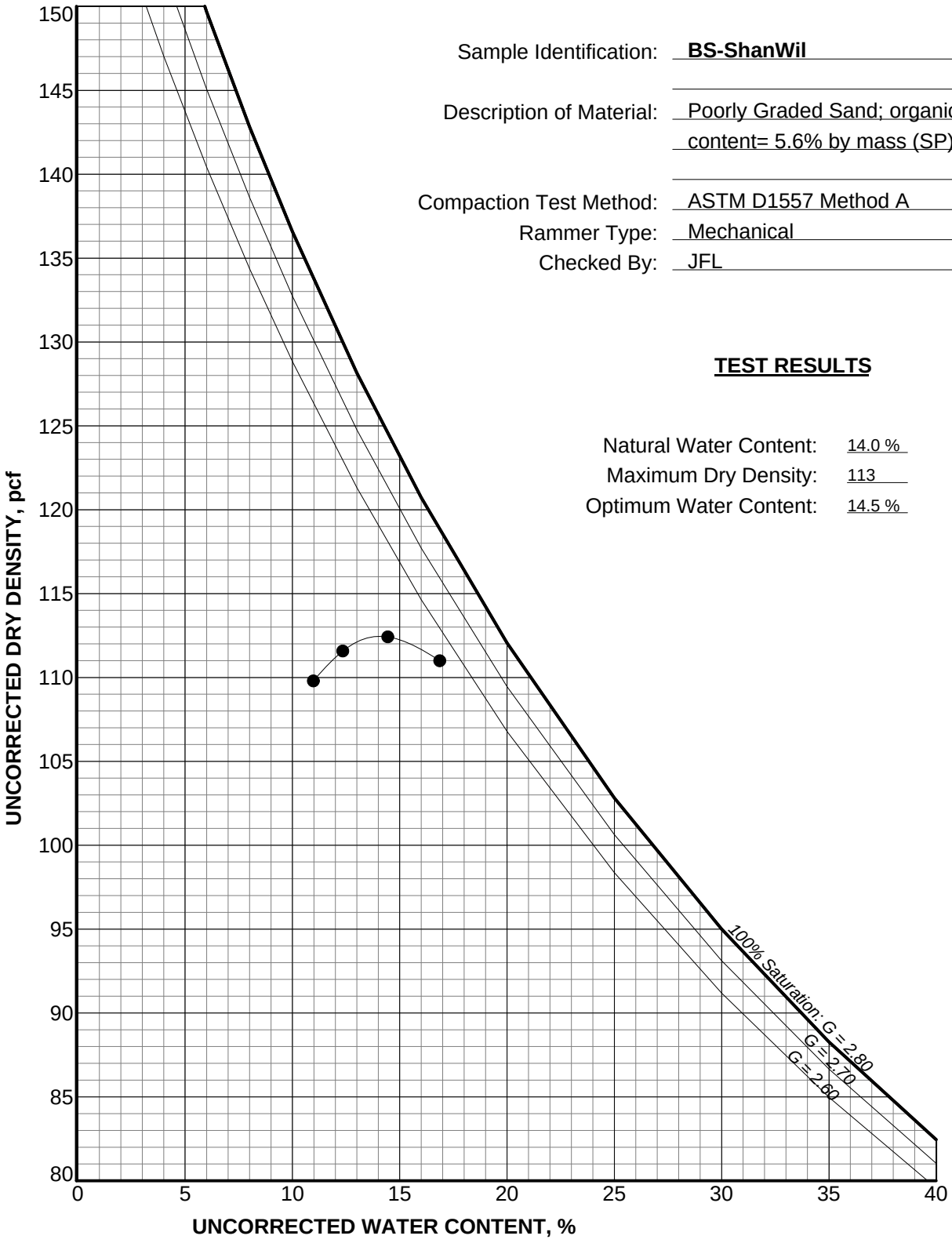
Data Summary*	
Percent Oversize	<5%
Max. Dry Density (pcf)*	109.6
Optimum Moisture (%)*	15.3

Test Values At Other Oversize Percentages						
0.0%	5.0%	10.0%	15.0%	20.0%	25.0%	30.0%
109.6	111.5	113.4	115.4	117.5	119.7	121.9
15.3	14.6	13.9	13.2	12.4	11.7	11.0

* values corrected for oversize material per ASTM D4718, using assumed Specific Gravity shown and oversize moisture content of 1%

Reviewed By: H Bauer **FIGURE** 1

This report applies only to the items tested, and may be reproduced in full, with written approval of HWA GEOSCIENCES INC.



Sample Identification: **BS-ShanWil**

Description of Material: Poorly Graded Sand; organic content= 5.6% by mass (SP)

Compaction Test Method: ASTM D1557 Method A

Rammer Type: Mechanical

Checked By: JFL

TEST RESULTS

Natural Water Content: 14.0 %

Maximum Dry Density: 113

Optimum Water Content: 14.5 %

OTHER TEST RESULTS

GRAIN SIZE ANALYSIS:

% Gravel: 0.4

% Sand: 95.7

% Fines: 3.9

Biosoils Testing Workshop
Seattle, Washington

MOISTURE-DENSITY TEST

April 2011 21-1-63100-004

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. Biosoils

DATA SHEET FOR LABORATORY COMPACTION CHARACTERISTICS OF SOIL

GENERAL INFORMATION

PROJECT **SPU Modified Proctor Biofiltration Workshop**	PROJECT NUMBER	SAMPLE ID	REPORT ID
MATERIAL (Type - section 9-03.16) / SUPPLIER (PIT NUMBER)	DATE RECEIVED **April 11, 2011**	DATE PERFORMED **April 12, 2011**	
LOCATION	LAB TEST BY: **TR** / MATERIALS LEAD: **TR**	ASTM STANDARD: **D1557**	PROCEDURE: (A) B C D
DESCRIPTION OF MATERIAL (D 2487 or D2488) **Sand w/ Organic material**	Mass of Moist Total Sample (.05LBS): **37.35** / Mass of Dry Test Fraction (lbs): 31.3	PREPARATION METHOD: (MOIST) DRY BOTH	
MOISTURE CONTENT of **Test Fraction (.001lb)**	Mass of Moist Oversize (.01LBS) / Mass of Dry Oversize (lbs)	OVERSIZE PERCENTAGE	

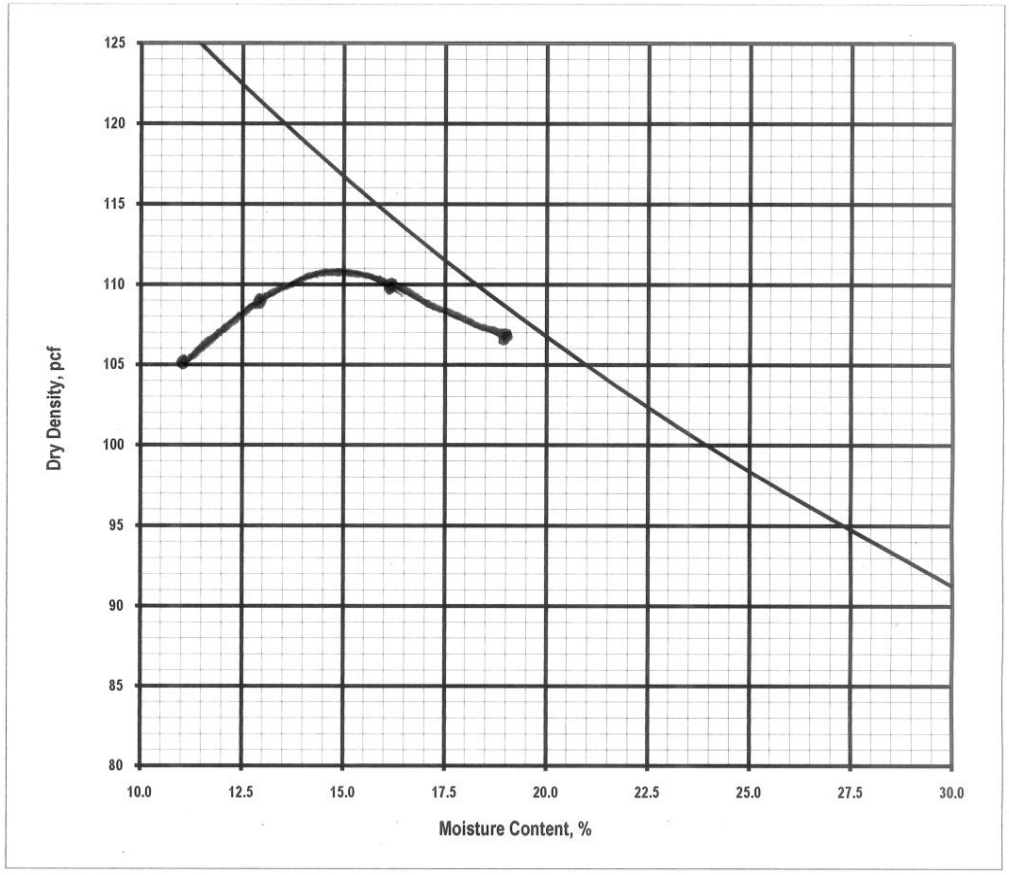
TARE WT	WET WT	DRY WT	MOISTURE CONTENT
0.2410	**2.5170**	**2.1460**	19.5

MOISTURE CONTENT of **Oversize (.001 lbs)**

MOLD VOLUME **0.03321**

TESTING INFORMATION

TRIAL	A	B	C	D
WATER ADDED (ml) or TIME DRIED (min)	**3 hours Dry**	**2 hours Dry**	**1 hour dry**	**Field**
WEIGHT OFBASE PLATE & MOLD (.001 *lbs*)	**9.476**	**9.476**	**9.476**	**9.476**
WEIGHT OF BASE PLATE, MOLD & SPECIMEN (*.001 lb*	**13.358**	**13.567**	**13.716**	**13.706**
WET DENSITY(*pcf*)	116.9	123.2	127.7	127.4
WEIGHT OF DRYING CONTAINER (.001 lbs)	**1.432**	**1.331**	**1.394**	**1.463**
WEIGHT OF WET SOIL & CONTAINER (.001lbs)	**5.350**	**5.410**	**5.629**	**5.621**
WEIGHT OF DRY SOIL & CONTAINER (.001lbs)	**4.960**	**4.945**	**5.040**	**4.957**
MOISTURE(%) (ASTM D 2216)	11.1	12.9	16.2	19.0
DRY DENSITY(*pcf*)	105.3	109.1	109.9	107.0



SUMMARY

MAXIMUM DRY DENSITY OF FINER PORTION (.1 *pcf*)	**111.0**
SPECIFIC GRAVITY OF OVERSIZE PARTICLES (ASTM C 127)	**2.6**
MAXIMUM DRY DENSITY (pcf) WITH OVERSIZE CORRECTION (ASTM D 4718)	
OPTIMUM MOISTURE (.1%)	**15.0**

* Round the Density and Moisture Content to the nearest .1 %
** Graph the 100% Saturation Line
*** SPU Materials Laboratory uses a mechanically operated proctor machine with a sector face plate.

Note:

APPENDIX D

Permeability Test Results

ASSOCIATED EARTH SCIENCES, INC

Constant Head Permeability
ATSM D2434-68

Date Sampled	Project Name	Project No.	Soil Description
4/15/2011	SPU Bioretention Soil Workshop	KE110139A	Poorly graded Sand; organics

Tested By	Location	EB/EP No.	Depth	Intended Use / Specification
MS	Ceder Grove Composting			Bioretention soil

Equation and Variables

Permeability	k	variable
Discharge/Flow volume	Q	variable
Total Head Loss	h	variable
Area of Soil Sample (sq. inches)	A	28.27
Distance between Manometers (inches)	L	6
Time of Test	t	variable

Start Saturation Date+Time
6/6/11 9:55

$k = QL/Aht$

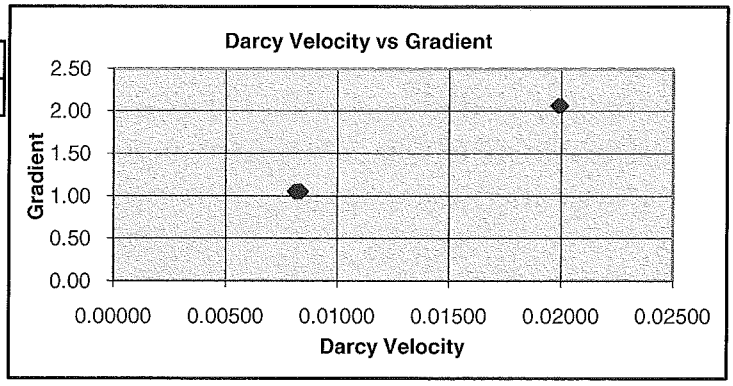
Specified Percent Proctor	85	%
Soil Max Dry Density	111.5	lbs/ft^3
Initial Moisture Content	14.4	%
Sample thickness	9	inches
Mold Diameter	6	inches
Weight of Soil for test	15.97	lb
Dry Unit Weight of Soil for test	94.78	lbs/ft^3

Moisture After Test Completion			
	tare wt	220.08	g
	wet wt + tare	893.02	g
	Dry wt + tare	764.98	g
	Final Moisture	23.5	%

		Trial 1	Trail 2	Trail 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8		
Basin Elevation (cm)		63.5	63.5	63.5	63.5	92.5	92.5	92.5	92.5		
Lower Manometer (cm)		62.5	62.5	62.5	62.5	91.5	91.5	91.5	91.5		
Upper Manometer (cm)		46.5	46.5	46.5	46.5	60	60	60	60		
Flow Volume (ml)		500	500	500	500	500	500	500	500		
Water Temperature°C		22	22	22	22	22	22	22	22		
Head Difference (cm) between Manometers		16	16	16	16	31.5	31.5	31.5	31.5		
Gradient h/L		1.05	1.05	1.05	1.05	2.07	2.07	2.07	2.07		
Time for test	Min	5	5	5	5	2	2	2	2		
	Sec	39	34	30	27	17	18	17	17		
Q/At		0.00809	0.00821	0.00831	0.00838	0.02001	0.01986	0.02001	0.02001		
k Value	in/hour	4.1	4.2	4.2	4.2	5.1	5.1	5.1	5.1		
	cm/sec	0.0029	0.0029	0.0030	0.0030	0.0036	0.0036	0.0036	0.0036		
Time of Test	Date	06/14/11	06/14/11	06/14/11	06/14/11	06/14/11	06/14/11	06/14/11	06/14/11		
	Time	8:30	8:40	8:50	9:00	9:30	9:40	9:50	10:00		
Total Soak (hrs)		190.6	190.7	190.9	191.1	191.6	191.8	191.9	192.1		

Total average K (permeability)	4.7	in/hour
	0.0033	cm/sec

Soil Void Ratio	0.55
Percent Voids	36%



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Constant Head Permeability
ATSM D2434-68

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Equation and Variables

Permeability	k	variable
Discharge/Flow volume	Q	variable
Total Head Loss	h	variable
Area of Soil Sample (sq. inches)	A	28.27
Distance between Manometers (inches)	L	6
Time of Test	t	variable

Start Saturation Date+Time
6/6/11 9:55

$k = QL/Aht$

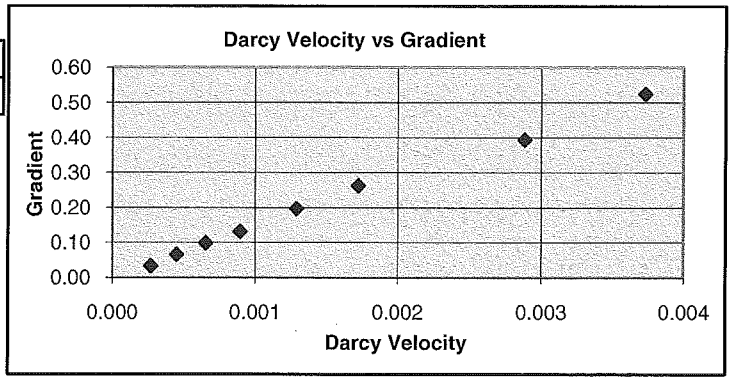
Specified Percent Proctor	85	%
Soil Max Dry Density	111.5	lbs/ft^3
Initial Moisture Content	14.4	%
Sample thickness	9	inches
Mold Diameter	6	inches
Weight of Soil for test	15.97	lb
Dry Unit Weight of Soil for test	94.78	lbs/ft^3

Moisture After Test Completion			
	tare wt	220.08	g
	wet wt + tare	893.02	g
	Dry wt + tare	764.98	g
	Final Moisture	23.5	%

		Trial 1	Trail 2	Trail 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8		
Basin Elevation (cm)		63	63	63	63	63	63	63	63.5		
Lower Manometer (cm)		62.5	62.5	62.5	62.5	62.5	62.3	62	62.5		
Upper Manometer (cm)		62	61.5	61	60.5	59.5	58.3	56	54.5		
Flow Volume (ml)		25	25	25	25	100	100	100	100		
Water Temperature°C		24	24	24	24	24	24	24	24		
Head Difference (cm) between Manometers		0.5	1	1.5	2	3	4	6	8		
Gradient h/L		0.03	0.07	0.10	0.13	0.20	0.26	0.39	0.52		
Time for test	Min	8	5	3	2	7	5	3	2		
	Sec	29	4	29	33	5	18	10	27		
Q/At		0.00027	0.00045	0.00066	0.00090	0.00129	0.00172	0.00289	0.00373		
k Value	in/hour	4.2	3.5	3.4	3.5	3.3	3.3	3.7	3.6		
	cm/sec	0.0029	0.0025	0.0024	0.0024	0.0023	0.0023	0.0026	0.0025		
Time of Test	Date	06/07/11	06/07/11	06/07/11	06/07/11	06/07/11	06/07/11	06/07/11	06/07/11		
	Time	6:00	7:00	7:30	8:10	8:35	9:15	10:00	10:30		
Total Soak (hrs)		20.1	21.1	21.6	22.3	22.7	23.3	24.1	24.6		

Total average K (permeability)	3.6	in/hour
	0.0025	cm/sec

Soil Void Ratio	0.55
Percent Voids	36%



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ASSOCIATED EARTH SCIENCES, INC

Constant Head Permeability
ATSM D2434-68

Date Sampled	Project Name	Project No.	Soil Description
4/15/2011	SPU Bioretention Soil Workshop	KE110139A	Poorly graded sand; organics

Tested By	Location	EB/EP No.	Depth	Intended Use / Specification
MS	Cedar Grove Composting			Bioretention soil

Equation and Variables

Permeability	k	variable
Discharge/Flow volume	Q	variable
Total Head Loss	h	variable
Area of Soil Sample (sq. inches)	A	28.27
Distance between Manometers (inches)	L	6
Time of Test	t	variable

Start Saturation Date+Time
6/6/11 9:55

$$k = QL/Aht$$

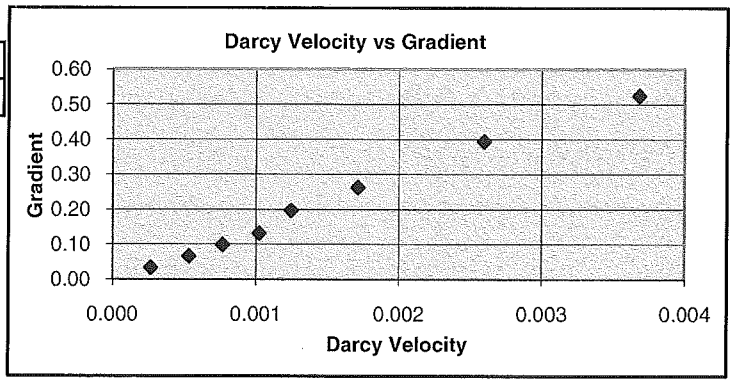
Specified Percent Proctor	85	%
Soil Max Dry Density	111.5	lbs/ft^3
Initial Moisture Content	14.4	%
Sample thickness	9	inches
Mold Diameter	6	inches
Weight of Soil for test	15.97	lb
Dry Unit Weight of Soil for test	94.78	lbs/ft^3

Moisture After Test Completion			
	tare wt	220.08	g
	wet wt + tare	893.02	g
	Dry wt + tare	764.98	g
	Final Moisture	23.5	%

		Trial 1	Trail 2	Trail 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8		
Basin Elevation (cm)		63.5	63.5	63.5	63.5	63.5	63	63.5	63.5		
Lower Manometer (cm)		63.1	63.1	63.1	63.1	63.4	63.4	63.2	63.1		
Upper Manometer (cm)		62.6	62.1	61.6	61.1	60.4	59.4	57.2	55.1		
Flow Volume (ml)		25	25	25	25	100	100	100	100		
Water Temperature°C		21	22	22	22	23	23	23	23		
Head Difference (cm) between Manometers		0.5	1	1.5	2	3	4	6	8		
Gradient h/L		0.03	0.07	0.10	0.13	0.20	0.26	0.39	0.52		
Time for test	Min	8	4	2	2	7	5	3	2		
	Sec	31	16	58	14	20	20	31	29		
Q/At		0.00027	0.00054	0.00077	0.00102	0.00125	0.00171	0.00260	0.00368		
k Value	in/hour	4.5	4.3	4.2	4.1	3.3	3.4	3.4	3.6		
	cm/sec	0.0031	0.0031	0.0029	0.0029	0.0023	0.0024	0.0024	0.0026		
Time of Test	Date	06/08/11	06/08/11	06/08/11	06/08/11	06/08/11	06/08/11	06/08/11	06/08/11		
	Time	6:55	7:40	8:05	8:30	8:53	9:35	10:20	10:45		
Total Soak (hrs)		45.0	45.8	46.2	46.6	47.0	47.7	48.4	48.8		

Total average K (permeability)	3.9	in/hour
	0.0027	cm/sec

Soil Void Ratio	0.55
Percent Voids	36%



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Constant Head Permeability
ATSM D2434-68

Date Sampled	Project Name	Project No.	Soil Description
4/15/2011	SPU Bioretention Soil Workshop	KE110139A	Poorly graded sand; organics

Tested By	Location	EB/EP No.	Depth	Intended Use / Specification
MS	Cedar Grove Composting			Bioretention soil

Equation and Variables

Permeability	k	variable
Discharge/Flow volume	Q	variable
Total Head Loss	h	variable
Area of Soil Sample (sq. inches)	A	28.27
Distance between Manometers (inches)	L	6
Time of Test	t	variable

Start Saturation Date+Time
6/6/11 9:55

$k = QL/Aht$

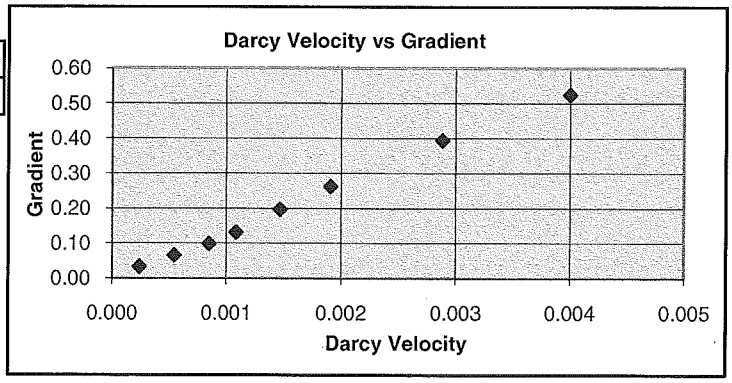
Specified Percent Proctor	85	%
Soil Max Dry Density	111.5	lbs/ft^3
Initial Moisture Content	14.4	%
Sample thickness	9	inches
Mold Diameter	6	inches
Weight of Soil for test	15.97	lb
Dry Unit Weight of Soil for test	94.78	lbs/ft^3

Moisture After Test Completion		
tare wt	220.08	g
wet wt + tare	893.02	g
Dry wt + tare	764.98	g
Final Moisture	23.5	%

		Trial 1	Trail 2	Trail 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8		
Basin Elevation (cm)		64	63.5	63.5	63.5	63.5	63.5	63.5	63.5		
Lower Manometer (cm)		63	63.2	63.2	63.2	63.2	63.2	63.2	63		
Upper Manometer (cm)		62.5	62.2	61.7	61.2	60.2	59.2	57.2	55		
Flow Volume (ml)		25	25	25	25	100	100	100	100		
Water Temperature°C		21	22	22	23	23	23	23	23		
Head Difference (cm) between Manometers		0.5	1	1.5	2	3	4	6	8		
Gradient h/L		0.03	0.07	0.10	0.13	0.20	0.26	0.39	0.52		
Time for test	Min	9	4	2	2	6	4	3	2		
	Sec	27	11	41	6	13	47	10	17		
Q/At		0.00024	0.00055	0.00085	0.00109	0.00147	0.00191	0.00289	0.00400		
k Value	in/hour	4.0	4.4	4.6	4.3	3.9	3.8	3.8	4.0		
	cm/sec	0.0028	0.0031	0.0032	0.0030	0.0027	0.0027	0.0027	0.0028		
Time of Test	Date	06/09/11	06/09/11	06/09/11	06/09/11	06/09/11	06/09/11	06/09/11	06/09/11		
	Time	8:00	9:10	9:35	10:10	10:40	11:30	12:10	12:35		
Total Soak (hrs)		70.1	71.3	71.7	72.2	72.8	73.6	74.3	74.7		

Total average K (permeability)	4.1	in/hour
	0.0029	cm/sec

Soil Void Ratio	0.55
Percent Voids	36%



ASSOCIATED EARTH SCIENCES, INC.

911 5th Ave., Suite 100 Kirkland, WA 98033 425-827-7701 FAX 425-827-5424

Biosoils Testing Workshop
GeoEngineers, Inc. – Permeability Test Results

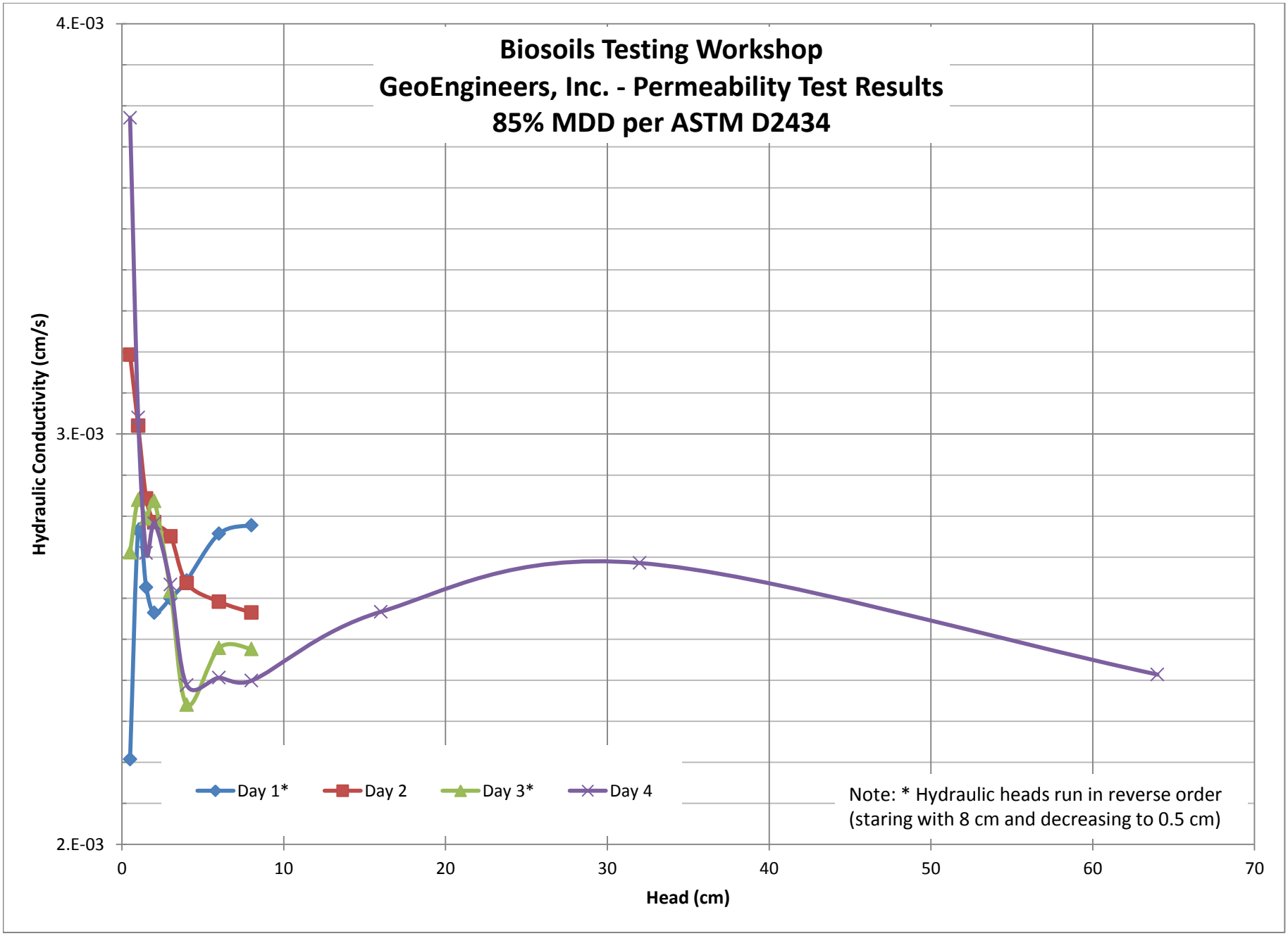
ASTM D2434 85%MDD (6-inch mold) *MC = 12.1%; Percent Compaction = 85.3% MDD*

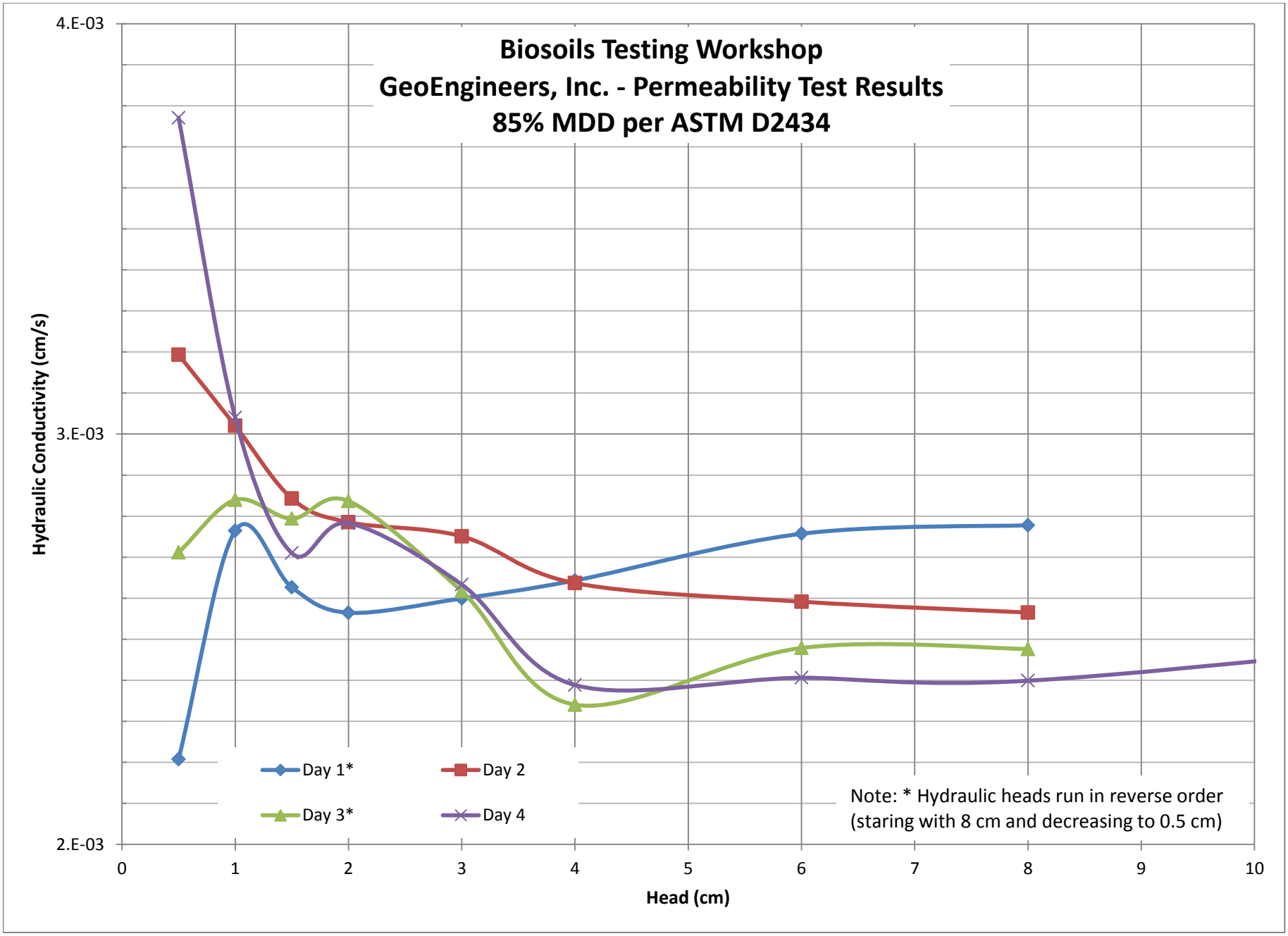
Head cm	Hydraulic Conductivity cm/s			
	Day 1*	Day 2	Day 3*	Day 4
0.5	2.21E-03	3.19E-03	2.71E-03	3.77E-03
1.0	2.76E-03	3.02E-03	2.84E-03	3.04E-03
1.5	2.63E-03	2.84E-03	2.79E-03	2.71E-03
2.0	2.56E-03	2.79E-03	2.84E-03	2.78E-03
3.0	2.60E-03	2.75E-03	2.62E-03	2.63E-03
4.0	2.64E-03	2.64E-03	2.34E-03	2.39E-03
6.0	2.76E-03	2.59E-03	2.48E-03	2.41E-03
8.0	2.78E-03	2.57E-03	2.48E-03	2.40E-03
16.0				2.57E-03
32.0				2.69E-03
64.0				2.41E-03

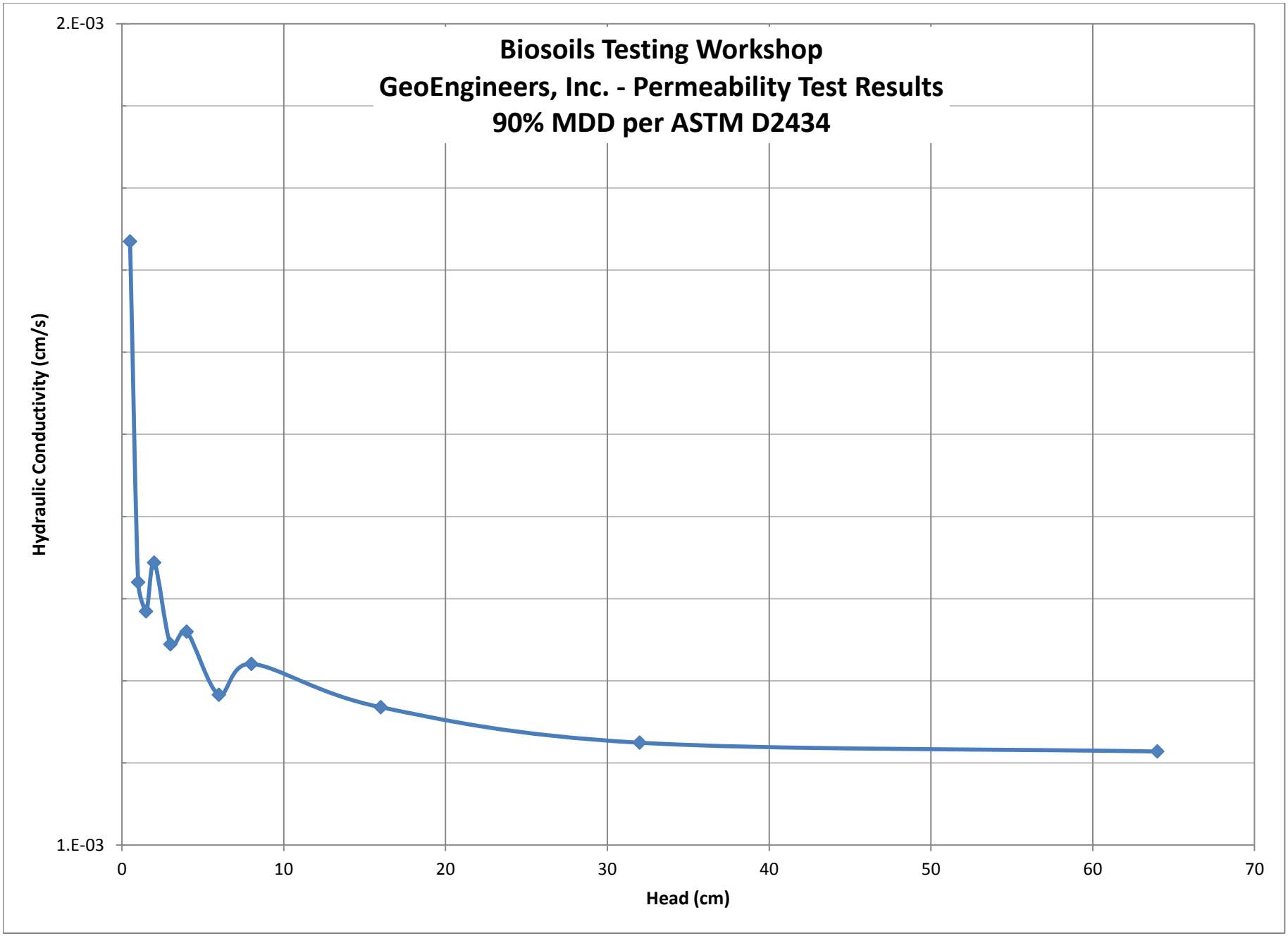
Note: * Hydraulic heads run in reverse order (staring with 8 cm and decreasing to 0.5 cm)

ASTM D2434 90%MDD (6-inch mold) *MC = 12.2%; Percent Compaction = 90.3% MDD*

Head cm	Hydraulic Conductivity cm/s
	Day 1
0.5	1.73E-03
1.0	1.32E-03
1.5	1.28E-03
2.0	1.34E-03
3.0	1.24E-03
4.0	1.26E-03
6.0	1.18E-03
8.0	1.22E-03
16.0	1.17E-03
32.0	1.12E-03
64.0	1.11E-03


Biosoils Testing Workshop
GeoEngineers, Inc. - Permeability Test Results
85% MDD per ASTM D2434
Hydraulic Conductivity (cm/s)
4.E-03
3.E-03
2.E-03
0
10
20
30
40
50
60
70
Head (cm)
Day 1*
Day 2
Day 3*
Day 4
Note: * Hydraulic heads run in reverse order
(staring with 8 cm and decreasing to 0.5 cm)


Biosoils Testing Workshop
GeoEngineers, Inc. - Permeability Test Results
85% MDD per ASTM D2434
Hydraulic Conductivity (cm/s)
4.E-03
3.E-03
2.E-03
0
1
2
3
4
5
6
7
8
9
10
Head (cm)
Day 1*
Day 2
Day 3*
Day 4
Note: * Hydraulic heads run in reverse order
(staring with 8 cm and decreasing to 0.5 cm)


Biosoils Testing Workshop
GeoEngineers, Inc. - Permeability Test Results
90% MDD per ASTM D2434
Hydraulic Conductivity (cm/s)
2.E-03
1.E-03
0
10
20
30
40
50
60
70
Head (cm)

Constant Head Permeability Test data

GEOENGINEERS

Project:	Biosoils Testing Workshop	Date:	6/14/11
Project #:	129-139-00	Tested by:	SAS
		Checked:	CMK

Boring #:	n/a	Sample #:	GEI-BS3	Depth:	n/a

Sample dia. (in):		6.00	(cm):	15.24	
Sample area (in^2):		28.274	(cm^2):	182.43	(A)
Sample length (in):		8.00	(cm):	20.32	(L)
Sample volume (in^3):		226.19	(cm^3):	3707.33	
Sample volume (ft^3):		0.1309			

Max. Dry Density (pcf)	113.6
Optimum Moisture Content (%)	12.5
Target Relative Density (%)	85.0
Sample Prepared Moisture Content (%)	12.1
Remolded Compaction (%)	85.3

Test Number	Manometer H_1 (cm)	Manometer H_2 (cm)	Head h (cm)	Length L (cm)	Volume Q (cm^3)	Time t (s)	Darcy Velocity Q/At (cm/s)	Gradient h/L	Hydraulic Conductivity k (cm/s)	Temp t (°C)	Viscosity μ (mPa•s)	Hydraulic Conductivity $k_{20°C}$ (cm/s)
1	73.90	81.90	8.0	15.24	48.5	186	1.43E-03	0.525	2.72E-03	20.0	1.0020	2.72E-03
2	73.90	81.90	8.0	15.24	80.0	300	1.46E-03	0.525	2.78E-03	20.0	1.0020	2.78E-03
3	73.90	81.90	8.0	15.24	79.5	301	1.45E-03	0.525	2.76E-03	20.0	1.0020	2.76E-03
4	73.90	81.90	8.0	15.24	80.0	301	1.46E-03	0.525	2.78E-03	20.0	1.0020	2.78E-03
5	73.90	81.90	8.0	15.24	80.5	301	1.47E-03	0.525	2.79E-03	20.0	1.0020	2.79E-03
											Geo Mean	2.78E-03
1	76.00	82.00	6.0	15.24	60.0	300	1.10E-03	0.394	2.78E-03	20.1	0.9995	2.78E-03
2	76.00	82.00	6.0	15.24	60.0	300	1.10E-03	0.394	2.78E-03	20.1	0.9995	2.78E-03
3	76.00	82.00	6.0	15.24	59.0	300	1.08E-03	0.394	2.74E-03	20.2	0.9971	2.72E-03
4	76.00	82.00	6.0	15.24	59.5	300	1.09E-03	0.394	2.76E-03	20.2	0.9971	2.75E-03
											Geo Mean	2.76E-03
1	78.00	82.00	4.0	15.24	39.0	300	7.13E-04	0.262	2.72E-03	20.7	0.9850	2.67E-03
2	78.00	82.00	4.0	15.24	39.0	300	7.13E-04	0.262	2.72E-03	20.7	0.9850	2.67E-03
3	78.00	82.00	4.0	15.24	38.5	300	7.03E-04	0.262	2.68E-03	20.7	0.9850	2.63E-03
4	78.00	82.00	4.0	15.24	38.0	300	6.94E-04	0.262	2.65E-03	20.7	0.9850	2.60E-03
											Geo Mean	2.64E-03
1	79.00	82.00	3.0	15.24	29.0	300	5.30E-04	0.197	2.69E-03	20.9	0.9803	2.63E-03
2	79.00	82.00	3.0	15.24	28.5	300	5.21E-04	0.197	2.65E-03	20.9	0.9803	2.59E-03
3	79.00	82.00	3.0	15.24	28.5	300	5.21E-04	0.197	2.65E-03	20.9	0.9803	2.59E-03
4	79.00	82.00	3.0	15.24	28.5	300	5.21E-04	0.197	2.65E-03	20.9	0.9803	2.59E-03
											Geo Mean	2.60E-03
1	80.00	82.00	2.0	15.24	18.5	300	3.38E-04	0.131	2.58E-03	21.0	0.9779	2.51E-03
2	80.00	82.00	2.0	15.24	19.0	300	3.47E-04	0.131	2.65E-03	21.0	0.9779	2.58E-03
3	80.00	82.00	2.0	15.24	19.0	300	3.47E-04	0.131	2.65E-03	21.0	0.9779	2.58E-03
4	80.00	82.00	2.0	15.24	19.0	300	3.47E-04	0.131	2.65E-03	21.0	0.9779	2.58E-03
											Geo Mean	2.56E-03
1	80.50	82.00	1.5	15.24	15.0	300	2.74E-04	0.098	2.78E-03	21.0	0.9779	2.72E-03
2	80.50	82.00	1.5	15.24	14.0	300	2.56E-04	0.098	2.60E-03	21.0	0.9779	2.54E-03
3	80.50	82.00	1.5	15.24	14.5	300	2.65E-04	0.098	2.69E-03	21.0	0.9779	2.63E-03
4	80.50	82.00	1.5	15.24	14.5	300	2.65E-04	0.098	2.69E-03	21.0	0.9779	2.63E-03
											Geo Mean	2.63E-03
1	81.00	82.00	1.0	15.24	10.5	300	1.92E-04	0.066	2.92E-03	20.8	0.9826	2.87E-03
2	81.00	82.00	1.0	15.24	10.0	300	1.83E-04	0.066	2.78E-03	20.8	0.9826	2.73E-03
3	81.00	82.00	1.0	15.24	10.0	300	1.83E-04	0.066	2.78E-03	20.8	0.9826	2.73E-03
4	81.00	82.00	1.0	15.24	10.0	300	1.83E-04	0.066	2.78E-03	20.8	0.9826	2.73E-03
											Geo Mean	2.76E-03
1	81.50	82.00	0.5	15.24	6.5	480	7.42E-05	0.033	2.26E-03	21.0	0.9779	2.21E-03
2	81.50	82.00	0.5	15.24	12.0	940	7.00E-05	0.033	2.13E-03	21.0	0.9779	2.08E-03
3	81.50	82.00	0.5	15.24	10.0	752	7.29E-05	0.033	2.22E-03	21.0	0.9779	2.17E-03
4	81.50	82.00	0.5	15.24	8.5	554	8.41E-05	0.033	2.56E-03	21.0	0.9779	2.50E-03
5	81.50	82.00	0.5	15.24	7.0	479	8.01E-05	0.033	2.44E-03	21.0	0.9779	2.38E-03
											Geo Mean	2.21E-03

References: Viscosity: Kestin, Sokolov & Wakeham (1978)

Constant Head Permeability Test data

GEOENGINEERS

Project:	Biosoils Testing Workshop	Date:	6/15/11
Project #:	129-139-00	Tested by:	SAS
		Checked:	CMK

Boring #:	n/a	Sample #:	GEI-BS3	Depth:	n/a

Sample dia. (in):		6.00	(cm):	15.24	
Sample area (in^2):		28.274	(cm^2):	182.43	(A)
Sample length (in):		8.00	(cm):	20.32	(L)
Sample volume (in^3):		226.19	(cm^3):	3707.33	
Sample volume (ft^3):		0.1309			

Max. Dry Density (pcf)	113.6
Optimum Moisture Content (%)	12.5
Target Relative Density (%)	85.0
Sample Prepared Moisture Content (%)	12.1
Remolded Compaction (%)	85.3

Test Number	Manometer H_1 (cm)	Manometer H_2 (cm)	Head h (cm)	Length L (cm)	Volume Q (cm^3)	Time t (s)	Darcy Velocity Q/At (cm/s)	Gradient h/L	Hydraulic Conductivity k (cm/s)	Temp t (°C)	Viscosity μ (mPa•s)	Hydraulic Conductivity $k_{20°C}$ (cm/s)
1	81.40	81.90	0.5	15.24	9.0	482	1.02E-04	0.033	3.12E-03	19.5	1.0144	3.16E-03
2	81.40	81.90	0.5	15.24	13.5	700	1.06E-04	0.033	3.22E-03	19.5	1.0144	3.26E-03
3	81.40	81.90	0.5	15.24	10.0	526	1.04E-04	0.033	3.18E-03	19.5	1.0144	3.22E-03
4	81.40	81.90	0.5	15.24	9.5	498	1.05E-04	0.033	3.19E-03	19.5	1.0144	3.23E-03
5	81.40	81.90	0.5	15.24	9.0	480	1.03E-04	0.033	3.13E-03	19.5	1.0144	3.17E-03
											Geo Mean	3.19E-03
1	80.90	81.90	1.0	15.24	11.0	300	2.01E-04	0.066	3.06E-03	20.1	0.9995	3.06E-03
2	80.90	81.90	1.0	15.24	11.0	300	2.01E-04	0.066	3.06E-03	20.1	0.9995	3.06E-03
3	80.90	81.90	1.0	15.24	10.5	300	1.92E-04	0.066	2.92E-03	20.1	0.9995	2.92E-03
4	80.90	81.90	1.0	15.24	11.0	300	2.01E-04	0.066	3.06E-03	20.1	0.9995	3.06E-03
											Geo Mean	3.02E-03
1	80.40	81.90	1.5	15.24	19.5	385	2.78E-04	0.098	2.82E-03	20.5	0.9898	2.79E-03
2	80.40	81.90	1.5	15.24	15.5	300	2.83E-04	0.098	2.88E-03	20.5	0.9898	2.84E-03
3	80.40	81.90	1.5	15.24	18.0	347	2.84E-04	0.098	2.89E-03	20.5	0.9898	2.85E-03
4	80.40	81.90	1.5	15.24	15.5	301	2.82E-04	0.098	2.87E-03	20.5	0.9898	2.83E-03
5	80.40	81.90	1.5	15.24	15.0	300	2.74E-04	0.098	2.78E-03	20.5	0.9898	2.75E-03
6	80.40	81.90	1.5	15.24	15.5	300	2.83E-04	0.098	2.88E-03	20.5	0.9898	2.84E-03
											Geo Mean	2.84E-03
1	79.90	81.90	2.0	15.24	20.0	300	3.65E-04	0.131	2.78E-03	20.5	0.9898	2.75E-03
2	79.90	81.90	2.0	15.24	20.5	300	3.75E-04	0.131	2.85E-03	20.5	0.9898	2.82E-03
3	79.90	81.90	2.0	15.24	20.5	300	3.75E-04	0.131	2.85E-03	20.5	0.9898	2.82E-03
4	79.90	81.90	2.0	15.24	20.0	300	3.65E-04	0.131	2.78E-03	20.5	0.9898	2.75E-03
											Geo Mean	2.79E-03
1	78.90	81.90	3.0	15.24	30.0	300	5.48E-04	0.197	2.78E-03	20.5	0.9898	2.75E-03
2	78.90	81.90	3.0	15.24	37.5	409	5.03E-04	0.197	2.55E-03	20.5	0.9898	2.52E-03
3	78.90	81.90	3.0	15.24	30.0	300	5.48E-04	0.197	2.78E-03	20.5	0.9898	2.75E-03
4	78.90	81.90	3.0	15.24	30.0	300	5.48E-04	0.197	2.78E-03	20.5	0.9898	2.75E-03
5	78.90	81.90	3.0	15.24	30.0	300	5.48E-04	0.197	2.78E-03	20.5	0.9898	2.75E-03
											Geo Mean	2.75E-03
1	77.90	81.90	4.0	15.24	39.0	300	7.13E-04	0.262	2.72E-03	20.4	0.9922	2.69E-03
2	77.90	81.90	4.0	15.24	38.0	300	6.94E-04	0.262	2.65E-03	20.4	0.9922	2.62E-03
3	77.90	81.90	4.0	15.24	38.0	300	6.94E-04	0.262	2.65E-03	20.4	0.9922	2.62E-03
4	77.90	81.90	4.0	15.24	38.0	300	6.94E-04	0.262	2.65E-03	20.4	0.9922	2.62E-03
											Geo Mean	2.64E-03
1	75.90	81.90	6.0	15.24	56.0	300	1.02E-03	0.394	2.60E-03	20.3	0.9947	2.58E-03
2	75.90	81.90	6.0	15.24	56.5	300	1.03E-03	0.394	2.62E-03	20.3	0.9947	2.60E-03
3	75.90	81.90	6.0	15.24	56.0	300	1.02E-03	0.394	2.60E-03	20.3	0.9947	2.58E-03
4	75.90	81.90	6.0	15.24	56.5	300	1.03E-03	0.394	2.62E-03	20.3	0.9947	2.60E-03
											Geo Mean	2.59E-03
1	73.90	81.90	8.0	15.24	74.5	300	1.36E-03	0.525	2.59E-03	20.1	0.9995	2.59E-03
2	73.90	81.90	8.0	15.24	74.0	300	1.35E-03	0.525	2.58E-03	20.1	0.9995	2.57E-03
3	73.90	81.90	8.0	15.24	74.0	300	1.35E-03	0.525	2.58E-03	20.1	0.9995	2.57E-03
4	73.90	81.90	8.0	15.24	73.0	300	1.33E-03	0.525	2.54E-03	20.1	0.9995	2.53E-03
											Geo Mean	2.57E-03

References: Viscosity: Kestin, Sokolov & Wakeham (1978)

Constant Head Permeability Test data

GEOENGINEERS

Project:	Biosoils Testing Workshop	Date:	6/16/11
Project #:	129-139-00	Tested by:	SAS
		Checked:	CMK
Boring #:	n/a	Sample #:	GEI-BS3
Depth:	n/a		

Sample dia. (in):	6.00	(cm):	15.24	
Sample area (in^2):	28.274	(cm^2):	182.43	(A)
Sample length (in):	8.00	(cm):	20.32	(L)
Sample volume (in^3):	226.19	(cm^3):	3707.33	
Sample volume (ft^3):	0.1309			

Max. Dry Density (pcf)	113.6
Optimum Moisture Content (%)	12.5
Target Relative Density (%)	85.0
Sample Prepared Moisture Content (%)	12.1
Remolded Compaction (%)	85.3

Test Number	Manometer H_1 (cm)	Manometer H_2 (cm)	Head h (cm)	Length L (cm)	Volume Q (cm^3)	Time t (s)	Darcy Velocity Q/At (cm/s)	Gradient h/L	Hydraulic Conductivity k (cm/s)	Temp t (°C)	Viscosity μ (mPa•s)	Hydraulic Conductivity $k_{20°C}$ (cm/s)
1	73.90	81.90	8.0	15.24	69.0	300	1.26E-03	0.525	2.40E-03	19.2	1.0220	2.45E-03
2	73.90	81.90	8.0	15.24	69.5	300	1.27E-03	0.525	2.42E-03	19.2	1.0220	2.47E-03
3	73.90	81.90	8.0	15.24	70.5	300	1.29E-03	0.525	2.45E-03	19.2	1.0220	2.50E-03
4	73.90	81.90	8.0	15.24	70.0	300	1.28E-03	0.525	2.44E-03	19.2	1.0220	2.49E-03
											Geo Mean	2.48E-03
1	75.90	81.90	6.0	15.24	53.0	300	9.68E-04	0.394	2.46E-03	19.4	1.0169	2.50E-03
2	75.90	81.90	6.0	15.24	52.0	300	9.50E-04	0.394	2.41E-03	19.4	1.0169	2.45E-03
3	75.90	81.90	6.0	15.24	52.5	300	9.59E-04	0.394	2.44E-03	19.4	1.0169	2.47E-03
4	75.90	81.90	6.0	15.24	53.0	300	9.68E-04	0.394	2.46E-03	19.4	1.0169	2.50E-03
											Geo Mean	2.48E-03
1	77.90	81.90	4.0	15.24	32.5	300	5.94E-04	0.262	2.26E-03	19.7	1.0094	2.28E-03
2	77.90	81.90	4.0	15.24	34.0	300	6.21E-04	0.262	2.37E-03	19.7	1.0094	2.38E-03
3	77.90	81.90	4.0	15.24	34.0	300	6.21E-04	0.262	2.37E-03	19.7	1.0094	2.38E-03
4	77.90	81.90	4.0	15.24	35.0	318	6.03E-04	0.262	2.30E-03	19.7	1.0094	2.32E-03
											Geo Mean	2.34E-03
1	78.90	81.90	3.0	15.24	36.0	359	5.50E-04	0.197	2.79E-03	19.9	1.0045	2.80E-03
2	78.90	81.90	3.0	15.24	28.5	300	5.21E-04	0.197	2.65E-03	19.9	1.0045	2.65E-03
3	78.90	81.90	3.0	15.24	28.0	300	5.12E-04	0.197	2.60E-03	19.9	1.0045	2.61E-03
4	78.90	81.90	3.0	15.24	28.0	300	5.12E-04	0.197	2.60E-03	19.9	1.0045	2.61E-03
5	78.90	81.90	3.0	15.24	28.0	300	5.12E-04	0.197	2.60E-03	19.9	1.0045	2.61E-03
											Geo Mean	2.62E-03
1	79.90	81.90	2.0	15.24	20.5	300	3.75E-04	0.131	2.85E-03	20.0	1.0020	2.85E-03
2	79.90	81.90	2.0	15.24	20.0	300	3.65E-04	0.131	2.78E-03	20.0	1.0020	2.78E-03
3	79.90	81.90	2.0	15.24	20.5	300	3.75E-04	0.131	2.85E-03	20.0	1.0020	2.85E-03
4	79.90	81.90	2.0	15.24	20.5	300	3.75E-04	0.131	2.85E-03	20.0	1.0020	2.85E-03
											Geo Mean	2.84E-03
1	80.40	81.90	1.5	15.24	15.5	300	2.83E-04	0.098	2.88E-03	20.2	0.9971	2.86E-03
2	80.40	81.90	1.5	15.24	15.0	300	2.74E-04	0.098	2.78E-03	20.2	0.9971	2.77E-03
3	80.40	81.90	1.5	15.24	15.0	300	2.74E-04	0.098	2.78E-03	20.2	0.9971	2.77E-03
4	80.40	81.90	1.5	15.24	15.0	300	2.74E-04	0.098	2.78E-03	20.2	0.9971	2.77E-03
											Geo Mean	2.79E-03
1	80.90	81.90	1.0	15.24	10.0	300	1.83E-04	0.066	2.78E-03	20.7	0.9850	2.74E-03
2	80.90	81.90	1.0	15.24	10.5	300	1.92E-04	0.066	2.92E-03	20.7	0.9850	2.87E-03
3	80.90	81.90	1.0	15.24	10.5	300	1.92E-04	0.066	2.92E-03	20.7	0.9850	2.87E-03
4	80.90	81.90	1.0	15.24	10.5	300	1.92E-04	0.066	2.92E-03	20.7	0.9850	2.87E-03
											Geo Mean	2.84E-03
1	81.40	81.90	0.5	15.24	5.0	300	9.14E-05	0.033	2.78E-03	20.8	0.9826	2.73E-03
2	81.40	81.90	0.5	15.24	4.5	300	8.22E-05	0.033	2.51E-03	20.8	0.9826	2.46E-03
3	81.40	81.90	0.5	15.24	6.0	348	9.45E-05	0.033	2.88E-03	20.8	0.9826	2.83E-03
4	81.40	81.90	0.5	15.24	5.5	316	9.54E-05	0.033	2.91E-03	20.8	0.9826	2.85E-03
											Geo Mean	2.71E-03

References: Viscosity: Kestin, Sokolov & Wakeham (1978)

Constant Head Permeability Test data

GeoEngineers

Project:	Biosoils Testing Workshop	Date:	6/17/11
Project #:	129-139-00	Tested by:	SAS
		Checked:	CMK

Boring #:	n/a	Sample #:	GEI-BS3	Depth:	n/a

Sample dia. (in):		6.00	(cm):	15.24	
Sample area (in^2):		28.274	(cm^2):	182.43	(A)
Sample length (in):		8.00	(cm):	20.32	(L)
Sample volume (in^3):		226.19	(cm^3):	3707.33	
Sample volume (ft^3):		0.1309			

Max. Dry Density (pcf)	113.6
Optimum Moisture Content (%)	12.5
Target Relative Density (%)	85.0
Sample Prepared Moisture Content (%)	12.1
Remolded Compaction (%)	85.3

Test Number	Manometer H_1 (cm)	Manometer H_2 (cm)	Head h (cm)	Length L (cm)	Volume Q (cm^3)	Time t (s)	Darcy Velocity Q/At (cm/s)	Gradient h/L	Hydraulic Conductivity k (cm/s)	Temp t (°C)	Viscosity μ (mPa•s)	Hydraulic Conductivity $k_{20°C}$ (cm/s)
1	81.4	81.9	0.5	15.24	7.0	300	1.28E-04	0.033	3.90E-03	19.1	1.0245	3.99E-03
2	81.4	81.9	0.5	15.24	6.5	300	1.19E-04	0.033	3.62E-03	19.1	1.0245	3.70E-03
3	81.4	81.9	0.5	15.24	6.5	300	1.19E-04	0.033	3.62E-03	19.1	1.0245	3.70E-03
4	81.4	81.9	0.5	15.24	6.5	300	1.19E-04	0.033	3.62E-03	19.1	1.0245	3.70E-03
											Geo Mean	3.77E-03
1	80.9	81.9	1.0	15.24	10.5	300	1.92E-04	0.066	2.92E-03	19.7	1.0094	2.95E-03
2	80.9	81.9	1.0	15.24	11.0	304	1.98E-04	0.066	3.02E-03	19.7	1.0094	3.05E-03
3	80.9	81.9	1.0	15.24	11.0	300	2.01E-04	0.066	3.06E-03	19.7	1.0094	3.09E-03
4	80.9	81.9	1.0	15.24	11.0	300	2.01E-04	0.066	3.06E-03	19.7	1.0094	3.09E-03
											Geo Mean	3.04E-03
1	80.4	81.9	1.5	15.24	13.0	300	2.38E-04	0.098	2.41E-03	19.9	1.0045	2.42E-03
2	80.4	81.9	1.5	15.24	14.5	300	2.65E-04	0.098	2.69E-03	19.9	1.0045	2.70E-03
3	80.4	81.9	1.5	15.24	18.0	351	2.81E-04	0.098	2.86E-03	19.9	1.0045	2.86E-03
4	80.4	81.9	1.5	15.24	15.5	300	2.83E-04	0.098	2.88E-03	19.9	1.0045	2.88E-03
											Geo Mean	2.71E-03
1	79.9	81.9	2.0	15.24	21.0	302	3.81E-04	0.131	2.90E-03	20.8	0.9826	2.85E-03
2	79.9	81.9	2.0	15.24	20.0	300	3.65E-04	0.131	2.78E-03	20.8	0.9826	2.73E-03
3	79.9	81.9	2.0	15.24	21.5	314	3.75E-04	0.131	2.86E-03	20.8	0.9826	2.80E-03
4	79.9	81.9	2.0	15.24	21.0	313	3.68E-04	0.131	2.80E-03	20.8	0.9826	2.75E-03
											Geo Mean	2.78E-03
1	78.9	81.9	3.0	15.24	31.0	300	5.66E-04	0.197	2.88E-03	21.0	0.9779	2.81E-03
2	78.9	81.9	3.0	15.24	32.5	350	5.09E-04	0.197	2.59E-03	21.0	0.9779	2.52E-03
3	78.9	81.9	3.0	15.24	20.5	212	5.30E-04	0.197	2.69E-03	21.0	0.9779	2.63E-03
4	78.9	81.9	3.0	15.24	28.5	300	5.21E-04	0.197	2.65E-03	21.0	0.9779	2.58E-03
											Geo Mean	2.63E-03
1	77.9	81.9	4.0	15.20	35.0	300	6.40E-04	0.263	2.43E-03	21.0	0.9779	2.37E-03
2	77.9	81.9	4.0	15.20	35.5	300	6.49E-04	0.263	2.46E-03	21.0	0.9779	2.41E-03
3	77.9	81.9	4.0	15.20	36.0	313	6.30E-04	0.263	2.40E-03	21.0	0.9779	2.34E-03
4	77.9	81.9	4.0	15.20	36.0	300	6.58E-04	0.263	2.50E-03	21.0	0.9779	2.44E-03
											Geo Mean	2.39E-03
1	75.9	81.9	6.0	15.24	52.5	300	9.59E-04	0.394	2.44E-03	21.0	0.9779	2.38E-03
2	75.9	81.9	6.0	15.24	54.0	300	9.87E-04	0.394	2.51E-03	21.0	0.9779	2.45E-03
3	75.9	81.9	6.0	15.24	53.0	300	9.68E-04	0.394	2.46E-03	21.0	0.9779	2.40E-03
4	75.9	81.9	6.0	15.24	53.0	300	9.68E-04	0.394	2.46E-03	21.0	0.9779	2.40E-03
											Geo Mean	2.41E-03
1	73.9	81.9	8.0	15.24	69.0	300	1.26E-03	0.525	2.40E-03	21.0	0.9779	2.34E-03
2	73.9	81.9	8.0	15.24	71.5	300	1.31E-03	0.525	2.49E-03	21.0	0.9779	2.43E-03
3	73.9	81.9	8.0	15.24	71.0	300	1.30E-03	0.525	2.47E-03	21.0	0.9779	2.41E-03
4	73.9	81.9	8.0	15.24	71.0	300	1.30E-03	0.525	2.47E-03	21.0	0.9779	2.41E-03
											Geo Mean	2.40E-03
1	65.6	81.6	16.0	15.24	81.5	165	2.71E-03	1.050	2.58E-03	21.0	0.9779	2.52E-03
2	65.6	81.6	16.0	15.24	83.5	165	2.77E-03	1.050	2.64E-03	21.0	0.9779	2.58E-03
3	65.6	81.6	16.0	15.24	83.5	165	2.77E-03	1.050	2.64E-03	21.0	0.9779	2.58E-03
4	65.6	81.6	16.0	15.24	84.0	165	2.79E-03	1.050	2.66E-03	21.0	0.9779	2.59E-03
											Geo Mean	2.57E-03
1	49.0	81.0	32.0	15.24	94.5	90	5.76E-03	2.100	2.74E-03	21.0	0.9779	2.68E-03
2	49.0	81.0	32.0	15.24	95.0	90	5.79E-03	2.100	2.76E-03	21.0	0.9779	2.69E-03
3	49.0	81.0	32.0	15.24	95.0	90	5.79E-03	2.100	2.76E-03	21.0	0.9779	2.69E-03

4	49.0	81.0	32.0	15.24	95.0	90	5.79E-03	2.100	2.76E-03	21.0	0.9779	2.69E-03
											Geo Mean	2.69E-03
1	16.0	80.0	64.0	15.24	95.5	50	1.05E-02	4.199	2.49E-03	21.0	0.9779	2.43E-03
2	16.0	80.0	64.0	15.24	95.0	50	1.04E-02	4.199	2.48E-03	21.0	0.9779	2.42E-03
3	16.0	80.0	64.0	15.24	94.5	50	1.04E-02	4.199	2.47E-03	21.0	0.9779	2.41E-03
4	16.0	80.0	64.0	15.24	92.5	50	1.01E-02	4.199	2.41E-03	21.0	0.9779	2.36E-03
5	16.0	80.0	64.0	15.24	94.0	50	1.03E-02	4.199	2.45E-03	21.0	0.9779	2.39E-03
											Geo Mean	2.41E-03

References: Viscosity: Kestin, Sokolov & Wakeham (1978)

Constant Head Permeability Test data

GEOENGINEERS

Project:	Biosoils Testing Workshop	Date:	6/21/11
Project #:	129-139-00	Tested by:	SAS
		Checked:	CMK
Boring #:	n/a	Sample #:	GEI-BS3
Depth:	n/a		

Sample dia. (in):	6.00	(cm):	15.24	
Sample area (in^2):	28.274	(cm^2):	182.43	(A)
Sample length (in):	8.00	(cm):	20.32	(L)
Sample volume (in^3):	226.19	(cm^3):	3707.33	
Sample volume (ft^3):	0.1309			

Max. Dry Density (pcf)	113.6
Optimum Moisture Content (%)	12.5
Target Relative Density (%)	90.0
Sample Prepared Moisture Content (%)	12.2
Remolded Compaction (%)	90.3

Test Number	Manometer H_1 (cm)	Manometer H_2 (cm)	Head h (cm)	Length L (cm)	Volume Q (cm^3)	Time t (s)	Darcy Velocity Q/At (cm/s)	Gradient h/L	Hydraulic Conductivity k (cm/s)	Temp t (°C)	Viscosity μ (mPa•s)	Hydraulic Conductivity $k_{20°C}$ (cm/s)
1	81.40	81.90	0.5	15.2	6.0	312	1.05E-04	0.033	3.20E-03	20.3	0.9947	3.18E-03
2	81.40	81.90	0.5	15.2	6.5	581	6.13E-05	0.033	1.86E-03	20.3	0.9947	1.85E-03
3	81.40	81.90	0.5	15.2	7.0	635	6.04E-05	0.033	1.84E-03	20.3	0.9947	1.82E-03
4	81.40	81.90	0.5	15.2	6.0	601	5.47E-05	0.033	1.66E-03	20.3	0.9947	1.65E-03
5	81.40	81.90	0.5	15.2	6.0	611	5.38E-05	0.033	1.64E-03	20.3	0.9947	1.62E-03
											Geo Mean	1.73E-03
1	81.00	82.00	1.0	15.2	8.0	327	1.34E-04	0.066	2.04E-03	21.0	0.9779	1.99E-03
2	81.00	82.00	1.0	15.2	5.5	310	9.73E-05	0.066	1.48E-03	21.0	0.9779	1.44E-03
3	81.00	82.00	1.0	15.2	7.5	489	8.41E-05	0.066	1.28E-03	21.0	0.9779	1.25E-03
4	81.00	82.00	1.0	15.2	6.5	402	8.86E-05	0.066	1.35E-03	21.0	0.9779	1.31E-03
5	81.00	82.00	1.0	15.2	6.5	412	8.65E-05	0.066	1.31E-03	21.0	0.9779	1.28E-03
											Geo Mean	1.32E-03
1	80.50	82.00	1.5	15.2	10.0	433	1.27E-04	0.099	1.28E-03	21.0	0.9779	1.25E-03
2	80.50	82.00	1.5	15.2	10.0	421	1.30E-04	0.099	1.32E-03	21.0	0.9779	1.29E-03
3	80.50	82.00	1.5	15.2	9.5	387	1.35E-04	0.099	1.36E-03	21.0	0.9779	1.33E-03
4	80.50	82.00	1.5	15.2	11.0	470	1.28E-04	0.099	1.30E-03	21.0	0.9779	1.27E-03
											Geo Mean	1.28E-03
1	80.00	82.00	2.0	15.2	10.0	301	1.82E-04	0.132	1.38E-03	21.2	0.9732	1.34E-03
2	80.00	82.00	2.0	15.2	10.0	302	1.82E-04	0.132	1.38E-03	21.2	0.9732	1.34E-03
3	80.00	82.00	2.0	15.2	11.0	334	1.81E-04	0.132	1.37E-03	21.2	0.9732	1.33E-03
4	80.00	82.00	2.0	15.2	9.0	268	1.84E-04	0.132	1.40E-03	21.2	0.9732	1.36E-03
											Geo Mean	1.34E-03
1	79.00	82.00	3.0	15.2	14.5	322	2.47E-04	0.197	1.25E-03	21.5	0.9662	1.21E-03
2	79.00	82.00	3.0	15.2	12.0	252	2.61E-04	0.197	1.32E-03	21.5	0.9662	1.28E-03
3	79.00	82.00	3.0	15.2	14.5	317	2.51E-04	0.197	1.27E-03	21.5	0.9662	1.22E-03
4	79.00	82.00	3.0	15.2	12.5	263	2.61E-04	0.197	1.32E-03	21.5	0.9662	1.27E-03
											Geo Mean	1.24E-03
1	78.00	82.00	4.0	15.2	18.5	300	3.38E-04	0.263	1.28E-03	20.8	0.9826	1.26E-03
2	78.00	82.00	4.0	15.2	17.0	274	3.40E-04	0.263	1.29E-03	20.8	0.9826	1.27E-03
3	78.00	82.00	4.0	15.2	18.5	300	3.38E-04	0.263	1.28E-03	20.8	0.9826	1.26E-03
4	78.00	82.00	4.0	15.2	19.0	310	3.36E-04	0.263	1.28E-03	20.8	0.9826	1.25E-03
											Geo Mean	1.26E-03
1	76.00	82.00	6.0	15.2	29.0	344	4.62E-04	0.395	1.17E-03	21.0	0.9779	1.14E-03
2	76.00	82.00	6.0	15.2	26.5	300	4.84E-04	0.395	1.23E-03	21.0	0.9779	1.20E-03
3	76.00	82.00	6.0	15.2	27.0	303	4.88E-04	0.395	1.24E-03	21.0	0.9779	1.21E-03
4	76.00	82.00	6.0	15.2	26.5	303	4.79E-04	0.395	1.21E-03	21.0	0.9779	1.19E-03
											Geo Mean	1.18E-03
1	73.80	81.80	8.0	15.2	35.5	300	6.49E-04	0.526	1.23E-03	20.8	0.9826	1.21E-03
2	73.80	81.80	8.0	15.2	36.0	300	6.58E-04	0.526	1.25E-03	20.8	0.9826	1.23E-03
3	73.80	81.80	8.0	15.2	36.0	300	6.58E-04	0.526	1.25E-03	20.8	0.9826	1.23E-03
4	73.80	81.80	8.0	15.2	31.0	259	6.56E-04	0.526	1.25E-03	20.8	0.9826	1.22E-03
											Geo Mean	1.22E-03
1	65.60	81.60	16.0	15.2	63.0	270	1.28E-03	1.053	1.22E-03	21.3	0.9708	1.18E-03
2	65.60	81.60	16.0	15.2	63.5	270	1.29E-03	1.053	1.22E-03	21.3	0.9708	1.19E-03
3	65.60	81.60	16.0	15.2	92.0	404	1.25E-03	1.053	1.19E-03	21.3	0.9708	1.15E-03
4	65.60	81.60	16.0	15.2	62.0	270	1.26E-03	1.053	1.20E-03	21.3	0.9708	1.16E-03
											Geo Mean	1.17E-03
1	49.10	81.10	32.0	15.2	60.5	134	2.47E-03	2.105	1.18E-03	21.1	0.9755	1.14E-03

2	49.10	81.10	32.0	15.2	60.0	134	2.45E-03	2.105	1.17E-03	21.1	0.9755	1.14E-03
3	49.10	81.10	32.0	15.2	81.0	186	2.39E-03	2.105	1.13E-03	21.1	0.9755	1.10E-03
4	49.10	81.10	32.0	15.2	66.0	150	2.41E-03	2.105	1.15E-03	21.1	0.9755	1.12E-03
											Geo Mean	1.12E-03
1	16.00	80.00	64.0	15.2	63.5	73	4.77E-03	4.211	1.13E-03	21.0	0.9779	1.11E-03
2	16.00	80.00	64.0	15.2	64.5	73	4.84E-03	4.211	1.15E-03	21.0	0.9779	1.12E-03
3	16.00	80.00	64.0	15.2	64.0	73	4.81E-03	4.211	1.14E-03	21.0	0.9779	1.11E-03
4	16.00	80.00	64.0	15.2	64.0	73	4.81E-03	4.211	1.14E-03	21.0	0.9779	1.11E-03
											Geo Mean	1.11E-03

References: Viscosity: Kestin, Sokolov & Wakeham (1978)

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BIORETENTION SOIL PERMEABILITY ANALYSIS

PROJECT:	**City of Seattle Bioretention Soil Workshop**	JOB #:	**11-0162**
CLIENT:	**Aspect Consulting**	REPORT #:	**01**
SOURCE:	**Cedar Grove**	DATE:	**5/23/11-5/26/11**
MATERIAL:	**Bioretention / Rain Garden Mix**	PAGE #:	**1 of 9**
		INSPECTOR:	**DPB**

UNIT WEIGHT		
1	LENGTH BETWEEN MAN, OUTLETS, L	15.24 cm
2	DIAMETER OF SOIL SPECIMENT, D	15.24 cm
3	CROSS-SECTIONAL AREA	182.32 cm^2
4	HEIGHT, H_1	25.60 cm
5	HEIGHT, H_2	5.09 cm
6	HEIGHT OF SPECIMEN	20.51 cm
7	VOLUME OF SPECIMEN	3739.4 cm^3
8	WEIGHT OF SOIL TOTAL, W_1	7593.4 g
9	WEIGHT OF SOIL UNUSED, W_2	1198.9 g
10	WEIGHT OF SOIL SPECIMENT	6394.5 g
11	WET DENSITY	106.7 lb/ft^3

MOISTURE		
	CONTAINER NO.	G8
a	WET WEIGHT + TARE	1898.5 g
b	DRY WEIGHT + TARE	1836.3 g
c	TARE WEIGHT	1461.5 g
d	WATER WEIGHT	62.2 g
e	DRY SOIL WEIGHT	374.8 g
12	WATER CONTENT	16.6%

13	DRY DENSITY	91.5 lb/ft^3
14	MAXIMUM DRY DENSITY	-
15	WATER CONTENT	84.3%

Day 1 Permeability Test Results

DAY 1 (0.5 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	0.5	32	600	18.2	182.32	15.24
2	0.5	32	600	18.2	182.32	15.24
3	0.5	32	600	18.2	182.32	15.24
4	0.5	32	600	18.2	182.32	15.24
Average	**0.5**	**32**	**600**	**18.2**	**182.32**	**15.24**

$i = 3.28 \times 10^{-2}$
$v = 2.93 \times 10^{-4}$ cm/s
$k = 8.92 \times 10^{-3}$ cm/s, $k_{20} = 9.28 \times 10^{-3}$ cm/s

DAY 1 (1.0 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	1.0	54	600	18.2	182.32	15.24
2	1.0	54	600	18.2	182.32	15.24
3	1.0	54	600	18.2	182.32	15.24
4	1.0	54	600	18.2	182.32	15.24
Average	**1.0**	**54**	**600**	**18.2**	**182.32**	**15.24**

$i = 6.56 \times 10^{-2}$
$v = 4.94 \times 10^{-4}$ cm/s
$k = 7.52 \times 10^{-3}$ cm/s, $k_{20} = 7.83 \times 10^{-3}$ cm/s

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DAY 1 (1.5 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	1.5	70	600	18.2	182.32	15.24
2	1.5	71	600	18.2	182.32	15.24
3	1.5	71	600	18.2	182.32	15.24
4	1.5	72	600	18.2	182.32	15.24
Average	**1.5**	**71**	**600**	**18.2**	**182.32**	**15.24**

$i = 9.84 \times 10^{-2}$
$v = 6.49 \times 10^{-4}$ cm/s
$k = 6.59 \times 10^{-3}$ cm/s, $k_{20} = 6.86 \times 10^{-3}$ cm/s

DAY 1 (2.0 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	2.0	98	600	18.2	182.32	15.24
2	2.0	98	600	18.2	182.32	15.24
3	2.0	100	600	18.2	182.32	15.24
4	2.0	100	600	18.2	182.32	15.24
Average	**2.0**	**99**	**600**	**18.2**	**182.32**	**15.24**

$i = 1.31 \times 10^{-1}$
$v = 9.05 \times 10^{-4}$ cm/s
$k = 6.90 \times 10^{-3}$ cm/s, $k_{20} = 7.17 \times 10^{-3}$ cm/s

DAY 1 (3.0 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	3.0	161	600	18.2	182.32	15.24
2	3.0	162	600	18.2	182.32	15.24
3	3.0	158	600	18.2	182.32	15.24
4	3.0	156	600	18.2	182.32	15.24
Average	**3.0**	**159**	**600**	**18.2**	**182.32**	**15.24**

$i = 1.97 \times 10^{-1}$
$v = 1.46 \times 10^{-3}$ cm/s
$k = 7.40 \times 10^{-3}$ cm/s, $k_{20} = 7.69 \times 10^{-3}$ cm/s

DAY 1 (4.0 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	4.0	220	600	18.2	182.32	15.24
2	4.0	218	600	18.2	182.32	15.24
3	4.0	221	600	18.2	182.32	15.24
4	4.0	220	600	18.2	182.32	15.24
Average	**4.0**	**220**	**600**	**18.2**	**182.32**	**15.24**

$i = 2.62 \times 10^{-1}$
$v = 2.01 \times 10^{-3}$ cm/s
$k = 7.65 \times 10^{-3}$ cm/s, $k_{20} = 7.96 \times 10^{-3}$ cm/s

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DAY 1 (6.0 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	6.0	170	300	18.2	182.32	15.24
2	6.0	173	300	18.2	182.32	15.24
3	6.0	174	300	18.2	182.32	15.24
4	6.0	175	300	18.2	182.32	15.24
Average	**6.0**	**173**	**300**	**18.2**	**182.32**	**15.24**

$i = 3.94 \times 10^{-1}$
$v = 3.16 \times 10^{-3}$ cm/s
$k = 8.03 \times 10^{-3}$ cm/s, $k_{20} = 8.36 \times 10^{-3}$ cm/s

DAY 1 (8.0 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	8.0	264	300	18.2	182.32	15.24
2	8.0	262	300	18.2	182.32	15.24
3	8.0	266	300	18.2	182.32	15.24
4	8.0	267	300	18.2	182.32	15.24
Average	**8.0**	**265**	**300**	**18.2**	**182.32**	**15.24**

$i = 5.25 \times 10^{-1}$
$v = 4.84 \times 10^{-3}$ cm/s
$k = 9.22 \times 10^{-3}$ cm/s, $k_{20} = 9.59 \times 10^{-3}$ cm/s

Day 2 Permeability Test Results

DAY 2 (0.5 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	0.5	32	600	18.2	182.32	15.24
2	0.5	30	600	18.2	182.32	15.24
3	0.5	29	600	18.2	182.32	15.24
4	0.5	30	600	18.2	182.32	15.24
Average	**0.5**	**30.25**	**600**	**18.2**	**182.32**	**15.24**

$i = 3.28 \times 10^{-2}$
$v = 2.77 \times 10^{-4}$ cm/s
$k = 8.43 \times 10^{-3}$ cm/s, $k_{20} = 8.79 \times 10^{-3}$ cm/s

DAY 2 (1.0 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	1.0	65	600	18.2	182.32	15.24
2	1.0	65	600	18.2	182.32	15.24
3	1.0	64	600	18.2	182.32	15.24
4	1.0	64	600	18.2	182.32	15.24
Average	**1.0**	**64.5**	**600**	**18.2**	**182.32**	**15.24**

$i = 6.56 \times 10^{-2}$
$v = 5.90 \times 10^{-4}$ cm/s
$k = 8.99 \times 10^{-3}$ cm/s, $k_{20} = 9.38 \times 10^{-3}$ cm/s

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DAY 2 (1.5 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	1.5	100	600	18.2	182.32	15.24
2	1.5	100	600	18.2	182.32	15.24
3	1.5	100	600	18.2	182.32	15.24
4	1.5	100	600	18.2	182.32	15.24
Average	**1.5**	**100**	**600**	**18.2**	**182.32**	**15.24**

$i = 9.84 \times 10^{-2}$
$v = 9.14 \times 10^{-4}$ cm/s
$k = 9.29 \times 10^{-3}$ cm/s, $k_{20} = 9.69 \times 10^{-3}$ cm/s

DAY 2 (2.0 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	2.0	134	600	18.2	182.32	15.24
2	2.0	134	600	18.2	182.32	15.24
3	2.0	134	600	18.2	182.32	15.24
4	2.0	134	600	18.2	182.32	15.24
Average	**2.0**	**134**	**600**	**18.2**	**182.32**	**15.24**

$i = 1.31 \times 10^{-2}$
$v = 1.23 \times 10^{-3}$ cm/s
$k = 9.33 \times 10^{-3}$ cm/s, $k_{20} = 9.74 \times 10^{-3}$ cm/s

DAY 2 (3.0 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	3.0	106	300	18.2	182.32	15.24
2	3.0	106	300	18.2	182.32	15.24
3	3.0	105	300	18.2	182.32	15.24
4	3.0	155	300	18.2	182.32	15.24
Average	**3.0**	**105.5**	**300**	**18.2**	**182.32**	**15.24**

$i = 1.97 \times 10^{-2}$
$v = 1.93 \times 10^{-3}$ cm/s
$k = 9.80 \times 10^{-3}$ cm/s, $k_{20} = 1.02 \times 10^{-2}$ cm/s

DAY 2 (4.0 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	4.0	144	300	18.2	182.32	15.24
2	4.0	144	300	18.2	182.32	15.24
3	4.0	144	300	18.2	182.32	15.24
4	4.0	144	300	18.2	182.32	15.24
Average	**4.0**	**144**	**300**	**18.2**	**182.32**	**15.24**

$i = 2.62 \times 10^{-1}$
$v = 2.63 \times 10^{-3}$ cm/s
$k = 1.00 \times 10^{-2}$ cm/s, $k_{20} = 1.05 \times 10^{-2}$ cm/s

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DAY 2 (6.0 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	6.0	170	300	18.2	182.32	15.24
2	6.0	173	300	18.2	182.32	15.24
3	6.0	174	300	18.2	182.32	15.24
4	6.0	175	300	18.2	182.32	15.24
Average	**6.0**	**173**	**300**	**18.2**	**182.32**	**15.24**

$i = 3.94 \times 10^{-1}$
$v = 4.01 \times 10^{-3}$ cm/s
$k = 1.04 \times 10^{-2}$ cm/s, $k_{20} = 1.08 \times 10^{-2}$ cm/s

DAY 2 (8.0 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	8.0	312	300	18.2	182.32	15.24
2	8.0	312	300	18.2	182.32	15.24
3	8.0	312	300	18.2	182.32	15.24
4	8.0	312	300	18.2	182.32	15.24
Average	**8.0**	**312**	**300**	**18.2**	**182.32**	**15.24**

$i = 5.23 \times 10^{-1}$
$v = 5.70 \times 10^{-3}$ cm/s
$k = 1.09 \times 10^{-2}$ cm/s, $k_{20} = 1.13 \times 10^{-2}$ cm/s

<u>Day 3 Permeability Test Results</u>

DAY 3 (0.5 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	0.5	43	600	18.2	182.32	15.24
2	0.5	43	600	18.2	182.32	15.24
3	0.5	42	600	18.2	182.32	15.24
4	0.5	43	600	18.2	182.32	15.24
Average	**0.5**	**42.75**	**600**	**18.2**	**182.32**	**15.24**

$i = 3.28 \times 10^{-2}$
$v = 3.91 \times 10^{-4}$ cm/s
$k = 1.19 \times 10^{-2}$ cm/s, $k_{20} = 1.24 \times 10^{-2}$ cm/s

DAY 3 (1.0 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	1.0	67	600	18.2	182.32	15.24
2	1.0	67	600	18.2	182.32	15.24
3	1.0	67	600	18.2	182.32	15.24
4	1.0	67	600	18.2	182.32	15.24
Average	**1.0**	**67**	**600**	**18.2**	**182.32**	**15.24**

$i = 6.56 \times 10^{-2}$
$v = 6.12 \times 10^{-4}$ cm/s
$k = 9.33 \times 10^{-3}$ cm/s, $k_{20} = 9.74 \times 10^{-3}$ cm/s

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DAY 3 (1.5 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	1.5	116	600	18.2	182.32	15.24
2	1.5	116	600	18.2	182.32	15.24
3	1.5	116	600	18.2	182.32	15.24
4	1.5	116	600	18.2	182.32	15.24
Average	**1.5**	**116**	**600**	**18.2**	**182.32**	**15.24**

$i = 9.84 \times 10^{-2}$
$v = 1.06 \times 10^{-3}$ cm/s
$k = 1.08 \times 10^{-2}$ cm/s, $k_{20} = 1.12 \times 10^{-2}$ cm/s

DAY 3 (2.0 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	2.0	85	300	18.2	182.32	15.24
2	2.0	85	300	18.2	182.32	15.24
3	2.0	85	300	18.2	182.32	15.24
4	2.0	85	300	18.2	182.32	15.24
Average	**2.0**	**85**	**300**	**18.2**	**182.32**	**15.24**

$i = 1.31 \times 10^{-1}$
$v = 1.55 \times 10^{-3}$ cm/s
$k = 1.18 \times 10^{-2}$ cm/s, $k_{20} = 1.24 \times 10^{-2}$ cm/s

DAY 3 (3.0 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	3.0	123	300	18.2	182.32	15.24
2	3.0	123	300	18.2	182.32	15.24
3	3.0	123	300	18.2	182.32	15.24
4	3.0	123	300	18.2	182.32	15.24
Average	**3.0**	**123**	**300**	**18.2**	**182.32**	**15.24**

$i = 1.97 \times 10^{-1}$
$v = 2.25 \times 10^{-3}$ cm/s
$k = 1.14 \times 10^{-2}$ cm/s, $k_{20} = 1.19 \times 10^{-2}$ cm/s

DAY 3 (4.0 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	4.0	165	300	18.2	182.32	15.24
2	4.0	165	300	18.2	182.32	15.24
3	4.0	165	300	18.2	182.32	15.24
4	4.0	165	300	18.2	182.32	15.24
Average	**4.0**	**165**	**300**	**18.2**	**182.32**	**15.24**

$i = 2.62 \times 10^{-1}$
$v = 3.02 \times 10^{-3}$ cm/s
$k = 1.15 \times 10^{-2}$ cm/s, $k_{20} = 1.20 \times 10^{-2}$ cm/s

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DAY 3 (6.0 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	6.0	251	300	18.2	182.32	15.24
2	6.0	251	300	18.2	182.32	15.24
3	6.0	251	300	18.2	182.32	15.24
4	6.0	251	300	18.2	182.32	15.24
Average	**6.0**	**251**	**300**	**18.2**	**182.32**	**15.24**

$i = 3.94 \times 10^{-1}$
$v = 4.59 \times 10^{-3}$ cm/s
$k = 1.17 \times 10^{-2}$ cm/s, $k_{20} = 1.22 \times 10^{-2}$ cm/s

DAY 3 (8.0 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	8.0	343	300	18.2	182.32	15.24
2	8.0	343	300	18.2	182.32	15.24
3	8.0	343	300	18.2	182.32	15.24
4	8.0	343	300	18.2	182.32	15.24
Average	**8.0**	**343**	**300**	**18.2**	**182.32**	**15.24**

$i = 5.25 \times 10^{-1}$
$v = 6.27 \times 10^{-3}$ cm/s
$k = 1.19 \times 10^{-2}$ cm/s, $k_{20} = 1.27 \times 10^{-2}$ cm/s

<u>Day 4 Permeability Test Results</u>

DAY 4 (0.5 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	0.5	62	600	17.8	182.32	15.24
2	0.5	62	600	17.8	182.32	15.24
3	0.5	62	600	17.8	182.32	15.24
4	0.5	63	600	17.8	182.32	15.24
Average	**0.5**	**62.25**	**600**	**17.8**	**182.32**	**15.24**

$i = 3.28 \times 10^{-2}$
$v = 5.69 \times 10^{-4}$ cm/s
$k = 1.73 \times 10^{-2}$ cm/s, $k_{20} = 1.83 \times 10^{-2}$ cm/s

DAY 4 (1.0 cm)						
Trial	**h (cm)**	**V (ml)**	**t (sec)**	**T (° C)**	**A (cm^2)**	**L (cm)**
1	1.0	103	600	17.8	182.32	15.24
2	1.0	104	600	17.8	182.32	15.24
3	1.0	104	600	17.8	182.32	15.24
4	1.0	104	600	17.8	182.32	15.24
Average	**1.0**	**103.75**	**600**	**17.8**	**182.32**	**15.24**

$i = 6.56 \times 10^{-2}$
$v = 9.48 \times 10^{-4}$ cm/s
$k = 1.45 \times 10^{-2}$ cm/s, $k_{20} = 1.52 \times 10^{-2}$ cm/s

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DAY 4 (1.5 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	1.5	162	600	19.1	182.32	15.24
2	1.5	163	600	19.1	182.32	15.24
3	1.5	162	600	19.1	182.32	15.24
4	1.5	162	600	19.1	182.32	15.24
Average	**1.5**	**162**	**600**	**19.1**	**182.32**	**15.24**

$i = 9.48 \times 10^{-2}$
$v = 1.48 \times 10^{-3}$ cm/s
$k = 1.51 \times 10^{-2}$ cm/s, $k_{20} = 1.54 \times 10^{-2}$ cm/s

DAY 4 (2.0 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	2.0	203	600	19.1	182.32	15.24
2	2.0	202	600	19.1	182.32	15.24
3	2.0	202	600	19.1	182.32	15.24
4	2.0	203	600	19.1	182.32	15.24
Average	**2.0**	**202.5**	**600**	**19.1**	**182.32**	**15.24**

$i = 1.31 \times 10^{-1}$
$v = 1.85 \times 10^{-3}$ cm/s
$k = 1.41 \times 10^{-2}$ cm/s, $k_{20} = 1.44 \times 10^{-2}$ cm/s

DAY 4 (3.0 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	3.0	157	300	19.1	182.32	15.24
2	3.0	157	300	19.1	182.32	15.24
3	3.0	158	300	19.1	182.32	15.24
4	3.0	157	300	19.1	182.32	15.24
Average	**3.0**	**157.25**	**300**	**19.1**	**182.32**	**15.24**

$i = 1.97 \times 10^{-1}$
$v = 2.88 \times 10^{-3}$ cm/s
$k = 1.46 \times 10^{-2}$ cm/s, $k_{20} = 1.49 \times 10^{-2}$ cm/s

DAY 4 (4.0 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	4.0	208	300	19.2	182.32	15.24
2	4.0	207	300	19.2	182.32	15.24
3	4.0	206	300	19.2	182.32	15.24
4	4.0	209	300	19.2	182.32	15.24
Average	**4.0**	**207.5**	**300**	**19.2**	**182.32**	**15.24**

$i = 2.62 \times 10^{-1}$
$v = 3.79 \times 10^{-3}$ cm/s
$k = 1.45 \times 10^{-2}$ cm/s, $k_{20} = 1.47 \times 10^{-2}$ cm/s

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PROJECT: **City of Seattle Bioretention Soil Workshop** PAGE #: **9 of 9**

DAY 4 (6.0 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	6.0	316	300	19.2	182.32	15.24
2	6.0	320	300	19.2	182.32	15.24
3	6.0	320	300	19.2	182.32	15.24
4	6.0	318	300	19.2	182.32	15.24
Average	**6.0**	**318.5**	**300**	**19.2**	**182.32**	**15.24**

$i = 3.94 \times 10^{-1}$
$v = 5.82 \times 10^{-3}$ cm/s
$k = 1.48 \times 10^{-2}$ cm/s, $k_{20} = 1.51 \times 10^{-2}$ cm/s

DAY 4 (8.0 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	8.0	420	300	19.2	182.32	15.24
2	8.0	421	300	19.2	182.32	15.24
3	8.0	417	300	19.2	182.32	15.24
4	8.0	419	300	19.2	182.32	15.24
Average	**8.0**	**419.25**	**300**	**19.2**	**182.32**	**15.24**

$i = 5.25 \times 10^{-1}$
$v = 7.67 \times 10^{-3}$ cm/s
$k = 1.46 \times 10^{-2}$ cm/s, $k_{20} = 1.49 \times 10^{-2}$ cm/s

DAY 4 (16.0 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	16.0	176	60	19.2	182.32	15.24
2	16.0	175	60	19.2	182.32	15.24
3	16.0	172	60	19.2	182.32	15.24
4	16.0	174	60	19.2	182.32	15.24
Average	**16.0**	**174.25**	**60**	**19.2**	**182.32**	**15.24**

i = 1.05
v = 57.0 cm/s
$k = 1.52 \times 10^{-2}$ cm/s, $k_{20} = 1.55 \times 10^{-2}$ cm/s

DAY 4 (32.0 cm)

Trial	h (cm)	V (ml)	t (sec)	T (° C)	A (cm^2)	L (cm)
1	32.0	173	30	19.2	182.32	15.24
2	32.0	177	30	19.2	182.32	15.24
3	32.0	178	30	19.2	182.32	15.24
4	32.0	177	30	19.2	182.32	15.24
Average	**32.0**	**176.25**	**30**	**19.2**	**182.32**	**15.24**

i = 2.10
v = 29.0
$k = 1.53 \times 10^{-2}$ cm/s, $k_{20} = 1.57 \times 10^{-2}$ cm/s

Test Reference: ASTM D2434

David Bufalini
Reviewed by

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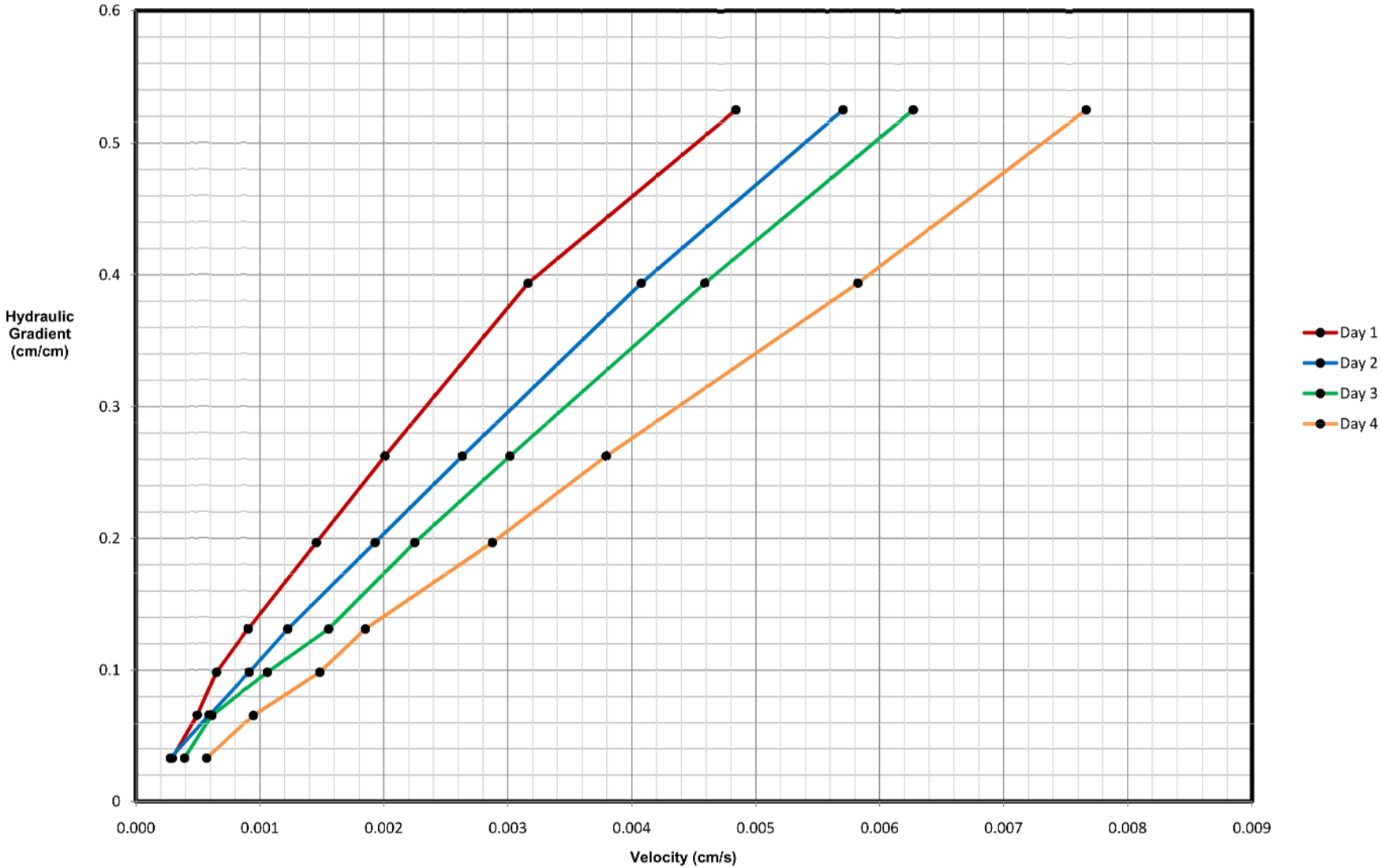
Hydraulic Gradient vs. Velocity by Day



HWA Permeability Results

6-inch Summary

Head	Conductivity, cm/s Day 1	Day 2	Day 3	Day 4
1	2.92E-03	3.03E-03		
1.5	6.13E-03	9.63E-03	1.15E-02	1.02E-02
2	8.47E-03	1.32E-02	1.21E-02	1.15E-02
3	1.28E-02	1.67E-02	1.50E-02	1.59E-02
4	1.42E-02	1.88E-02	1.76E-02	1.53E-02

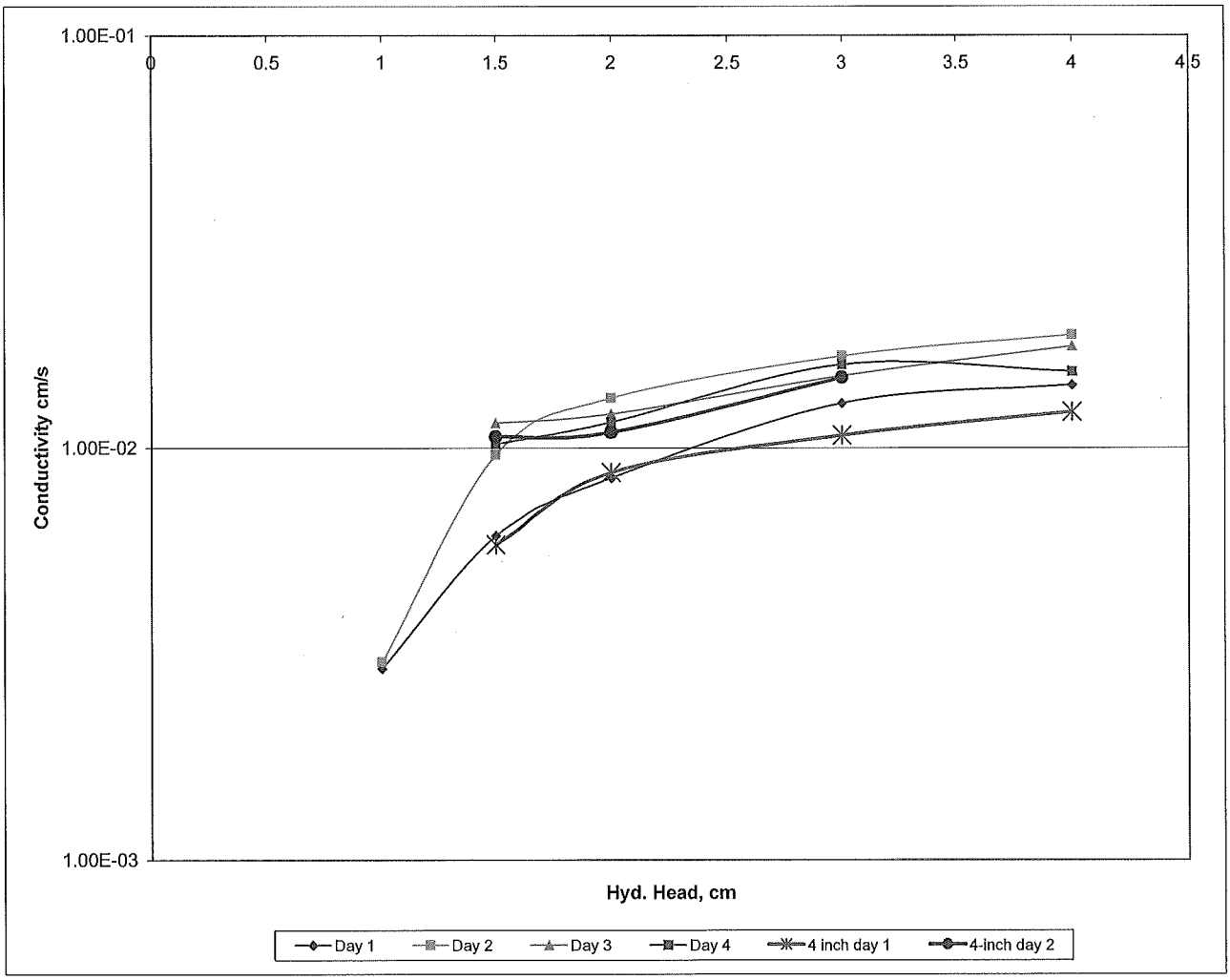
4-inch summary

1.5	5.83E-03	1.06E-02
2	8.73E-03	1.09E-02
3	1.07E-02	1.48E-02
4	1.22E-02	

Summary

Head	Conductivity, in/h Day 1	Day 2	Day 3	Day 4
1	4.14	4.30		
1.5	8.69	13.66	16.29	14.50
2	12.00	18.74	17.13	16.37
3	18.20	23.68	21.23	22.57
4	20.17	26.64	25.00	21.72

	Day 1	Day 2
1.5	8.26	15.09
2	12.37	15.48
3	15.23	21.03
4	17.36	0.00



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PERMEABILITY TEST ON GRANULAR SOIL
CONSTANT HEAD (6" MOLD)
ASTM D 2434

Project: **City of Seattle Biosoils Permeability Rate Testing Workshop**
Job No: 21-1-63100-004
Sample: Bioretention Soil
Test By: AKV 8/1/2011
Comp By: AKV 8/8/2011
Check By: JFL 8/9/2011

MC Before Test= 14.2%
Initial Dry Density= 95.6 pcf
Final Dry Density= 95.0 pcf
Maximum Dry Density= 113 pcf
Percent Compaction= 85.0%
Fines Washout= 18.8 g
Washout= 0.59%

Sample Classification:
Bioretention Soil

Remarks:
*Bioretention soil held near Optimum Moisture Content (OMC) for 3.7 months prior to testing.

*Day 1- Began after 19hr, 50min soak time.

*Day 2- Unable to achieve flow at 0.5cm of head difference across the specimen.

*Day 3- Unable to achieve flow at 0.5cm and1.0 cm of head difference across the specimen.

*Day 4- Unable to achieve flow on second day at 0.5cm, 1.0cm, 1.5cm, 2.0cm, and 3.0cm of head difference across the specimen. Maximum 48.0cm of head difference because of equipment limitations.

Sample compacted by hand in five lifts of equal mass and equal height with 2" round tamper to 85% Maximum Dry Density at OMC (+/- 0.5%).

Mold Diameter = 5.98in
Mold Height = 4.50in

Testing confined, with rigid upper and lower porous plate but without spring.

No hydro-compaction observed.

Day-	Reservoir Level		Δh	H	t	Q				
Increment	h_1 (cm)	h_2 (cm)	(cm)	(cm)	(s)	(cm^3)	I	Q/at	k (in/hr)	k (cm/s)
Day 1-1	47.0	46.2	0.8	0.5	3571	145.0	0.04	2.2E-04	7.3	0.0051
Day 1-2	46.2	45.2	1.0	1.0	2397	181.2	0.09	4.2E-04	6.8	0.0048
Day 1-3	45.2	44.0	1.2	1.5	2134	217.5	0.13	5.6E-04	6.1	0.0043
Day 1-4	44.0	43.0	1.0	2.0	1320	181.2	0.18	7.6E-04	6.1	0.0043
Day 1-5	43.0	40.6	2.4	3.0	2176	434.9	0.26	1.1E-03	6.0	0.0042
Day 1-6	40.6	37.0	3.6	4.0	2475	652.4	0.35	1.5E-03	5.9	0.0042
Day 1-7	37.0	34.7	2.3	6.0	1046	416.8	0.53	2.2E-03	5.9	0.0042
Day 1-8	34.6	31.2	3.4	8.0	1192	616.1	0.70	2.9E-03	5.8	0.0041
Day 2-1	49.9	49.4	0.5	1.0	4810	90.6	0.09	1.0E-04	1.7	0.0012
Day 2-2	49.4	48.4	1.0	1.5	2097	181.2	0.13	4.8E-04	5.1	0.0036
Day 2-3	48.3	46.1	2.2	2.0	3388	398.7	0.18	6.5E-04	5.3	0.0037
Day 2-4	46.0	42.5	3.5	3.0	3479	634.3	0.26	1.0E-03	5.4	0.0038
Day 2-5	42.5	37.9	4.6	4.0	3437	833.6	0.35	1.3E-03	5.4	0.0038
Day 2-6	37.7	33.5	4.2	6.0	1980	761.1	0.53	2.1E-03	5.7	0.0040
Day 2-7	31.5	21.5	10.0	8.0	3682	1812.2	0.70	2.7E-03	5.5	0.0039
Day 3-1	51.8	48.8	3.0	1.5	6430	543.7	0.13	4.7E-04	5.0	0.0036
Day 3-2	48.7	46.2	2.5	2.0	3763	453.0	0.18	6.6E-04	5.4	0.0038
Day 3-3	46.3	42.5	3.8	3.0	4002	688.6	0.26	9.5E-04	5.1	0.0036
Day 3-4	42.4	38.3	4.1	4.0	3209	743.0	0.35	1.3E-03	5.2	0.0036
Day 3-5	38.2	33.0	5.2	6.0	2659	942.3	0.53	2.0E-03	5.3	0.0037
Day 3-6	32.9	28.6	4.3	8.0	1604	779.2	0.70	2.7E-03	5.4	0.0038
Day 4-1	42.8	38.1	4.7	4.0	3712	851.7	0.35	1.3E-03	5.1	0.0036
Day 4-2	38.0	30.4	7.6	6.0	4045	1377.3	0.53	1.9E-03	5.1	0.0036
Day 4-3	30.3	14.8	15.5	8.0	6227	2808.9	0.70	2.5E-03	5.0	0.0036
Day 4-4	53.8	48.0	5.8	16.0	1012	1051.1	1.40	5.7E-03	5.8	0.0041
Day 4-5	47.8	43.2	4.6	32.0	386	833.6	2.80	1.2E-02	6.0	0.0043
Day 4-6	53.1	46.6	6.5	48.0	370	1177.9	4.20	1.8E-02	5.9	0.0042
								Average k	**5.5**	**0.0039**

h_1 : Initial reservoir water level
h_2 : Final reservoir water level
Δh : Change in reservoir water level during test
H : Head difference across the specimen
t : Elapsed time for changing water level
Q : Volume of water discharged
I : Hydraulic gradient (Head/Height)
a : Cross-section area of the specimen
k : Hydraulic conductivity of the specimen

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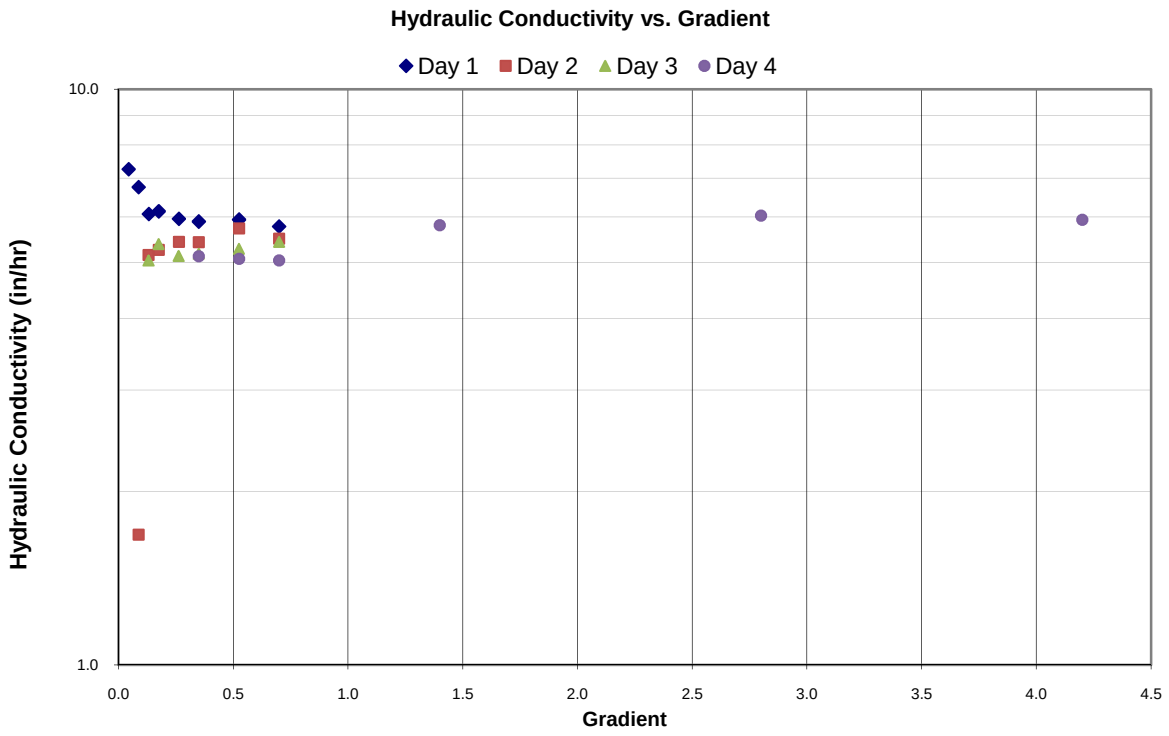
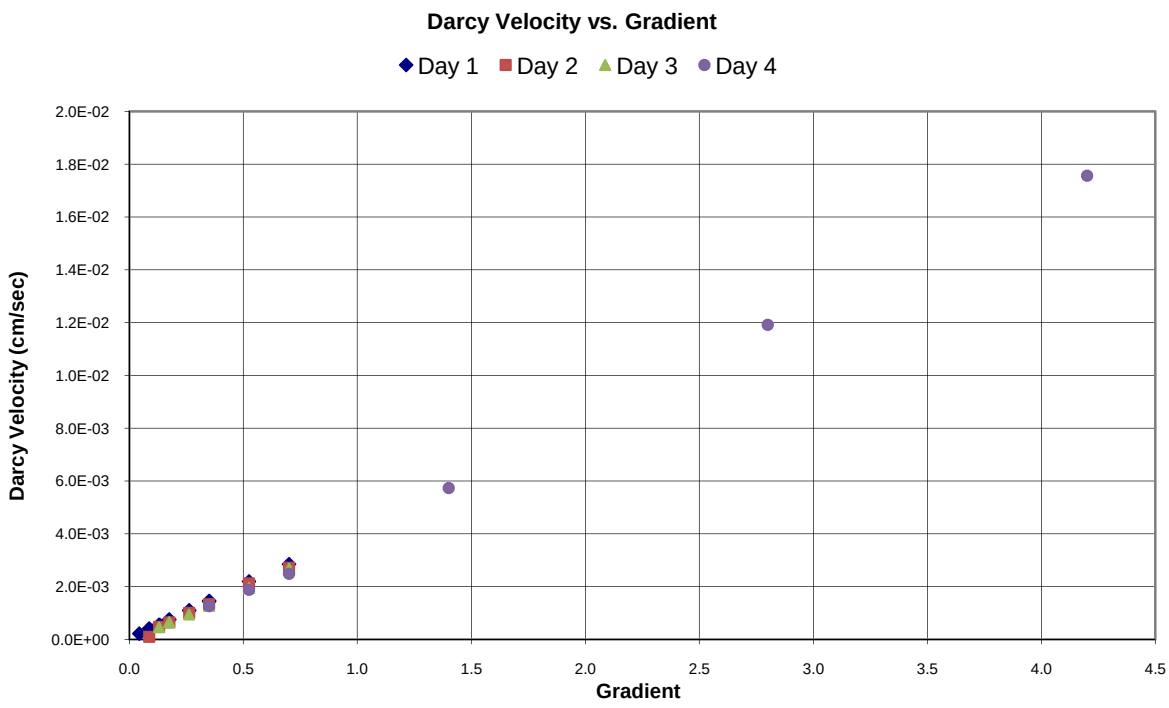
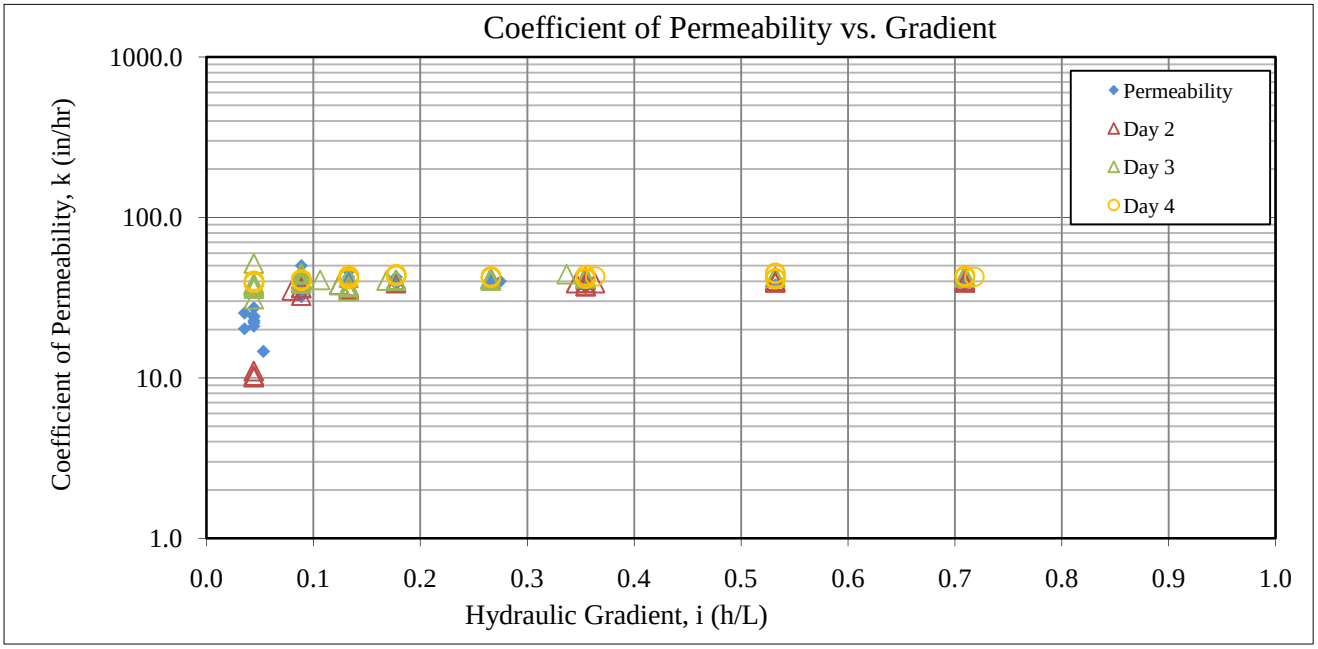
City of Seattle Biosoils Permeability Rate Testing Workshop
Bioretention Soil
21-1-63100-004
8/9/2011



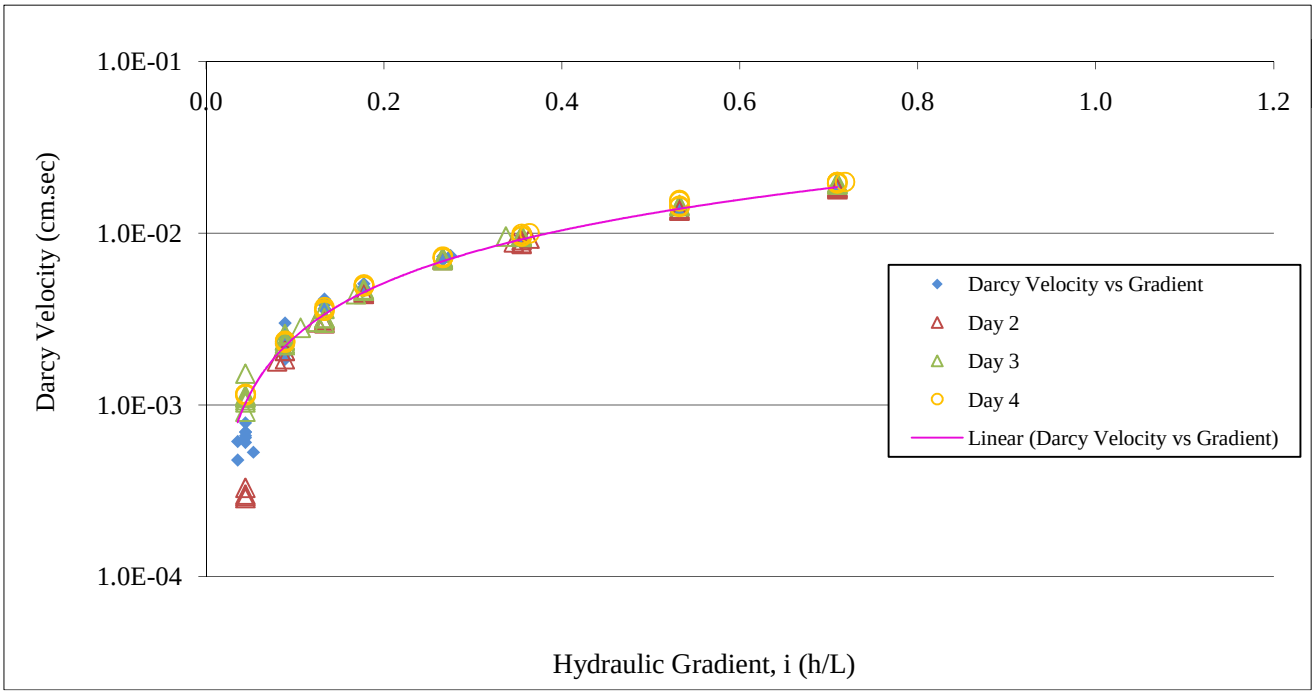


Seattle
Public Utilities
Materials Laboratory

Permeability Test on Granular Soils
ASTM D-2434



Coefficient of Permeability, k: k=QL/Ath



Darcy Velocity, v: v = Q/At

Seattle Public Utilities Materials Laboratory

Permeability Test on Granular Soils
ASTM D-2434

Project Name :	**ASTM 2434 Workshop**	Tested By :	**CAN**	Date :	**6/6/2011**
Project No. :	**N400102 U07 MG4**	Checked By :		Date :	
Location :	**Cedar Grove Compost**	Test # Que:	**104**	Depth (ft) :	
Description :	**Poorly graded sand (SP), 4.7% organic material**				
Comments:					
Supposed to run at 85% MDD, calculated pre-test: 86.3%					

DAY 1	DAY 2	DAY 3	DAY 4		Average k (in/hr) = 38.66
36.02	35.72	40.77	42.13	in/hr	

Area of permeameter cm^2 (constant) (A):	102.56
Volume of Sample Pre-Test cm^3 (V_1):	1695.42
Volume of Sample Post-Consolidation cm^3 (V_2):	1686.73
Volume of Sample Post-Test cm^3 (V_3):	1684.59

Total Sample (W_1)		**Sieved Test Sample (Minus 3/4-in.)**	
Air Dried WET Wt. + Tare (g) :		Wt. retained on 3/4-in. sieve (g)	
Tare No. _____ (g) :		Wt. remaining (g) :	
Air Dried DRY Wt. + Tare (g) :		Wt. remaining Oven Dried (g) :	
Wt. H_2O (g):	0	Percent oversize:	
Total Sample Air Dried Wt. (g) :	0		
Moisture Content Air Dried (g) :	#DIV/0!		

Hygroscopic Moisture Content		**Permeameter Test Sample (Minus 3/4-in.)**	
Air Dried Wt. + Tare (g) :		Wt. remaining in pan + Tare (g):	
Oven Dried Wt. + Tare (g):		Wt. remaining in pan (W_2) (g):	0
Tare No. _____ (g) :		Total Sample (W_1) (g)	0
Wt. H_2O (g):	0.00	Test Sample Net Wt. (W_1-W_2) (g):	0
Wt. Dried Soil (g):	0.00		
Hygroscopic Moisture (%) :	#DIV/0!		

Permeameter Test Specimen (after compaction & consolidation)			
Height of sample Pre-Test, H_1-H_2 (cm):	16.53	dist. between top of top plate and top of bottom porous stone	
Volume of sample, V_2 (cm^3):	1695.42	(area*H_2)	
Dry Unit Weight, W (lb/ft^3) : (Bulk Density)	95.76	(net wt/volume)	converted from g/cm^3
Relative Density, RD (as placed):	86.3%		
Height of sample Post-Consolidation, H_1-H_2-(H_2-H_3)(cm):	16.45		

Permeameter Test Specimen (after test)			
Dry Unit Weight, W (lb/ft^3) : (Bulk Density)	95.93	(net wt/volume)	converted from g/cm^3
Relative Density, RD (as placed):	86.4%		
Height of sample Post-Test, H_1-H_2-(H_2-H_4) (cm):	16.43		

Conversions	one pound = 453.6 grams			one cm^3=0.000035 ft^3				
	one foot = 30.5 cm			one inch = 2.53 cm				
			Diameter of Permeameter Cell:	4.5 inches	11.43 cm			
			Length between Manometer outlets:	4.4 inches	11.28 cm			
$H_{1\ (inches)}$=	####	7.576	7.570	7.570	avg in:	7.573	cm:	19.158
$H_{2\ (inches)}$=	####	1.072	1.091	1.003	avg in:	1.038	cm:	2.627
$H_{3\ (inches)}$=	####	0.955	1.051	1.045	avg in:	1.005	cm:	2.542
H_4 (inches)=	####	0.943	1.084	1.034	avg in:	0.997	cm:	2.521

0.973" is where we want top of stone, 19.16-2.46=16.17 cm sample height

H1-H2=sample height

(H1-H2)-H3=sample height after consolidation (before test) (H1-H2)-(H2-H3)=sample height after test

For this sample:

Maximum Dry Density		111.0
Optimum Moisture		15.0
Want to run test at	85%	of MDD

Target Density = 94.35 pcf

Vol of Permeameter =

APPENDIX E

Recommended Modifications for Permeability Testing of Bioretention Soils

Recommended Modifications for Permeability Testing of Bioretention Soils
Aspect Consulting, LLC
August 22, 2011

Proctor method ASTM D1557 Method C (6-inch mold) shall be used to determine maximum dry density values for compaction of bioretention soil sample. Sample preparation for the Proctor test shall be amended in the following ways:

1) Maximum grainsize within the sample shall be no more than ½ inches in size.
2) Snip larger organic particles (if present) into ½ inch long pieces.
3) When adding water to the sample during the Proctor test, allow the sample to pre-soak for at least 48 hours to allow the organics to fully saturate before compacting the sample. This pre-soak ensures the organics have been fully saturated at the time of the test.

ASTM D2434 shall be used and amended in the following ways:

1) Apparatus:
    a. 6-inch mold size shall be used for the test.
    b. If using porous stone disks for the testing, the permeability of the stone disk shall be measured before and after the soil tests to ensure clogging or decreased permeability has not occurred during testing.
    c. Use the confined testing method, with 5- to 10-pound force spring
    d. Use de-aired water.
2) Sample:
    a. Maximum grainsize within the sample shall not be more than ½ inches in size.
    b. Snip larger organic particles (if present) into ½-inch long pieces.
    c. Pre-soak the sample for at least 48 hours prior to loading it into the mold. During the pre-soak, the moisture content shall be higher than optimum moisture but less than full saturation (i.e., there shall be no free water). This pre-soak ensures the organics have been fully saturated at the time of the test.
3) Preparation of Sample:
    a. Place soil in cylinder via a scoop.
    b. Place soil in 1-inch lifts and compact using a 2-inch-diameter round tamper. Pre-weigh how much soil is necessary to fill 1-inch lift at 85% of maximum dry density, then tamp to 1-inch thickness. Once mold is full, verify that density is at 85% of maximum dry density (+ or – 0.5%). Apply vacuum (20 inches Hg) for 15 minutes before inundation.
    c. Inundate sample slowly under a vacuum of 20 inches Hg over a period of 60 to 75 minutes.
    d. Slowly remove vacuum (> 15 seconds).
    e. Sample shall be soaked in the mold for 24 to 72 hours before starting test.
4) Procedure:
    a. The permeability test shall be conducted over a range of hydraulic gradients between 0.1 and 2.
    b. Steady state flow rates shall be documented for four consecutive measurements before increasing the head.
    c. The permeability test shall be completed within one day (one-day test duration).