

March 04, 2013

Project No. 12-1111-0089

Mr. Gary Vandergaast
Port Hope Area Initiative Management Office
Atomic Energy of Canada Limited
115 Toronto Road
Port Hope, Ontario
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**SURVEY OF POTENTIAL SOURCES OF CLAY LINER MATERIAL
FOLLOW-UP LABORATORY TESTING FOR HYDRAULIC CONDUCTIVITY
PORT HOPE AND PORT GRANBY PROJECTS**

Dear Gary,

This letter presents the results of laboratory hydraulic conductivity tests on composite clayey soil samples from three private borrow pits identified by Golder as potential sources of clay liner material for the Port Hope and Port Granby Projects. The pits are referred to as Westone (Omeme), McGee (Campbellford) and Young (Omeme). A preliminary test pit investigation, including geotechnical laboratory testing for grain size distribution and plasticity, was carried out by Golder for each borrow pit in the Fall of 2012. The results were presented in our draft letter dated December 20, 2012. The hydraulic conductivity testing was performed on clayey soil material collected from the preliminary investigation as a means of further assessing the likelihood that the material is suitable for constructing a soil liner having a hydraulic conductivity $\leq 1 \times 10^{-7}$ cm/s.

COMPOSITE SAMPLE PREPARATION

Table A.1 (Appendix A) lists the individual samples that were collected from test pits at the three borrow pits, together with the results of grain size distribution and plasticity tests. The hydraulic conductivity testing was performed on a composite sample for each borrow pit, prepared by combining what was left of the individual samples listed in Table A.1. Each composite sample was then screened to remove gravel particles larger than 9.5 mm (3/8 inch). This is a normal requirement for laboratory hydraulic conductivity testing, due to the small diameter of the test specimen (i.e., 70 mm diameter). Grain size distribution curves obtained for the composite samples after removal of gravel particles larger than 9.5 mm are presented in Figures 1 to 3 and are summarized in Table 1. Also shown in Table 1 are the results of plasticity and Standard Proctor tests.

HYDRAULIC CONDUCTIVITY TESTING

The composite samples were compacted in a 100 mm diameter Standard Proctor mould at Standard Proctor effort with a water content 1% to 2% above the optimum water content. The compacted sample was then



extracted from the mould and trimmed to 70 mm diameter for testing in a flexible wall permeameter according to ASTM Method D 5084 (constant head). The effective confining stress was 150 kPa and the hydraulic gradient was 20.

The results of the hydraulic conductivity tests are presented in Appendix B and are summarized below:

<u>Composite Sample</u>	<u>Hydraulic Conductivity (cm/s)</u>
McGee (Campbellford)	3×10^{-8}
Young (Omeme)	3×10^{-8}
Westone (Omeme)	4×10^{-8}

All three composite samples gave hydraulic conductivity values meeting the design criteria of $\leq 1 \times 10^{-7}$ cm/s. Therefore, the laboratory testing, albeit on a limited number of samples, supports that the clayey material from these borrow pits is suitable for achieving the design hydraulic conductivity.

As recommended in our previous letter, the results of our preliminary testing should be included in the tender documents for the Port Hope and Port Granby Projects as background reference information. The Contractor should develop and complete detailed investigations, testing and test pads to confirm their proposed liner material source and method of liner construction.

Yours truly,

GOLDER ASSOCIATES LTD.

Frank Barone, Ph.D., P. Eng.
Principal
FSB/jl

Attachments:

Attachment A – List of Test Pit Samples and Laboratory Testing Results

Attachment B - Hydraulic Conductivity Test Results

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**TABLE 1 – CHARACTERISTICS OF COMPOSITE
SAMPLES TESTED FOR HYDRAULIC
CONDUCTIVITY**

Composite Sample	Grain Size Distribution (%)				Atterberg Limits (%)			Optimum* Water Content (%)	Maximum* Dry Density (Mg/m ³)
	Gravel (> 4.75 mm)	Sand (0.075 mm – 4.75 mm)	Fines (<0.075 mm)	Clay (<0.002 mm)	PL	LL	PI		
McGee (Campbellford)	1	36	63	19	12.2	19.0	6.8	11.2	1.996
Young (Omeme)	0	12	88	24	15.2	28.3	13.1	17.2	1.812
Westone (Omeme)	7	41	52	15	12.2	19.9	7.7	10.0	2.044

PL = Plastic Limit

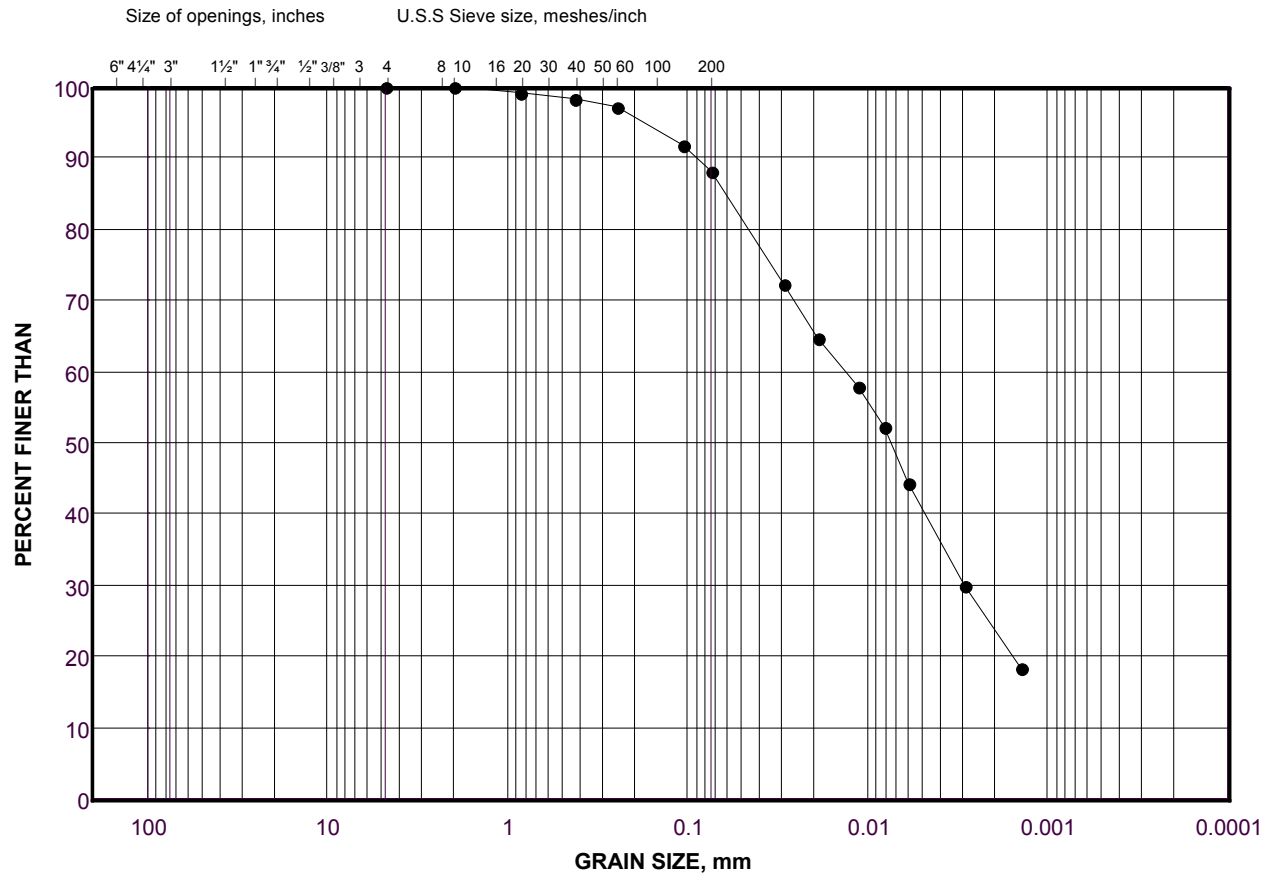
LL = Liquid Limit

PI = Plasticity Index

* Approximate values based on preliminary (3 to 4 point) Standard Proctor test with a small 100 mm diameter mould.

GRAIN SIZE DISTRIBUTION

FIGURE 2



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL



SAMPLE

Bag 2 Young (Omeme)

Project Number: 12-1111-0089

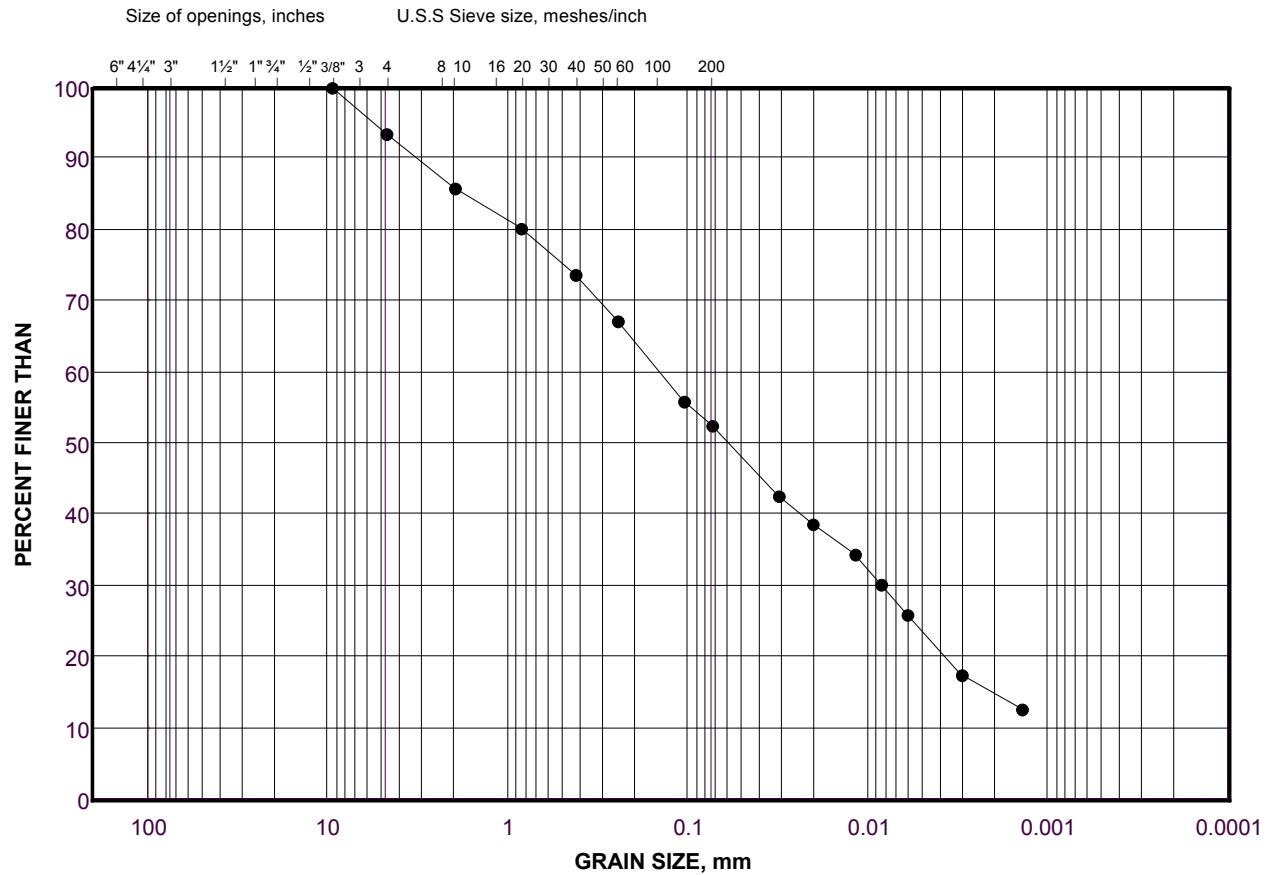
Checked By: _____

Golder Associates

Date: 01-Mar-13

GRAIN SIZE DISTRIBUTION

FIGURE 3



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL



SAMPLE

Bag 3 Westone (Omeme)

Project Number: 12-1111-0089

Checked By: _____

Golder Associates

Date: 01-Mar-13



ATTACHMENT A

List of Test Pit Samples and Laboratory Testing Results

TABLE A.1
LABORATORY TESTING RESULTS

Name of Supplier	Pit Location	Sample Number	Sample Depth (m)	Natural Water Content (%)	Percent Gravel (4.75 mm - 75 mm) (%)	Percent Sand (0.075 mm - 4.75 mm) (%)	Percent Fines (<0.075 mm) (%)	Percent Clay Size (<0.002 mm) (%)	Atterberg Limits		
									PL (%)	LL (%)	PI (%)
Westone Aggregates	Esker Road, Omemee	12-1, Sa# 1	0.90-1.20	12.9	18	32	42	8	13.3	22.6	9.3
		12-2, Sa#1	1.80-2.10	12.9	17	29	43	11	13.4	24.5	11.1
		12-3, Sa# 1	0.60-0.90	6.1	18	40	36	6	10.8	16.8	6.0
		12-5, Sa#1	0.90-1.20	10.6	27	40	29	4	12.7	18.2	5.5
Mcgee	Faux Road, Campbellford	12-9, Sa# 1	0.60-0.90	13.0	42	30	22	6	13.7	22.6	8.9
		12-9, Sa#2	1.80-2.10	12.6	18	36	35	11	11.3	18.7	7.4
		12-9, Sa#3	3.40-3.70	10.2	20	35	32	13	10.0	18.1	8.1
		12-10, Sa#1	0.90-1.20	18.1	28	8	52	12	14.8	23.1	8.3
		12-10, Sa# 2	2.10-2.40	13.2	3	14	66	17	14.9	21.3	6.4
		12-10, Sa#3	3.70-4.00	16.9	0	3	63	34	16.1	31.8	15.7
		12-11, Sa#1	1.20-1.50	10.1	13	39	37	11	11.0	17.7	6.7
		12-11, Sa#2	2.40-2.70	9.8	8	31	52	9	11.4	18.3	6.9
		12-11, Sa#3	3.70-4.00	7.9	34	28	30	8	10.2	17.8	7.6
		12-12, Sa#1	0.60-0.90	10.8	11	39	38	12	13.9	22.3	8.4
		12-12, Sa#2	2.10-2.40	10.3	9	40	38	13	10.2	16.1	5.9
		12-12, Sa#3	3.40-3.70	10.8	12	37	37	14	11.1	18.0	6.9
		12-13, Sa#1	0.80-1.10	7.1	14	39	35	12	11.8	19.6	7.8
		12-13, Sa#2	2.30-2.60	11.6	8	38	40	14	10.6	18.5	7.9
		12-13, Sa#3	3.80-4.10	7.9	21	35	33	11	9.9	16.6	6.7
Robert Young Construction Ltd	Mt. Horeb Road, Omemee	12-14, Sa#1	0.60-0.90	21.2	2	6	59	33	17.2	35.3	18.1
		12-14, Sa#2	1.80-2.10	17.2	0	11	52	37	13.9	27.3	13.4
		12-16, Sa#1	0.90-1.20	22.2	0	9	58	33	16.6	33.3	16.7
		12-16, Sa#2	2.70-3.00	16.0	0	12	68	20	13.5	24.4	10.9

Notes:

PL = Plastic Limit
 LL = Liquid Limit
 PI = Plasticity Index



ATTACHMENT B

Hydraulic Conductivity Test Results

HYDRAULIC CONDUCTIVITY TEST

ASTM D 5084 (CONSTANT HEAD)

SAMPLE IDENTIFICATION

PROJECT NUMBER	12-1111-0089	SAMPLE	McGee	Bag 1
PROJECT TITLE	AECL / Geotechnical Report / Port Granby	SAMPLE DEPTH, m	(Campbellford)	-
BOREHOLE NUMBER	-	DATE		02/21/2013

SPECIMEN PROPERTIES AND DIMENSIONS (INITIAL)

SAMPLE HEIGHT, cm	7.22	UNIT WEIGHT, kN/m ³	21.75
SAMPLE DIAMETER, cm	6.99	DRY UNIT WEIGHT, kN/m ³	19.40
SAMPLE AREA, cm ²	38.42	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm ³	277.23	VOLUME OF SOLIDS, cm ³	203.11
TOTAL MASS, g	614.80	VOLUME OF VOIDS, cm ³	74.12
DRY MASS, g	548.39	VOID RATIO	0.36
WATER CONTENT, %	12.1		

SATURATION STAGE

CELL PRESSURE, kPa	280	EFFECTIVE CONFINING STRESS, kPa	5
HEAD PRESSURE, kPa	275	DURATION, min	5,850
BACK PRESSURE, kPa	275	B COEFFICIENT	0.96

CONSOLIDATION STAGE

CELL PRESSURE, kPa	425	EFFECTIVE CONFINING STRESS, kPa	150
HEAD PRESSURE, kPa	275	DURATION, min	1,680
BACK PRESSURE, kPa	275	VOLUME CHANGE, cm ³	5.7
		DRAINAGE	Top and Bottom

SPECIMEN PROPERTIES AND DIMENSIONS (AFTER CONSOLIDATION)

SAMPLE HEIGHT, cm	7.17	SAMPLE AREA, cm ²	37.89
SAMPLE DIAMETER, cm	6.95	SAMPLE VOLUME, cm ³	271.55

HYDRAULIC CONDUCTIVITY STAGE

CELL PRESSURE, kPa	439	EFFECTIVE CONFINING STRESS, kPa	150
HEAD PRESSURE, kPa	289	DURATION, min	3395.0
BACK PRESSURE, kPa	275	HYDRAULIC GRADIENT, i	20

SPECIMEN PROPERTIES AND DIMENSIONS (FINAL)

SAMPLE HEIGHT, cm	7.17	UNIT WEIGHT, kN/m ³	22.16
SAMPLE DIAMETER, cm	6.95	DRY UNIT WEIGHT, kN/m ³	19.80
SAMPLE AREA, cm ²	37.89	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm ³	271.55	VOLUME OF SOLIDS, cm ³	203.11
TOTAL MASS, g	613.54	VOLUME OF VOIDS, cm ³	68.45
DRY MASS, g	548.39	VOID RATIO	0.34
WATER CONTENT, %	11.9		

TEST RESULTS

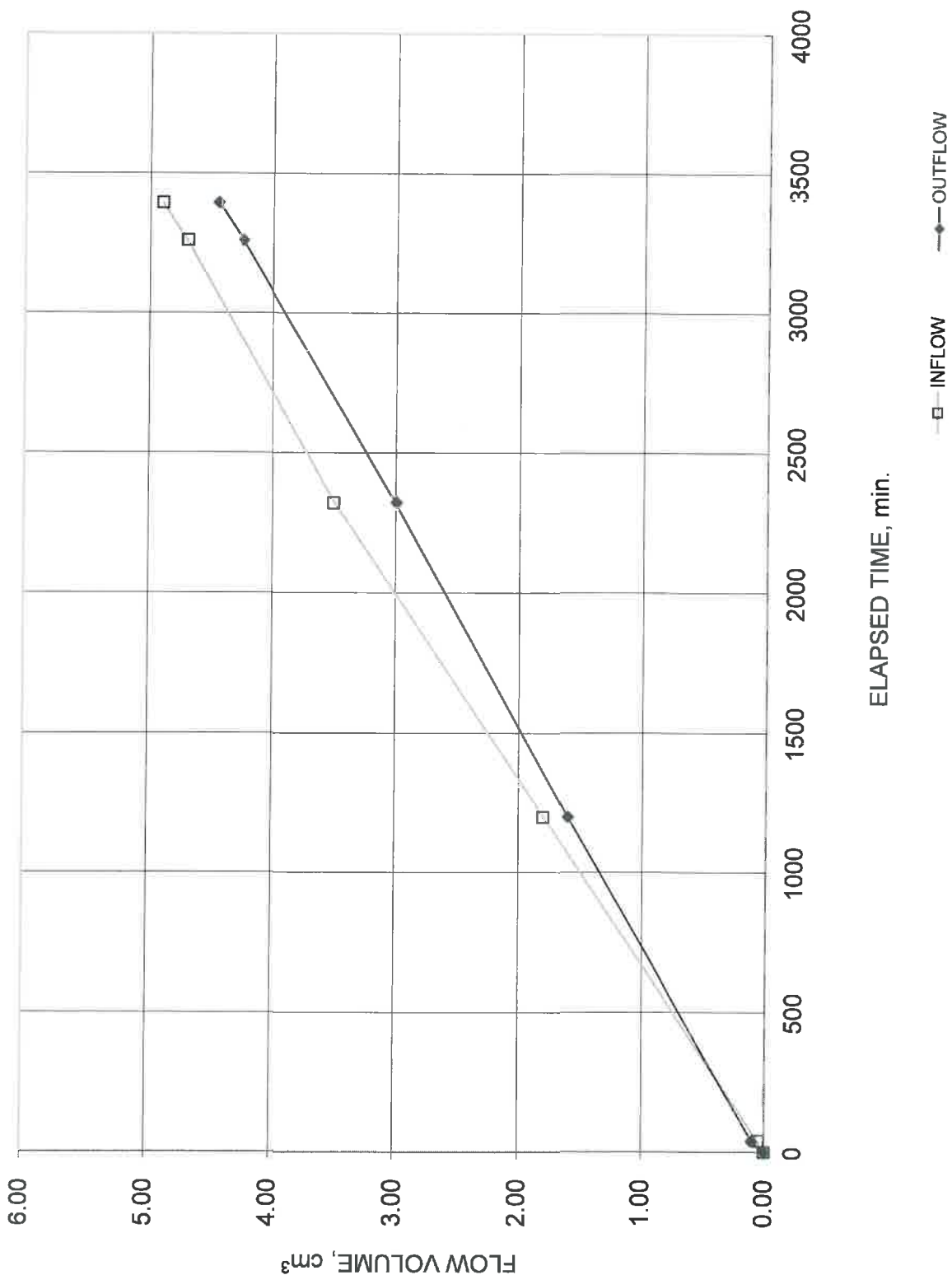
ELAPSED TIME TO STEADY STATE FLOW (min)	0.0
DURATION OF STEADY STATE FLOW (min)	3395.0
INFLOW VOLUME UNDER STEADY STATE FLOW (cm ³)	4.9
OUTFLOW VOLUME UNDER STEADY STATE FLOW (cm ³)	4.5
HYDRAULIC CONDUCTIVITY (INFLOW) (cm/s)	3.19E-08
HYDRAULIC CONDUCTIVITY (OUTFLOW) (cm/s)	2.89E-08
HYDRAULIC CONDUCTIVITY, K, cm/s	3.04E-08

NOTES:

PERMEANT FLUID Deaired tap water

HYDRAULIC CONDUCTIVITY TEST

Sample Bag 1 (McGee Campbellford)



HYDRAULIC CONDUCTIVITY TEST

ASTM D 5084 (CONSTANT HEAD)

SAMPLE IDENTIFICATION

PROJECT NUMBER	12-1111-0089	SAMPLE	Young(Ome mee) Bag 2
PROJECT TITLE	AECL / Geotechnical Report / Port Granby	SAMPLE DEPTH, m	
BOREHOLE NUMBER	-	DATE	02/25/2013

SPECIMEN PROPERTIES AND DIMENSIONS (INITIAL)

SAMPLE HEIGHT, cm	7.15	UNIT WEIGHT, kN/m ³	20.53
SAMPLE DIAMETER, cm	6.98	DRY UNIT WEIGHT, kN/m ³	17.42
SAMPLE AREA, cm ²	38.23	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm ³	273.24	VOLUME OF SOLIDS, cm ³	179.81
TOTAL MASS, g	571.90	VOLUME OF VOIDS, cm ³	93.44
DRY MASS, g	485.48	VOID RATIO	0.52
WATER CONTENT, %	17.8		

SATURATION STAGE

CELL PRESSURE, kPa	280	EFFECTIVE CONFINING STRESS, kPa	5
HEAD PRESSURE, kPa	275	DURATION, min	6,990
BACK PRESSURE, kPa	275	B COEFFICIENT	0.98

CONSOLIDATION STAGE

CELL PRESSURE, kPa	425	EFFECTIVE CONFINING STRESS, kPa	150
HEAD PRESSURE, kPa	275	DURATION, min	4,320
BACK PRESSURE, kPa	275	VOLUME CHANGE, cm ³	5.6
		DRAINAGE	Top and Bottom

SPECIMEN PROPERTIES AND DIMENSIONS (AFTER CONSOLIDATION)

SAMPLE HEIGHT, cm	7.10	SAMPLE AREA, cm ²	37.71
SAMPLE DIAMETER, cm	6.93	SAMPLE VOLUME, cm ³	267.67

HYDRAULIC CONDUCTIVITY STAGE

CELL PRESSURE, kPa	439	EFFECTIVE CONFINING STRESS, kPa	150
HEAD PRESSURE, kPa	289	DURATION, min	7424.0
BACK PRESSURE, kPa	275	HYDRAULIC GRADIENT, i	20

SPECIMEN PROPERTIES AND DIMENSIONS (FINAL)

SAMPLE HEIGHT, cm	7.10	UNIT WEIGHT, kN/m ³	21.22
SAMPLE DIAMETER, cm	6.93	DRY UNIT WEIGHT, kN/m ³	17.79
SAMPLE AREA, cm ²	37.71	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm ³	267.67	VOLUME OF SOLIDS, cm ³	179.81
TOTAL MASS, g	579.20	VOLUME OF VOIDS, cm ³	87.86
DRY MASS, g	485.48	VOID RATIO	0.49
WATER CONTENT, %	19.3		

TEST RESULTS

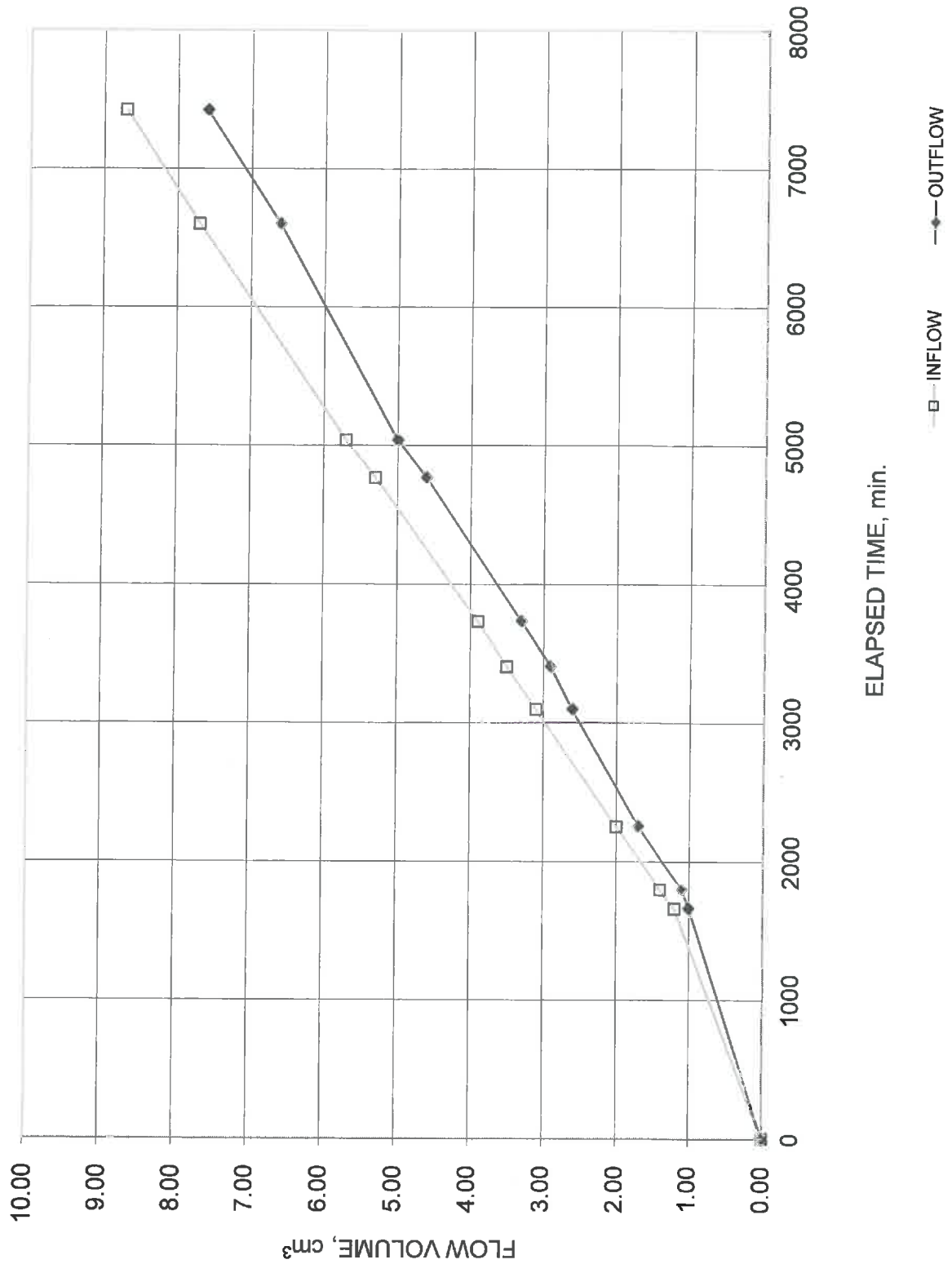
ELAPSED TIME TO STEADY STATE FLOW (min)	1660.0
DURATION OF STEADY STATE FLOW (min)	5764.0
INFLOW VOLUME UNDER STEADY STATE FLOW (cm ³)	7.5
OUTFLOW VOLUME UNDER STEADY STATE FLOW (cm ³)	6.6
HYDRAULIC CONDUCTIVITY (INFLOW) (cm/s)	2.86E-08
HYDRAULIC CONDUCTIVITY (OUTFLOW) (cm/s)	2.52E-08
HYDRAULIC CONDUCTIVITY, K , cm/s	2.69E-08

NOTES:

PERMEANT FLUID Deaired tap water

HYDRAULIC CONDUCTIVITY TEST

Sample Bag 2 (Young Ome mee)



[Signature]

HYDRAULIC CONDUCTIVITY TEST

ASTM D 5084 (CONSTANT HEAD)

SAMPLE IDENTIFICATION			
PROJECT NUMBER	12-1111-0089	SAMPLE	<i>Westone (Omamee)</i> Bag 3
PROJECT TITLE	AECL / Geotechnical Report / Port Granby	SAMPLE DEPTH, m	-
BOREHOLE NUMBER	-	DATE	02/25/2013

SPECIMEN PROPERTIES AND DIMENSIONS (INITIAL)

SAMPLE HEIGHT, cm	7.14	UNIT WEIGHT, kN/m ³	21.78
SAMPLE DIAMETER, cm	6.96	DRY UNIT WEIGHT, kN/m ³	19.45
SAMPLE AREA, cm ²	38.02	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm ³	271.36	VOLUME OF SOLIDS, cm ³	199.34
TOTAL MASS, g	602.80	VOLUME OF VOIDS, cm ³	72.02
DRY MASS, g	538.21	VOID RATIO	0.36
WATER CONTENT, %	12.0		

SATURATION STAGE

CELL PRESSURE, kPa	280	EFFECTIVE CONFINING STRESS, kPa	5
HEAD PRESSURE, kPa	275	DURATION, min	5,820
BACK PRESSURE, kPa	275	B COEFFICIENT	0.97

CONSOLIDATION STAGE

CELL PRESSURE, kPa	425	EFFECTIVE CONFINING STRESS, kPa	150
HEAD PRESSURE, kPa	275	DURATION, min	3,660
BACK PRESSURE, kPa	275	VOLUME CHANGE, cm ³	7.0
		DRAINAGE	Top and Bottom

SPECIMEN PROPERTIES AND DIMENSIONS (AFTER CONSOLIDATION)

SAMPLE HEIGHT, cm	7.08	SAMPLE AREA, cm ²	37.37
SAMPLE DIAMETER, cm	6.90	SAMPLE VOLUME, cm ³	264.40

HYDRAULIC CONDUCTIVITY STAGE

CELL PRESSURE, kPa	439	EFFECTIVE CONFINING STRESS, kPa	150
HEAD PRESSURE, kPa	289	DURATION, min	6683.0
BACK PRESSURE, kPa	275	HYDRAULIC GRADIENT, i	20

SPECIMEN PROPERTIES AND DIMENSIONS (FINAL)

SAMPLE HEIGHT, cm	7.08	UNIT WEIGHT, kN/m ³	22.30
SAMPLE DIAMETER, cm	6.90	DRY UNIT WEIGHT, kN/m ³	19.96
SAMPLE AREA, cm ²	37.37	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm ³	264.40	VOLUME OF SOLIDS, cm ³	199.34
TOTAL MASS, g	601.30	VOLUME OF VOIDS, cm ³	65.06
DRY MASS, g	538.21	VOID RATIO	0.33
WATER CONTENT, %	11.7		

TEST RESULTS

ELAPSED TIME TO STEADY STATE FLOW (min)	0.0
DURATION OF STEADY STATE FLOW (min)	6683.0
INFLOW VOLUME UNDER STEADY STATE FLOW (cm ³)	12.8
OUTFLOW VOLUME UNDER STEADY STATE FLOW (cm ³)	12.9
HYDRAULIC CONDUCTIVITY (INFLOW) (cm/s)	4.23E-08
HYDRAULIC CONDUCTIVITY (OUTFLOW) (cm/s)	4.27E-08
HYDRAULIC CONDUCTIVITY, K, cm/s	4.25E-08

NOTES:

PERMEANT FLUID

Deaired tap water

HYDRAULIC CONDUCTIVITY TEST

Sample Bag 3 (Westone, Onemee)

