



**THURBER** ENGINEERING LTD.

**FINAL  
FOUNDATION INVESTIGATION AND DESIGN REPORT  
WOLFE ISLAND FERRY AND DOCKING IMPROVEMENTS  
NAVIGATIONAL CHANNEL  
COUNTY OF FRONTENAC  
AGREEMENT NO.: 4017-E-0015, ASSIGNMENT 5**

**GEOCRES NO.: 31C-280**

Report to:

**Morrison Hershfield**

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**PART 1. FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the factual findings obtained from an offshore foundation investigation along the alignment of the ferry channel between the Kingston Terminal in the City of Kingston and the Marysville Wolfe Island Terminal in the Township of Frontenac Islands within the County of Frontenac. The foundation investigation was completed in support of the Wolfe Island Ferry and Docking Improvements Detail Design Project. The full project also includes foundation investigations at the three existing terminals: Kingston, Marysville and Dawson's Point which are reported separately.

The purpose of this investigation was to explore the subsurface conditions along the ferry channel and based on the data obtained, to provide borehole location plans, records of boreholes, laboratory test results and a written description of the subsurface conditions.

Thurber Engineering Ltd. (Thurber) carried out the current investigation as a sub-consultant to Morrison Hershfield (MH) under Agreement No. 4017-E-0015, Assignment 5.

No previous information was available in the online GEOCRES library for the navigational channel. Relevant portions of the data from the Foundation Investigation and Design Reports (FIDRs) from the Kingston and Marysville Terminals have been included in the present report. In addition, to the foundation drilling program carried out by Thurber, it is noted that MH engaged ASI Marine (ASI) to carry out a geophysical survey of portions of the navigational channel.

**2 SITE DESCRIPTION**

The Wolfe Island Ferry services three terminals consisting of the Kingston Terminal located in downtown Kingston and the Dawson Point and Marysville Terminals located on Wolfe Island. The Wolfe Islander III currently operates between the Kingston and Marysville terminals during spring, summer and fall and between Kingston and Dawson Point terminals during the winter months (when ice is present and/or low water conditions are encountered at Marysville).

The foundation investigations targeted two locations along the ferry route which had been identified by others to have shallow water, as defined by a lakebed elevation of 69.1 m Geodetic or higher. The approximate areas are delineated in plan view on Drawings 1 and 2 in Appendix A based on information from ASI received prior to the investigation.



The first location, labeled the Kingston Shoal, is located near the entrance to the harbour approximately 300 m southeast of the existing Kingston Terminal, see Drawing 1 in Appendix A. The investigated area is approximately 150 m wide and located from approximately 300 m to 550 m from the Kingston Terminal along the ferry's route to Wolfe Island.

The second location is in Barrett's Bay along the ferry's route to Kingston between the Marysville Terminal to just beyond Garden Island. The investigated area is approximately 150 m wide and 2 km long and is indicated on Drawing 2 in Appendix A.

In September 2018, a refinement carried out by others based on ferry operational requirements raised the critical lakebed elevation to 69.25 m. This reduced the area of the two previously identified shallow water areas. In addition, the ferry route was modified at the approach to the Kingston dock and two additional shallow water locations were identified, the approximate locations are indicated on Drawing 1 in Appendix A. The first additional area (Kingston 1) is approximately 100 m long by 30 m wide and is located 40 m east of the existing dock. The second additional location (Kingston 2) is approximately 120 m long by 40 m wide and located 150 m south-east of the existing dock.

### **3 SITE INVESTIGATION AND FIELD TESTING**

The field investigation consisted of advancing the following Boreholes between July 24 and July 31, 2018:

- Kingston Shoal Area: K18-1A, K18-1 through K18-3
- Marysville Approach Area: M18-1 through M18-7

The previous investigation at the Marysville Terminal included several boreholes relevant to the current assignment. The following Boreholes were drilled between August 29 and September 5, 2017:

- Marysville Terminal: M17-01, M17-02 and M17-03

In addition, a geophysical survey was carried out at the Kingston dock site in 2015 (report received in 2016) in support of the Foundation Investigation. Portions of the study area from that work overlap with the Kingston 1 area described above and the results are included in this report. Please refer to the Kingston Terminal FIDR for additional details on the survey.

The northings, eastings and elevations of each borehole are shown on the Borehole Location Drawings No. 1 and No. 2 in Appendix A, on the Borehole Records in Appendix B and are summarized in Table 3-1 below. The site is within MTM Zone 9. The elevations were taken relative to the water level which was measured daily based on site benchmark HCP 140 which has a geodetic elevation of 76.440. Northing and easting coordinates were provided by a surveyor using a Trimble R10 GPS receiver.

**Table 3-1: Borehole Summary**

Location	Borehole No.	Northing (m)	Easting (m)	Lakebed Elevation (m)	Borehole Termination Depth Below Lakebed (m)
Kingston Shoal	K18-1A	4 898 809.3	306 860.9	69.3	0.6
	K18-1	4 898 788.7	306 794.6	69.3	3.3
	K18-2	4 898 749.0	306 838.4	69.1	3.7
	K18-3	4 898 635.7	306 816.7	70.2	4.3
Marysville Approach Area	M18-1	4 896 427.9	308 415.4	69.9	3.1
	M18-2	4 895 503.9	309 273.6	70.5	4.5
	M18-3	4 895 790.1	308 876.4	70.6	5.1
	M18-4	4 896 026.4	308 790.2	70.8	4.8
	M18-5	4 896 192.5	308 653.7	70.9	6.7
	M18-6	4 895 303.7	309 413.0	70.2	4.2
	M18-7	4 895 615.2	309 077.4	70.2	4.2
	M17-01	4 895 079.7	309 430.4	72.3	29.2
	M17-02	4 895 118.0	309 503.5	71.1	34.3
	M17-03	4 895 174.2	309 447.8	70.7	11.2

Prior to commencement of drilling, permission from regulatory authorities and utility clearances were obtained for the borehole locations. Morrison Hershfield arranged for a diving team to locate the submarine Bell cable which crossed the alignment of the ferry route.

The drilling equipment was floated on a sectional barge and braced at the drilling locations with spuds (Photo 3, Appendix D) attached to the corners of the barge. The barge was positioned with a support boat. The drilling was carried out with a CME drill rig. NW casing was used to advance the boreholes through the overburden. Prior to advancing the boreholes, HW casing was lowered to the lakebed encompassing the drilling location and facilitating capture of the drill cuttings. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with SPT testing. Where encountered, bedrock was cored with NQ coring.

The near surface samples were collected for Morrison Hershfield's environmental investigation, testing and reporting.

The drilling and sampling operations were supervised on a full-time basis by a member of Thurber's technical staff. The drilling supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory in Ottawa, Ontario.

#### **4 LABORATORY TESTING**

The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to Atterberg Limit testing and gradation analysis (hydrometer and/or sieve). Several samples of the recovered bedrock core underwent unconfined compressive strength (UCS) testing. In addition, two Micro-

Deval Abrasion tests were carried out on bedrock samples. Two samples of the sediment from Marysville were submitted for organic content testing. The results of these tests are summarized on the Record of Borehole sheets included in Appendix B and are presented on the laboratory figures included in Appendix C.

## **5 DESCRIPTION OF SUBSURFACE CONDITIONS**

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata drawings included in Appendix A. A general description of the stratigraphy is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. It must be recognized that soil conditions may vary between and beyond borehole and sample locations.

An inferred lake bed elevation of 72.3 to 69.1 m was interpreted within the offshore boreholes from drop tape measurements. Soil sampling commenced at the depth where the drill casing became supported by the lakebed deposits.

### **5.1 Kingston Alignment**

#### **5.1.1 Water Level**

The water level in the lake which was observed to range in elevation from 74.9 to 75.0 m during the time of the site investigation. The water depth at each of the boreholes is presented in Table 5-1 below.

**Table 5-1: Water Level Summary**

Borehole No.	Water Depth (m)	Lakebed Elevation (m)
K18-1A	5.7	69.3
K18-1	5.6	69.3
K18-2	5.8	69.1
K18-3	4.7	70.2

#### **5.1.2 Surficial Sediment**

A layer of very soft or very loose material was present in Borehole K18-2 at the inferred lake bed as determined by drop tape. Attempts at sampling this sediment with and without the use of casing resulted in no sample recovery. This layer was noted to have a thickness of 0.5 m with an underside elevation of 68.6 m.

#### **5.1.3 Clay (Cl)**

A clay deposit was encountered at the lake bed surface in Boreholes K18-1A, K18-1 and K18-3. The sampled thickness of the clay varied from less than 0.1 to 3.3 m. The clay in Borehole K18-3 had an underside elevation 70.2 m. Boreholes K18-1A and K18-1 were terminated within this layer.

SPT tests performed within the clay gave N-values ranging from 7 to 32 blows. Two field vane tests were attempted in Borehole K18-1 but were unable to shear the soil, indicating undrained shear strengths in excess of 100 kPa and a very stiff to hard consistency.

Recorded moisture contents ranged from 23 to 36%. Gradation analysis was completed on one sample of the clay. The results are summarized on the Record of Borehole sheet in Appendix B and the grain size distribution curve for this sample is included in Figure C1 of Appendix C. The results of the laboratory tests are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0
Sand	1
Silt	45
Clay	54

Atterberg Limit testing was also completed on a sample of the clay. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graph is included in Figure C2 in Appendix C. The laboratory results are summarized below and indicate that the clay is of intermediate plasticity (CI):

Parameter	Value
Liquid Limit	45
Plastic Limit	24
Plasticity Index	21

#### 5.1.4 Bedrock

Limestone with shale and sandstone bedrock was encountered below the soil and cored in Boreholes K18-2 and K18-3. The surface of the bedrock was encountered at elevations of 68.6 and 70.2 m in Boreholes K18-2 and K18-3, respectively. The bedrock was cored to base elevations of 65.4 and 65.9 m. The elevation at which bedrock was encountered is summarized in Table 5-2.

**Table 5-2: Bedrock Summary**

Borehole No.	Bedrock Elevation (m)
K18-1A	Not encountered above 68.7
K18-1	Not encountered above 66.0
K18-2	68.6
K18-3	70.2

Total Core Recovery (TCR) in the bedrock was 100%. Solid Core Recovery (SCR) ranged from 81 to 100%. The Rock Quality Designation (RQD) values ranged from 67 to 95%

indicating a rock quality ranging from good to excellent. Unconfined compressive strength (UCS) testing carried out on 4 intact core samples resulted in a strength of 96 MPa for the limestone and from 80 MPa to 225 MPa for the sandstone, indicating strong to very strong rock. A Micro-Deval Abrasion test was carried out on a combination of rock core from Runs 1 and 2 in Borehole K18-3 and generated a result of 22.6% loss. Photographs of the recovered core are provided in Appendix C.

#### 5.1.5 Results of Analytical Tests

Samples for analytical testing were obtained as part of the drilling program. Retained soil samples were provided to Morrison Hershfield who performed the sample selection and submission to Caducean Environmental Laboratories in Kingston, Ontario for various analytical parameters. A list of samples submitted by Morrison Hershfield follows:

- K18-1A: SS1
- K18-1: SS1, SS2

The results of the analytical testing from these soil samples can be found in their environmental report.

#### 5.1.6 2016 Geophysical Survey Report

Please refer to the FIDR for the Kingston Terminal site for a copy of the 2016 Geophysics GPR International Inc. (GPR) report for bedrock mapping at the Kingston Terminal. That report provides a description of the methodology and results of the November 2015 survey which included the use of a Sub-bottom Profiler and Seismic Refraction equipment. Drawing T-158621\_A1 from the GPR report is presented in Appendix E. The approximate boundaries of the geophysical survey are indicated on Drawing 1 in Appendix A.

It is apparent from Drawing 1 in Appendix A that the Kingston 1 area is almost completely covered by the 2015 geophysical survey. The contouring of Drawing T-158621\_A1 in Appendix E indicates that the depth to bedrock is estimated to be at or greater than 20m below chart datum throughout Kingston 1. Chart datum is indicated to be 74.2m above IGLD85 (Geodetic). The top of bedrock is therefore estimated to be at or below 54.2 m throughout this zone.

## 5.2 Marysville Alignment

### 5.2.1 Water Level

The water level in the lake was observed at elevation 75.2 m and 74.9 m during the 2017 and 2018 site investigations, respectively. The water depth at each of the boreholes is presented in Table 5-3 below.

**Table 5-3: Water Level Summary**

<b>Borehole No.</b>	<b>Water Depth (m)</b>	<b>Lakebed Elevation (m)</b>
M18-1	5.0	69.9
M18-2	4.4	70.5
M18-3	4.3	70.6
M18-4	4.1	70.8
M18-5	4.0	70.9
M18-6	4.7	70.2
M18-7	4.7	70.2
M17-01	2.9	72.3
M17-02	4.1	71.1
M17-03	4.5	70.7

#### 5.2.2 Organic Silt

A deposit of organic silt was encountered at the lake bed surface in Boreholes M18-4 and M18-7. The organic silt deposit varied from 0.8 to 1.4 m in thickness with an underside elevation of 69.4 m.

SPT tests recorded N-values of weight of hammer indicating a very loose relative density. Recorded moisture contents on two samples were 155 and 391%. Organic content testing completed on two samples had results of 10.7% and 37.5% organic content.

#### 5.2.3 Silt

A thin layer of silt was encountered at the lake bed surface in Boreholes M18-3 and M18-5. The silt deposit varied from 0.1 to 0.3 m in thickness with an underside elevation of 70.5 to 70.6 m.

A SPT test conducted in this layer recorded an N-value of 1 blow indicating a very loose relative density.

#### 5.2.4 Clay (CL to CH)

A clay deposit was encountered below the organic silt layer in Boreholes M18-4 and M18-7, and at the lake bed surface in Boreholes M17-01, M17-02, M18-2 and M18-6. Sandy silt interlayers were noted in the clay in Borehole M17-02. Occasional organics were noted in the clay in Borehole M17-01. The sampled thickness of the clay varied from 2.3 to 4.5 m. Boreholes M18-2, M18-4, M18-6 and M18-7 were terminated within this layer. The base of the clay strata was at elevation 68.4 m and 68.8 m in Boreholes M17-01 and M17-02.

SPT tests performed within the clay gave N-values ranging from 2 to 39 blows. Field vane tests were attempted but were generally unable to shear the soil, indicating undrained shear strengths in excess of 100 kPa. One vane shear test completed in Borehole M18-7 indicated an undrained shear strength of 51 kPa. The vane tests indicate the clay is of stiff to very

stiff consistency. In some locations near the lakebed surface, the clay is inferred to have a firm consistency. Recorded moisture contents ranged from 21 to 58%.

Gradation analysis was completed on seven samples of the clay. The results are summarized on the Record of Borehole sheets in Appendix B and the grain size distribution curves for these samples are included in Figures C3 and C4 of Appendix C. The results of the laboratory tests are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0 to 2
Sand	1 to 9
Silt	25 to 62
Clay	36 to 73

Atterberg Limit testing was also completed on seven samples of the clay. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graphs are included in Figures C11 and C12 in Appendix C. The laboratory results are summarized below and indicate that the clay is typically of high plasticity (CH) with low (CL) and intermediate (CI) zones:

Parameter	Value
Liquid Limit	28 to 62
Plastic Limit	16 to 30
Plasticity Index	12 to 36

#### 5.2.5 Sandy Silt (ML)

A sandy silt deposit was encountered below the clay in Borehole M17-02 and at the lake bed surface in Borehole M17-03. A 50 mm thick clay seam was noted within the sandy silt in Borehole M17-02. The silt layer ranged from 0.5 to 0.9 m in thickness with an underside elevation of 70.2 to 67.9 m.

SPT tests performed within the sandy silt gave an N-value ranging from 9 to 20 blows indicating loose to compact relative consistency. Recorded moisture contents ranged from 15 to 21%.

Gradation analysis was completed on two samples of the sandy silt. The results are summarized on the Record of Borehole sheets in Appendix B and the grain size distribution curves for these samples are included in Figure C5 of Appendix C. The results of the laboratory test are as follows and indicate an ML material:

Soil Particle	Percentage (%)
Gravel	6 to 13
Sand	25 to 33
Silt	47 to 50
Clay	12 to 14

Atterberg Limit testing completed on the sandy silt indicated a non-plastic material.

#### 5.2.6 Silty Sand (SM)

Silty sand was encountered below the clay in Borehole M17-01 and below the sandy silt in Borehole M17-02. Discontinuous clay seams were interbedded within the silty sand in both boreholes. Cobbles and boulders were noted in this unit in Borehole M17-02. The thickness of this layer ranged from 3.2 to 15.4 m with an underside elevation of 65.2 to 52.5 m.

SPT tests performed within the silty sand gave N-values ranging from 4 to greater than 100 blows indicating loose to very dense relative density. Recorded moisture contents ranged from 4 to 22%.

Gradation analysis were completed on two samples of the sand. The results are summarized on the Record of Borehole sheets in Appendix B and the grain size distribution curves for these samples are included in Figure C6 of Appendix C. The results of the laboratory tests are summarized as follows and indicate an SM material.

Soil Particle	Percentage (%)
Gravel	1 to 2
Sand	55 to 58
Silt	40 to 44
Clay	

#### 5.2.7 Sand with Silt and Gravel (SW-SM)

Sand with silt and gravel was encountered below the silty sand layer in Borehole M17-01. The thickness of this layer was 6.1 m with an underside elevation of 59.1 m.

SPT tests performed within the sand gave N-values ranging from 17 to 33 blows indicating a compact to dense material. Recorded moisture contents ranged from 3 to 13%.

Gradation analysis was completed on one sample of the sand with silt and gravel. The results are summarized on the Record of Borehole sheet in Appendix B and the grain size distribution curve for this sample is included in Figure C7 of Appendix C. The results of the laboratory tests are summarized as follows and indicate an SW-SM material.



Soil Particle	Percentage (%)
Gravel	43
Sand	52
Silt	5
Clay	

## 5.2.8 Glacial Till

### 5.2.8.1 Sandy Clay Till

Sandy clay till with trace gravel deposits was encountered below the sand in Boreholes M17-01 and M17-02. The thickness of this layer ranged from 2.7 m to 2.9 m with an underside elevation of 57.4 m to 49.6 m). Cobbles and boulders were noted within the till deposit.

SPT tests performed within the clay gave N-values ranging from 69 blows per 300 mm of penetration to 100 blows for 200 mm of penetration indicating a very stiff to hard relative consistency. Coring was required to advance through the upper part of till in M17-02. Recorded moisture contents ranged from 7 to 19%.

Gradation analysis was completed on one sample of the clay till. The results are summarized on the Record of Borehole sheets in Appendix B and the grain size distribution curves are included in Figure C8 of Appendix C. The results of the laboratory tests are summarized as follows:

Soil Particle	Percentage (%)
Gravel	6
Sand	39
Silt	36
Clay	19

Atterberg Limit testing was also completed on one sample of the clay till. The results are summarized on the Record of Borehole sheet in Appendix B and the Atterberg Limit graph is included in Figure C13 in Appendix C. The laboratory results are summarized below and indicate that the clay till is of low plasticity (CL):

Parameter	Value
Liquid Limit	18
Plastic Limit	11
Plasticity Index	7

#### 5.2.8.2 Silty Sand with Gravel Till

Silty sand till with varying amounts of gravel and clay were encountered beneath the upper clay till layer in Boreholes M17-01 and M17-02 and beneath the silt layer in Borehole M18-5. The thickness of this layer ranged from 1.5 m to 3.2 m with an underside elevation of 67.4 m to 48.1 m. Cobbles and boulders were noted with the till deposit.

SPT tests performed within the sand gave N-values ranging from 13 blows per 300 mm of penetration to 100 blows for 250 mm of penetration indicating a loose to very dense relative density. Recorded moisture contents ranged from 8 to 22%.

Gradation analysis was completed on a sample of the silty sand till. The result is summarized on the Record of Borehole sheet in Appendix B and the grain size distribution curve for this sample is included in Figure C9 of Appendix C. The results of the laboratory tests are summarized as follows and indicate an SW-SM material:

Soil Particle	Percentage (%)
Gravel	14
Sand	49
Silt	22
Clay	15

#### 5.2.8.3 Sandy Clay Till

A sandy clay with a trace of gravel till was encountered in Boreholes M17-01 and M17-02 beneath the silty sand till. The thickness of this layer ranged from 1.0 m to 6.7 m with an underside elevation of 54.5 m to 41.4 m. Cobbles and boulders were noted within the till deposit. SPT tests performed within the sandy clay gave N-values ranging from 24 to 66 blows indicating a compact to dense material. A moisture content of 10% was recorded.

#### 5.2.8.4 Silty Sand with Gravel Till

A silty sand with gravel till was encountered below the sandy clay till in Borehole M17-01. The thickness of this layer was 5.3 m with an underside elevation of 49.2 m. SPT tests performed within the sand gave N-values in excess of 100 blows indicating a very dense material. Moisture contents of 10% and 18% were recorded.

#### 5.2.8.5 Sandy Clay Till

A lower layer of sandy clay till with gravel was encountered below the silty sand till in Borehole M17-01. The thickness of this layer was 2.0 m with an underside elevation of 47.2 m. An SPT test performed within the sandy clay gave an N-value of 55 blows indicating a hard material. A moisture content of 13% was recorded.

Gradation analysis was completed on one sample of the clay till. The results are summarized on the Record of Borehole sheet in Appendix B and the grain size distribution curves are included in Figure C10 of Appendix C. The results of the laboratory tests are summarized as follows:

Soil Particle	Percentage (%)
Gravel	6
Sand	37
Silt	37
Clay	20

Atterberg Limit testing was also completed on one sample of the clay till. The results are summarized on the Record of Borehole sheet in Appendix B and the Atterberg Limit graph is included in Figure C14 in Appendix C. The laboratory results are summarized below and indicate that the clay till is of low plasticity (CL):

Parameter	Value
Liquid Limit	21
Plastic Limit	11
Plasticity Index	10

#### 5.2.9 Bedrock

Limestone bedrock with shale interbeds was encountered at lake bed surface in Borehole M18-1, below the surficial silt in Borehole M18-3, below the sandy silt in Borehole M17-03, below the silty sand till in Borehole M18-5, and below the clay till in Boreholes M17-01 and M17-02. The surface of the bedrock was encountered at elevations ranging from 67.4 to 70.5 m. The elevation at which bedrock was encountered is summarized in Table 5-4.

**Table 5-4: Bedrock Summary**

Borehole No.	Bedrock Elevation (where encountered) (m)
M18-1	69.9
M18-2	Not encountered above 66.0
M18-3	70.5
M18-4	Not encountered above 66.0
M18-5	67.4
M18-6	Not encountered above 66.0
M18-7	Not encountered above 66.0
M17-01	47.2
M17-02	41.4
M17-03	70.2

Total Core Recovery (TCR) in the bedrock ranged from 55% to 100%. Equipment difficulties resulted in poor core recovery in Borehole M18-3 Run 2 and Borehole M18-5 Run 1. Solid

Core Recovery (SCR) ranged from 52 to 100%. The Rock Quality Designation (RQD) values ranged from 0 to 97% indicating a rock quality ranging from very poor to excellent. The Fracture Index ranged from 0 to greater than 10 fractures per 150 mm. Unconfined compressive strength (UCS) testing carried out on eight intact core samples resulted in strengths ranging from 101 to 181 MPa, indicating a very strong rock. A Micro-Deval Abrasion test was carried out on a combination of rock core from Run 1 in Borehole M18-1 and Run 1 from Borehole M18-3 and generated a result of 9.0% loss.

#### 5.2.10 Results of Analytical Tests

Samples for analytical testing were obtained as part of the drilling program. Retained soil samples were provided to Morrison Hershfield who performed the sample selection and submission to Caducean Environmental Laboratories in Kingston, Ontario for various analytical parameters. A list of samples submitted by Morrison Hershfield follows:

- M18-2: SS1, SS2
- M18-4: SS1, SS2
- M18-5: SS1, SS2
- M18-6: SS1, SS2
- M18-7: SS1, SS2

The results of the analytical testing from these soil samples can be found in the MH environmental report.

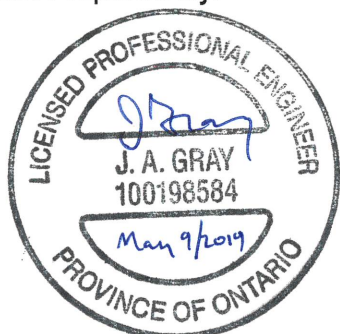
## 6 MISCELLANEOUS

Borehole locations were selected based on sub-bottom bathymetry information provided to Thurber by Morrison Hershfield. Borehole locations were chosen to avoid conflict with both submarine utilities and the Wolfe Islander III's active path of operation. Hopkins Chitty Land Surveyors Inc. and McIntosh Perry Consulting Engineers provided survey support during the 2017 and 2018 field investigations respectively.

Geophysics GPR International Inc. completed the geophysical survey for bedrock mapping at the Kingston Terminal. Eastern Ontario Diamond Drilling Ltd. from Hawkesbury, Ontario supplied the drill rig and conducted the drilling, sampling and in-situ testing. The barge and support boat were supplied and operated by ODS Marine from Greely Ontario. The field investigation was supervised by Mr. Justin Gray, P.Eng. of Thurber. Overall supervision of the investigation programs was conducted by Mr. Stephen Peters, P.Eng.

Routine geotechnical laboratory testing was carried out by Thurber's laboratory in Ottawa, Ontario. Interpretation of the data and preparation of this report were carried out by Dr. Fred Griffiths, P.Eng, Justin Gray, P.Eng. and Stephen Peters, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng a Designated Principal Contact for MTO Foundation Projects.

Thurber Engineering Ltd.  
Report Prepared By:



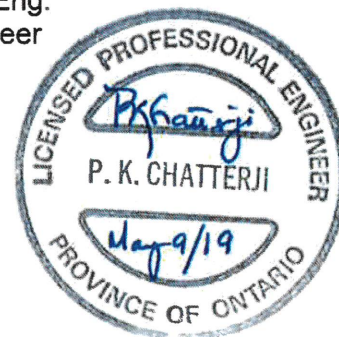
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**FINAL  
FOUNDATION INVESTIGATION AND DESIGN REPORT  
WOLFE ISLAND FERRY AND DOCKING IMPROVEMENTS  
NAVIGATIONAL CHANNEL  
COUNTY OF FRONTENAC  
AGREEMENT NO.: 4017-E-0015, ASSIGNMENT 5  
  
GEOCRES NO.: 31C-280**

**PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**7 GENERAL**

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents geotechnical assessment and recommendations to support the project team in designing a suitable approach towards the proposed dredging between Kingston and Wolfe Island. The proposed work is part of the Wolfe Island Ferry and Docking Improvements Detailed Design Assignment. Thurber Engineering Ltd. (Thurber) carried out the current investigation as a sub-consultant to Morrison Hershfield under Agreement No. 4017-E-0015 Assignment 5.

This foundation design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The construction or design-build contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

The following sections of this report address the foundation engineering aspects of the proposed dredging. The discussion and recommendations presented in this report are based on the information provided by the client and the factual data obtained during the course of the offshore investigation conducted by Thurber.

**7.1 Proposed Works**

The project consists of dredging the navigational channel used by the ferries between the Kingston and Marysville terminals to elevation 69.25 m. Preliminary drawings showing the dredge areas was provided by others and has been utilized to generate Drawings 1 and 2 in Appendix A. The design recommendations for the dredging and construction at and near the ferry terminals is covered within the separate Foundation Investigation Design Reports for those terminals.

The selection of the dredging methods must consider costs, staging requirements with the operating ferry, the depth (and variation in depth) to lake bed, soil types, presence of bedrock and the environmental conditions. Additional discussion on dredging and disposal

operations have been provided in the Kingston Shoal Dredge Plan (March 2019) and the Marysville Dredge Plan (May 2019) prepared by Shoreplan Engineering Limited.

It should be expected that the lakebed and bedrock elevations will vary between and beyond the investigated borehole locations.

## 7.2 Stratigraphy Above Elevation 69.25 m

It is understood that the existing navigational channel is to be deepened to an elevation of 69.25 m. Summaries of the stratigraphy encountered above elevation 69.25 m are presented in the sections below for each of the navigational channel areas.

### 7.2.1 Kingston 1

No borehole information is available for the Kingston 1 area (see Drawing 1 in Appendix A). However, the GPR data that Geophysics GPR International Inc. collected between November 10 to 23, 2015 for the Kingston Terminal covers this zone (see Drawing 1 in Appendix A for approximate area; GPR Drawing T-158621\_A1 is included in Appendix E). From the GPR data it does not appear that hard till/bedrock is present above elevation 69.25 m. Based on boreholes drilled at the Barrack Terminal approximately 100 m west of the Kingston 1 area, the overburden above the bedrock is predominately clay (see Kingston Terminal FIDR).

Sub-bottom profiling data was collected by ASI Marine (May 2018) and indicates that the lakebed surface within this area could be as high as elevation ~70.0 m resulting in a dredging depth of as much as 0.75 m.

### 7.2.2 Kingston 2

There is no borehole or GPR information from the 2015, 2017 or 2018 investigations in this area.

Sub-bottom profiling data was collected by ASI Marine (May 2018) and indicates that the lakebed surface within this area could be as high as elevation ~69.75 m resulting in a dredging depth of as much as 0.5 m.

### 7.2.3 Kingston Shoal

The materials above elevation 69.25 m are presented in Table 7-1 for the Kingston Shoal.

**Table 7-1: Kingston Shoal**

Borehole	Estimated Lake Bottom Elevation (m)	Depth to Elevation 69.25 m (m)	Material Above El. 69.25 m	Fracture Index (per 0.15 m)	Rock Quality Designation (RQD)	Unconfined Compressive Strength, UCS (MPa)
K18-1	69.3	0.05	V. Stiff Clay	-	-	-
K18-1A	69.3	0.05	V. Stiff to Hard Clay	-	-	-
K18-2	69.1	0.0	-	-	-	-
K18-3	70.2	0.95	Limestone	1,5,6,3	67% to 86%	96

The quality of the rock above elevation 69.25 m within the Kingston Shoal area is considered to be of fair to good quality based on the Fracture Index (FI) and Rock Quality Designation (RQD) measurements. Based on Unconfined Compressive Strength (UCS) test completed in this area, the rock is considered strong.

#### 7.2.4 Marysville Approach Alignment

The materials above elevation 69.25 m are presented in Table 7-2 for the Marysville Approach Alignment.

**Table 7-2: Marysville Approach Alignment**

Borehole	Estimated Lake Bottom Elevation (m)	Depth to Elevation 69.25 m (m)	Material Above El. 69.25 m	Fracture Index (per 150 mm)	Rock Quality Designation (RQD)	Unconfined Compressive Strength, UCS (MPa)
M18-1	69.9	0.65	Limestone	4,1	67%	177
M18-2	70.5	1.25	Firm to V. Stiff Clay	-	-	-
M18-3	70.6	1.35	Limestone	10,5,>10*	7%*	151
M18-4	70.8	1.55	V. Loose Org. Silt and Stiff to V. Stiff Clay	-	-	-
M18-5	70.9	1.65	V. Loose Silt and V. Loose to Compact Silty Sand Till	-	-	-
M18-6	70.2	0.95	Firm to V. Stiff Clay	-	-	-
M18-7	70.2	0.95	V. Loose Org. Silt and Firm to V. Stiff Clay	-	-	-
M17-01	72.3	3.05	Stiff to V. Stiff Clay	-	-	-
M17-02	71.1	1.85	V. Stiff Clay	-	-	-
M17-03	70.7	1.45	Compact Sandy Silt (0.5m) and Limestone	>10,>5,6	0, 40%	133

(\*) Note: poor core recovery due to machine difficulties.

The quality of the rock above elevation 69.25 m within the Marysville Dredge area is considered generally very poor to poor based on FI and RQD measurements with fair quality rock encountered in Borehole M18-1. It is noted that the quality may be artificially low due to wave action on the coring equipment and machine difficulties encountered during drilling (as noted in Borehole M18-3). The rock is considered strong to very strong based on UCS tests completed in the upper portion of the rock in this area.



## 8 FOUNDATION DESIGN RECOMMENDATIONS

Dredging to elevation 69.25 m is proposed in four locations to ensure adequate water depth for ferry operation. Dredging operations must be carried out in accordance with OPSS.PROV 182. Dredging must not interfere with ferry operations or destabilize existing and/or temporary foundations. Utility locates must be completed and conflicts resolved in advance of the dredging work. Known utilities include a submerged Bell line. MTO has an existing bubbler system servicing the ferry route which traverses the dredging areas which should also be protected and/or relocated as directed by MTO.

The overburden soils observed higher than elevation 69.25 m typically consist of firm to stiff clay. Very loose organic silt and compact silty sand were also observed. For permanent slopes, the sides of the dredging must be sloped at 5H:1V (or flatter) in overburden slopes. It is expected that dredging of overburden could be achieved using an excavator bucket or clam shell although other mechanical and hydraulic operations may be proposed by the Contractor. The selection of dredging equipment and methodology is the responsibility of the Contractor. The contract documents should alert the Contractor to this responsibility. Additional comments on potential dredging methodology are contained in the Dredging Reports prepared by Shoreplan Engineering Limited.

The bedrock observed higher than elevation 69.25 m typically consists of very poor to fair quality limestone bedrock. For permanent slopes, a side slope of 1.5H:1V in fractured bedrock is recommended. In more competent limestone, a side slope of 1H:1V is recommended. The limited thickness of bedrock to be removed precludes effective use of blasting techniques. Portions of the bedrock can likely be removed with mechanical shovels. The use of rock breakers/hoe rams will likely be required in some areas. Predrilling may also be required. Given a typical water elevation of approximately 75 m and the target dredge line of 69.25, long reach mechanical equipment will likely be needed.

It is anticipated that the dredged material will be placed onto a barge. The dredged overburden will be heavily saturated and could be in a loose/disturbed state. Decanting of the excavated overburden materials should be anticipated. Runoff should be contained to prohibit fines from re-entering the waterbody and the use of an enclosed barge is recommended.

Based on the 10 boreholes in the dredged area at Marysville we expect the material above elevation 69.1m to include limestone bedrock, firm to very stiff high plastic clay, compact sandy silt, compact silty sand till and very loose organic silt. Typical MTO Contracts are paid based on in-place volume for earth and rock excavation as described in OPSS 206 and do not account for bulking. The bulking factor is highly dependent on construction methodology thus the following values should be treated as rough estimates only:

**Table 8-1 Bulking Factors**

Material	In-Place, Saturated Unit Weight, kN/m <sup>3</sup>	Bulking Factor	Excavated, Saturated* Unit Weight, kN/m <sup>3</sup>
Limestone Bedrock	23 to 28	1.3 to 1.7	17.6 to 23.9
Firm to Very Stiff, High Plastic Clay	17 to 19	1.2 to 1.5	14.7 to 17.5
Compact Sandy Silt to Silty Sand	19 to 20	1.05 to 1.3	16.9 to 19.5
Very Loose Organic Silt	14	1.05 to 1.1	13.3 to 13.6

*\*Note that excavated unit weights will change over time as the material drains from the saturated condition. This will occur very quickly for excavated bedrock.*

All materials excavated from the site should be handled, stockpiled and disposed of in accordance with environmental regulations. Analytical testing results are provided in a separate environmental report prepared by Morrison Hershfield. Further analytical testing may be required based on the requirements of the receiver.

Should off-shore disposal be considered, it is recommended that the disposal area be determined, in part, using side slopes of 5H:1V for material placed from barges to limit the potential of subsequent lateral spread of materials generated by the 1 in 2475 year design seismic event. Additional comments on disposal of materials are presented in the Dredging Reports prepared by Shoreplan Engineering Limited.

Consideration could be given to reusing the excavated bedrock however this will require careful separation of the excavated rock from overburden materials. If the excavated bedrock will be re-used at the Kingston, Marysville or Dawson Docks for structural backfill purposes, the respective FIDRs (Geocres 31C-278, 31C-279 and 31C-283, respectively) should be referenced for additional requirements. Two Micro-Deval tests were completed on samples acquired from bedrock core, both test results met the requirements for Clear Stone as per Table 1 of OPSS 1004. Confirmatory, production testing should be carried out if the bedrock is to be used as a source for clear stone. If the material is to be re-used for non-structural purposes away from the terminals, the requirements should be based on intended use. Regardless of the proposed reuse, environmental requirements, as identified separately, must be satisfied.

It is noted that the submarine environment is not static; some migration of sediments should be anticipated over time and there may be a need for periodic re-dredging of the navigation channel in the future. In addition, it is noted that lateral spread generated by the 1 in 2475 year design seismic event could result in sediment moving into the channel. This could prompt the need for dredging at the edges of the channel to re-establish the full width of the passageway.

## **9 CONSTRUCTION CONCERNS**

Potential construction concerns include, but are not necessarily limited to:

- The depth to bedrock was noted to vary between borehole locations.
- No geotechnical borehole data is present at the Kingston 1 & 2 locations. Therefore, the presence of bedrock or till at that location cannot be confirmed.

- Buried obstructions may be encountered during the dredging process, obstructions may include both natural and manmade objects.
- Existing submarine utilities were noted to be present within the dredge areas.

A risk register of these issues is provided in Appendix F.

The successful performance of the project will depend largely upon good workmanship and quality control during construction.

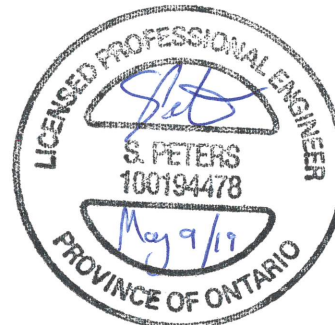
## 10 CLOSURE

Engineering analysis and preparation of this report were carried out by Dr. Fred Griffiths, P.Eng., Ms. Deanna Pizycki, P.Eng. and Mr. Stephen Peters, P.Eng. The report was reviewed Dr. P.K. Chatterji, P.Eng the Designated Principal Contact for MTO Foundation Projects.

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**Appendix A.**

**Borehole Location Plan Drawings**

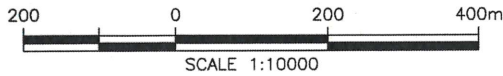




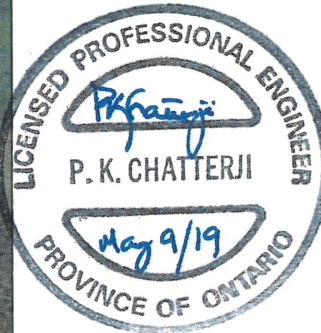




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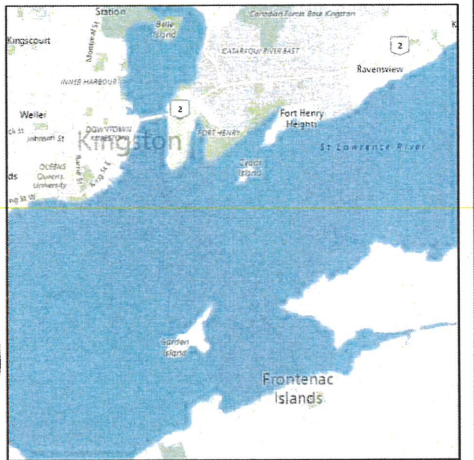
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN



CONT No GWP No 4061-14-00	
WOLFE ISLAND FERRY DOCKS MARYSVILLE AREA BOREHOLE LOCATIONS	SHEET



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND



Borehole (Present Investigation by Thurber)

NO	ELEVATION	NORTHING	EASTING
M18-1	74.9	4 896 427.9	308 415.4
M18-2	74.9	4 895 503.9	309 273.6
M18-3	74.9	4 895 790.1	308 876.4
M18-4	74.9	4 896 026.4	308 790.2
M18-5	74.9	4 896 192.5	308 653.7
M18-6	74.9	4 895 303.7	309 413.0
M18-7	74.9	4 895 615.2	309 077.4
M17-1	75.2	4 895 079.7	309 430.0
M17-2	75.2	4 895 118.0	309 503.5
M17-3	75.2	4 895 174.2	309 447.8

-NOTES-

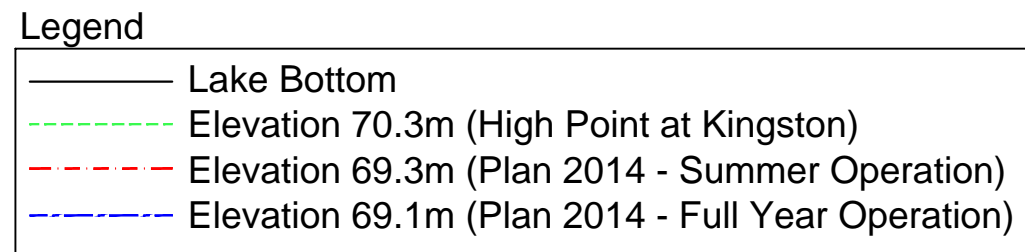
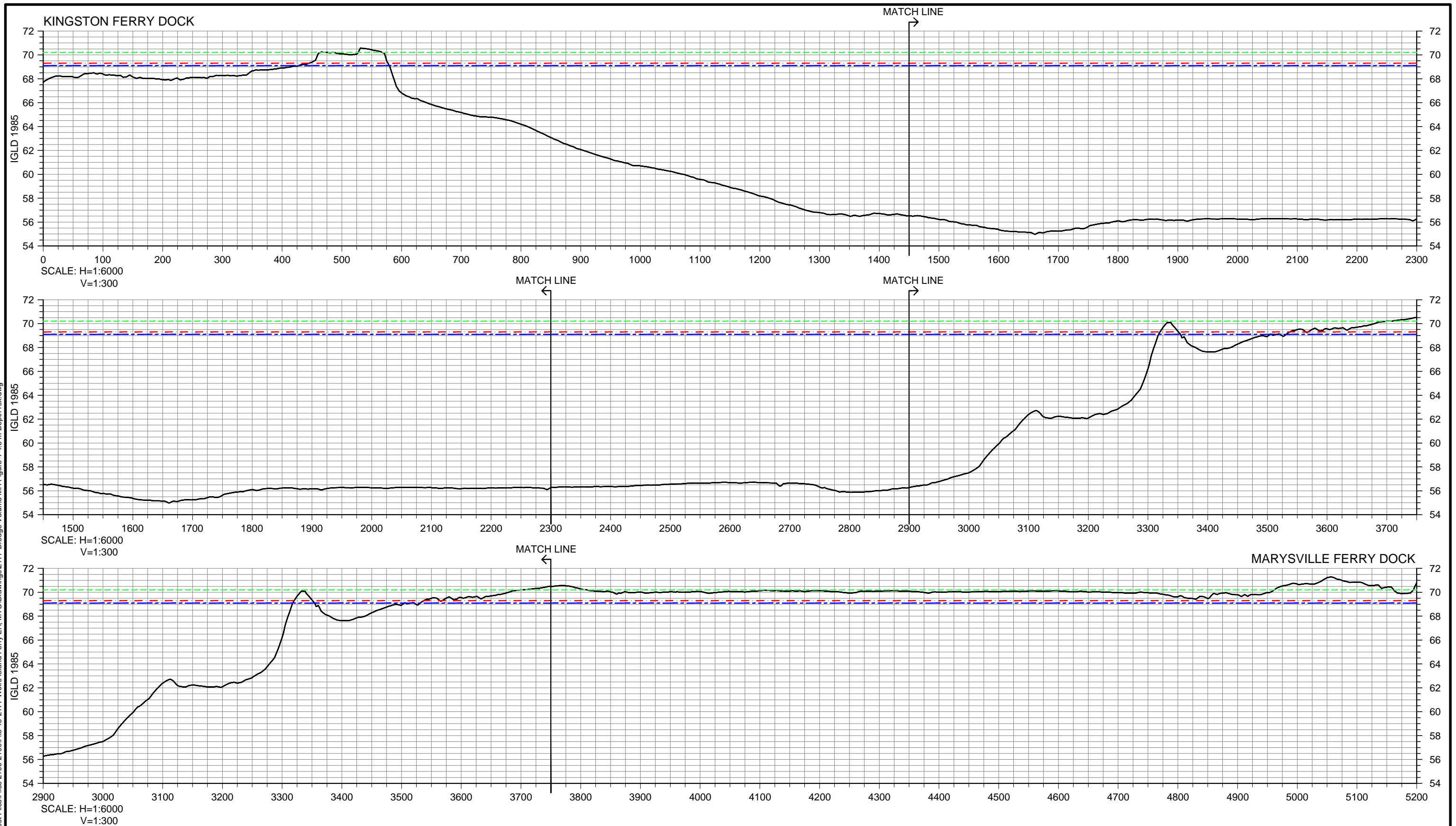
- SHALLOW NAVIGATIONAL CHANNEL AREA APPROXIMATED FROM ASI MARINE DRAWING "WOLFE ISLAND FERRY AND DOCKING IMPROVEMENTS PROJECT, KINGSTON, ONTARIO, SUB-BOTTOM PROFILE SURVEY, BEDROCK/TILL ELEVATION CONTOURS PLAN VIEW" DATED JUNE 6, 2018.
- DREDGE AREA APPROXIMATED FROM SHOREPLAN PRELIMINARY DRAWING "KINGSTON TERMINAL DREDGE PLAN" DATED SEPTEMBER 7, 2018.

GEOCRES No. 31C-280

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	JG	CHK --	CODE
DRAWN	JG	CHK SP	SITE
			LOAD
			DATE
			SEPT 2018
			STRUCT
			DWG 1



Drawing Location: S:\Shoreplan Project Files\Files 2100-2199\File 15-2177 Wolfe Island Ferry EA, MTO\Drawings\2177 Dredge Volume MH Figure 4 4.5 m Depth r0x.dwg



Scale: As Noted  
Project # 15-2177  
**SHOREPLAN**

**Figure 3.2**  
**Kingston to Marysville**  
**Navigation Channel Profile**

**Appendix B.**

**Record of Borehole Sheets**





## SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

### TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

### TERMINOLOGY DESCRIBING SOIL STRUCTURE:

Desiccated	having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

### RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

### N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

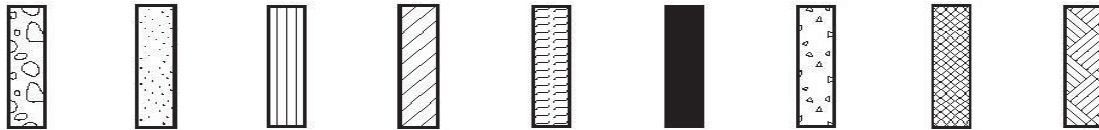
### DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "A" size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.



### STRATA PLOT:

Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders  
Cobbles  
Gravel      Sand      Silt      Clay      Organics      Asphalt      Concrete      Fill      Bedrock

### TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

### TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

### SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

### TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT “N” Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

### MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note -  $W_L$  = Liquid Limit



## EXPLANATION OF ROCK LOGGING TERMS

### ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structures are preserved.

### TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

### DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 to 2 m
Medium bedded	0.2 to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 to 60 mm
Laminated	6 to 20 mm
Thinly laminated	Less than 6 mm

### STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

# RECORD OF BOREHOLE No K18-1

1 OF 1

METRIC

GWP# 4061-14-00 LOCATION Lat: 44.2290967° Long: -76.4750328° Kingston Shoal, MTM z9: N 4 898 788.7 E 306 794.6 ORIGINATED BY JG  
 HWY Wolfe Island Ferry Docks BOREHOLE TYPE HW Casing / NW Casing COMPILED BY JG  
 DATUM Geodetic DATE 2018.07.31 - 2018.07.31 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
74.9														
0.0	WATER													
69.3														
5.6	CLAY (Cl) Very Stiff Grey		1	SS	13									
			2	SS	19									0 1 45 54
			3	SS	7									
			4	SS	9									
66.0														
8.9	End of Borehole													

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
15  
10  
5  
0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No K18-1A

1 OF 1

METRIC

GWP# 4061-14-00 LOCATION Lat: 44.2292819° Long: -76.4742029° Kingston Shoal, MTM z9: N 4 898 809.3 E 306 860.9 ORIGINATED BY JG  
 HWY Wolfe Island Ferry Docks BOREHOLE TYPE HW Casing COMPILED BY JG  
 DATUM Geodetic DATE 2018.07.24 - 2018.07.24 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
								○ UNCONFINED      + FIELD VANE					W P      W      W L				
75.0							20	40	60	80	100		20	40	60		
0.0	WATER						● QUICK TRIAXIAL      × LAB VANE										
																</	

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

## METRIC

SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT		NATURAL MOISTURE CONTENT		LIQUID LIMIT		UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80	100	W P	W		
74.9 0.0	WATER														kN/m <sup>3</sup>	GR SA SI CL
70.2 4.7	CLAY LIMESTONE BEDROCK with shale interbedding Slightly weathered to fresh Strong Thinly Bedded Grey		1	SS	100/25mm										FI	RUN #1 TCR=100% SCR=81% RQD=67%
67.9 7.0	SANDSTONE BEDROCK Fresh Very strong Thickly bedded Green		2	RUN											3	RUN #2 TCR=100% SCR=97% RQD=86% UCS=96MPa
65.9 9.0	End of Borehole		3	RUN											1	RUN #3 TCR=100% SCR=100% RQD=95% UCS=225MPa
			4	RUN											2	RUN #4 TCR=100% SCR=100% RQD=83%

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity


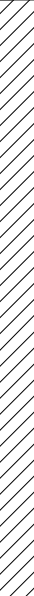
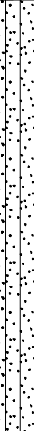


# RECORD OF BOREHOLE No M17-01

1 OF 4

METRIC

GWP# 4061-14-00 LOCATION Lat: 44.1957019° Long: -76.4420723° Marysville Dock, MTM z9: N 4 895 079.7 E 309 430.4 ORIGINATED BY DJP  
 HWY Wolfe Island Ferry BOREHOLE TYPE HW Casing / NW Casing / NQ Coring COMPILED BY KE  
 DATUM Geodetic DATE 2017.08.31 - 2017.09.03 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE						
								● QUICK TRIAXIAL	× LAB VANE						
75.2							20 40 60 80 100	20 40 60							
0.0	<b>WATER</b>														
72.3															
2.9	<b>CLAY (CH to CL)</b> Stiff to very stiff Grey to brown-grey		1	SS	5									0 2 29 69	
			2	SS	20										
	- occasional organics at elev. 70.5 m		3	SS	13										
			4	SS	26										
			5	SS	5									0 2 62 36	
68.4			6	SS	10										
6.8	<b>Silty SAND (SM)</b> Compact to loose Grey														
			7	SS	14										
			8	SS	13									1 55 44 (SI+CL)	
	- 150 mm clay seam at elev. 66.1 m		9	SS	4										
65.2															

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

ONTMT4S\_DA WOLFE ISLAND MARYSVILLE - WITH 2018 DREDGE PROGRAM.GPJ 2017TEMPLATE(MTO).GDT 24/9/18

# RECORD OF BOREHOLE No M17-01

2 OF 4

METRIC

GWP# 4061-14-00 LOCATION Lat: 44.1957019° Long: -76.4420723° Marysville Dock, MTM z9: N 4 895 079.7 E 309 430.4 ORIGINATED BY DJP  
 HWY Wolfe Island Ferry BOREHOLE TYPE HW Casing / NW Casing / NQ Coring COMPILED BY KE  
 DATUM Geodetic DATE 2017.08.31 - 2017.09.03 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
Continued From Previous Page							<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><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+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

ONTMT4S\_DA\_WOLFE ISLAND MARYSVILLE - WITH 2018 DREDGE PROGRAM.GPJ 2017TEMPLATE(MTO).GDT 24/9/18

## METRIC

Continued Next Page


+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No M17-01

4 OF 4

METRIC

GWP# 4061-14-00 LOCATION Lat: 44.1957019° Long: -76.4420723° Marysville Dock, MTM z9: N 4 895 079.7 E 309 430.4 ORIGINATED BY DJP  
 HWY Wolfe Island Ferry BOREHOLE TYPE HW Casing / NW Casing / NQ Coring COMPILED BY KE  
 DATUM Geodetic DATE 2017.08.31 - 2017.09.03 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE      LIQUID CONTENT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P      W      W L					
								20   40   60   80   100				20   40   60					
Continued From Previous Page																	
	LIMESTONE BEDROCK Moderately weathered to fresh Strong Medium bedded Grey		2	RUN			45										
			3	RUN			44										
43.1																	
32.1	End of Borehole																

ONTMT4S\_DA WOLFE ISLAND MARYSVILLE - WITH 2018 DREDGE PROGRAM.GPJ 2017TEMPLATE(MTO).GDT 24/9/18

# RECORD OF BOREHOLE No M17-02

1 OF 4

METRIC

GWP# 4061-14-00 LOCATION Lat: 44.1960465° Long: -76.4411572° Marysville Dock, MTM z9: N 4 895 118.0 E 309 503.5 ORIGINATED BY DJP  
 HWY Wolfe Island Ferry BOREHOLE TYPE HW Casing / NW Casing / NQ Coring COMPILED BY KE  
 DATUM Geodetic DATE 2017.08.29 - 2017.08.31 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>		
75.2								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%) 20 40 60				
0.0	WATER						75						
71.1							74						
4.1	CLAY (Cl), occasional Silt seams Very stiff Brown - grey		1	SS	11		73						
	- sandy silt interbedded with 10 mm clay beds from elev. 70.2 to 69.6 m		2	SS	11		72						
68.8			3	SS	9		71						
6.4	Sandy SILT (ML) trace gravel Loose Grey - 50 mm clay seam at elev. 68.4 m		4	SS	9		70						
67.9							69						
7.3	Silty SAND (SM) with gravel Compact Grey		5	SS	24		68						
	- 590 mm boulder at elev. 66.6 m		6	SS	20		67						
	- frequent cobbles and boulders from elev. 66.0 to 64.8 m						66						

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
5  
0  
-5  
-10  
(%) STRAIN AT FAILURE

ONTMT4S\_DA\_WOLFE ISLAND MARYSVILLE - WITH 2018 DREDGE PROGRAM.GPJ 2017TEMPLATE(MTO).GDT 24/9/18

## METRIC

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

## METRIC

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

## METRIC

[illegible]

ONTMT4S DA WOLFE ISLAND MARYSVILLE - WITH 2018 DREDGE PROGRAM.GPJ 2017TEMPLATE(MTO).GDT 24/9/18

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity



## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No M17-03

2 OF 2

METRIC

GWP# 4061-14-00 LOCATION Lat: 44.1965524° Long: -76.4418538° Marysville Dock, MTM z9: N 4 895 174.2 E 309 447.8 ORIGINATED BY DJP  
 HWY Wolfe Island Ferry BOREHOLE TYPE HW Casing / NW Casing / NQ Coring COMPILED BY DJP  
 DATUM Geodetic DATE 2017.09.05 - 2017.09.05 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE      LIQUID CONTENT      LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P      W      W L				
								20   40   60   80   100				20   40   60				
	Continued From Previous Page															
	LIMESTONE BEDROCK Highly weathered to fresh Strong Medium bedded Grey  <															

ONTMT4S\_DA WOLFE ISLAND MARYSVILLE - WITH 2018 DREDGE PROGRAM.GPJ 2017TEMPLATE(MTO).GDT 24/9/18

# RECORD OF BOREHOLE No M18-1

1 OF 1

METRIC

GWP# 4061-14-00 LOCATION Lat: 44.2078421° Long: -76.4547609° Marysville, MTM z9: N 4 896 427.9 E 308 415.4 ORIGINATED BY JG  
 HWY Wolfe Island Ferry BOREHOLE TYPE HW Casing / NW Casing / NQ Coring COMPILED BY JG  
 DATUM Geodetic DATE 2018.07.31 - 2018.07.31 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
								○ UNCONFINED      + FIELD VANE	● QUICK TRIAXIAL      × LAB VANE								
74.9								20	40	60	80	100	20	40	60		
0.0	WATER																
69.9																	
5.0	LIMESTONE BEDROCK with shale interbedding Slightly weathered to fresh Very strong Thinly bedded Grey		1	SS	100/0mm											FI	
			1	RUN												4	
																1	
																2	RUN #1 TCR=100% SCR=100% RQD=67% UCS=177MPa
																3	
																0	
																0	
			2	RUN												1	
																2	RUN #2 TCR=98% SCR=98% RQD=97% UCS=152MPa
																1	
66.8																0	
8.1	End of Borehole																

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

ONTMT4S\_DA WOLFE ISLAND MARYSVILLE - WITH 2018 DREDGE PROGRAM.GPJ 2017TEMPLATE(MTO).GDT 24/9/18

## METRIC

[illegible]

ONTMT4S DA WOLFE ISLAND MARYSVILLE - WITH 2018 DREDGE PROGRAM.GPJ 2017TEMPLATE(MTO).GDT 24/9/18

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

## METRIC

[illegible]

ONTMT4S DA WOLFE ISLAND MARYSVILLE - WITH 2018 DREDGE PROGRAM.GPJ 2017TEMPLATE(MTO).GDT 24/9/18

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

## METRIC

[illegible]

ONTMT4S DA WOLFE ISLAND MARYSVILLE - WITH 2018 DREDGE PROGRAM.GPJ 2017TEMPLATE(MTO).GDT 24/9/18

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

**METRIC**

SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa	WATER CONTENT (%)			
74.9 0.0	WATER	[Pattern]										
70.9 4.0 70.6 4.3	SILT Very loose SILTY SAND, clayey TILL Very loose to compact Grey	[Pattern]	1	SS	1							
69.9 5.0	SAND with silt and gravel TILL Compact Grey	[Pattern]	2	SS	13							
69.1 5.8	SAND with silt and gravel TILL Compact Grey	[Pattern]	3	SS	29							
69.1 5.8	SILTY SAND TILL Compact Grey	[Pattern]	4	SS	27							
67.4 7.5	- frequent cobbles from elevation 67.9 to 67.4 m	[Pattern]	5	SS	24							
67.4 7.5	LIMESTONE BEDROCK Slightly weathered to fresh Very strong Thinly bedded Grey	[Pattern]	6	NQ								
		[Pattern]	1	RUN								

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No M18-5

2 OF 2

METRIC

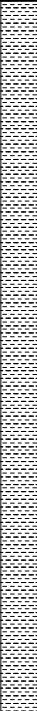

GWP# 4061-14-00 LOCATION Lat: 44.2057222° Long: -76.4517809° Marysville, MTM z9: N 4 896 192.5 E 308 653.7 ORIGINATED BY JG  
 HWY Wolfe Island Ferry BOREHOLE TYPE HW Casing / NW Casing / NQ Coring COMPILED BY JG  
 DATUM Geodetic DATE 2018.07.30 - 2018.07.30 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)					
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE										
	Continued From Previous Page							20	40	60	80	100		W P	W	W L		
64.2	LIMESTONE BEDROCK Slightly weathered to fresh Very strong Thinly bedded Grey		2	RUN														RUN #2 TCR=100% SCR=98% RQD=57% UCS=123MPa
10.7	End of Borehole																	
														</				

ONTMT4S\_DA WOLFE ISLAND MARYSVILLE - WITH 2018 DREDGE PROGRAM.GPJ 2017TEMPLATE(MTO).GDT 24/9/18



## METRIC

SOIL PROFILE				SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIMIT MOISTURE CONTENT		UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)						
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE	W <sub>P</sub>	W <sub>L</sub>					
74.9 0.0	WATER															
70.2 4.7			CLAY (CH) Firm to very stiff Grey		1	SS	7									
					2	SS	12									
					3	SS	30									
	4	SS			9											
66.0 8.9	End of Borehole		5	SS	8											

ONTMT4S DA WOLFE ISLAND MARYSVILLE - WITH 2018 DREDGE PROGRAM.GPJ 2017TEMPLATE(MTO).GDT 24/9/18

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

## METRIC

Lat: 44.2005239°, Long: -76.4464841°  
 Marvsville, MTM z9: N 4 895 615.2 E 309 077.4

ONTMT4S DA WOLFE ISLAND MARYSVILLE - WITH 2018 DREDGE PROGRAM.GPJ 2017TEMPLATE(MTO).GDT 24/9/18

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

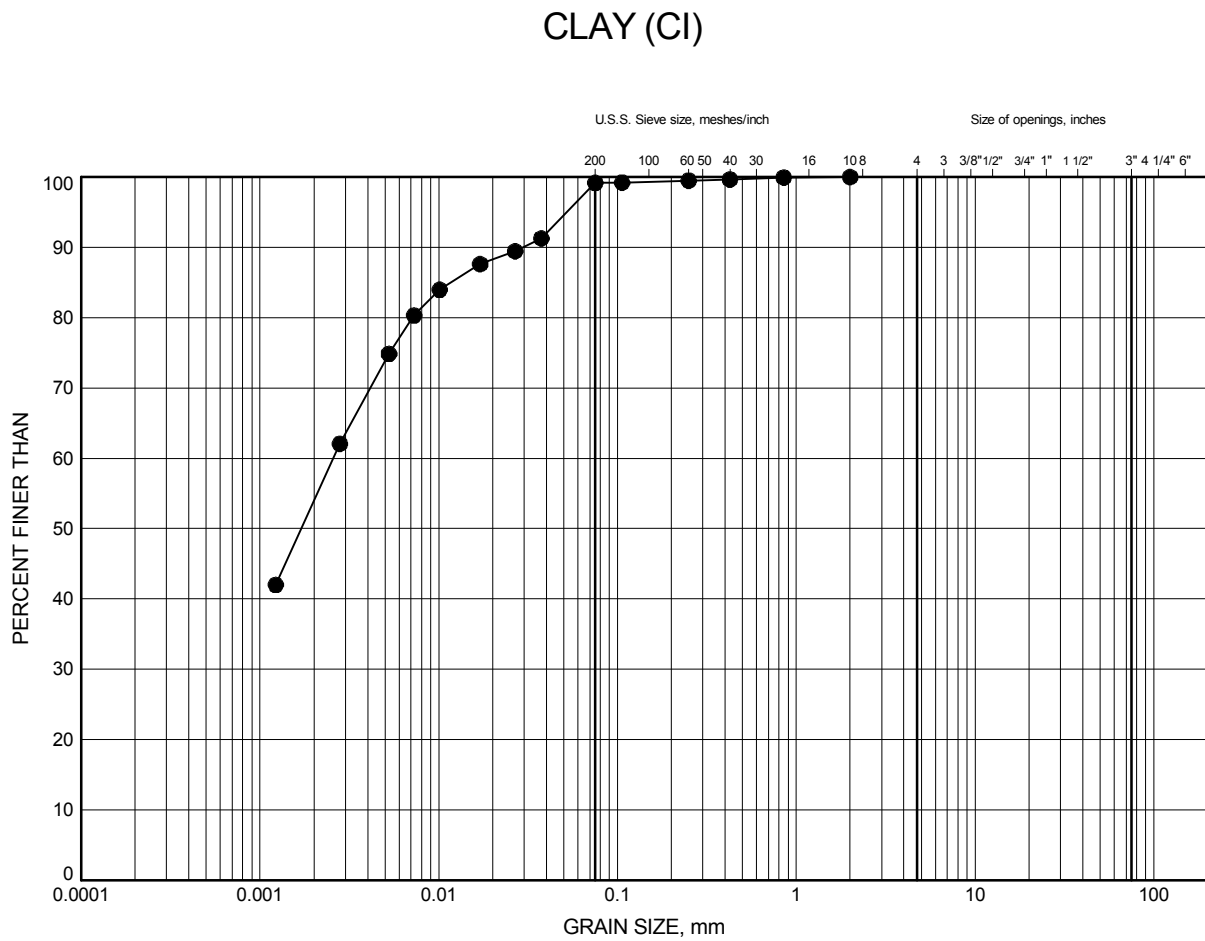
**Appendix C.**  
**Laboratory Testing**

## **Appendix C.1**

### **Particle Size Analysis and Atterberg Limit Figures**

# Wofle Island Ferry GRAIN SIZE DISTRIBUTION

FIGURE C1



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	K18-1	6.3	68.6

Date September 2018

GWP# 4061-14-00

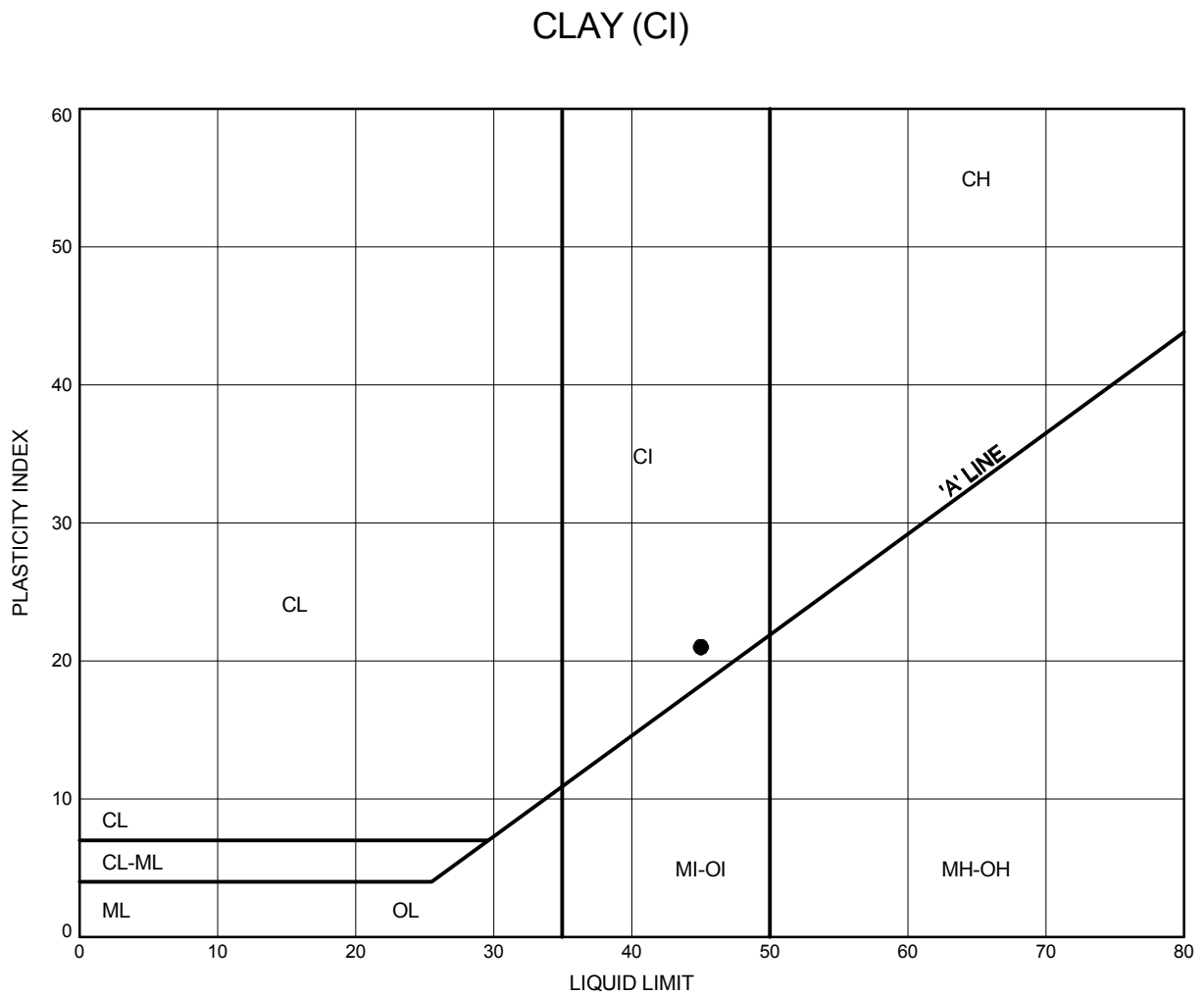


Prep'd JG

Chkd. SP

Wofle Island Ferry  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE C2



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	K18-1	6.3	68.6

Date ..September 2018.....  
 GWP# ..4061-14-00.....

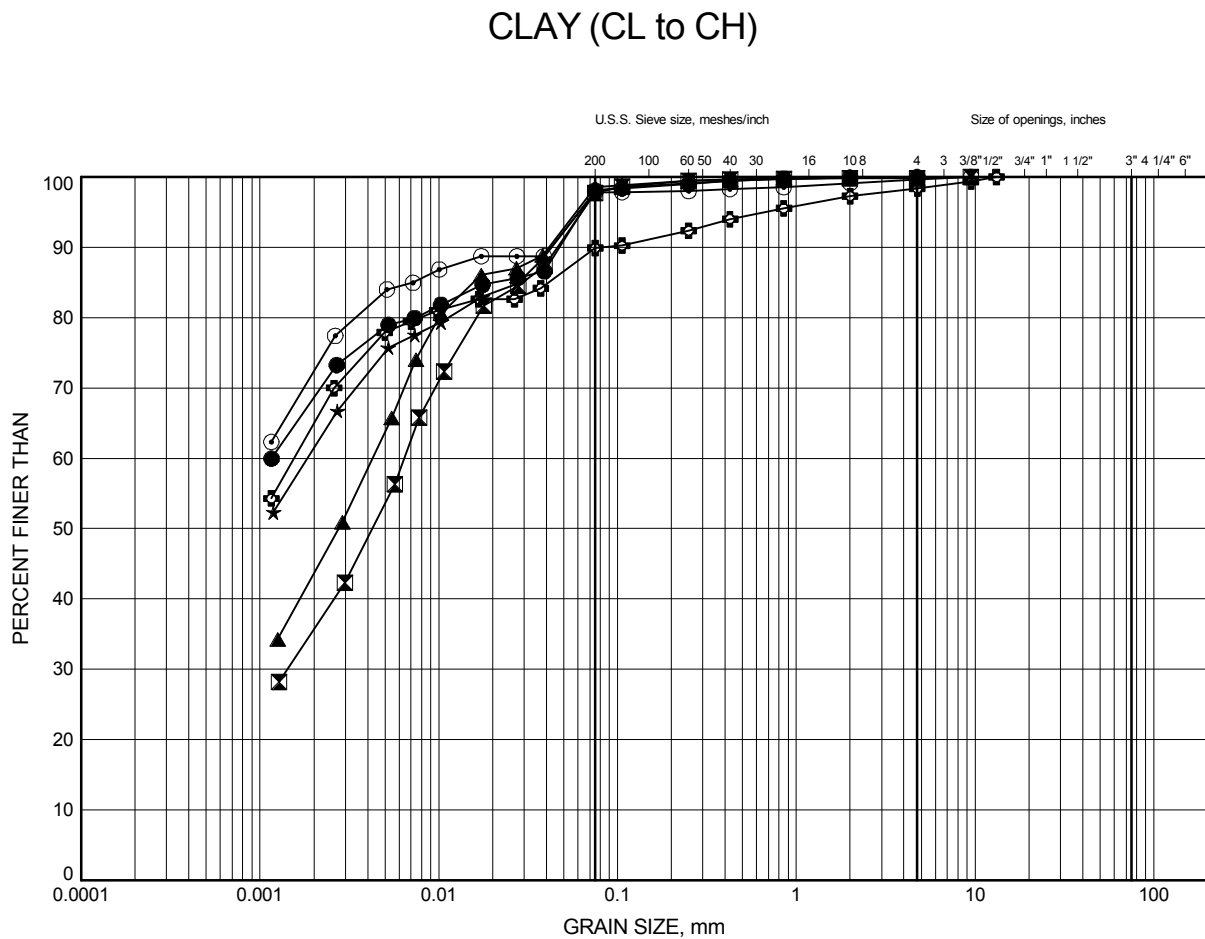


Prep'd .....JG.....  
 Chkd. ....SP.....

# Wofle Island Ferry - Marysville

## GRAIN SIZE DISTRIBUTION

FIGURE C3



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M17-01	3.1	72.0
⊠	M17-01	6.1	69.0
▲	M17-02	4.7	70.4
★	M18-2	5.3	69.6
⊙	M18-4	6.1	68.8
⊕	M18-6	7.0	67.9

Date September 2018

GWP# 4061-14-00



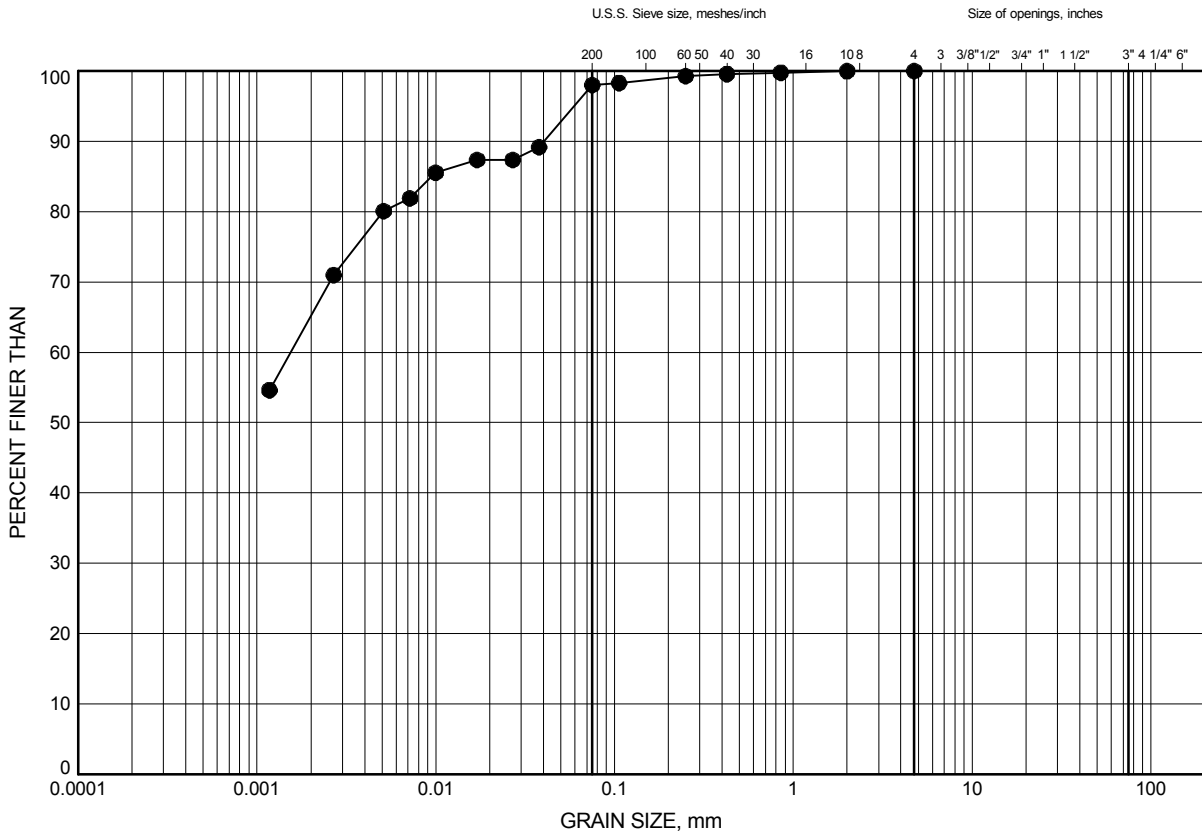
Prep'd JG

Chkd. SP

Wofle Island Ferry - Marysville  
GRAIN SIZE DISTRIBUTION

FIGURE C4

CLAY (CL to CH)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M18-7	7.0	67.9

Date September 2018  
GWP# 4061-14-00



Prep'd JG  
Chkd. SP

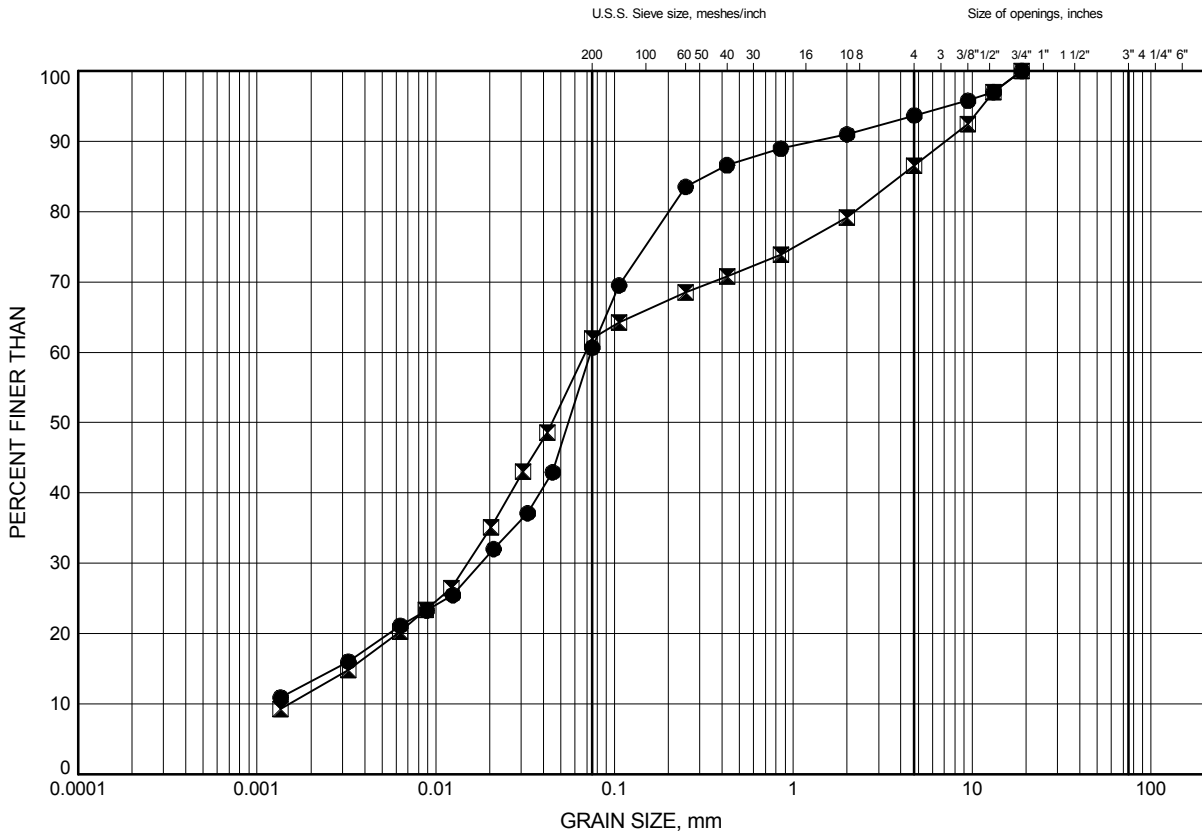


# Wofle Island Ferry - Marysville

## GRAIN SIZE DISTRIBUTION

FIGURE C5

### SANDY SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M17-02	6.8	68.4
◻	M17-03	4.7	70.5

Date ..September 2018.....

GWP# ..4061-14-00.....



Prep'd .....JG.....

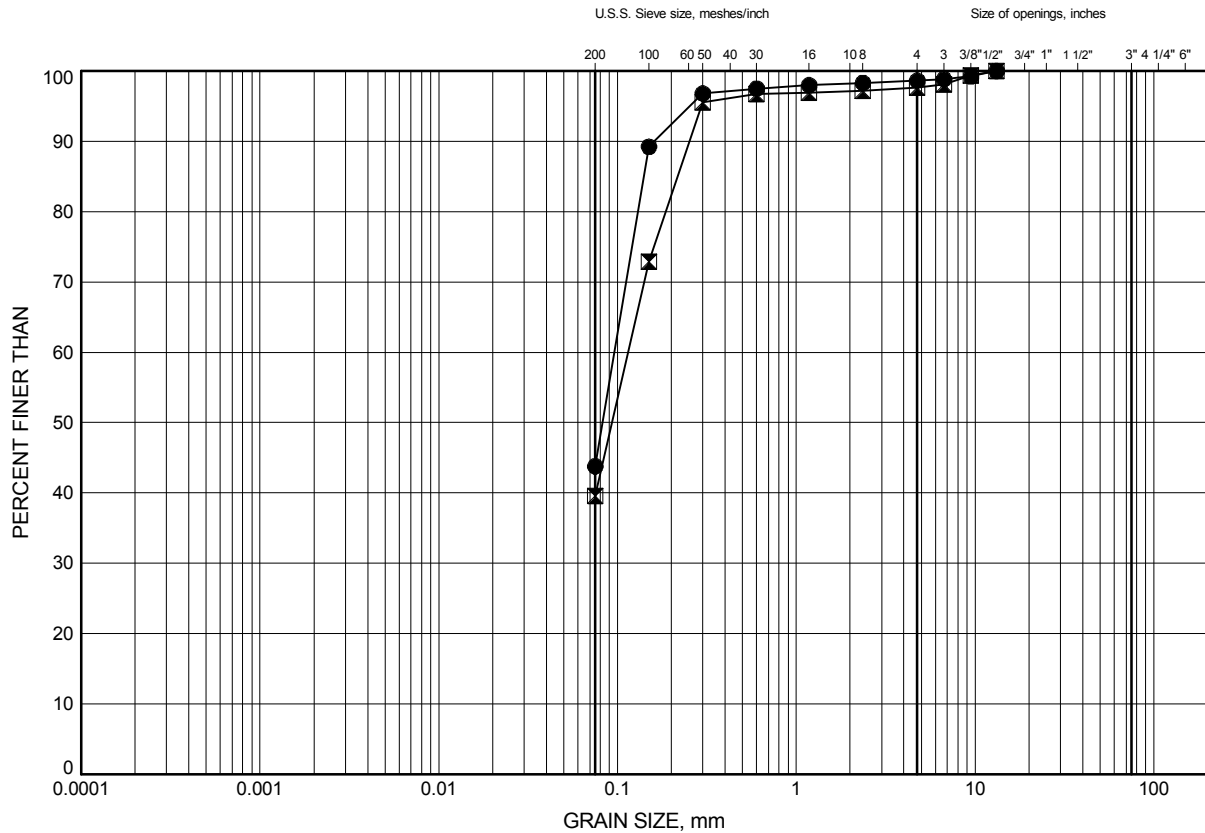
Chkd. ....SP.....

# Wofle Island Ferry - Marysville

## GRAIN SIZE DISTRIBUTION

FIGURE C6

### SILTY SAND



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M17-01	8.3	66.9
⊠	M17-02	13.7	61.5

Date ..September 2018.....  
GWP# ..4061-14-00.....

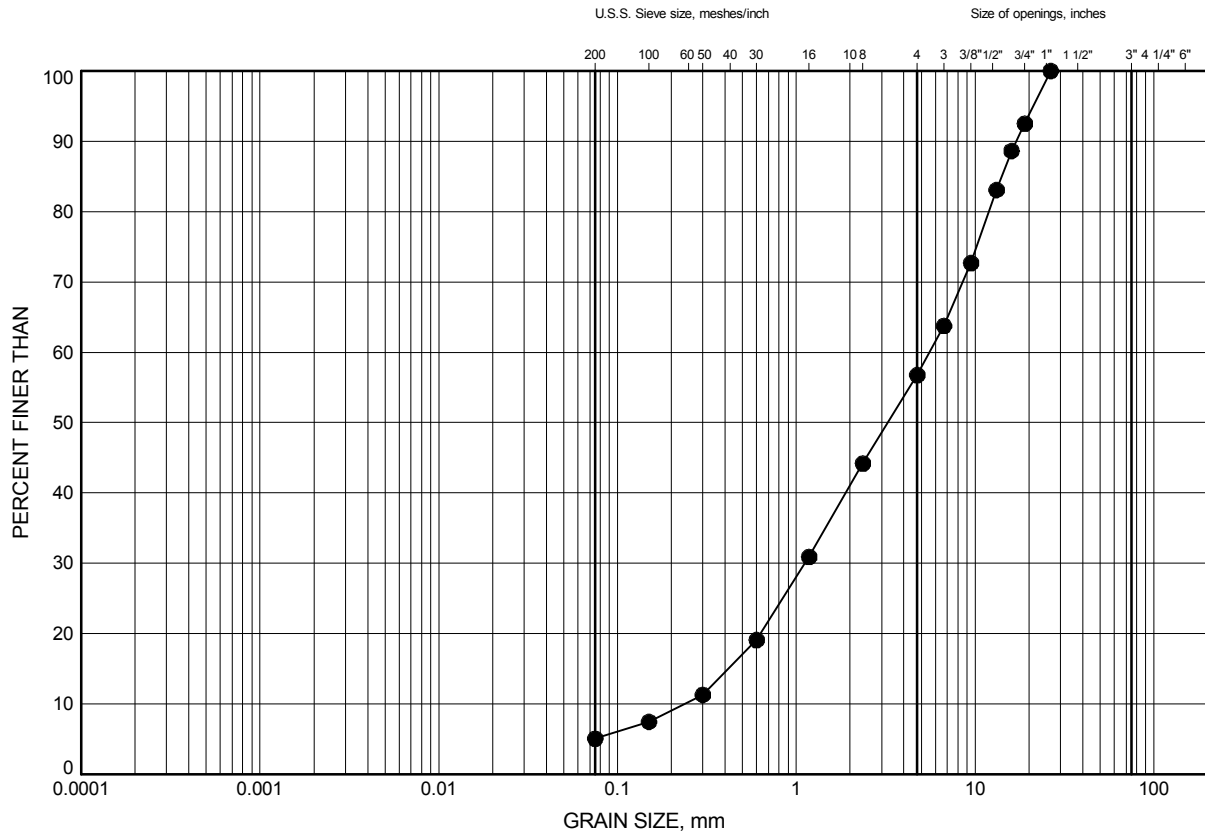


Prep'd .....JG.....  
Chkd. ....SP.....

Wofle Island Ferry - Marysville  
**GRAIN SIZE DISTRIBUTION**

FIGURE C7

**SAND with SILT and GRAVEL**



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M17-01	12.3	62.9

Date September 2018  
 GWP# 4061-14-00

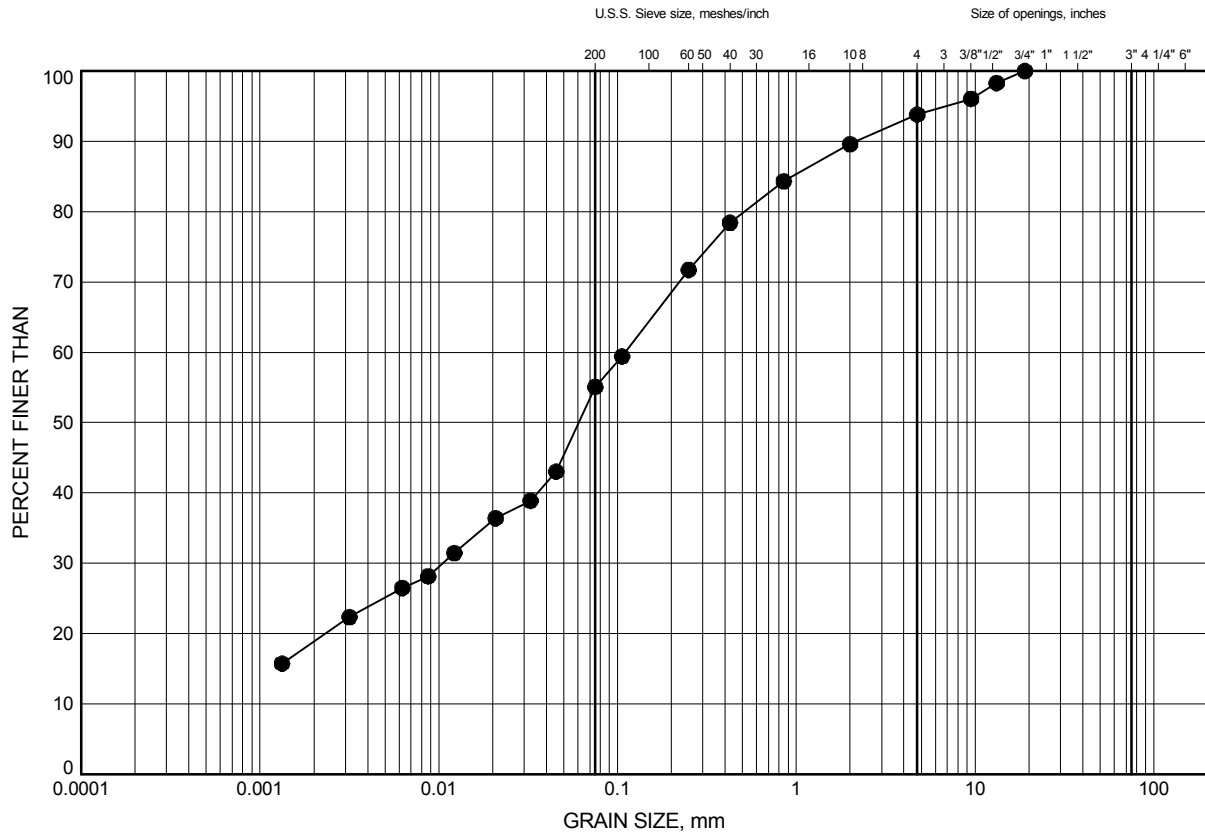


Prep'd JG  
 Chkd. SP

Wofle Island Ferry - Marysville  
GRAIN SIZE DISTRIBUTION

FIGURE C8

CLAY TILL (UPPER)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M17-02	23.0	52.2

Date September 2018  
GWP# 4061-14-00

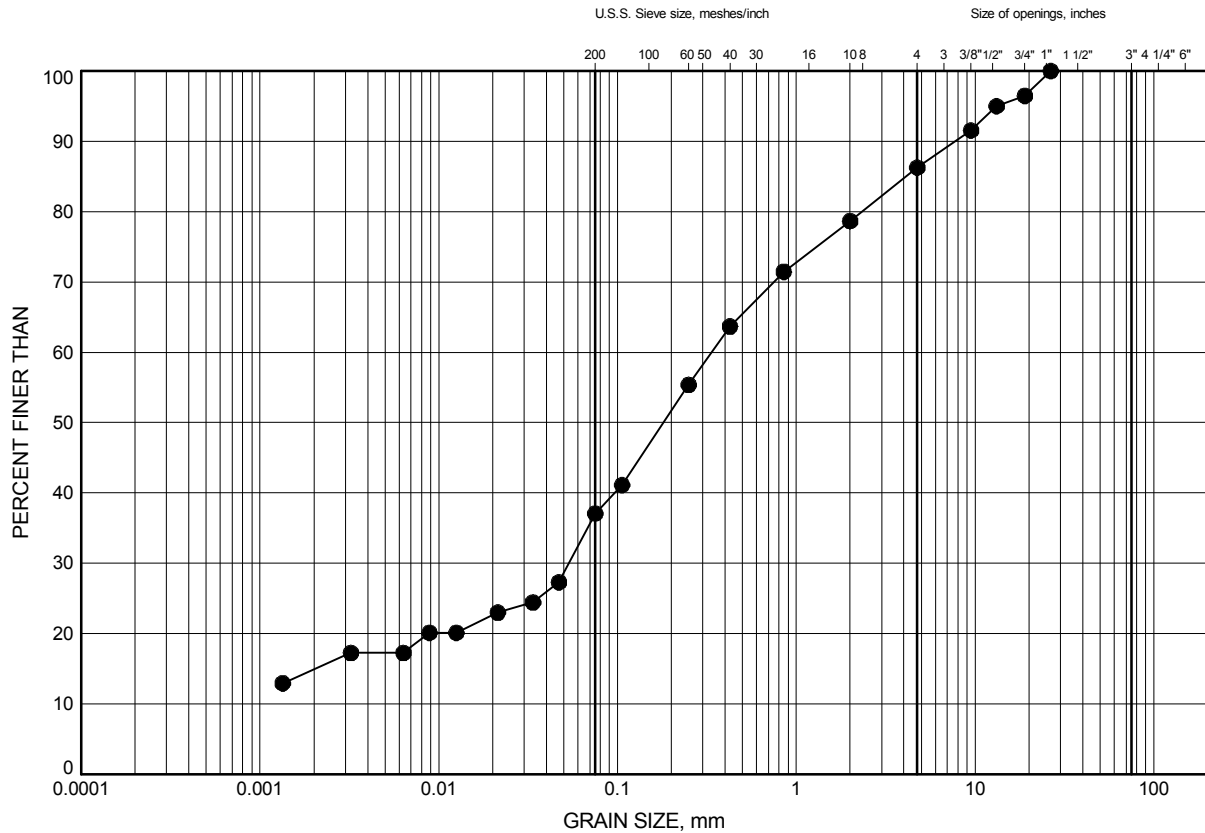


Prep'd JG  
Chkd. SP

Wofle Island Ferry - Marysville  
GRAIN SIZE DISTRIBUTION

FIGURE C9

SILTY SAND TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M18-5	4.9	70.0

Date September 2018

GWP# 4061-14-00



Prep'd JG

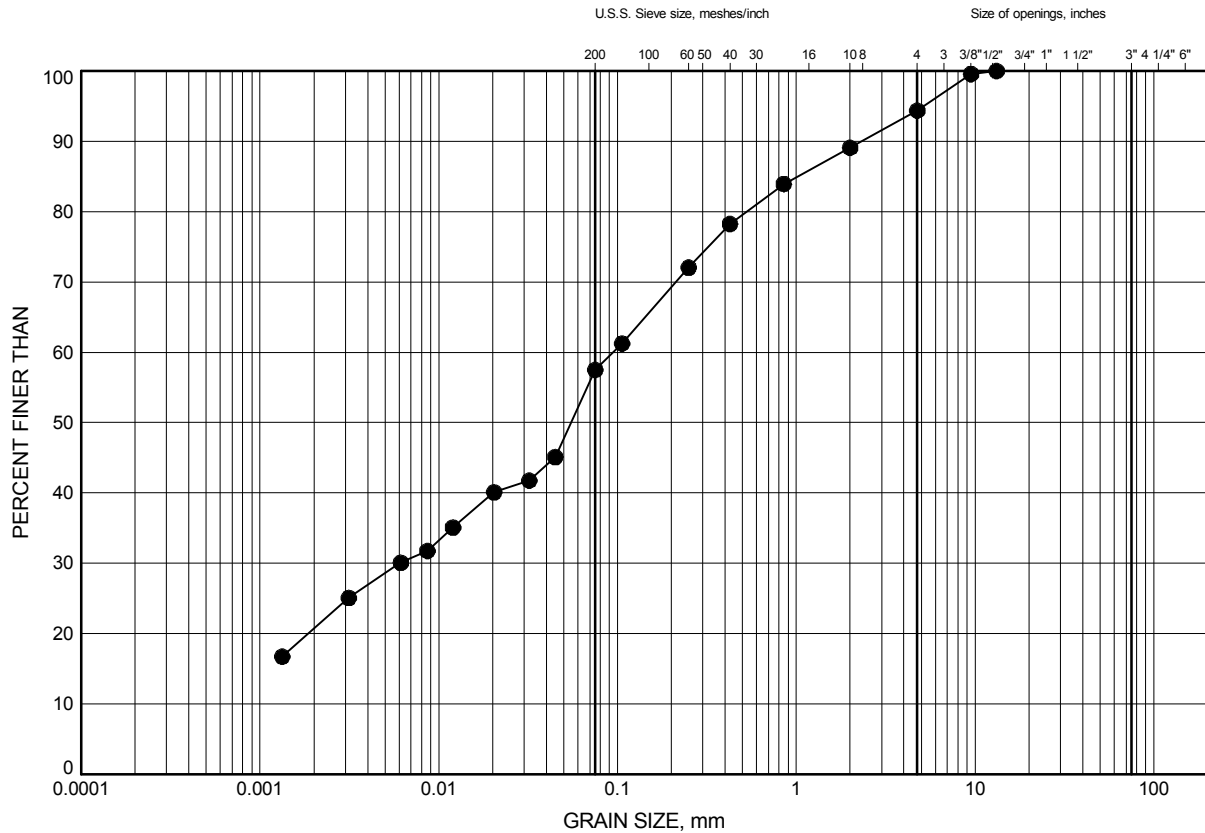
Chkd. SP

# Wofle Island Ferry - Marysville

## GRAIN SIZE DISTRIBUTION

FIGURE C10

### CLAY TILL (LOWER)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M17-01	27.5	47.7

Date September 2018  
GWP# 4061-14-00

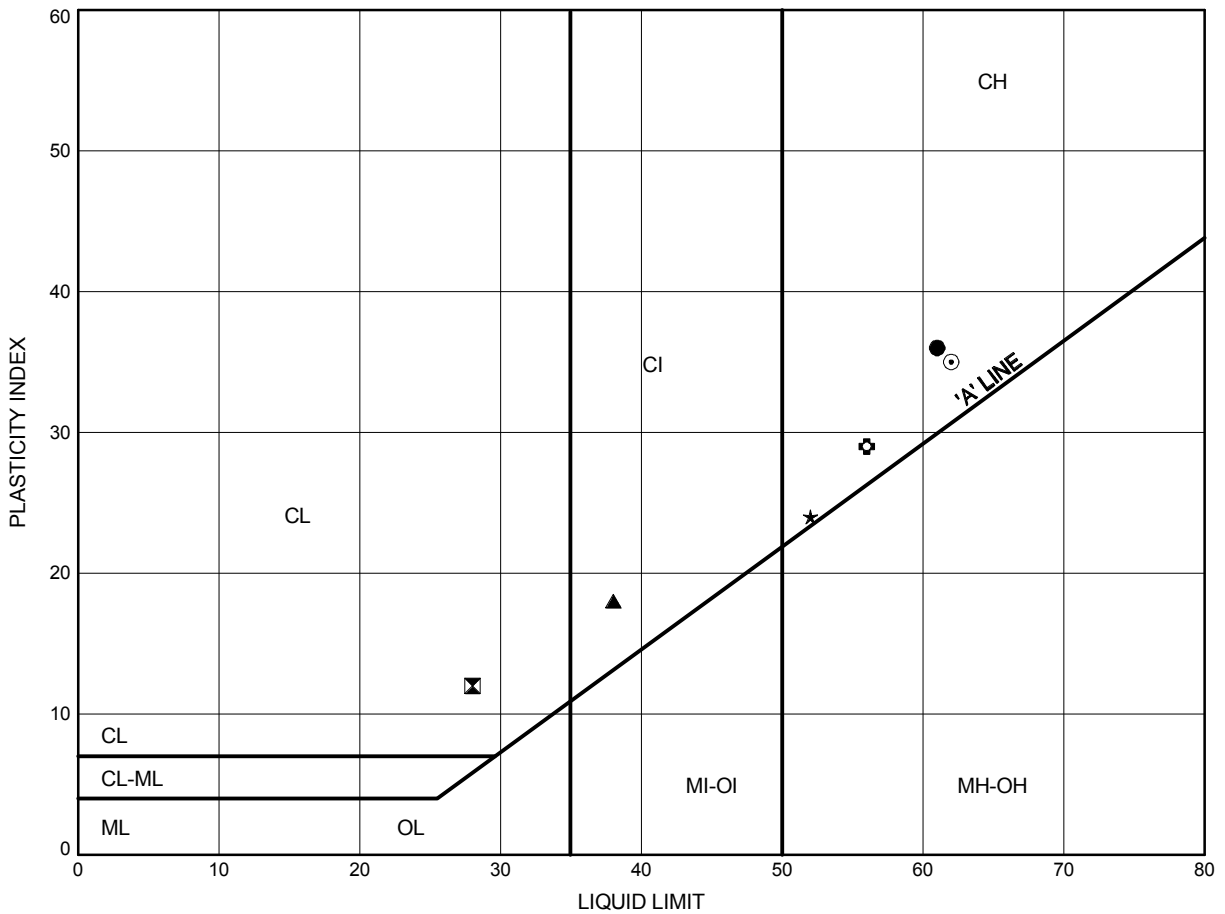


Prep'd JG  
Chkd. SP

Wofle Island Ferry - Marysville  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE C11

CLAY (CL to CH)



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M17-01	3.1	72.0
⊠	M17-01	6.1	69.0
▲	M17-02	4.7	70.4
★	M18-2	5.3	69.6
⊙	M18-4	6.1	68.8
⊕	M18-6	7.0	67.9

Date September 2018  
 GWP# 4061-14-00

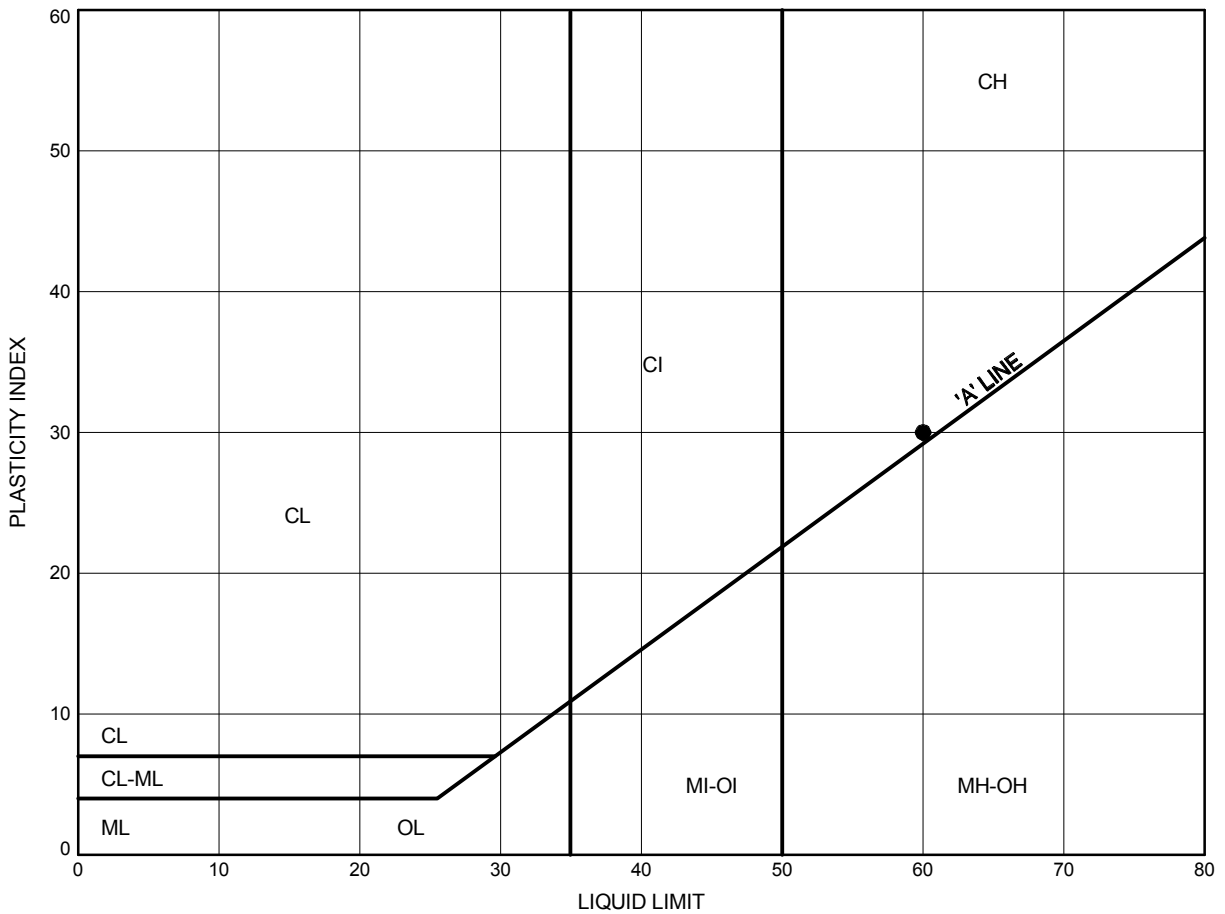


Prep'd JG  
 Chkd. SP

Wofle Island Ferry - Marysville  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE C12

CLAY (CL to CH)



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M18-7	7.0	67.9

Date ..September 2018.....  
 GWP# ..4061-14-00.....



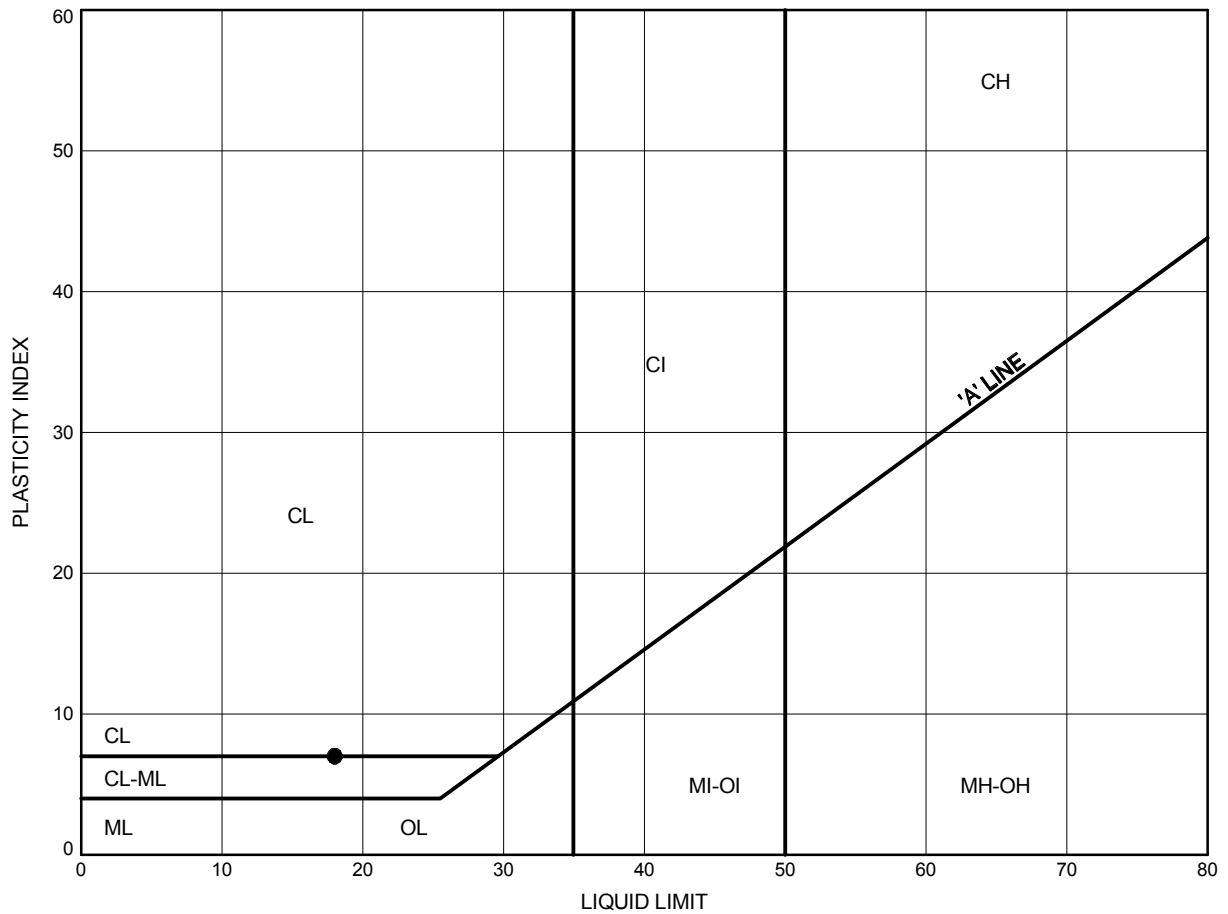
Prep'd .....JG.....  
 Chkd. ....SP.....



Wofle Island Ferry - Marysville  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE C13

**CLAY TILL (UPPER)**



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M17-02	23.0	52.2

Date ..September 2018.....  
 GWP# ..4061-14-00.....

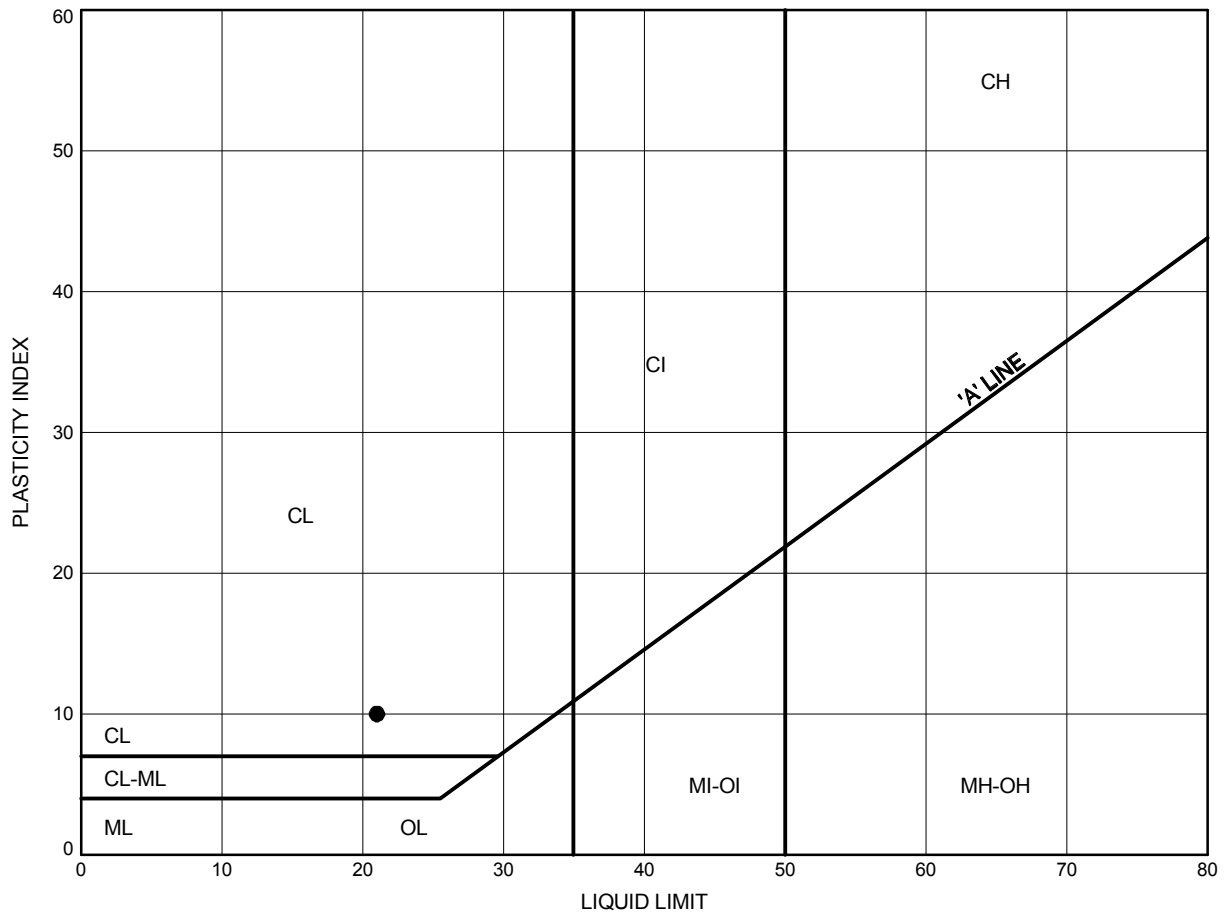


Prep'd .....JG.....  
 Chkd. ....SP.....

Wofle Island Ferry - Marysville  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE C14

**CLAY TILL (LOWER)**



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M17-01	27.5	47.7

Date September 2018  
 GWP# 4061-14-00



Prep'd JG  
 Chkd. SP

## **Appendix C.2**

### **Organic Content Results**



**Stantec**

**Stantec Consulting Ltd**  
100 A&B – 2781 Lancaster Rd  
Ottawa, ON K1B 1A7  
Tel: (613) 738-6075  
Fax: (613) 738-6067

August 21, 2018  
File: 122410864

**Attention:**     **Thurber Engineering, File #19777, Wolfe Island Ferry**

**Reference:**     **ASTM D2974 Organic Matter of Peat & Other Soils**

The table below summarizes test results for one Organic Matter of Peat and Other Soils.

Source	Depth	Location	Organic Content
M18-7 SS1	18'9"-20'9"	Marysville Site	37.5%
M18-4 SS2	18'-20'	Marysville Site	10.7%

Sincerely,

**Stantec Consulting Ltd.**

*Brian Prevost*

Brian Prevost  
Laboratory Supervisor  
Tel: 613-738-6075  
Fax: 613-738-6067  
[brian.prevost@stantec.com](mailto:brian.prevost@stantec.com)

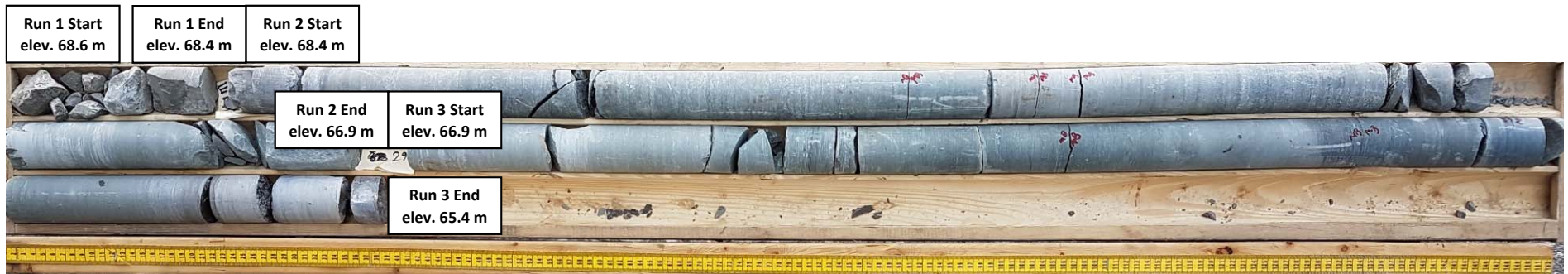
### **Appendix C.3**

#### **Rock Core Photographs, UCS and Micro Deval Test Results**

## Borehole K18-02

Run 1 to 3 (of 3)

Elevation 68.6 m to 65.4 m



**THURBER** ENGINEERING LTD.

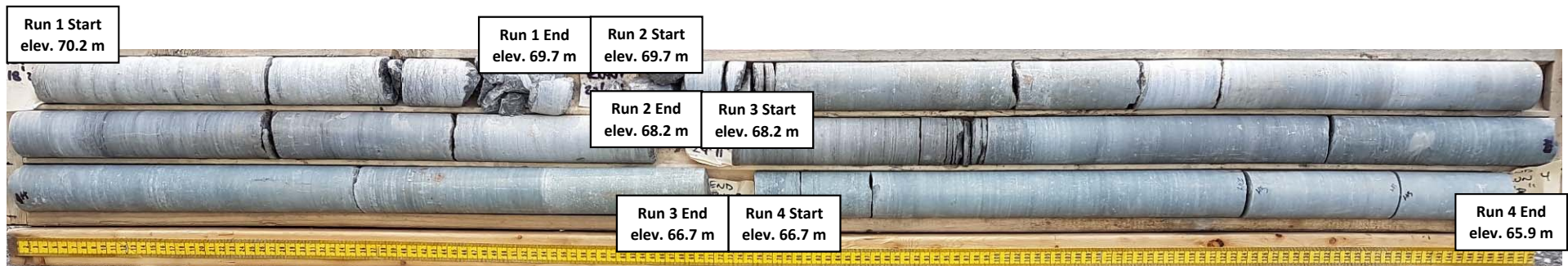
**Foundation Investigation  
Wolfe Island Ferry Terminals  
Kingston, Ontario**

**Kingston Shoal  
Project No.: 19777**

## Borehole K18-03

Run 1 to 4 (of 4)

Elevation 70.2 m to 65.9 m



**THURBER** ENGINEERING LTD.

**Foundation Investigation  
Wolfe Island Ferry Terminals  
Kingston, Ontario**

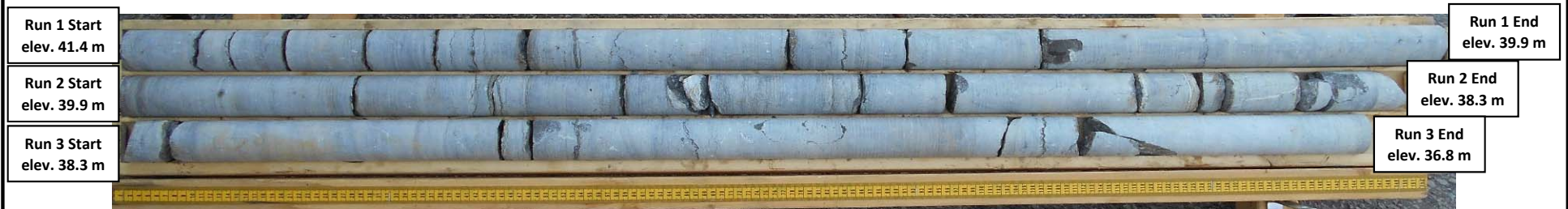
**Kingston Shoal  
Project No.: 19777**



**Borehole M17-01**  
**Run 1 to 3 (of 3)**  
**Elevation 47.2 m to 43.1 m**



**Borehole M17-02**  
**Run 1 to 3 (of 3)**  
**Elevation 41.4 m to 36.8 m**

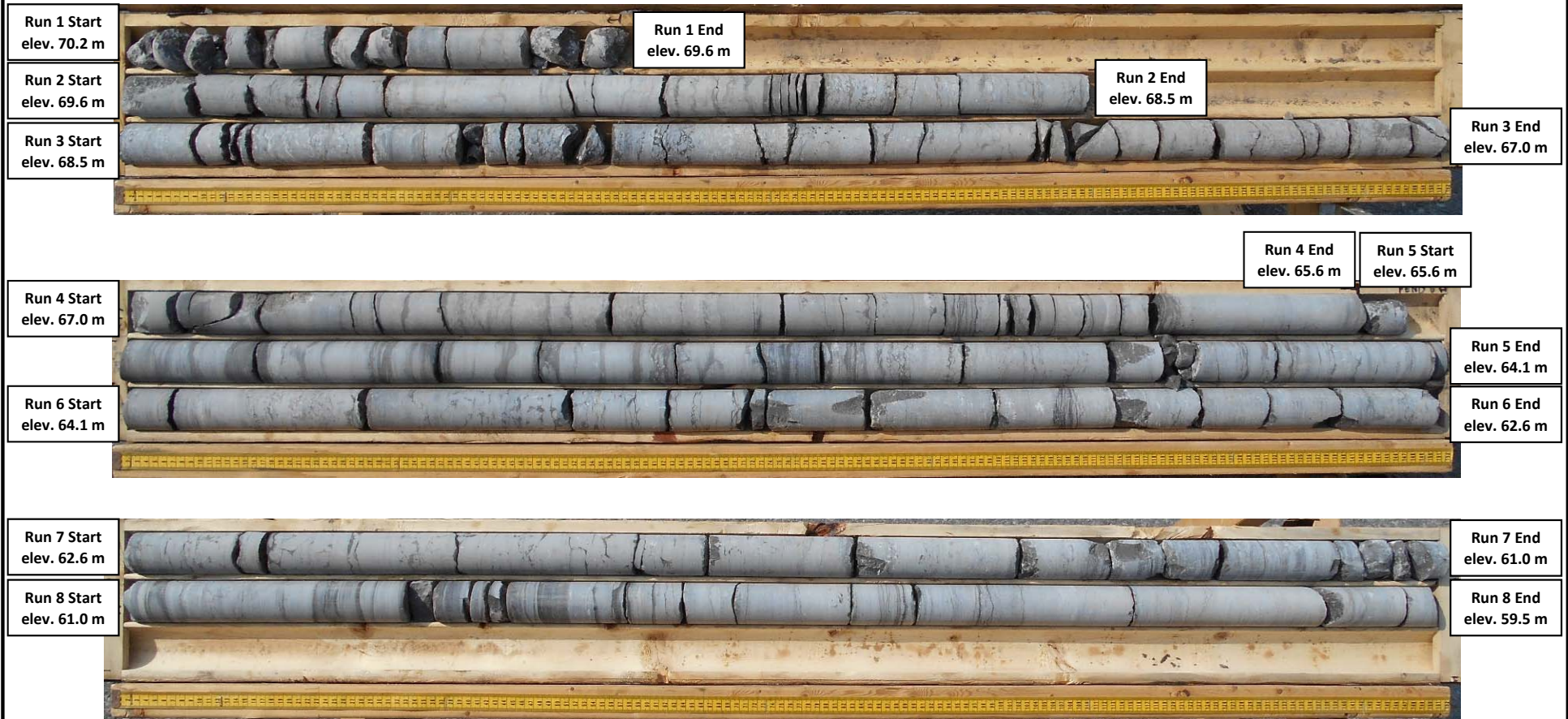


**THURBER** ENGINEERING LTD.

**Foundation Investigation**  
**Wolfe Island Ferry Terminals**  
**Township of Wolfe Island, Ontario**

**Marysville Dock**  
**Project No.: 19777**

**Borehole M17-03**  
**Run 1 to 8 (of 8)**  
**Elevation 70.2 m to 59.5 m**





**Borehole M18-01**  
**Run 1 to 2 (of 2)**  
**Elevation 69.9 m to 66.8 m**



**THURBER** ENGINEERING LTD.

**Foundation Investigation  
Wolfe Island Ferry Terminals  
Township of Wolfe Island, Ontario**

**Marysville  
Project No.: 19777**

# Borehole M18-03

Run 1 to 4 (of 4)  
Elevation 70.5 m to 65.5 m



**Borehole M18-05**  
**Run 1 to 2 (of 2)**  
**Elevation 67.4 m to 64.2 m**





**Stantec**

**Stantec Consulting Ltd**  
2781 Lancaster Rd, Suite 100 A&B  
Ottawa, ON K1B 1A7  
Tel: (613) 738-6075  
Fax: (613) 722-2799

August 15, 2018  
File: 122410864

**Attention: Thurber Engineering Ltd., File #19777**

**Reference: ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core**

The table below summarizes four (4) rock core unconfined compressive strength results.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
K18-2. Run 2	24'9"	124.8	Well-formed cone on both ends
K18-2. Run 3	29'5"	79.9	Well-formed cone on both ends
K18-3. Run 2	20'10"	95.9	Well-formed cone on both ends
K18-3. Run 3	25'4"	224.7	Reasonable well-formed cone on one end

Sincerely,

**Stantec Consulting Ltd**

Denis Rodriguez  
Laboratory Technician  
Tel: 613-738-6075  
denis.rodriquez@stantec.com





**Stantec**

**Stantec Consulting Ltd**  
2781 Lancaster Rd, Suite 100 A&B  
Ottawa, ON K1B 1A7  
Tel: (613) 738-6075  
Fax: (613) 722-2799

August 15, 2018  
File: 122410864

**Attention:**      **Thurber Engineering Ltd., File #19777**

**Reference:**      **ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core**

The table below summarizes five (5) rock core unconfined compressive strength results.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
M18-1. Run 1	20'6"	176.6	Specimen shattered
M18-1. Run 2	26'2"	151.7	Specimen shattered
M18-3. Run 2	26'8"	151.1	Well-formed cone on one end
M18-3. Run 3	31'4"	100.5	Well-formed cone on one end
M18-5. Run2	35'	123.2	Well-formed cone on both end

Sincerely,

**Stantec Consulting Ltd**

A handwritten signature in blue ink, appearing to read "Rodriguez".

Denis Rodriguez  
Laboratory Technician  
Tel: 613-738-6075  
denis.rodriquez@stantec.com



**Stantec**

**Stantec Consulting Ltd**  
100 A&B – 2781 Lancaster Rd  
Ottawa, ON K1B 1A7  
Tel: (613) 738-6075  
Fax: (613) 738-6067

---

December 5, 2018  
File: 122410864

**Attention: Thurber Engineering, File #19777**

**Reference: Wolfe Island, LS-618 Micro-Deval Abrasion on Coarse Aggregate**

The following table summarizes Micro-Deval coarse aggregate test results on crushed rock core.

Source	Depth	Material Type	Micro-Deval (% Loss)
MB18-1/3	Run-1	Rock Core	9.0
MB18-3	Run 1/2	Rock Core	22.6

Sincerely,

**Stantec Consulting Ltd.**

*Brian Prevost*

Brian Prevost  
Laboratory Supervisor  
Tel: 613-738-6075  
Fax: 613-738-6067  
[brian.prevost@stantec.com](mailto:brian.prevost@stantec.com)

**Appendix D.**  
**Site Photographs**



**Photo 1. Looking north towards Kingston Terminal from K18-2.**



**Photo 2. Looking northwest towards Garden Island from M18-6 (taken July 2018)**



**Photo 3. Barge Setup, Supported with Spuds, Near Marysville Terminal (taken July 2018)**

**Appendix E.**

**2015 Geophysical Results (Report Issued in 2016)**



**Appendix F.**  
**Risk Register**



**Table F1: Risk Register**

Issue	Risk Evaluation		Possible Mitigation Methods
	Probability of Occurrence	Relative Cost	
Construction			
Variable Bedrock Elevation – bedrock higher than anticipated increases bedrock quantities.	Moderate	Moderate	Bedrock quantities were estimated from geophysical investigations calibrated with geotechnical boreholes.  Conservative approach to quantity estimation.
The dredging technique for rock removal is anticipated to be mechanical due to limited thickness of rock removal. Water depth may affect mechanical effectiveness.	Moderate	Low	Long reach excavator with rock breaker likely required.  Note that use of blasting as a technique could result in deeper excavations which would increase quantities and would also increase environmental impact.
Lack of data at Kingston Area 2, could affect bedrock excavation quantity and/or quantity of contaminated materials	High	Low	Conservative approach to quantity estimation: assume all material is either rock or contaminated soil.
Buried obstructions – cobbles, boulders or man-made	Low to Moderate	Low	Equipment will be on site to remove bedrock and should be capable of removing obstructions.
Know, unknown or poorly documented existing submarine utilities	Low to Moderate	Low	Require completion of utility locates off-shore prior to construction. Require visual inspection and survey with divers. Additional care required in affected areas.
Design			
Sediment may migrate into the dredged channel over time.	Low	Moderate	Could require additional dredging of sediment at edges of channel.
Lateral Spread from the design seismic event could result in sediment moving into the channel	Very Low	Moderate	Could require additional dredging of sediment at edges of channel.