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FOUNDATION INVESTIGATION AND DESIGN REPORT

HEADWALL REPLACEMENT HIGHWAY 144, CHELMSFORD G.W.P. 5176-12-00, W.P.5176-12-02 AGREEMENT NO. 5015-E-0033, SUDBURY AREA

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REPORT



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PART A

**FOUNDATION INVESTIGATION REPORT
HEADWALL REPLACEMENT
HIGHWAY 144, CHELMSFORD
G.W.P. 5176-12-00, W.P.5176-12-02
AGREEMENT NO. 5015-E-0033, SUDBURY AREA**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) is providing pavement and foundation engineering services as a sub-consultant to AECOM to complete the following Ministry of Transportation, Ontario (MTO) Northeast Region projects under Agreement 5015-E-0033:

- WP 5176-12-01 – Resurfacing of Highway 144 Northbound Lanes (NBL), from Municipal Roads 35 & 15, northerly 2.1 km to Omer/Leroux Street;
- WP 5176-12-02 – Resurfacing of Highway 144 Southbound Lanes (SBL), from Municipal Roads 35 & 15, northerly 2.1 km to Omer/Leroux Street;
- WP 5176-12-03 – Resurfacing of Highway 144, from 100 m South of Bishop Road Northerly to the Intersection of Highway 144 and Municipal Road 15 & 35, for 3.3 km; and
- WP 5414-15-01 – Upgrade the intersection of Highway 144 and Municipal Roads 15 & 35 to a Roundabout configuration.

The original scope of work indicates that the above listed WPs will be delivered in two Contracts: Contract 1 includes the resurfacing of Highway 144; and Contract 2 includes the Roundabout construction at the intersection of Highway 144 and Municipal Roads 15 & 35 (refer to Key Plan on Drawing 1). The requirements for this assignment include: soils investigation and laboratory testing for the rehabilitation of Highway 144 including turn tapers, sideroads and commercial entrances; culvert replacements, drainage improvements, temporary staging requirements during culvert replacement/rehabilitation; new illumination/signal poles; a new roundabout; and pavement rehabilitation.

Following award of the project, additional work has been specified for the replacement of a culvert head wall (retaining wall) located on the south side of Highway 144, immediately west of the Errington Avenue intersection (refer to Drawing 1). The scope of work for the foundation investigation at this retaining wall site is outlined in Golder's Technical Memorandum dated September 13, 2016. The purpose of this investigation is to establish the subsurface conditions at the retaining wall structure by methods of borehole drilling, in situ testing and laboratory testing on selected samples.

2.0 SITE DESCRIPTION AND BACKGROUND INFORMATION

The retaining wall is located on the south side of Highway 144 about 75 m west of the Errington Avenue intersection, abutting the asphalt boulevard and sidewalk, centered at about Sta. 11+304, in Balfour Twp. The outlet ends of twin, 1200 mm diameter culverts have been constructed flush with the retaining wall. It is understood that the existing culverts will be lined as part of the overall rehabilitation of this section of Highway 144.

Based on existing design drawings¹ and field measurements, the existing concrete cantilever retaining wall is approximately 10.7 m long and about 2.85 m high from the top of the wall to the top of the footing. The existing retaining wall is supported by a concrete footing approximately 2.0 m wide and 0.6 m thick with a 0.4 m wide central "keel" located along the bottom of the footing, adding an additional 0.3 m thickness to the footing along the wall. The original design drawings specify a 2.0 m wide zone of granular backfill behind the wall.

¹ Ministry Transportation and Communications, Ontario. Contract Drawings. Contract No. 82-200



The top of wall noted on the original design drawings is Elevation 270.3 m, the top of the footing is at about Elevation 267.5 m, and both of the culvert inverts at the outlet end is at about Elevation 268.1 m, while the ditch grade is noted to be slightly above the culverts' invert. The base of the footing is at about Elevation 266.5 m

Based on Golder's survey of the borehole locations, the bottom of the ditch at the toe of the slope is about Elevation 268.7 m, indicating some sediment build-up at the outlet of the culverts. Site photographs, attached as Figures 1 and 2, of the culvert outlets appear to show the existing culverts about half covered by water and sediments and the ditch at the culvert outlets overgrown with vegetation.

3.0 INVESTIGATION PROCEDURES

The foundation investigation at this retaining wall site was carried out from February 6 to 8, 2017, during which time a total of two boreholes (BH17-1 and BH17-2) were advanced at either end of the existing wall, at the toe of the wall and through the roadway platform adjacent to the top of the wall at the locations shown on Drawing 1.

Prior to the beginning of the field investigation Golder completed a site reconnaissance to assess access for drilling equipment and layout the borehole locations. The boreholes were located in the field based on the existing site features and positioned with due consideration to site specific health and safety and traffic management issues and the locations of buried services/utilities. Based on clearance limitation placed by the City of Sudbury (no machine digging within 3 m of City Owned infrastructure), the borehole positioned on the roadway platform was advanced from surface to a depth of about 2.8 m by hydro-vacuuming equipment, to ensure the location was clear of all buried infrastructure.

The field investigation was carried out using a truck-mounted CME 75 drill rig and portable wash-boring equipment supplied and operated by Landcore Drilling of Chelmsford, Ontario. The borehole at the toe of the wall (BH17-1) was advanced using 76 mm inner diameter NW casing and wash boring techniques. The borehole adjacent to the top of the wall (BH17-2) was advanced using 108 mm inner diameter hollow-stem augers. In general, soil samples were obtained at depth intervals of 0.75 m and 1.5 m, using a 50 mm O.D. split-spoon sampler driven by an automatic hammer for Borehole BH17-2 and a manual hammer for Borehole BH17-1 and carried out in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586, Standard Test Method for Standard Penetration Test). The boreholes were advanced to a depth of 10.4 and 15.9 m below ground surface, and all boreholes were backfilled with bentonite and cuttings upon completion in accordance with Ontario Regulation 903 Wells (as amended).

The groundwater conditions and water levels in the open boreholes were observed during the drilling operations and are described on the Record of Borehole sheets provided in Appendix A.

The fieldwork was observed by a member of our engineering and technical staff who located the boreholes, arranged for the clearance of underground services using Ontario One Call, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Whitby Geotechnical Laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, grain size distribution, and Atterberg limits) were carried out on selected samples. The results of the laboratory testing on selected samples from the boreholes are presented on the Record of Borehole sheets in Appendix A and are shown on Figures B1 to B4 included in Appendix B. A soil sample of the deposit encountered at about the footing level in Borehole 17-2 was obtained under an environmental sampling protocol and submitted to an analytical



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laboratory under chain-of-custody procedure for analysis of a suite of parameters including pH, resistivity, conductivity, sulphate, sulphide, and chloride. The results of the analytical laboratory testing are presented in Appendix C and summarized in Section 4.4.

The location of the boreholes was measured relative to known points (sewer grates and fire hydrants) and the coordinates and station of the borehole locations were obtained by referencing the measured borehole locations to a digital drawing of the site survey and a digital terrain model of the site provided by AECOM. In addition, the coordinates of the borehole locations were obtained using a hand-held GPS device (accuracy to +/- 5 m) to confirm the measured positions of the boreholes. Borehole elevations were surveyed by a member of our technical staff in reference to the highway centerline at the Borehole station. The highway centreline elevation was obtained from existing contract drawings² provided to Golder by MTO. The borehole locations given on the Record of Borehole sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 (Zone 12) northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, including geographic coordinates, ground surface elevations and borehole depths are as follows:

Borehole	Location (MTM NAD 83)		Geographic Coordinates (Degrees)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting	Latitude	Longitude		
BH17-1	5158805.8	289546.4	46.568724	-81.198986	268.7	10.4
BH17-2	5158810.8	289556.4	46.568769	-81.198856	270.2	15.9

4.0 SUBSURFACE CONDITIONS

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are provided on the Record of Borehole sheets contained in Appendix A. The results of geotechnical laboratory testing are contained in Appendix B. The results of the in situ tests (i.e., SPT 'N'-values) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

4.1 Regional Geology

Digital geologic mapping in the Northern Ontario Engineering Geological Terrain Study (NOEGTS),³ study 94, indicates that this portion of Highway 144 is located within a glaciolacustrine plain characterized by primarily clayey and silty soils with low relief drainage conditions and a high water table.

Based on the NOEGTS³ study, the glaciolacustrine plain deposits in this area can be up to 110 m thick, but are typically between 30 m and 60 m thick. Based on digital mapping of the Bedrock Geology of Ontario⁴, the bedrock underlying this portion of Highway 144 is mainly carbonaceous slate.

² Ministry of Transportation, Ontario. Contract Drawings. Contract No.: 99-261.

³ Gartner, John F., 1980: Cartier Area (NTS 411/NW), Districts of Algoma and Sudbury; Ontario Geological Survey, Northern Ontario Engineering Geology Terrain Study 94, 18p. Accompanied by Maps 5000 and 5004, scale 1:100,000.

⁴ Ontario Geological Society. Bedrock Geology of Ontario, Scale 1:250,000. MRD-126 Revision 1.



4.2 Subsoil Conditions

In general, the subsurface conditions encountered at the site consist of surficial sediments and fill at the toe of the wall and pavement structure and sand and gravel fill adjacent to the top of the wall. Native soil underlies the fill and surficial sediment consisting of non-cohesive deposits/interlayers of sand, silty sand and silt. A more detailed description of the soil deposits encountered in the boreholes is provided below.

Ice/Water and Surficial Organics

In Borehole BH17-1 an approximately 75 mm thick layer of ice, overlying an approximately 225 mm deep column of water was encountered from the borehole surface. A 0.4 m thick layer of black to grey sandy organic silt was encountered underlying the water at about Elevation 268.4 m and extends to a depth of 0.7 m below ground surface. One Standard Penetration Test (SPT) completed within the organic silt stratum measured an 'N'-value of 5 blow for 0.3 m of penetration, indicating a loose relative density.

Sand and Gravel (Fill)

A 1.3 m thick layer of fill comprised of grey to dark grey sand and gravel with trace to some silt, trace clay, and trace organics at the surface of the deposit, was encountered underlying the surficial organic silt soil in Borehole 17-1 at about Elevation 268.0 and extends to a depth of 2.0 m below ground surface. In Borehole 17-2 the fill layer was 2.6 m thick and encountered underlying a 165 mm thick layer of asphalt at about Elevation 270.0 m and extends to a depth of 2.8 m below ground surface.

Three SPTs completed within the stratum measured 'N'-values ranging from 6 blows to 17 blows for 0.3 m of penetration, indicating a loose to compact relative density. One natural moisture content test on a sample from this stratum resulted in a value of about 16 per cent.

The results of two grain size distribution tests of samples obtained from within this stratum are shown on Figure B1, in Appendix B.

Sand

An 8.4 m thick layer of grey sand, trace to some silt, trace clay and trace to some gravel was encountered underlying the sand and gravel fill stratum in Borehole 17-1 at about Elevation 266.7 and extends to the borehole termination depth at about 10.4 m below ground surface (Elevation 258.3 m).

Eight SPTs completed within the sand stratum measured 'N'-values ranging from 4 blows to 20 blows for 0.3 m of penetration, indicating a loose to compact relative density.

The natural moisture content of two samples from this stratum is about 19 per cent and 23 per cent. The results of two grain size distribution tests on samples from within this stratum are shown on Figure B2, in Appendix B.

Silty Sand

A 5.4 m thick layer of grey silty sand trace clay, trace gravel and trace organics (at the top of the layer) was encountered underlying the sand and gravel fill in Borehole 17-2 at about Elevation 267.4 and extends to a depth of about 8.2 m below ground surface.

Seven SPTs completed within the silty sand stratum measured 'N'-values ranging from 0 blows (weight of rods) to 15 blows for 0.3 m of penetration, indicating a very loose to compact relative density. One SPT measured an 'N'-



value of 41 blows for 0.3 m of penetration but is not considered representative of in-situ conditions due to “blow back” of material into the stem of the augers while completing the test.

One natural moisture content test on a sample from this stratum resulted in a value of about 27 per cent. The result of one grain size distribution test of a sample of this stratum is shown on Figure B3, in Appendix B.

Silt

A 7.7 m thick layer of grey silt, trace to some clay and trace sand was encountered underlying the silty sand stratum in Borehole 17-2 at Elevation 262.0 m and extends to the borehole termination depth at about 15.9 m below ground surface (Elevation 254.3 m). A 1.5 m thick grey sandy silt interlayer, trace to some clay was encountered within the silt stratum at Elevation 260.0 m.

Four SPTs completed within the silt stratum measured ‘N’-values ranging from 5 blows to 23 blow for 0.3 m of penetration, indicating a loose to compact relative density. One SPT completed within the sandy silt interlayer measured an ‘N’-value of 2 blows for 0.3 m penetration, indicating a very loose relative density.

The natural moisture content of two samples from the silt stratum is about 28 per cent and 29 per cent. The results of two grain size distribution tests of samples from the silt stratum are shown on Figure B4, in Appendix B. Two Atterberg limits tests on samples of this stratum indicate the silt is non-plastic.

4.3 Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. Groundwater levels as encountered in the boreholes may not be representative of static levels since the levels in the boreholes may not have stabilized on completion of drilling. Furthermore, groundwater elevations will vary depending on seasonal fluctuations, precipitation and local soil permeability.

Borehole	Depth to Groundwater (m bgs)	Groundwater Elevation (m)
BH17-1	Surface	268.7
BH17-2	1.5	268.7



4.4 Analytical Testing of Soil Samples

The results of chemical analysis for of one sample of the near surface native silty sand deposit are summarized below and the analytical test results are included in Appendix C.

Parameter	Units	BH17-2, SA 2
pH	n/a	8.01
Sulphate	µg/g	<20
Sulphide	µg/g	0.92
Chloride	µg/g	340
Resistivity	Ohm-cm	1700
Conductivity	umho/cm	574

5.0 CLOSURE

This Foundation Investigation Report was prepared by Mr. David Marmor E.I.T., and the technical aspects were reviewed by Mr. John Hagan, P.Eng., a geotechnical engineer of Golder. Mr. Jorge M.A. Costa, P.Eng., a Senior Consultant of Golder and Designated MTO Foundations Contact for Golder, conducted an independent quality control review of this report.



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Report Signature Page

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PART B

FOUNDATION DESIGN REPORT
HEADWALL REPLACEMENT
HIGHWAY 144, CHELMSFORD
G.W.P. 5176-12-00, W.P.5176-12-02
AGREEMENT NO. 5015-E-0033, SUDBURY AREA



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for replacement of a concrete headwall located adjacent to the Southbound Lanes of Highway 144 in Chelmsford, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the foundation investigation at the site. The interpretation and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to design the proposed structure foundations. The foundation investigation report, discussion and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purpose or by any other parties including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided in order to highlight those aspects which could affect the design of the project, and for which special provisions or operational constraints may be required in the Contract Documents. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

Golder Associates Ltd. (Golder) is providing pavement and foundation engineering services as a sub-consultant to AECOM to complete the Ministry of Transportation, Ontario (MTO) Northeastern Region Project G.W.P. 5176-12-00 under Agreement No. 5015-E-0033. As part of this project a culvert head wall (retaining wall) located on the south side of Highway 144, immediately west of the Errington Avenue intersection (refer to Drawing 1) is specified for replacement.

As noted in Part A of this report based on existing design drawings (MTO Contract 82-200) and field measurements, the existing concrete cantilever retaining wall is approximately 10.7 m long and about 2.85 m high from the top of the wall to the top of the footing. The existing retaining wall is supported by a concrete footing approximately 2.0 m wide and 0.6 m thick with a 0.4 m wide central “keel”, located along the bottom of the footing, adding an additional 0.3 m thickness to the footing along the wall. The original design drawings specify a 2.0 m wide zone of granular backfill behind the wall.

The top of wall noted on the original design drawings is Elevation 270.3 m, the top of the footing is at about Elevation 267.5 m, and the invert the twin CSP culverts, at the outlet end is about Elevation 268.1 m, while the ditch grade is noted to be slightly above the culverts’ invert. The base of the footing is at about Elevation 266.5 m.

Based on discussion with AECOM we understand that the preferred replacement option for the existing cantilevered concrete retaining wall is a new cantilevered concrete retaining wall of approximately the same length/height as the existing wall and positioned at approximately the same location. Golder notes that replacing the existing wall “like for like” would limit the need for over excavation beyond that required for removal of the existing wall, as would otherwise be required if a different type of wall was specified such as a Retained Soil System (RSS) wall or concrete gravity wall. In addition, Golder notes that the existing cantilevered concrete wall appears to be performing adequately, and that the need for replacement of the wall appears to be due to deterioration of the materials, such as spalling of the concrete and corrosion of the reinforcing steel and handrail, and not due to foundation issues or stability concerns. Based on the above comparisons of advantages/disadvantages between the existing and proposed replacement structure, Golder concurs with AECOM’s preferred replacement design. Golder also notes that replacing the existing wall with a similar structure



is an adequate system for retaining soil and providing support to the highway embankment and pavement structure. Recommendations and analysis provided in this report are limited to replacing the existing wall with a similar structure at approximately the same location.

In general, the subsurface conditions encountered at the site consist of surficial sediments and fill at the toe of the wall and pavement structure, and sand and gravel fill adjacent to the top of the wall. Native soil underlying the fill and surficial sediment consisting of non-cohesive deposits/interlayers of sand, silty sand and silt, ranging from very loose to compact relative density. The unstabilized groundwater level was measured at surface near the base of the wall, and at a depth of 1.5 m below the roadway surface, at about Elevation of 268.7 m.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the 2014 *Canadian Highway Bridge Design Code* (CHBDC) and its *Commentary*, the proposed structure and foundation system may be classified as having large traffic volumes and its performance as having potential impacts on other transportation corridors, hence having a “typical consequence level” associated with exceeding limits states design. In addition, given the level of foundation investigation completed to date as presented in Sections 3.0 and 4.0, in comparison to the degree of site understanding in Section 6.5 of *CHBDC (2014)*, the level of confidence for design is considered to be a “typical degree of site and prediction model understanding.” Accordingly, the appropriate corresponding ULS and SLS consequence factor, Ψ , and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs} , from Tables 6.1 and 6.2 of the *CHBDC (2014)* have been used for design, as indicated in Sections 6.3 to 6.6.

6.3 Foundations

Based on the proposed wall design (replacing existing concrete cantilever headwall with a similar structure), subsurface conditions at this site, and previous experience with similar structures, deep foundations are not considered to be a practical, nor a necessary foundation option for the replacement wall. We recommend that the replacement wall be supported on shallow foundations comprised of a strip footing founded on/within the native loose to compact sand and silty sand deposits at a similar Elevation as the existing foundation. The strip footing may either be placed on the undisturbed native deposit, or, if higher geotechnical resistances are required, placed on a granular pad constructed to provide additional support for the foundation. Both foundation options will require dewatering/unwatering as the excavation will extend below the groundwater/creek water design levels. Both options for foundation design are considered in this report and recommendations are provided below.

6.3.1 Footing Elevation

Strip footings should be founded below the depth of frost penetration and at a similar elevation or lower as that of the existing footing. The following founding elevations for the underside of strip footings are recommended for design. These founding elevations should be checked relative to the adjacent grades to ensure that the recommended soil cover for each option below the lowest surrounding final grade is achieved to provide adequate protection against frost penetration (refer to section 6.3.4).



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Options	Maximum (Highest) Footing Founding Elevation	Founding Stratum	Depth Below Existing Grade at Borehole Locations
Option 1	266.5 m	Loose to Compact Sand and Silty Sand	2.2 m to 3.7 m
Option 2	266.5 m (Subgrade Level at Elevation 266.0 m)	500 mm Granular 'A' or 'B' Type II pad over Loose to Compact Sand and Silty Sand	2.2 m to 3.7 m

6.3.2 Geotechnical Resistance

A strip footing placed on the properly prepared subgrade (i.e. native loose to compact sand and silty sand, or on a granular pad) at the design elevations given in Section 6.3.1, should be designed based on the factored ultimate geotechnical axial resistance at ULS and the factored serviceability geotechnical resistance at SLS (for 25 mm of settlement) given below.

Options	Foundation Elevation	Footing Width (m)	Factored Ultimate Geotechnical Axial Resistance at ULS (kPa)	Factored Serviceability Geotechnical Reaction at SLS (for 25 mm settlement) (kPa)
Option 1	266.5 m	1	175	90
		2	185	45
Option 2	266.5 m on Granular Pad 0.5 m Thick (min)	1	195	100
		2	205	50

The values provided above have been determined by methods outlined in the *Canadian Engineering Foundation Manual (CFEM) 2006*, and the *(CHBDC)* and its *Commentary (2014)*. The ULS resistance and the SLS settlement are dependent on the footing size, depth of embedment, configuration and applied loads. The geotechnical resistances should, therefore, be reviewed if the selected footing width or founding elevation differs from those provided above. In addition, the geotechnical resistances are provided for loads applied perpendicular to the surface of the footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.10.4 of the *CHBDC* and its *Commentary (2014)*.

The footing subgrade should be inspected by a Quality Verification Engineer following excavation, in accordance with OPSS 902 (Excavating and Backfilling - Structures) to verify that the founding elevation is reached and that all unsuitable material, including organic or loose/soft material, has been removed. If the conditions at the time of construction are wet, from rainfall, snow or groundwater, the founding soils may be susceptible to disturbance and if the concrete for the footings cannot be poured or the granular pad cannot be constructed immediately after excavation and inspection, it is recommended that a concrete working slab be placed on the prepared native sand and silty sand subgrade within four hours of its inspection and approval. A Non-Standard Special Provision (NSSP) for the working slab should be included in the Contract Documents; an example is provided in Appendix C.



6.3.3 Resistance to Lateral Loads

Resistance to lateral forces/sliding resistance between the base of the concrete footings and the proposed founding material should be calculated in accordance with Section 6.10.4 of the *CHBDC (2014)*. The coefficient of friction, $\tan \delta$, for cast-in-place concrete footings on the properly prepared subgrade soils or working slab (see Section 6.3.2) is provided below. These values assume that construction is carried out in dry conditions. These values represent unfactored values and the appropriate factors should be applied as outlined in the *CHBDC (2014)*.

Founding Elevation	Founding Stratum	Footing Type	$\tan \delta$ (Navfac, 1986)
266.5 m	Footing or Working Slab on Loose to Compact Sand and Silty Sand	Cast-in-place	0.32
266.5 m	Footing on 500 mm Granular 'A' or 'B' Type II pad over Loose to Compact Sand and Silty Sand	Cast-in-place	0.60

6.3.4 Frost Protection

The footings should be provided with a minimum 2.0 m of soil cover for frost protection as interpreted from OPSD 3090.101 (Foundation, Frost Penetration Depths for Southern Ontario). In addition, the bearing soil and fresh concrete should be protected from freezing during cold weather construction.

6.4 Seismic Site Classification

Subsurface ground conditions for seismic site characterization were established based on the results of the borehole investigations. The site may be classified as Site Class E in accordance with Table 4.1 of the *CHBDC (2014)*, in the absence of any geophysical testing. Geophysics testing, if carried out, could provide a more favourable Site Class designation.

In accordance with Section 4.4.3.4 of the *CHBDC (2014)*, the peak ground acceleration (PGA) values and design spectral acceleration (S_a) values at this site, as derived from seismic information from the *National Building Code of Canada (NBCC) 2010*, are presented below.

Seismic Hazard Values	10% Exceedance in 50 years (475-year return period)	5% Exceedance in 50 years (975-year return period)	2% Exceedance in 50 years (2,475 return period)
PGA (g)	0.031	0.049	0.081
Sa (0.2) (g)	0.096	0.148	0.240
Sa (0.5) (g)	0.096	0.148	0.240
Sa (1.0) (g)	0.065	0.104	0.160
Sa (2.0) (g)	0.023	0.038	0.058



6.5 Lateral Earth Pressure for Design

The lateral earth pressures acting on the retaining headwalls will depend on the type and method of placement of the backfill material, the nature of the soils behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the wall.

The following recommendations are made concerning the design of the retaining headwall. These design recommendations and parameters assume level backfill and ground surface behind the wall. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free draining granular fill meeting the specifications of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II, should be used as backfill behind the wall. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting). Other aspects of the granular backfill requirements with respect to sub-drains and frost tapers should be in accordance with OPSD 3121.150 (Walls, Retaining, Backfill, Minimum Granular Requirement) and OPSD 3190.100 (Walls, Retaining and Abutment, Wall Drain).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the wall stem, in accordance with *CHBDC (2014)* Section 6.12.3 and Figure 6.6. Other surcharge loadings should be accounted for in the design as required.
- For a restrained wall, the granular backfill should be placed in a zone with the width equal to at least 2.0 m behind the back of the wall (in accordance with Figure C6.20(a) of the *Commentary* to the *CHBDC (2014)*). For unrestrained wall, the granular backfill should be placed within the wedge-shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (in accordance with Figure C6.20(b) of the *Commentary* to the *CHBDC (2014)*). The pressures are based on the proposed granular backfill material and the following parameters (unfactored) may be used:

Fill Type	Soil Unit Weight	Coefficients of Static Lateral Earth Pressure		
		At-Rest, K_o	Active, K_a	Passive, K_p
Granular 'A'	22 kN/m ³	0.44	0.28	3.54
Granular 'B' Type II	21 kN/m ³	0.44	0.28	3.54

- Where the wall support allows lateral yielding of the stem, active earth pressures should be used in the geotechnical design of the wall structure(s). The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure should be calculated in accordance with Section C6.12.1 and Table C6.6 of the *Commentary* to the *CHBDC (2014)*.
- If the wall does not allow lateral yielding (i.e., restrained structure where the rotational or horizontal movement is not sufficient to mobilize an active earth pressure condition), at-rest earth pressures (plus any compaction surcharge) should be assumed for geotechnical design.



6.5.1 Seismic Lateral Earth Pressure

Seismic (earthquake) loading must also be taken into account in the design in accordance with Section 4.6.5 of the *CHBDC (2014)*. In this regard, the following should be included in the assessment of lateral earth pressures:

- Seismic loading will result in increased lateral earth pressures acting on the retaining wall. The wall should be designed to withstand the combined lateral loading for the appropriate static pressure conditions given above, plus the earthquake-induced dynamic earth pressure.
- In accordance with Sections 4.6.5 and C.4.6.5 of the *CHBDC* and its *Commentary (2014)*, for structures which allow lateral yielding, the horizontal seismic coefficient, k_h , used in the calculation of the seismic active pressure coefficient, is taken as 0.5 times the site-specific PGA. For structures that do not allow lateral yielding, k_h is taken as equal to the site-specific PGA. For both cases the value of the vertical seismic coefficient k_v is taken as zero.
- The following seismic active pressure coefficients (K_{AE}) may be used in design; these coefficients reflect the maximum K_{AE} obtained for each of the earthquake design periods and backfill conditions. It should be noted that these seismic earth pressure coefficients assume that the back of the wall is vertical and the ground surface behind the wall is level. Where sloping backfill is present above the top of the wall, the lateral earth pressures under seismic loading conditions should be calculated by treating the weight of the backfill located above the top of the wall as a surcharge.

	Design Earthquake	Site PGA	Seismic Active Pressure Coefficients, K_{AE}	
			Granular A	Granular B Type II
Yielding Wall	475-Yr	0.031	0.29	0.29
	975-Yr	0.049	0.30	0.30
	2,475 Yr	0.081	0.31	0.31
Non-Yielding Wall	475-Yr	0.031	0.30	0.30
	975-Yr	0.049	0.32	0.32
	2,475 Yr	0.081	0.34	0.34

- The K_{AE} value for a yielding wall is applicable provided that the wall can move up to $250k_h$ mm, where k_h is the site specific PGA as given in the table above. This corresponds to displacements of 8 mm, 12 mm and 20 mm for the 475-year, 975-year, and 2,475-year design earthquakes at this site.
- The earthquake-induced dynamic pressure distribution, which is to be added to the static earth pressure distribution, is a linear distribution with maximum pressure at the top of the wall and minimum pressure at its toe (i.e. an inverted triangular pressure distribution). The total pressure distribution (static plus seismic) may be determined as follows:

$$\sigma_h(d) = K_a \gamma d + (K_{AE} - K_a) \gamma (H-d), \text{ yielding wall}$$

$$\sigma_h(d) = K_o \gamma d + (K_{AE} - K_a) \gamma (H-d), \text{ non-yielding wall}$$

Where: $\sigma_h(d)$ is the (static plus seismic) lateral earth pressure (kPa) at depth, d ;

K_a is the static active earth pressure coefficient;



- K_o is the static at-rest earth pressure coefficient;
- K_{AE} is the seismic active earth pressure coefficient;
- γ is the unit weight of the backfill soil (kN/m^3), as given in Section 6.5;
- d is the depth below the top of the wall (m); and,
- H is the total height of the wall (m).

6.6 Global Stability Analysis

Stability analyses have been performed for the maximum height of the retaining headwall, including footing thickness, equal to 3.8 m, using the commercially available program *GeoStudio 2007 (Version 7.23) produced by Geo-Slope International Ltd*, employing the Morgenstern Price method of analysis. For the analysis, the Factors of Safety (FoS) of numerous potential failure surfaces were computed for the critical cross-section in order to establish the minimum FoS. The FoS is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. For the purpose of the stability analysis, the FoS is equal to the inverse of the product of the consequence factor, Ψ , and the geotechnical resistance factor, ϕ_{gu} . (i.e. $FoS = 1/(\Psi \cdot \phi_{gu})$). Accordingly, a target minimum FoS of 1.54 has been used to assess the global stability of the retaining wall, as per Table 6.2 of *CHBDC (2014)*.

The following summarizes the strength parameters and unit weights employed for the different materials, as interpreted from *Kulhway and Mayne (1990)*:

Material	Unit Weight (kN/m^3)	Strength Parameters
Concrete (Wall and Footing)	24	$c' = 20,000 \text{ kPa}$ $\phi' = 0^\circ$
Granular Backfill (Granular 'A' or 'B' Type II)	21	$c' = 0 \text{ kPa}$ $\phi' = 34^\circ$
Loose to Compact Sand and Very Loose to Compact Silty Sand	19	$c' = 0 \text{ kPa}$ $\phi' = 28^\circ$
Loose to Compact Silt	18	$c' = 0 \text{ kPa}$ $\phi' = 28^\circ$

The stability analyses assumes that all topsoil and native soils containing organics have been removed prior to construction of the footing, the top of the wall is at Elevation 270.3 m, the ground surface at the toe of the wall is at about Elevation 268.5 m, and the base of the wall/footing is at Elevation 266.5 m. For the analysis the water level within the soil and in the ditch was assumed to be that observed in the boreholes at Elevation 268.7 m. The analysis also assumes the general size and location of the replacement wall is the same as the existing wall. A factor of safety greater than 1.54 is obtained for a global failure surface; the result from a selected stability analysis is presented on Figure 3.

6.7 Site Preparation and Engineered Fill Construction

Any fill materials required within the retaining headwall footprint should consist of suitable material placed/compacted to engineered fill standards. All topsoil, if encountered and any portions of the cohesionless deposits that are loose/disturbed or contain organics and/or other deleterious materials are not considered to be



suitable for the subgrade support of the wall foundation. Any softened/loosened or poorly performing areas of the native subgrade soils should be sub-excavated and replaced with engineered fill comprised of free-draining material, such as OPSS.PROV 1010 (Aggregates) Granular 'A'.

If a granular fill pad is specified to support the footing, the pad should be constructed with material meeting the specification of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II, compacted to not less than 100% of the material's Standard Proctor Maximum Dry Density (SPMDD) and placed in maximum 200 mm loose lifts. The top of the granular pad should extend at least 300 mm beyond the edges of the foundation footprint and extend downwards and outwards at 1 horizontal to 1 vertical (1H:1V) to the base of the pad.

All fill material should be placed in accordance with OPSS.PROV 501 (Compacting). Within the granular fill envelope in front and behind the headwall, the fill should be compacted to not less than 100 per cent of the material's SPMDD. Filling should continue until the design subgrade elevation is achieved, with full-time inspection and in-situ density testing carried out by a qualified geotechnical engineering firm during placement of engineered fill beneath the structure and settlement-sensitive areas.

6.8 Construction Considerations

6.8.1 Temporary Excavations and Groundwater Control

All excavations must be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. The excavations will extend to depths between about 3.7 m and 4.2 m below ground surface relative to the top of the wall and between 2.0 m and 2.5 m below ground surface relative to the toe of the wall, depending on the footing founding elevation and inclusion of a granular pad. Based on observations in the boreholes during drilling, the water level is expected to be at about Elevation 268.7 m (i.e. at ground surface relative to the toe of the wall and at a depth about 1.5 m below ground surface relative to the top of the wall). The strip footing founding level is Elevation 266.5 m, with the base of excavation expected to be between about Elevations 266.5 m or 266.0 m if the footing is to be supported on a granular pad, which is about 2.2 m to 2.7 m below the water level.

The fill and native soils above the groundwater level at this site are classified as Type 3 soil according to OHSA. The native soils below the water table would be classified as Type 4 soil unless a suitable dewatering system is installed to lower the water level below the base of the excavation. Temporary excavations above the water table may be made with side slopes no steeper than 1H:1V. Where excavations extend below the groundwater table at the site, the temporary side slopes will have to be formed at 3H:1V unless proper groundwater control is implemented.

If steeper side slopes are necessary, temporary excavation support will be required. Temporary excavation support should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539.

Given the gradation of existing sand and gravel fill and native deposits composed of sand, silty sand and silt below the groundwater table, and the need to lower the water level by up to 2.7 m below the highest subgrade level for a footing founded on a native subgrade and below the depth of frost penetration, active dewatering will be required to maintain the stability of the excavation and install the footing. Groundwater control measures will likely extract more than 50,000 L/day of water but likely less than 400,000 L/day. Under the Environmental Protection Act by



the Ontario Ministry of the Environment and Climate Change (“MOECC”), water taking for construction site dewatering for volumes greater than 50,000 L/day but less than 400,000 L/day qualify for the Environmental Activity Section Registry (EASR). Under the EASR, a Permit to Take Water is not required for water taking for construction site dewatering for volumes less than 400,000 L/day, however an application for an EASR would be required, including a water taking report and discharge plan.

The contractor should be made aware that, based on anticipated excavation depth, the excavation into/through the sand and gravel fill, sand and silty sand soils below the groundwater table will require pro-active groundwater controls (which may need to take the form of installation of well points) to ensure the stability of slopes and base of the proposed excavation/footing founding level, in addition to pumping from sumps. It should be noted that the water levels in this area may fluctuate depending on the time of year. It is recommended that excavations for foundations be carried out in late summer when water levels are anticipated to be lower. An example of NSSP concerning dewatering of the native soils during excavation and foundation construction is attached in Appendix C.

6.8.2 Obstructions

Although cobbles or boulders were not encountered during the drilling operations cobbles are likely present within the fill materials at the site, however conventional excavation equipment should be suitable for excavating through the site soils.

6.8.3 Summary of Recommended NSSPs

As noted in the preceding discussions, it is recommended that the following Non-Standard Special Provisions (NSSPs) be provided in the Contract Documents to address geotechnical aspects of excavation and foundation construction at this site:

- NSSP regarding placement of a concrete working slab on the foundation subgrade immediately following inspection of the prepared native subgrade, to protect the sand/silt soils from disturbance.
- NSSP concerning dewatering of the site soils during excavation and foundation construction.

6.8.4 Analytical Testing for Construction Materials

The results of an analytical test on one sample of near-surface, native, silty sand deposit (BH17-2 SA#2) are summarized in Section 4.4 and presented in Appendix C. The potential for sulphate attack and corrosion are discussed in the following paragraphs, however, it is ultimately up to the designer to determine the appropriate construction materials, including the exposure class and ensuring that all aspects of *CSA A23.1-14 Section 4.1.1 “Durability Requirements”* are followed when designing concrete elements.

The analytical test results were compared to *CSA A23.1-14 Table 3 (“Additional requirements for concrete subjected to sulphate attack”)* for the potential sulphate attack on concrete. The water soluble-sulphate concentration measured in the native silty sand is less than the detectable limit of 0.002 per cent, which is below the exposure class of S-3 (Moderate). Therefore, based on the single sample of native silty sand tested, when the designer is selecting the exposure class for the structure, the effects of sulphates from within the native silty sand may not need to be considered. In addition, given the location of the retaining headwall, it is expected that the replacement wall will be exposed to de-icing salts and selection of the exposure class should consider this.

The analytical test results were also compared to the Table 2 Criteria of the U.S. Criteria for Assessing Ground Corrosion Potential (as outlined by *Lazarte et al. 2015*) for the potential corrosion of buried steel. Based on the



measured values of pH, resistivity, chlorides, and sulfates in the native silty sand the soil has “strong corrosion potential”. In addition, given the location of the retaining headwall, it is expected that the replacement wall will be exposed to de-icing salts; and therefore consideration should be given to providing corrosion protection to reinforcing elements.

7.0 CLOSURE

This report was prepared by Mr. David Marmor, E.I.T. and the technical aspects were reviewed by Mr. John Hagan, P.Eng., a geotechnical engineer with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder’s Designated MTO Contact for Foundations for this assignment and Senior Consultant with Golder, conducted an independent quality control review of the report.



FOUNDATION REPORT – HEADWALL REPLACEMENT
HIGHWAY 144, CHELMSFORD

Report Signature Page

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\\Golder\gds\gal\Whitby\Active\2016\3 Proj\1648346 AECOM_5015-E-0033_Hwy 144 NER\6. Report\W.P. 5176-12-01.02 Urban Section\Headwall\Final\FIDR\1648346 Final FIDR Headwall Replacement 23June2017.docx



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- Unified Facilities Criteria, U.S. Navy. 1986. *NAVFAC Design Manuals 7.01 and 7.02. Soil Mechanics, Foundation and Earth Structures*. Alexandria, Virginia.

ASTM International

- ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

Commercial Software

- GeoStudio (Version 7.23) by Geo-Slope International Ltd.

Ontario Provincial Standard Drawings

- | | |
|---------------|---|
| OPSD 3090.101 | Foundation, Frost Penetration Depths for Southern Ontario |
| OPSD 3121.150 | Walls, Retaining, Backfill, Minimum Granular Requirement |
| OPSD 3190.100 | Walls, Retaining and Abutment, Wall Drain |

Ontario Provincial Standard Specifications

- | | |
|----------------|---|
| OPSS.PROV 501 | Construction Specification for Compacting |
| OPSS. PROV 539 | Construction Specification for Temporary Protection Systems |



**FOUNDATION REPORT – HEADWALL REPLACEMENT
HIGHWAY 144, CHELMSFORD**

OPSS 902 Construction Specification for Excavating and Backfilling - Structures
OPSS.PROV 1010 Material Specification for Aggregates – Base, Subbase, Select Subgrade and
Backfill Material

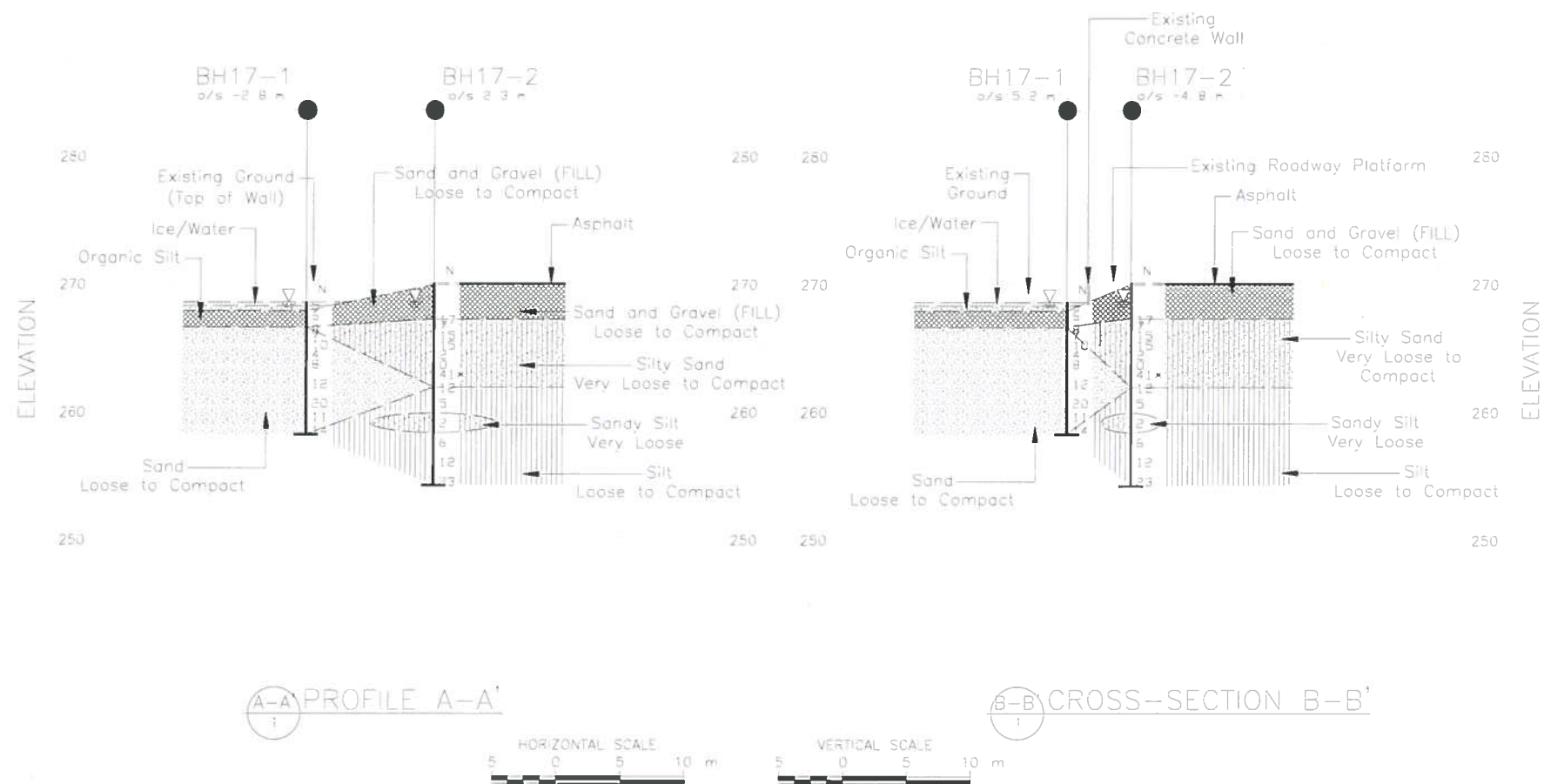
Ontario Water Resources Act

Ontario Regulation 903/90 Wells: O. Reg. 468/10 Amendment to Ontario Regulation 903



DRAWINGS

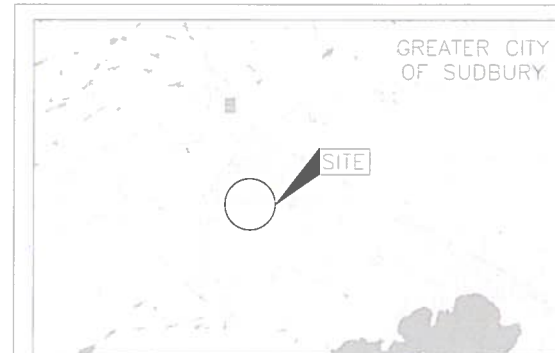
Drawing 1 - Borehole Locations and Soil Strata



A circular green seal for a Licensed Professional Engineer in the Province of Ontario. The outer ring contains the text "LICENSED PROFESSIONAL ENGINEER" at the top and "PROVINCE OF ONTARIO" at the bottom. The center of the seal features the name "J. B. HAGAN" and the license number "100171186" in green capital letters. Handwritten in black ink are the initials "J.B.H." in the upper center and the date "June/2017" in the lower center.

CONT No.
GWP No. 5176-12-00

HIGHWAY 144
HEADWALL REPLACEMENT
BOREHOLE LOCATIONS AND SOIL
STRATA



KEY PLAN
SCALE



LEGEND

- | | |
|----|---|
| ● | Borehole - Current Investigation |
| N | Standard Penetration Test Value |
| 16 | Blows/0.3m, unless otherwise stated
(Std. Pen. Test, 475.1/blow) |
| ▽ | WL upon completion of drilling |

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
BH17-1	266.7	5158505.8	289546.4
BH17-2	270.2	5158510.8	289556.4

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

*BH17-2 "N" Value for sample "SS7" considered not representative of in-situ conditions due to "blow back" within auger stem.

REFERENCE

Base plans provided in digital format by AECOM, drawing file B1446AL.dwg, dated MAR 09, 2017.

NO.	DATE	BY	REVISION		
Geocres No. 411-351					
HWY. 144		PROJECT NO. 1648346			DIST.
SUBM'D. BY	CHKD. BY	DATE: 6/19/2017		SITE:	
DRAWN: SMD	CHKD. JRW	APPD. JMAC		DWC. 1	



FIGURES

Figures 1 & 2 - Site Photos

Figure 3 - Stability Analysis - Global Stability

SITE PHOTOGRAPHS
Headwall Replacement, Highway 144, Chelmsford
G.W.P. 5176-12-00, W.P. 5176-12-02

FIGURE 1



Top of Existing Wall, Looking East towards Errington Ave.



Top of Existing Wall, Looking West

Project No.	1648346
Photo Date:	August 2016

Golder Associates Ltd.

Taken by:	DPM
Checked By:	JBH

SITE PHOTOGRAPHS
Headwall Replacement, Highway 144, Chelmsford
G.W.P. 5176-12-00, W.P. 5176-12-02

FIGURE 2



Looking towards West Toe of Wall



Looking North at Toe of Wall from Top of Ditch

Project No.	1648346
Photo Date:	August 2016

Golder Associates Ltd.

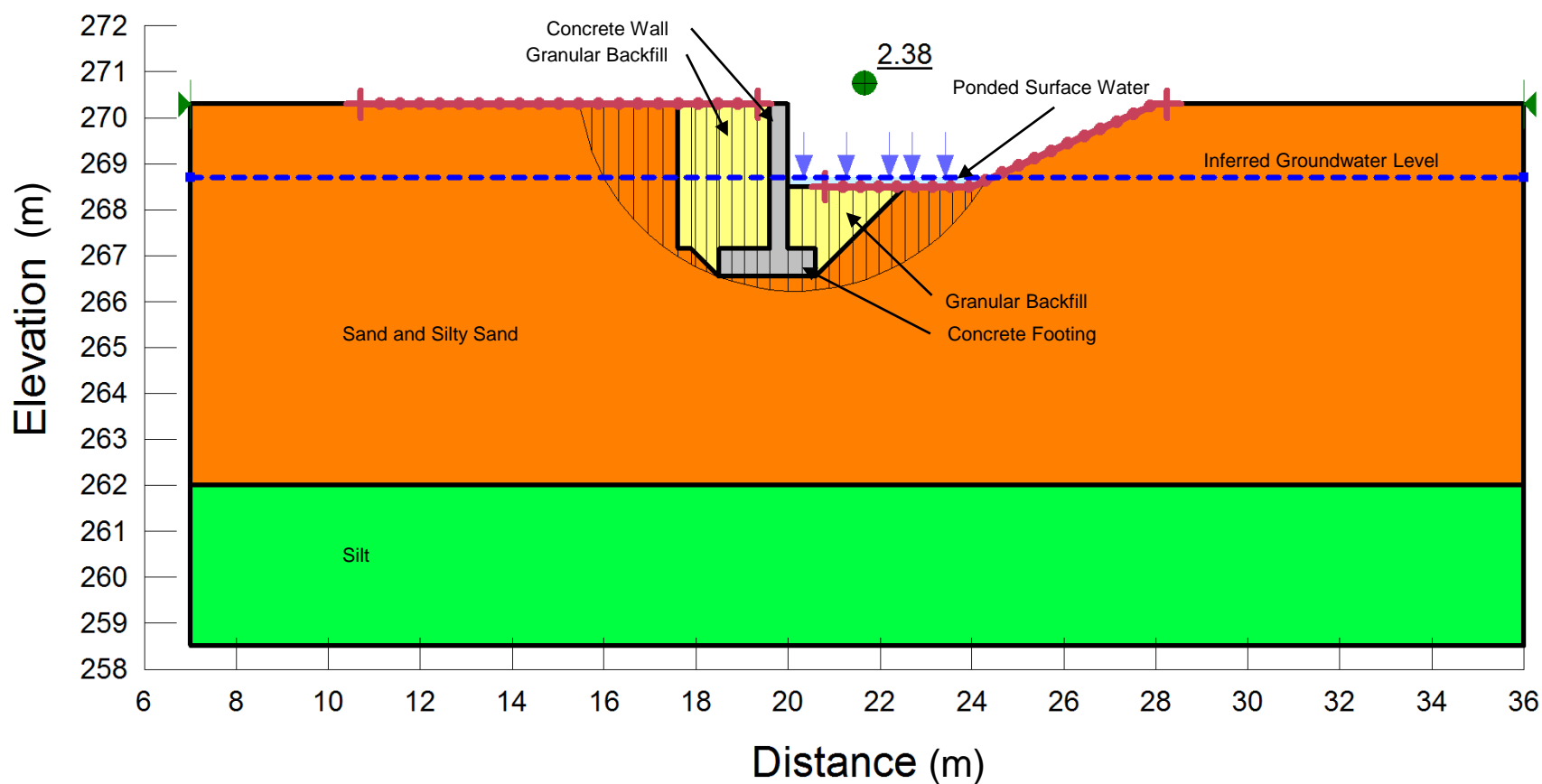
Taken by:	DPM
Checked By:	JBH



Global Stability Analysis (Static)
Headwall Replacement, Highway 144, Chelmsford
G.W.P. 5176-12-00, W.P. 5176-12-02

Figure 3

Material Name	Unit Weight (kN/m ³)	Cohesion (kPa)	Friction Angle (°)
Concrete	24	20,000	-
Granular Backfill (Granular A or B Type II)	21	-	34
Loose to Compact Sand and Very Loose to Compact Silty Sand	19	-	28
Loose to Compact Silt	18	-	28





APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$,	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a)	Index Properties
$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$



LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

	C_u, S_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand



LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

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

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	

PROJECT		1648346		RECORD OF BOREHOLE No BH17-1		SHEET 1 OF 1		METRIC						
G.W.P.		5176-12-00		LOCATION		N 5158805.8; E 289546.4 MTM ZONE 12 (LAT. 46.568724; LONG. -81.198986)		ORIGINATED BY						
DIST		HWY 144		BOREHOLE TYPE		76 mm I.D., 89 mm O.D. Casing, Portable Equipment		COMPILED BY						
DATUM		Geodetic		DATE		February 6 and 7, 2017		CHECKED BY						
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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L		
268.7	GROUND SURFACE													
0.0	ICE													
	WATER													
268.0	Sandy ORGANIC SILT, trace to some clay, some gravel		1	SS	5									41 46 10 3
0.7	Loose Black to grey Wet		2	SS	6									
	Sand and gravel, trace to some silt, trace clay, trace organics (FILL)		3A	SS	8									
266.7	Loose Dark grey to grey Wet		3B	SS										
2.0	SAND, trace to some silt, trace clay, trace to some gravel		4	SS	7									
	Loose to compact Grey Wet		5	SS	10									17 68 12 3
			6	SS	4									
			7	SS	8									
			8	SS	12									
			9	SS	20									2 90 4 4
			10	SS	11									
			11	SS	14									
258.3	END OF BOREHOLE													
10.4	NOTES:													
	1. Hole sloughed to 2.4 m upon removal of casing.													
	2. Borehole backfilled with bentonite upon completion.													
	3. Water level observed at ice surface (Elev. 268.7 m) upon completion of drilling.													

PROJECT <u>1648346</u>		RECORD OF BOREHOLE No BH17-2		SHEET 1 OF 2		METRIC	
G.W.P. <u>5176-12-00</u>		LOCATION <u>N 5158810.8; E 289556.4 MTM ZONE 12 (LAT. 46.568769; LONG. -81.198856)</u>		ORIGINATED BY <u>DM</u>			
DIST <u> </u> HWY <u>144</u>		BOREHOLE TYPE <u>108 mm I.D., 203 mm O.D. Hollow Stem Augers</u>		COMPILED BY <u>SMD</u>			
DATUM <u>Geodetic</u>		DATE <u>February 8, 2017</u>		CHECKED BY <u> </u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	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 × REMOULDED												
270.2	GROUND SURFACE						20	40	60	80	100	10	20	30						
0.0	ASPHALT (165 mm)																			
0.2	Sand and gravel, trace to some silt (FILL) Compact Brown to grey Moist to wet																			
267.4			1A	SS	17										36 58 (6)					
2.8	Silty SAND, trace clay, trace gravel, trace organics at top Very loose to compact Grey Wet		1B																	
			2	SS	7															
			3	SS	15										0 70 27 3					
			4	SS	15															
			5	SS	2															
			6	SS	WR															
			7	SS	41*															
			8A	SS	12															
262.0			8B																	
8.2	SILT, trace to some clay, trace sand Loose Grey Wet		9	SS	5										0 1 91 8 Non-Plastic					
260.0																				
10.2	Sandy SILT, trace to some clay Very loose Grey Wet		10	SS	2															
258.5																				
11.7	SILT, trace to some clay, trace sand Loose to compact Grey Wet		11	SS	6															
			12	SS	12										0 2 91 7 Non-Plastic					

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

GTA-MTO 001 S:\CLIENTS\MTOWHWY_144\02_DATA\GINT\1648346.GPJ GAL-GTA.GDT 22/03/17

PROJECT 1648346		RECORD OF BOREHOLE No BH17-2				SHEET 2 OF 2		METRIC								
G.W.P. 5176-12-00		LOCATION N 5158810.8; E 289556.4 MTM ZONE 12 (LAT. 46.568769; LONG. -81.198856)				ORIGINATED BY DM										
DIST _____ HWY 144		BOREHOLE TYPE 108 mm I.D., 203 mm O.D. Hollow Stem Augers				COMPILED BY SMD										
DATUM Geodetic		DATE February 8, 2017				CHECKED BY _____										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100					W _p W W _L 10 20 30				
254.4	SILT, trace to some clay, trace sand Loose to compact Grey Wet		13	SS	23		255									
15.9	END OF BOREHOLE															
	NOTES: 1. Water level measured at a depth of about 1.5 m (Elev. 268.7 m) below ground surface upon completion of drilling. 2. Borehole sloughed to 1.7 m below ground surface upon removal of augers. 3. Borehole backfilled with bentonite upon completion. 4. Borehole advanced by hydro-vacuum excavation to a depth of 2.7 m (Elev. 267.5 m). 5. "N" Value for sample "SS7" considered not representative of in-situ conditions due to "blow back" within auger stem.															

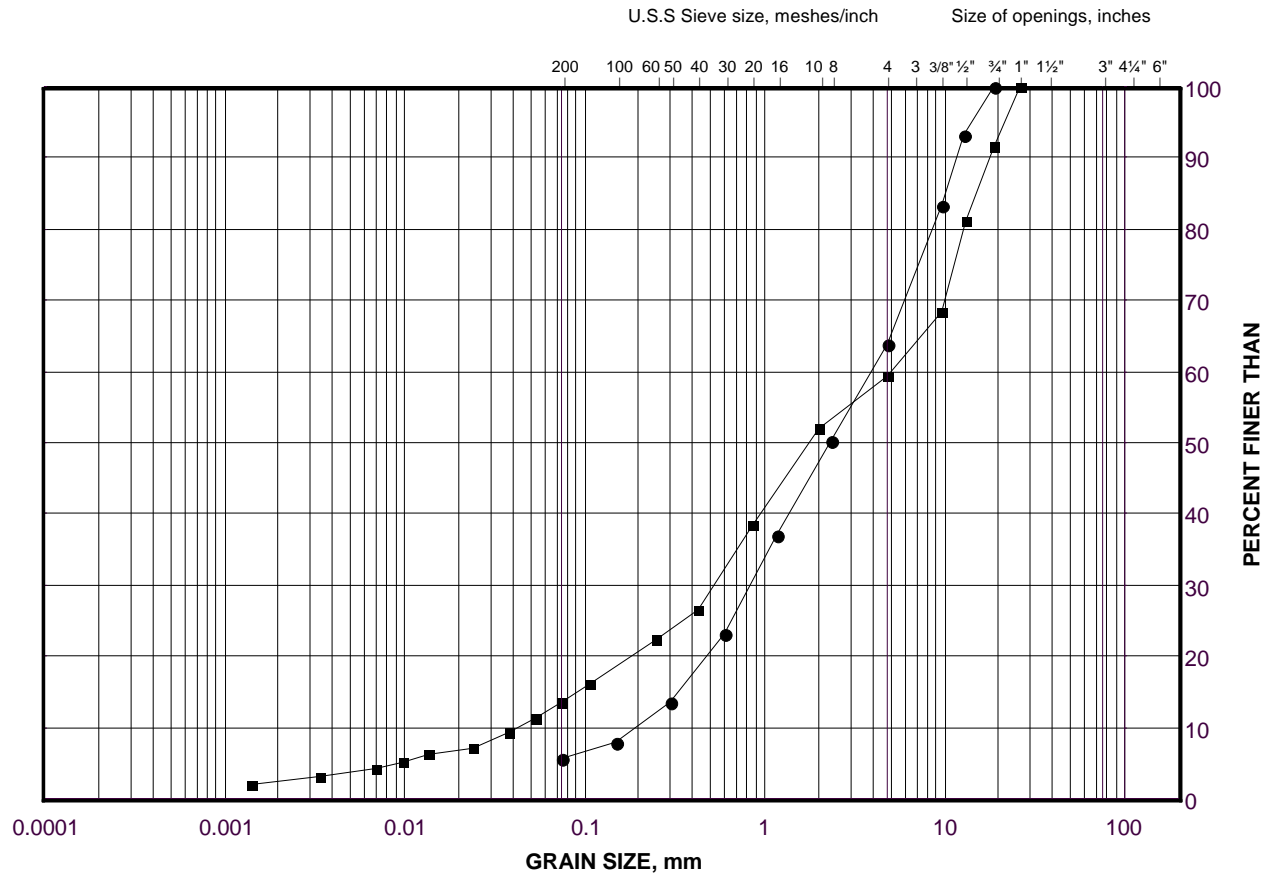


APPENDIX B

Laboratory Tests Results

GRAIN SIZE DISTRIBUTION SAND AND GRAVEL (FILL)

FIGURE B1



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH17-2	SS1A	267.6
■	BH17-1	SS2	267.6

Project Number: 1648346

Checked By: DPM

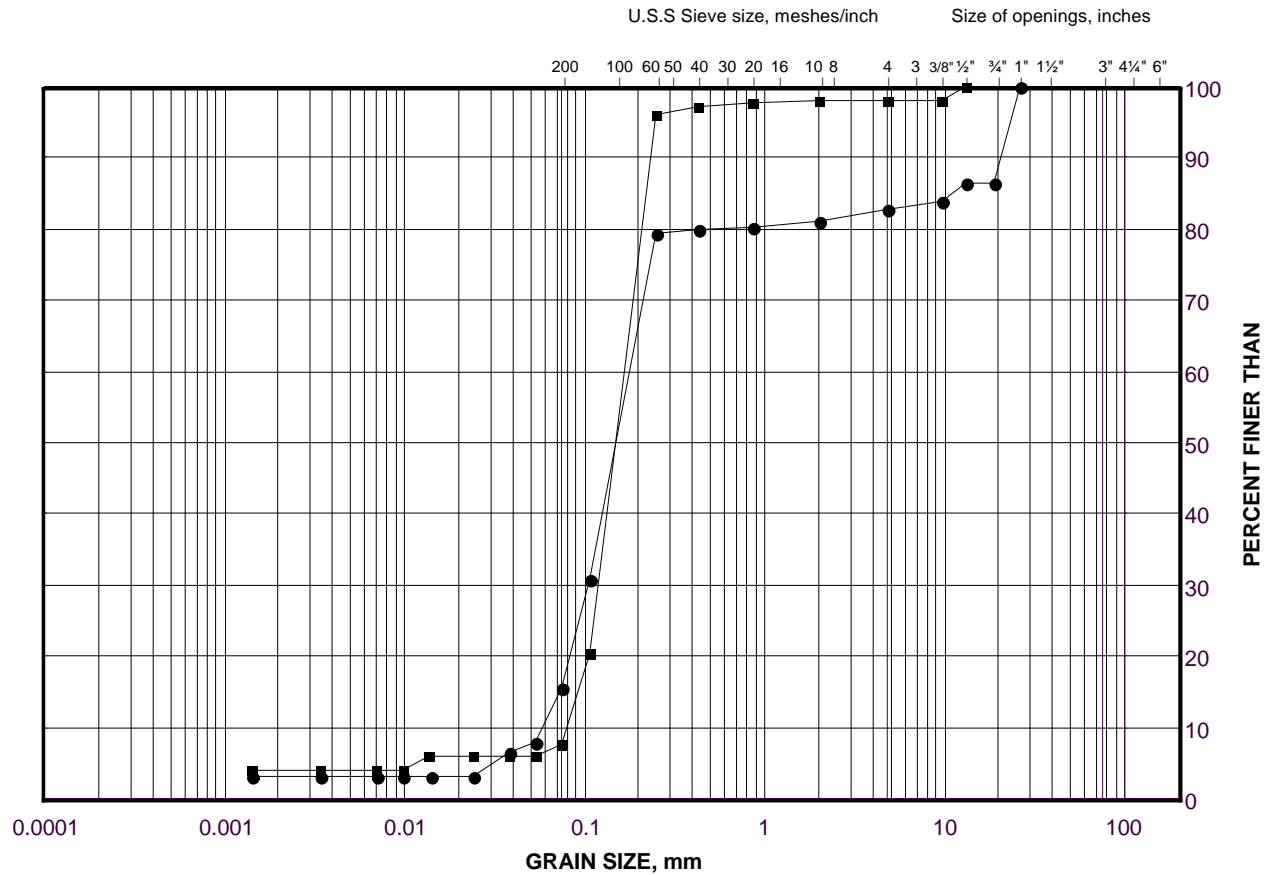
Golder Associates

Date: 15-Mar-17

GRAIN SIZE DISTRIBUTION

SAND

FIGURE B2



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH17-1	SS5	265.3
■	BH17-1	SS9	260.7

Project Number: 1648346

Checked By: DPM

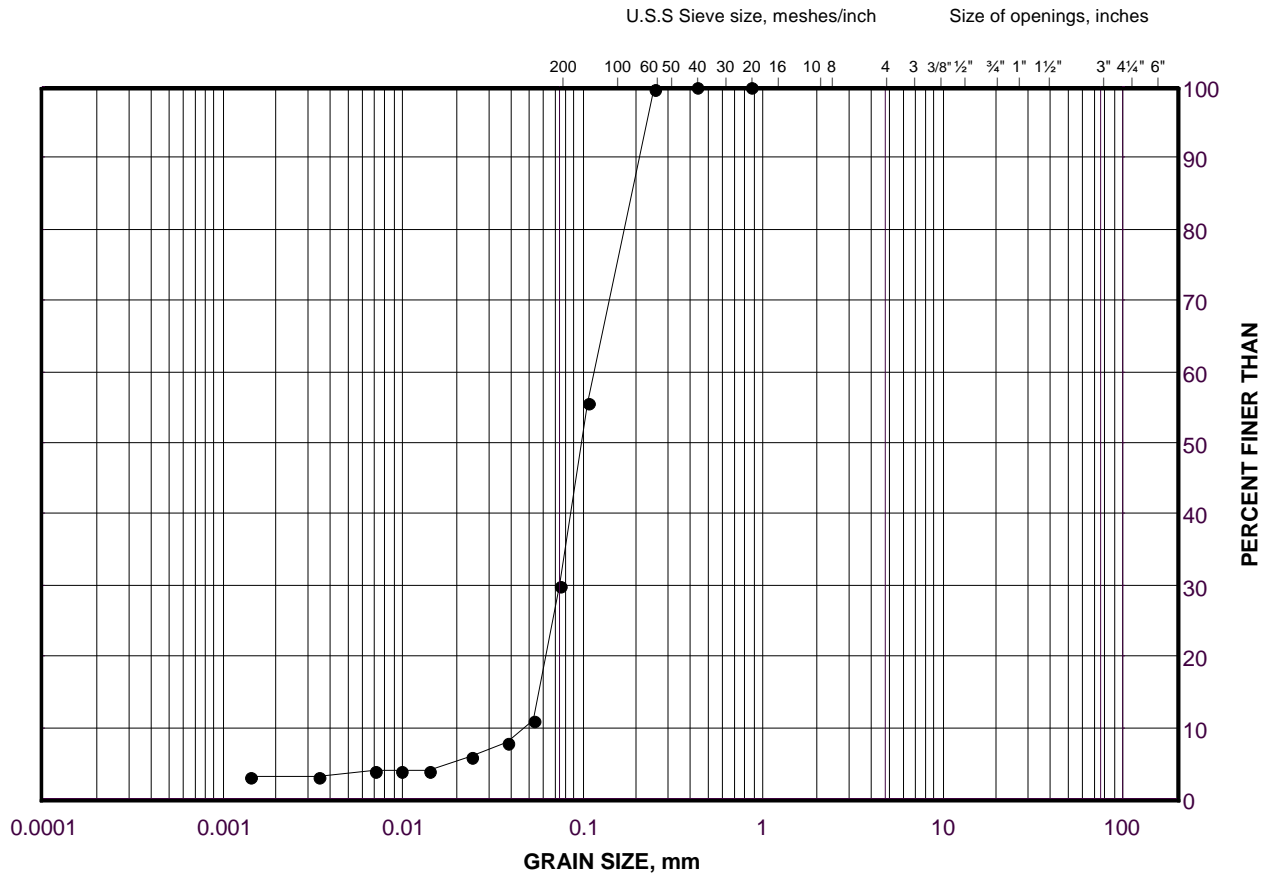
Golder Associates

Date: 15-Mar-17

GRAIN SIZE DISTRIBUTION

SILTY SAND

FIGURE B3



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	BH17-2	SS3	266.0

Project Number: 1648346

Checked By: DPM

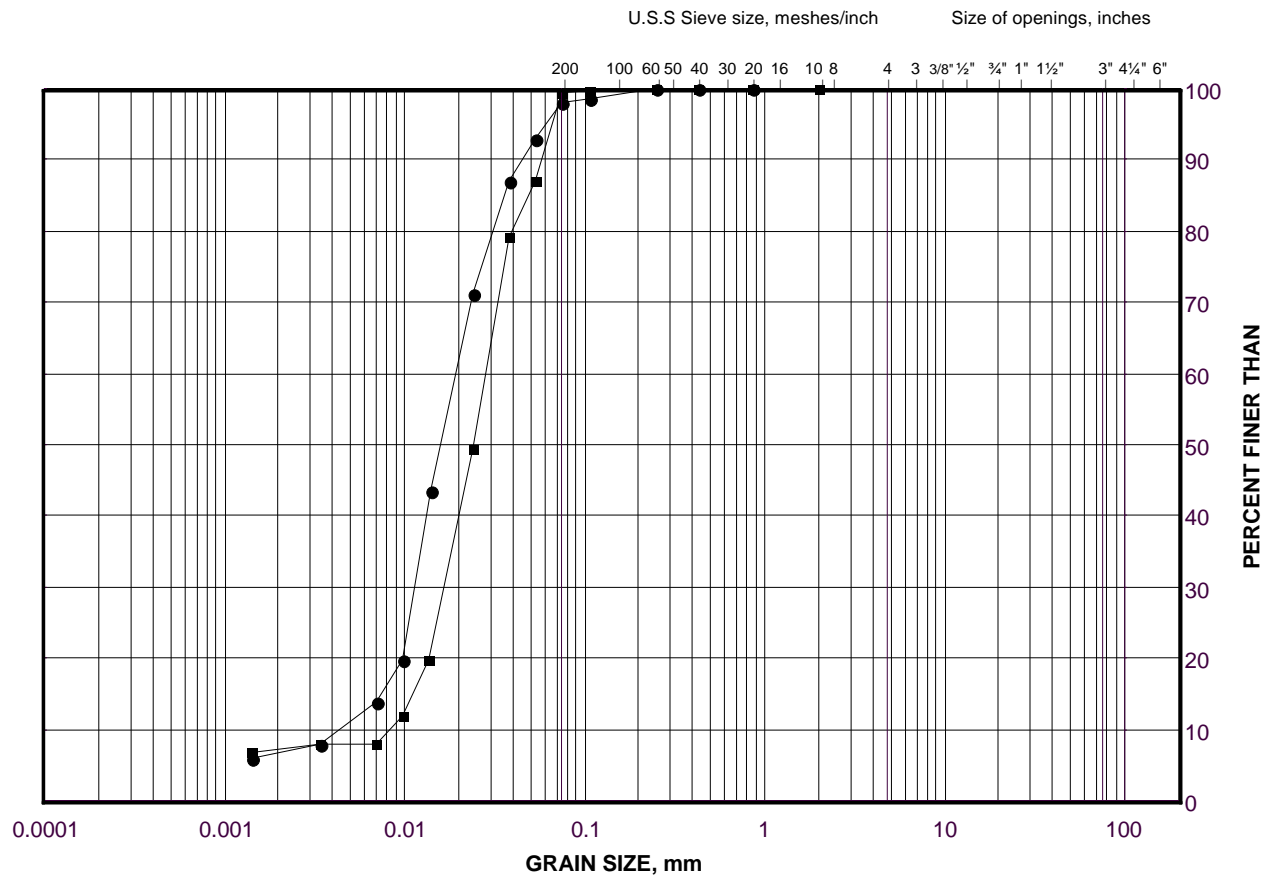
Golder Associates

Date: 15-Mar-17

GRAIN SIZE DISTRIBUTION

SILT

FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH17-2	SS12	256.1
■	BH17-2	SS9	260.7

Project Number: 1648346

Checked By: DPM

Golder Associates

Date: 15-Mar-17



APPENDIX C

Results of Soil Chemical Analysis

Your Project #: 1648346
Site Location: CULVERT-HWY 144
Your C.O.C. #: 59300

Attention:David Marmor

Golder Associates Ltd
121 Commerce Park Drive
Unit L
Barrie, ON
L4N 8X1

Report Date: 2017/02/22
Report #: R4366149
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B731145

Received: 2017/02/14, 13:42

Sample Matrix: Soil
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	1	N/A	2017/02/21	CAM SOP-00463	EPA 325.2 m
Conductivity	1	N/A	2017/02/21	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl ₂ EXTRACT	1	2017/02/17	2017/02/17	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	1	2017/02/15	2017/02/21	CAM SOP-00414	SM 22 2510 m
Sulphate (20:1 Extract)	1	N/A	2017/02/21	CAM SOP-00464	EPA 375.4 m
Oxidation-Reduction Potential (1, 2)	1	2017/02/16	2017/02/21	SLA SOP-00101	In house

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods. Results relate to samples tested.

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Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

(1) This test was performed by Maxxam Sladeview Petrochemical

(2) Oxidation-Reduction Potential (ORP) values are determined using a Ag/AgCl reference electrode.

Your Project #: 1648346
Site Location: CULVERT-HWY 144
Your C.O.C. #: 59300

Attention:David Marmor

Golder Associates Ltd
121 Commerce Park Drive
Unit L
Barrie, ON
L4N 8X1

Report Date: 2017/02/22
Report #: R4366149
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B731145

Received: 2017/02/14, 13:42

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Ema Gitej, Senior Project Manager

Email: EGitej@maxxam.ca

Phone# (905)817-5829

=====

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SOIL CORROSIVITY PACKAGE (SOIL)

Maxxam ID		DXK359	DXK359		
Sampling Date		2017/02/08 17:00	2017/02/08 17:00		
COC Number		59300	59300		
	UNITS	17-2 SA#2 10'-12'	17-2 SA#2 10'-12' Lab-Dup	RDL	QC Batch
Calculated Parameters					
Resistivity	ohm-cm	1700			4864606
Inorganics					
Soluble (20:1) Chloride (Cl)	ug/g	340		20	4867796
Conductivity	umho/cm	574	573	2	4869999
Available (CaCl2) pH	pH	8.01			4867824
Soluble (20:1) Sulphate (SO4)	ug/g	<20	<20	20	4867802
Subcontracted Analysis					
Oxidation-Reduction Potential	mV	+194	+195		4866035
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate					

Maxxam Job #: B731145
Report Date: 2017/02/22

Golder Associates Ltd
Client Project #: 1648346
Site Location: CULVERT-HWY 144
Sampler Initials: DM

TEST SUMMARY

Maxxam ID: DXK359
Sample ID: 17-2 SA#2 10'-12'
Matrix: Soil

Collected: 2017/02/08
Shipped:
Received: 2017/02/14

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4867796	N/A	2017/02/21	Deonarine Ramnarine
Conductivity	AT	4869999	N/A	2017/02/21	Tahir Anwar
pH CaCl2 EXTRACT	AT	4867824	2017/02/17	2017/02/17	Neil Dassanayake
Resistivity of Soil		4864606	2017/02/21	2017/02/21	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4867802	N/A	2017/02/21	Deonarine Ramnarine
Oxidation-Reduction Potential	PH	4866035	2017/02/16	2017/02/21	Bruce Reynolds

Maxxam ID: DXK359 Dup
Sample ID: 17-2 SA#2 10'-12'
Matrix: Soil

Collected: 2017/02/08
Shipped:
Received: 2017/02/14

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	4869999	N/A	2017/02/21	Tahir Anwar
Sulphate (20:1 Extract)	KONE/EC	4867802	N/A	2017/02/21	Deonarine Ramnarine
Oxidation-Reduction Potential	PH	4866035	2017/02/16		Bruce Reynolds

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	13.0°C
-----------	--------

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
4866035	EF	QC Standard	Oxidation-Reduction Potential	2017/02/21		+243	%	238 - 248
4866035	EF	Method Blank	Oxidation-Reduction Potential	2017/02/21	+99		mV	
4866035	EF	RPD [DXK359-01]	Oxidation-Reduction Potential		0.51		%	20
4867796	DRM	Matrix Spike	Soluble (20:1) Chloride (Cl)	2017/02/21		122	%	70 - 130
4867796	DRM	Spiked Blank	Soluble (20:1) Chloride (Cl)	2017/02/21		105	%	70 - 130
4867796	DRM	Method Blank	Soluble (20:1) Chloride (Cl)	2017/02/21	<20		ug/g	
4867796	DRM	RPD	Soluble (20:1) Chloride (Cl)	2017/02/21	NC		%	35
4867802	DRM	Matrix Spike [DXK359-01]	Soluble (20:1) Sulphate (SO4)	2017/02/21		117	%	70 - 130
4867802	DRM	Spiked Blank	Soluble (20:1) Sulphate (SO4)	2017/02/21		111	%	70 - 130
4867802	DRM	Method Blank	Soluble (20:1) Sulphate (SO4)	2017/02/21	<20		ug/g	
4867802	DRM	RPD [DXK359-01]	Soluble (20:1) Sulphate (SO4)	2017/02/21	NC		%	35
4867824	NYS	Spiked Blank	Available (CaCl2) pH	2017/02/17		99	%	97 - 103
4867824	NYS	RPD	Available (CaCl2) pH	2017/02/17	0.29		%	N/A
4869999	TA1	Spiked Blank	Conductivity	2017/02/21		100	%	90 - 110
4869999	TA1	Method Blank	Conductivity	2017/02/21	<2		umho/c	
4869999	TA1	RPD [DXK359-01]	Conductivity	2017/02/21	0.18		%	10

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).



Bruce Reynolds, Scientific Service Specialist, Sr



Ewa Pranjić, M.Sc., C.Chem, Scientific Specialist

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Your Project #: MB731145
Site#: CULVERT-HWY 144
Site Location: 1648346
Your C.O.C. #: B731145-M058-01-01

Attention: SUB CONTRACTOR

MAXXAM ANALYTICS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

Report Date: 2017/02/21
Report #: R2347949
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B711638

Received: 2017/02/17, 08:45

Sample Matrix: Soil
Samples Received: 1

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Moisture	1	2017/02/20	2017/02/21	BBY8SOP-00017	BCMOE BCLM Dec2000 m
Sulfide (AVS) (soil)	1	2017/02/20	2017/02/20	BBY6SOP-00006	SM 22 4500 S2- D m

Remarks:

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All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

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Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods. Results relate to samples tested.

This Certificate shall not be reproduced except in full, without the written approval of the laboratory.

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Letitia Prefontaine, B.Sc., Senior Project Manager
Email: LPrefontaine@maxxam.ca
Phone# (604)639-2616

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Maxxam Job #: B711638
Report Date: 2017/02/21

MAXXAM ANALYTICS
Client Project #: MB731145
Site Location: 1648346
Sampler Initials: DM

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		QO5030	QO5030		
Sampling Date		2017/02/08 17:00	2017/02/08 17:00		
COC Number		B731145-M058-01-01	B731145-M058-01-01		
	UNITS	17-2 SA#2 10'-12'	17-2 SA#2 10'-12' Lab-Dup	RDL	QC Batch
MISCELLANEOUS					
Sulphide	ug/g	0.92 (1)	0.60	0.50	8557157
RDL = Reportable Detection Limit Lab-Dup = Laboratory Initiated Duplicate (1) Sample arrived to laboratory past recommended hold time. Headspace in sample jar was noted at the time of extraction. Matrix spike exceeds acceptance limits due to matrix interference. Re-analysis yields similar results.					

Maxxam Job #: B711638
Report Date: 2017/02/21

MAXXAM ANALYTICS
Client Project #: MB731145
Site Location: 1648346
Sampler Initials: DM

PHYSICAL TESTING (SOIL)

Maxxam ID		Q05030		
Sampling Date		2017/02/08 17:00		
COC Number		B731145-M058-01-01		
	UNITS	17-2 SA#2 10'-12'	RDL	QC Batch
Physical Properties				
Moisture	%	19	0.30	8557397
RDL = Reportable Detection Limit				

Maxxam Job #: B711638
Report Date: 2017/02/21

MAXXAM ANALYTICS
Client Project #: MB731145
Site Location: 1648346
Sampler Initials: DM

TEST SUMMARY

Maxxam ID: QO5030
Sample ID: 17-2 SA#2 10'-12'
Matrix: Soil

Collected: 2017/02/08
Shipped:
Received: 2017/02/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL/BAL	8557397	2017/02/20	2017/02/21	Lolita Obusan
Sulfide (AVS) (soil)	SPEC/COL	8557157	2017/02/20	2017/02/20	Jamie Sun

Maxxam ID: QO5030 Dup
Sample ID: 17-2 SA#2 10'-12'
Matrix: Soil

Collected: 2017/02/08
Shipped:
Received: 2017/02/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulfide (AVS) (soil)	SPEC/COL	8557157	2017/02/20	2017/02/20	Jamie Sun

Maxxam Job #: B711638
Report Date: 2017/02/21

MAXXAM ANALYTICS
Client Project #: MB731145
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GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	1.7°C
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Results relate only to the items tested.

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QUALITY ASSURANCE REPORT

MAXXAM ANALYTICS
Client Project #: MB731145
Site Location: 1648346
Sampler Initials: DM

QC Batch	Parameter	Date	Matrix Spike		Spiked Blank		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
8557157	Sulphide	2017/02/20	65 (1)	75 - 125	101	75 - 125	<0.50	ug/g	NC	30
8557397	Moisture	2017/02/21					<0.30	%	1.2	20

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

(1) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.

Maxxam Job #: B711638
Report Date: 2017/02/21

MAXXAM ANALYTICS
Client Project #: MB731145
Site Location: 1648346
Sampler Initials: DM

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).



Rob Reinert, B.Sc., Scientific Specialist

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.



APPENDIX D

Non-Standard Special Provisions

WORKING SLAB - Item No.

Special Provision

1.0 SCOPE

This Special Provision covers the requirements for the supply and placement of a concrete working slab under structure foundations.

2.0 REFERENCES

This Special Provision refers to the following standards, specifications or publications:

Ontario Provincial Standard Specifications, Construction

OPSS 902 Excavating and Backfilling - Structures

3.0 DEFINITIONS - Not Used

4.0 DESIGN AND SUBMISSION REQUIREMENTS - Not Used

5.0 MATERIALS

Concrete for working slabs shall have a minimum 28 day strength of 20 MPa.

6.0 EQUIPMENT - Not Used

7.0 CONSTRUCTION

7.01 Excavation

Excavation for the working slab shall be according to OPSS 902.

7.02 Protection of Founding Soil

Following inspection and approval of the prepared subgrade, a working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade as specified in the Contract Documents.

7.03 Protection of Founding Bedrock

The surface of the footing founding rock shall be exposed, cleaned and any loose or fractured parts removed so that sound rock is exposed. The working slab shall be placed on the exposed cleaned sound founding rock surface as specified in the Contract Documents.

Thickness of the mass concrete pad shall depend on the slope and irregularities in the exposed founding rock surface. A nominal thickness and a footprint plan view area has been specified on the Contract Documents

7.04 Dewatering

Dewatering shall be carried out according to OPSS 902.

8.0 **QUALITY ASSURANCE - Not Used**

9.0 **MEASUREMENT FOR PAYMENT - Not Used**

10.0 **BASIS OF PAYMENT**

10.01 **Working Slab - Item**

Payment at the Contract price for the above tender item shall be full compensation for all labour, Equipment and Material to do the work.

DEWATERING FOR EXCAVATIONS – Item No.

Non-Standard Special Provision

Scope

The contractor shall be alerted that the soils at the Headwall Replacement site consist of water-bearing sand and gravel fill, sand, silty sand and silt. Foundation elements requiring construction below the groundwater level must be carried out in the dry. The excavation shall be kept stable during the work.

It should be noted that water levels within the area are known to fluctuate. As a result, it is recommended that excavation for the foundations or any other element be performed in mid to late summer.

Basis of Payment

Payment at the contract price for the above tender item shall be full compensation for all labour, equipment and materials required to do the work.

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