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REPORT ON

Foundation Investigation and Design Culvert Extension Highway 401 - Station 10+490 Kingston, Ontario G.W.P. 79-99-00

Submitted to:
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REPORT



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LIST OF ABBREVIATIONS AND SYMBOLS

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

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**FOUNDATION REPORT
CULVERT EXTENSION
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PART A

**FOUNDATION INVESTIGATION REPORT
CULVERT EXTENSION
HIGHWAY 401 – STATION 10+490
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by MMM Group Ltd. (MMM) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations associated with the detailed design of the Cataraqui River bridge replacement as well as a culvert extension and several overhead sign installations as part of the widening of Highway 401 between Gardiners Road and Highway 15.

This report presents the results of a foundation assessment conducted for the extension of the culvert located at Station 10+490 along Highway 401 in Kingston, Ontario as shown on Drawing 1. The purpose of this investigation was to assess the subsurface conditions at the location of the proposed culvert extension by borehole drilling and carrying out in-situ and laboratory testing on selected samples.

The terms of reference and scope of work for the foundation engineering services are outlined in MTO's Request for Proposal (RFP) for Assignment No. 4013-E-0027 dated March 2014, and in Golder's proposal for services related to this assignment submitted to MMM on May 6, 2014.



2.0 SITE DESCRIPTION

The location of the proposed culvert extension is along Highway 401, between Highway 15 and the Cataraqui River, in Kingston, Ontario. The culvert is located at Station 10+490, about 490 m east of the Cataraqui River, as shown on Drawing 1.

The existing structure is a 1.8 m wide by 1.2 m high, concrete rigid frame box culvert that is about 40 m in length. The culvert is in fair condition. The existing culvert profile is flat with an invert level of about Elevation 76.8 m at both the north and south ends, with the flow in the culvert from the north to the south. It is proposed that the culvert is to be extended at both the north and south ends to accommodate the new embankment width along Highway 401. The north extension will be about 6 m to 8 m in length and the south extension will be about 7 m to 9 m in length.

The existing pavement grade at the culvert location is about Elevation 79.7 m. Highway 401 is currently 2 lanes wide in each direction (i.e., a 4-lane highway) with no visual evidence of foundation-related settlement or distortion at the pavement surface at the time of the field investigation. The existing embankment slopes at the culvert location are about 3 m in height and are sloped from about 4 horizontal to 1 vertical (4H:1V) to 5H:1V. Based on visual observation at the time of the site investigation, the existing embankment slopes appear to be performing satisfactorily, with no evidence of settlement or instability.



3.0 INVESTIGATION PROCEDURES

The subsurface investigation for the proposed culvert extension was carried out between November 12 and 13, 2014 and March 26 and 31, 2015. During that time, five boreholes (numbered 15-201, 14-202, 14-203, 15-204, and 15-205) were advanced at the locations shown on Drawing 1. The boreholes were advanced as follows:

- Boreholes 15-201 and 15-205 were advanced at the north end of the culvert and 15-204 was advanced at the south end of the culvert using portable drilling equipment supplied and operated by Marathon Drilling Ltd. of Ottawa, Ontario. The boreholes were advanced to depths between about 1.8 m and 7.9 m, below the existing ground surface in the overburden.
- Boreholes 14-202 and 14-203 were advanced along the culvert alignment within the westbound and eastbound shoulders of Highway 401. The boreholes were advanced using a truck-mounted hollow-stem drill rig supplied and operated by Marathon Drilling Ltd. of Ottawa, Ontario. The boreholes were advanced to depths of about 3.3 m and 8.2 m, respectively, below the existing ground surface in the overburden. Borehole 14-202 was then cored about 3.3 m into the bedrock using NQ-size coring equipment.

Soil samples in the boreholes were obtained at vertical intervals of about 0.60 m to 1.52 m, using a 50 mm outer diameter split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures.

A standpipe piezometer was installed in Borehole 14-202 and a monitoring well was installed in Borehole 15-204 to monitor the groundwater level at the site. The installations consisted of either 19 mm (standpipe) or 32 mm (monitoring well) diameter rigid PVC pipe with a 1.5 m long slotted screen section, installed within silica sand backfill and sealed by a section of bentonite pellet backfill.

The boreholes were backfilled with bentonite pellets mixed with native soils in the overburden, and bentonite pellets in the bedrock. The site conditions were restored following completion of work.

The field work was supervised by a member of Golder's technical staff, who located the boreholes, supervised the drilling, sampling and in situ testing operations, logged the boreholes, and examined the soil and bedrock samples. The samples were identified in the field, placed in appropriate containers, labelled, and transported to Golder's laboratory facility in Ottawa for further examination. Index and classification tests consisting of grain size distributions, Atterberg limits, and water contents were carried out on selected soil samples at Golder's Mississauga and Ottawa laboratories. Unconfined compressive strength tests were carried out on selected rock core samples in Golder's Mississauga laboratory. All of the laboratory tests were carried out to MTO and/or ASTM standards as appropriate.

The borehole locations were determined by Golder in relation to existing site features. The ground surface elevations were also surveyed by Golder using a precision GPS survey unit. The boreholes locations, including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to Geodetic datum, are summarized in the following table and are shown on Drawing 1.



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Borehole Number	Borehole Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)
15-201	North end of culvert	4905053.6	309427.4	77.9
14-202	Westbound shoulder	4905039.1	309431.1	79.6
14-203	Eastbound shoulder	4905016.6	309439.9	79.7
15-204	South end of culvert	4905000.8	309445.5	77.5
15-205	North end of culvert	4905049.1	309430.6	77.8

Notes: 1) Northing and Easting coordinates shown are relative to the MTM NAD83 (Zone 9) coordinate system.
2) Ground surface elevations shown are relative to Geodetic Datum.



4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This area of Highway 401 lies within the southern portion of the physiographic region known as the Napanee Plain, as delineated in *The Physiography of Southern Ontario*¹.

The Napanee Plain is flat to undulating, and is characterized by relatively shallow soil deposits overlying bedrock. Geologic mapping² indicates that the bedrock within the southern portion of the area consists of both granitic rock and crystalline limestone. In many areas bedrock outcrops exist at ground surface, while deeper soil deposits (in the order of 10 m) are present in the northern and southern portion of the Plain, and within and adjacent to river valleys throughout the Plain.

The overburden soils within the Napanee Plain generally consist of glacial till, although alluvium is present in river and stream valleys and, in the southern portion of the Plain, low-lying areas are typically covered with deposits of stratified clay.

In particular, the study area lies within the lowland area surrounding the Cataraqui River. The Cataraqui River is characterized by a number of lakes joined by the river. This river flows southerly towards Kingston and is one of two major rivers in the area.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes put down as part of the current investigation, together with the results of related in-situ and laboratory testing are given on the Record of Borehole and Drillhole sheets contained in Appendix A. The results of geotechnical laboratory testing carried out as part of this investigation are also included in Figures B1 to B6 in Appendix B.

The interpreted stratigraphic conditions along the centreline of the culvert are shown on Drawing 1. The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic section 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.

In general, the subsurface conditions at the site consist of embankment fill overlying stiff to very stiff clayey silt, silty clay and clay, which is underlain by discontinuous layers of silty sand and glacial till. The soil deposits are underlain by granite bedrock.

A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Fill

The Highway 401 pavement structure was penetrated in the westbound shoulder at Borehole 14-202 and the eastbound shoulder at Borehole 14-203. At Borehole 14-202, the pavement structure at the shoulder consists of about 0.5 m of gravelly sand base course and 0.4 m of sand subbase course. At Borehole 14-203, the pavement structure at the shoulder consists of about 0.2 m of gravelly sand base course underlain by about 0.6 m of sand subbase course.

¹ Chapman, L.J. and D.F. Putnam. *The Physiography of Southern Ontario*. Ontario Geological Survey Special Volume 2, Third Edition, 1984. Accompanied by Map P.2715, Scale 1:600,000.

² Map 13-1965, Geological Survey of Canada, 1966.



The pavement structure at Boreholes 14-202 and 14-203 is underlain by embankment fill that extends to a depth of about 2.3 m below the existing ground surface (i.e., Elevations 77.3 m and 77.4 m, respectively). Fill was encountered at ground surface at Boreholes 15-201, 15-204, and 15-205 which were advanced at the north and south ends of the culvert, at the toe of the Highway 401 embankment. The fill at these locations extends to depths between about 0.6 to 1.8 m below the existing ground surface (i.e., between Elevations 76.0 m and 77.3 m).

The underlying fill is variable and consists of cohesive material (i.e., clayey silt, silty clay and clay) and granular material (i.e., sand to gravelling sand). Organic matter, wood fragments, and cobbles were also encountered within the fill.

The results of grain size distribution testing carried out on one sample of the granular embankment fill are shown on Figure B1 in Appendix B. The measured natural water content for the same sample was about 5 percent.

The results of grain size distribution testing carried out on a sample of the cohesive embankment fill are shown on Figure B2 in Appendix B. Atterberg limits tests carried out on one sample of the cohesive fill measured a plasticity index of about 46 percent and a liquid limit of about 79 percent. The results of the Atterberg limit test are shown on a plasticity chart on Figure B3 in Appendix B; these results indicate clay of high plasticity. The measured water contents of the clayey silt to clay fill typically ranged from about 22 to 35 percent.

The Standard Penetration Test (SPT) N values measured in the embankment fill range from 3 to 27 blows per 0.3 m of penetration, indicating a generally loose to compact relative density in the granular fill and a generally stiff to very stiff consistency in the clayey silt to clay fill.

4.2.2 Clayey Silt, Silty Clay and Clay

A deposit of clayey silt, silty clay and clay was encountered beneath the fill at all of the borehole locations, with the exception of Borehole 15-205 where no native overburden was encountered within the advancement depth. The clayey deposit was proven to depths ranging from about 2.8 m to 7.9 m below the existing ground surface (i.e., between Elevations 69.6 m and 76.6 m).

The measured SPT N values in the clayey deposit range from about 3 to 19 blows per 0.3 m of penetration, but more typically between 5 and 12 blows per 0.3 m of penetration. In-situ vane shear strength testing was carried out at Borehole 14-203 following lower SPT N values, where undrained shear strength of 86 and greater than 96 kPa were measured. The results of the in-situ testing in the clayey deposit therefore indicate a generally stiff to very stiff consistency.

The results of grain size distribution testing carried out on several samples of the clayey deposit are included on Figure B4 in Appendix B. Atterberg limits tests carried out on samples of the deposit gave plasticity index values ranging from 17 to 34 percent and liquid limit values ranging from about 35 to 64 percent; these results are presented on a plasticity chart on Figure B5 in Appendix B, indicating that the cohesive deposit consists of clayey silt to clay of low to high plasticity. The measured water contents of this deposit ranged from approximately 28 to 49 percent.

A thin discontinuous layer of silty sand was encountered above and below the silty clay deposit at Borehole 14-202.

4.2.3 Silt Till

A deposit of glacial till was encountered below the clayey silt in Borehole 14-203. The glacial till was not fully penetrated but was proven for a thickness of 0.3 m, to a depth of about 8.2 m below the existing ground surface (i.e., Elevation 71.5 m). The glacial till consists of a heterogeneous mixture of cobbles, boulders, and gravel in a matrix of silt with some clay.



The result of a grain size distribution testing carried out on one sample of the glacial till is included on Figure B6 in Appendix B.

4.2.4 Bedrock

Refusal to split-spoon sampler advancement was encountered in Boreholes 15-201 and 15-205; this refusal has been inferred to represent the bedrock surface. Bedrock was encountered beneath the silty clay and silty sand at Borehole 14-202 where it was cored for a depth about 3.3 m (i.e., Elevation 73.0).

The following table summarizes the bedrock surface depths and elevations encountered at the borehole locations. The bedrock surface elevation is variable within each proposed foundation area.

Borehole Number	Existing Ground Surface Elevation (m)	Depth to Bedrock (m)	Bedrock Surface Elevation (m)
15-201	77.9	2.8	75.1*
14-202	79.6	3.3	76.3
15-205	77.8	1.8	76.0*

Note: * Depth and elevation to bedrock inferred from refusal to augering and split-spoon penetration.

The bedrock encountered in the cored borehole consists of pink and brown granite bedrock. The bedrock is generally fresh, fine to medium grained, non-porous, and strong to very strong.

The Rock Quality Designation (RQD) values measured on the recovered bedrock core samples typically ranged from about 73 to 100 percent, indicating fair to excellent quality rock. The discontinuities observed in the rock core were associated with the joints, veins, faults and fractures of the bedrock.

Laboratory unconfined compressive strength testing was carried out on one selected specimen of the bedrock core. The results of that unconfined compressive strength test indicate a value of about 132 MPa, corresponding to very strong rock (CFEM, 2006).

4.3 Groundwater Conditions

The groundwater levels measured in the piezometers in Boreholes 14-202 and 15-204 are summarized in the table below:

Borehole	Ground Surface Elevation (m)	Water Level Depth (m)	Water Level Elevation (m)	Date
14-202	79.6	2.2	77.4	April 17, 2015
15-204	77.5	0.1	77.4	April 17, 2015

It should be noted that groundwater levels in the area are subject to fluctuations both seasonally and with precipitation events and they should be anticipated to be higher during and following wet periods.



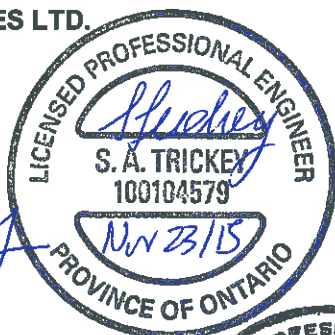
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5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Susan Trickey, P.Eng., and reviewed by Ms. Lisa Coyne, P.Eng., a geotechnical engineer and Principal with Golder. Mr. Fin Heffernan, P.Eng., the Designated MTO Foundations Contact for this assignment, conducted an independent quality review of this report.


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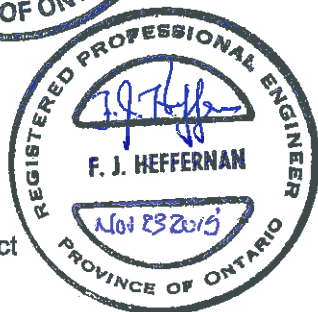

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PART B

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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides foundation design recommendations for the proposed extensions of the existing culvert at Station 10+490 along Highway 401, between Highway 15 and the Cataraqui River in Kingston, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes and drillholes advanced as close as practicable to the proposed extension locations. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives to carry out the detail design of the proposed foundations.

Where comments are made on construction, they are provided to highlight those aspects that could affect the detail design of the project, and for which special provisions 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 such interpretation may affect equipment selection, proposed construction methods, and scheduling.

The existing structure is a 1.8 m wide by 1.2 m high, concrete rigid frame box culvert that is about 40 m in length. The existing culvert is flat with an invert level of about Elevation 76.8 m at both the north and south ends, with the flow in the culvert from the north to the south. It is proposed that the culvert is to be extended at both the north and south ends to accommodate the new embankment width along Highway 401. The north extension will be about 6 m to 8 m in length and the south extension will be about 7 m to 9 m in length. The proposed invert level for the north and south extensions will also be maintained at about Elevation 76.8 m.

The existing culvert and proposed extension are shown on Drawing 1. The Highway 401 embankments will be widened at the culvert location to accommodate the additional lanes proposed for this area. The height of the new widened embankments will be up to about 3 m. It is understood that the grades of the existing Highway 401 eastbound and westbound lanes will remain the same.

6.2 Options for Culvert Extensions

The subsurface conditions at the culvert extension location consist of fill overlying stiff to very stiff clayey silt, silty clay and clay. The clayey deposit is underlain by silty sand and/or glacial till, underlain by granite bedrock.

Based on the subsurface conditions, only shallow foundation options have been considered for the culvert extensions. Deep foundations are not required or recommended as shallow foundations will provide sufficient bearing resistance and acceptable settlement performance for the proposed embankment widening geometry.

A summary of the advantages and disadvantages associated with each shallow foundation option for the culvert extensions is provided below, and a comparison of the alternative foundation options based on advantages, disadvantages, constructability and relative costs is provided in Table 1 following the text of this report.

- **Precast Concrete Box Culvert Extensions Founded on the Native Soils/Granular Pad on the Bedrock:**
Box culvert extensions could be considered for the culvert, founded on or within the native stiff to very stiff silty clay or bedrock. However, some limited bedrock excavation and removal could potentially be required for the north culvert extension, where the depth to bedrock is relatively shallow. It is expected that temporary protection systems and/or cofferdams would be required during excavation and construction. Precast culvert extensions would be preferred over cast-in-place culvert extensions for this option because it would likely be easier and quicker to install, and require less construction time and, therefore, potentially less disruption to traffic depending on the location of the protection system along Highway 401.



- **Cast-In-Place/Precast Rigid Frame Open Footing Culvert Extensions Founded on the Native Soils/Bedrock:** Rigid frame open footing culvert extensions could be considered for the culvert, founded on or within the native stiff to very stiff silty clay or bedrock. Given the limited thickness of the overburden at the north end of the culvert, the extension for this end could be founded directly on the granite bedrock without the need for bedrock removal. As above, it is expected that a temporary protection system and/or cofferdams would be required during excavation and construction. Cast-in-place culvert extensions would be preferred over the use of precast footings for the culvert extensions from a constructability perspective, as the footings for the north extension could be formed and poured directly on the bedrock surface without the need for bedrock removal or a granular bedding layer. A precast open footing culvert supported on cast-in-place variable height footings could also be considered as a viable option for this site.

From a foundation perspective either concrete box culvert extensions or rigid frame open (RFO) footing concrete culvert extensions founded on the overburden or bedrock are considered acceptable. However, the preferred option from a foundation perspective is a box culvert which would match the existing culvert foundations. This type of culvert would be easier to design and construct from a structural perspective (i.e., the joints between the existing culvert and the culvert extensions would be less difficult to design than joints between the existing box culvert and rigid frame open footing culvert foundations).

Recommendations for both concrete box culvert and RFO footing concrete culvert extensions are presented in the following sections.

6.3 Culvert Foundation Recommendations

6.3.1 Precast Concrete Box Culvert Extensions

6.3.1.1 Founding Level and Bedding

It is not necessary to found the box culvert extensions at the standard depth for frost protection purposes as box structures are tolerant of small magnitude movements related to freeze-thaw cycles should these occur. The box culvert extensions should, however, be founded below any existing fill and surficial organic materials.

The bedding and/or leveling pad requirements for a box culvert replacement should be in accordance with Ontario Provincial Standard Specification (OPSS) 422 (*Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut*) for concrete box culverts. It is recommended that the box culvert segments be placed on a minimum thickness of 300 mm of granular bedding material meeting OPSS.PROV 1010 (*Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material*) Granular A or Granular B Type II.

The table below summarizes the recommended founding levels for the culvert extensions, assuming a channel substrate thickness of 250 mm, a base slab thickness of 250 mm and bedding thickness as described above. Based on these elevations, the box culvert extensions will generally be founded on the stiff to very stiff silty clay. However, a portion of the north extension may be founded directly on the bedrock, or on a granular pad on the bedrock.

Invert Location	Existing Invert Elevation (m)	Box Culvert Founding Elevation (m)	Subgrade Level (m)
North End	76.8	76.3	76.0
South End	76.8	76.3	76.0



The depth to the bedrock surface at the location of the north culvert extension could be variable, particularly at the south limit of the extension, immediately adjacent to the existing north end of the culvert. Some minimal bedrock removal may be required in this area to permit placement of a granular bedding layer below the pre-cast box culvert segment(s). Alternatively, consideration may be given in the design stage to reducing the thickness of the substrate level so that the culvert founding elevation is increased, to minimize the potential for bedrock subexcavation. In addition, consideration may be given to reducing the thickness of the granular bedding in this local area to approximately 150 mm to minimize rock excavation requirements.

Where the subgrade consists of silty clay, the subgrade will be susceptible to disturbance and degradation on exposure to water and construction traffic. As an alternative to the placement of a minimum 300 mm thick layer of Granular A, a 100 mm thick concrete working slab could be placed on the subgrade within the culvert footprint, to protect the subgrade from such degradation. In this case, a 75 mm thick layer of OPSS.PROV 1010 Granular A or concrete fine aggregate meeting the gradation requirements set out in OPSS.PROV 1002 (*Material Specification for Aggregates - Concrete*) should be placed on top of the concrete mat to provide a "levelling pad" for the box culvert extensions. The working slab should be placed within four hours after inspection and approval of the subgrade.

The footing subgrade should be inspected in accordance with OPSS 902 (*Construction Specification for Excavating and Backfilling – Structures*). Further discussion regarding subgrade preparation and protection is provided in Section 6.7.3.

6.3.1.2 Geotechnical Resistances

For box culvert extensions founded at the elevations provided in Section 6.3.1.1 within the stiff to very stiff silty clay a factored geotechnical resistance at Ultimate Limit States (ULS) of 250 kPa and a geotechnical resistance at Serviceability Limit States (SLS) for 25 mm of settlement of 175 kPa may be used for design purposes. These values are based on the thicker clayey deposit at the south culvert extension location; the geotechnical resistance values and settlement performance at the north extension will likely be higher based on the relatively limited thickness of clayey soil, but the recommendations have been maintained similar to those at the south extension to account for potential variations in the thickness of the deposit due to variations in the bedrock surface.

Where the subgrade at founding level changes from bedrock to overburden (i.e., potentially at the southern extent of the north culvert extension), differential settlement could occur at this transition due to the different settlement properties of these materials. However, the differential settlement should be minimal (i.e., less than about 15 mm).

These 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 6.7.4 of the *Canadian Highway Bridge Design Code (CHBDC 2006)* and its *Commentary*.

The recommended resistances are dependent on the box culvert extension spans and applied loads; the geotechnical resistances should, therefore, be reviewed if the culvert span or founding elevation differs from that given above.

6.3.2 Cast-in-Place/Precast Rigid Frame Open Footing Culvert Extensions

6.3.2.1 Founding Level and Frost Protection Requirements

Strip footings for open footing culvert extensions should be founded on the silty clay for the south culvert extension and on the granite bedrock for the north culvert extension.



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As per Ontario Provincial Standard Drawing (OPSD) 3090.101 (*Foundation Frost Depths for Southern Ontario*) frost penetration depth in Kingston is 1.5 m. Therefore, the extensions should be provided with a minimum of 1.5 m of earth cover below the lowest surrounding grade to provide adequate protection against frost penetration. However, this requirement can be waived or reduced provided there is year round water flow/ice cover within the culvert of sufficient depth or where the founding level is on the bedrock (i.e., the bedrock at this site does not appear to contain any seams of frost susceptible soil).

In addition, the footings should extend below any existing fill and organic materials, where present. The table below summarizes the recommended founding levels for the culvert.

Invert Location	Proposed Invert Elevation (m)	Open Footing Culvert Founding Elevation (m)
North End	76.8	75.1/76.0*
South End	76.8	75.3

Note: *Founding levels based on the inferred depths to the bedrock surface.

If the bedrock is encountered at greater depth than indicated above for the north culvert extension, the footings could either be stepped down to found on the bedrock (where encountered) or founded within the very stiff silty clay.

The footing subgrade should be inspected in accordance with OPSS 902 (*Construction Specification for Excavating and Backfilling – Structures*). Following inspection and approval of the subgrade, it is recommended that a concrete working slab be placed to protect the subgrade from degradation during the preparation works for the concrete culvert extensions; further discussion regarding subgrade preparation and protection is provided in Section 6.7.3.

6.3.2.2 Geotechnical Resistance

Spread footings placed on the properly prepared stiff to very stiff silty clay deposit or on the bedrock, at the founding elevations identified above, should be designed based on the factored geotechnical resistances at ULS and geotechnical resistances at SLS given below. In the case of foundations on the bedrock, SLS resistances do not apply to the design of footings on the bedrock since the SLS resistance for 25 mm of settlement is greater than the factored axial geotechnical resistance at ULS. The values provided below are based on a footing width of up to about 1.5 m.

Foundation Location	Factored Geotechnical Resistance at ULS	Geotechnical Resistance at SLS*
Footings on silty clay – south or north end	250 kPa	175 kPa
Footings on bedrock – north end	5 MPa	Not applicable

Note: * For 25 mm of settlement



Where the subgrade at founding level changes from bedrock to overburden (i.e., potentially at the north culvert extension, if bedrock is deeper than expected), differential settlement could occur at this transition due to the different settlement properties of these materials. However, the differential settlement should be minimal (i.e., less than about 15 mm).

These 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 6.7.4 of the *CHBDC* and its *Commentary*.

The recommended resistances are dependent on the footing size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the footing size or founding levels differs from that given above.

6.3.3 Settlement

It is understood that the widening of the existing Highway 401 embankments at the culvert extension locations will require the placement of about 3 m of new fill in order to match the existing highway grade. For this thickness and width of fill placement, the total and differential culvert settlements should be minimal (i.e., less than about 25 and 15 mm, respectively). Most of this settlement will consist of recompression of the clayey silt, silty clay, and clay and will occur during construction.

6.3.4 Resistance to Lateral Forces/Sliding Resistance

The resistance to lateral forces/sliding resistances for the culvert extensions should be calculated in accordance with Section 6.7.5 of the *CHBDC*.

If box culvert extensions are used, the extensions would be constructed on a granular pad on the stiff to very stiff silty clay or bedrock. For this case the following parameters should be used:

Interface and Loading Condition	Parameter
Concrete – Granular A pad: short or long term loading	Effective interface friction angle = 33°
Granular A pad – clay subgrade: short term loading	Undrained adhesion = 65 kPa
Granular A pad – clay subgrade: long term loading	Effective interface friction angle = 25°

If rigid frame open footing culvert extensions are used, the footings would be constructed on a concrete working slab over the native clayey deposit (south extension) or directly on the bedrock surface (north extension). For this case the following parameters should be used:

Interface and Loading Condition	Parameter
Concrete footing – concrete working slab: short or long term loading	Effective interface friction angle = 30°
Concrete working slab – clay subgrade: short term loading	Undrained adhesion = 65 kPa
Concrete working slab – clay subgrade: long term loading	Effective interface friction angle = 25°
Concrete – bedrock: short or long term loading	Effective interface friction angle = 35°



These values are unfactored; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistances.

6.4 Culvert Backfill and Erosion Protection

Backfill, cover and construction of the frost taper (backfill transition) for concrete culverts should be completed in accordance with OPSS 422 (*Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut*) or OPSS 902 (*Construction Specification for Excavating and Backfilling - Structures*) as well as OPSD 803.010 (*Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m*) or OPSD 803.031 (*Frost Treatment – Pipe Culverts Frost Penetration Line Between Top of Pipe and Bedding Grade*), as appropriate.

Backfill to culvert walls should consist of granular fill meeting the requirements of OPSS.PROV 1010 Granular A or Granular B Type II, but with less than 5 per cent passing the No. 200 sieve. The backfill should be placed and compacted in accordance with OPSS.PROV 501 (*Construction Specification for Compacting*). The fill depth during placement should be maintained equal on both sides of the culvert walls, with one side not exceeding the other by more than 500 mm. The culvert extensions should be designed for the full overburden pressure and live load assuming that the embankment fill has a unit weight of 22 kN/m³ for Granular A and 21 kN/m³ for Granular B Type II or select earth fill above and/or surrounding the culvert. Consideration could also be given to constructing head walls at the inlet and outlet of the culvert.

To prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal should be provided at the upstream end of the culvert extension. If clay seals are adopted, the clay material should meet the requirements of OPSS.PROV 1205 (*Material Specification for Clay Seal*). The clay seals should have a thickness of 1 m, and the seal should extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the culvert inlet/outlet openings, and a minimum vertical height equivalent to the maximum 100 year water level including treatment of the adjacent side slopes. Alternatively, a clay blanket may be constructed that extends upstream a distance equal to three times the culvert height, extending along the adjacent side slopes to a height of two times the culvert height or the high water level, whichever is higher. If a cast-in-place concrete cut-off wall is adopted it should extend the full width of the culvert. The cut-off walls should be earth formed within trenches cut for their construction or precast and backfilled with compactable clay to maintain intimate contact between the concrete and the native low permeability soils.

If the flow velocities are sufficiently high, a provision should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert inlet and outlet. The requirements for and design of erosion protection measures for the culvert inlet should be assessed by the hydraulic design engineer. As a minimum, rip-rap treatment for the culvert outlet should be consistent with the standard Treatment Type A presented in OPSD 810.010 (*General Rip-Rap Layout for Sewer and Culvert Outlets*), with the rip-rap placed up to the toe of slope level, in combination with the cut-off measures noted above. Similarly, rip-rap should be provided over the full extent of the clay blanket if adopted, including the drain side slopes and embankment fill slope adjacent to the culvert.



6.5 Lateral Earth Pressures for Design

The lateral earth pressures acting on the culvert walls will depend on the type and method of placement of the backfill materials, the nature of the soils behind the backfill, the magnitude of the surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls. Seismic (earthquake) loading must also be taken into account in the design.

The following recommendations are made concerning the design of the culvert walls. These design recommendations and parameters assume level backfill and ground surface behind the culvert walls. Where there is sloping ground behind the culvert 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 Granular A or Granular B Type II but with less than 5 percent passing the No. 200 sieve should be used as backfill behind the culvert walls. Longitudinal drains and weep holes should be installed as necessary to provide positive drainage of the granular backfill. Other aspects of the culvert wall granular backfill requirements with respect to subdrains and frost taper should be in accordance with OPSS 3101.150 (*Walls, Abutment, Backfill, Minimum Granular Requirement*) and 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 culvert walls, in accordance with CHBDC Section 6.9.3 and Figure 6.6. Compaction equipment should be used in accordance with OPSS.PROV 501 (*Construction Specification for Compacting*). Other surcharge loadings should be accounted for in the design as required.
- The granular fill may be placed either in a zone with the width equal to at least 1.5 m behind the back of the culvert walls (see Case (a) in Figure C6.20(a) of the *Commentary* to the CHBDC), or 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 (see Case (b) in Figure C6.20(b) of the *Commentary* to the CHBDC).
- For Case (a), the pressures are based on the existing embankment fill and the existing overburden soils and the following parameters (unfactored) may be used:

	Existing Fill
Soil unit weight	20 kN/m ³
Coefficients of static lateral earth pressure: At rest, K_0	0.50

- For Case (b), where the pressures are based on OPSS.PROV 1010 Granular A or Granular B Type II fill behind the culvert wall, the following parameters (unfactored) may be assumed:

	Granular A	Granular B Type II
Soil unit weight:	22 kN/m ³	21 kN/m ³
Coefficients of static lateral earth pressure: At rest, K_0	0.43	0.43



Because the culvert walls do not allow lateral yielding, at-rest earth pressures should be assumed for the geotechnical design.

6.5.1 Seismic Considerations

Seismic (earthquake) loading should be assessed in the design in accordance with Section 4.6.4 of *CHBDC*, as significant seismic loading would result in increased lateral earth pressures acting on the culvert walls. The culvert walls should be designed to withstand the combined lateral loading for the appropriate static pressure conditions given above, plus the applicable earthquake-induced dynamic earth pressure. The earthquake-induced dynamic pressure distribution is a linear distribution with maximum pressure at the top of the culvert 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:

$$P = K_o \gamma d + (K_{AE} - K_o) \gamma (H - d)$$

Where:

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

According to Table C4.2 of the *Commentary* to the *CHBDC*, this site is located in Seismic Zone 2, and the site-specific zonal acceleration ratio for the Kingston area is 0.1 which is also applicable for the culvert extension site. The seismic lateral earth pressure coefficients given below have therefore, been derived based on a design zonal acceleration ratio of $A = 0.1$.

In accordance with Sections 4.6.4 and C.4.6.4 of the *CHBDC* and its *Commentary*, for structures which do not allow lateral yielding (i.e., culvert walls), the horizontal seismic coefficient, k_h , used in the calculation of the seismic active pressure coefficient is taken as 1.5 times the zonal acceleration ratio (i.e., $k_h = 0.15$).

The following seismic active pressure coefficients (K_{AE}) for the two backfill cases (Case A and Case B) may be used in design. These values include the effect of wall friction and assume that the back of the culvert wall is vertical and the ground surface behind the culvert wall is essentially flat.

Seismic Active Pressure Coefficients, K_{AE}

	Case (a)	Case (b)	
	Earth Fill	Granular A	Granular B Type II
Non-Yielding Wall	0.46 ¹	0.38 ¹	0.38 ¹

Note: ¹ The CHBDC seismic K_{AE} values reported above include the effect of wall friction ($\delta = \phi'/2$) and are less than the static values of K_o for the very low zonal acceleration ratio for this site. As such, for non-yielding culvert walls only static earth pressures need to be considered for this low seismicity ($A = 0.1$) location.



6.6 Embankment Construction and Stability

The embankment widenings at the location of the culvert extensions will be up to about 3 m in height relative to the existing ground surfaces and sloped between about 2H:1V and 6H:1V. The subsurface conditions at the extension locations, following the removal of any existing fill will consist of stiff to very stiff clayey soils, thin discontinuous layers of silty sand and glacial till, underlain by granite bedrock.

Any fill, organic matter and softened/loosened soils should be stripped from below the embankment areas. Within the immediate area of the culverts, proof rolling of the subgrade soils is not recommended since the soils will be wet and sensitive to disturbance. Travelling over the subgrade soils should be minimized to limit the disturbance.

The embankment fill for the widening areas at the culvert extensions should be placed and compacted in accordance with OPSS.PROV 206 (*Constuction Specification for Grading*) and OPSS.PROV 501 (*Construction Specification for Compacting*). Benching of the existing embankment side slopes should be carried out to “key in” the new fill materials for the widening, in accordance with OPSD 208.010 (*Benching of Earth Slopes*). Commonly in embankment widening construction, the fill material cut from the existing embankment side slope for creation of these benches is re-used for the embankment widening below/adjacent to each bench area. Additional fill for construction of the embankment widening above the level of the original ground surface (i.e., above the groundwater level) could consist of clean earth fill, granular fill or rock fill.

If earth fill or granular fill is used, placement of topsoil and seeding or pegged sod is recommended to reduce surface water erosion on the widened embankment side slopes, in accordance with OPSS 802 (*Construction Specification for Topsoil*), OPSS 803 (*Construction Specification for Sodding*), and/or OPSS.PROV 804 (*Construction Specification for Seed and Cover*).

For the soil conditions at the culvert extensions and the low embankment heights founded on the very stiff silty clay, the embankment will have an adequate factor of safety against both static and seismic slope instability (i.e., greater than 1.3 under static conditions, and greater than 1.1 under seismic conditions). The results of the stability analyses are provided on Figures 1 and 2.

Settlement of the embankments will occur as a result of compression of the new embankment fill itself as well as consolidation of the clayey soils on which the embankments will be founded.

Provided that the embankment material consists of Select Subgrade Material (SSM) or clean earth fill, the settlement of the embankment fill itself is expected to be less than 25 mm. The use of granular fill for the new embankment construction would reduce this magnitude of post-construction settlement (likely to less than half that value) since the majority of settlement of these fills will occur during construction.

Where rock fill is used, settlement of the rock fill itself will depend on the type of rock and on the method and sequence of placement and compaction of the fill. Assuming that the rock fill is placed in accordance with the requirements outlined in the OPSS.PROV 206 (*Construction Specification for Grading*), the settlement of the rock fill in embankments is estimated to be about 1 percent of the embankment height and it is anticipated that the majority of this settlement will occur during the first year following construction.



Some settlement of the embankment subgrade can be expected due to compression of the clayey deposit. These settlements will be limited since the stress increase in the underlying clay soils will be less than the preconsolidation pressure (i.e., the amount of current overconsolidation). The overall settlement due to compression of the clay soils should not exceed 25 mm and would be expected to occur within 3 months of embankment construction.

6.7 Construction Considerations

6.7.1 Groundwater and Surface Water Control

Control of the surface water and groundwater will be necessary for the construction of the culvert extensions, to allow excavation and foundation construction to be carried out in dry conditions.

Some groundwater inflow into the excavations should be expected, although this is expected to be limited due to the clayey nature of the subsoils. It should be possible to handle the groundwater inflow by pumping from well filtered sumps established in the floor of the excavations.

Depending on the creek flow at the time of construction, the surface water flow could be passed through the culvert extension area by means of a temporary pipe, or diverted by pumping from behind a temporary cofferdam. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the clayey subgrade soils; further discussion on this aspect is provided in Section 6.7.3

6.7.2 Excavations and Temporary Roadway Protection

Temporary excavations for the culvert extensions will be made through the existing fill, stiff to very stiff clayey deposit and, potentially, thin layer(s) of silty sand. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. The existing fill and clayey silt to clay would be classified as Type 3 soil, based on the OHSA. According to OHSA, excavations that extend to, or into, Type 3 soils should be made with side slopes no steeper than 1H:1V. The silty sand layer below the water table (if encountered) would be classified as Type 4 soil, based on OSHA and excavations in these materials should be sloped no steeper than 3H:1V.

If the above open cut excavation side slopes cannot be accommodated, then a protection system (i.e., temporary excavation shoring) will be required. Where shoring is required, the support system should be designed and constructed in accordance with OPSS.PROV 539 (*Construction Specification for Temporary Protection Systems*). The lateral movement of the temporary protection system should meet Performance Level 2 as specified in OPSS.PROV 539, provided that any utilities that may be present in the area can tolerate this magnitude of deformation.

A conventional shoring system for these conditions would consist of soldier piling and lagging or interlocking steel sheet piling supported against lateral movement using walers, tie backs (into the underlying bedrock) and/or internal struts/braces. The design of that system will be the responsibility of the contractor, and it must take into account the earth pressure loadings and any surcharge loadings from adjacent embankment side slopes and temporary construction conditions (construction equipment, stockpiling, etc.) as applicable.



6.7.3 Subgrade Protection

All fill, organics and soft or loose soils should be removed from below the proposed founding elevations and wasted or reused as landscaping fill, as required. Subgrade preparation should be performed and monitored in accordance with OPSS 902 (*Construction Specification For Excavating and Backfilling – Structures*). The cleaned excavation base should be inspected prior to pouring the footings for the rigid frame open footing culvert extensions or placing granular bedding for the box culvert extensions.

Where the subgrade is formed in the native clayey soils, this soil will be susceptible to softening and disturbance due to construction activities and ponded water. It is recommended that a minimum 300 mm thick layer of OPSS.PROV 1010 Granular A be placed below the base slab on the subgrade to form a bedding layer for the box culvert segments, and to limit the degradation of the clay subgrade. The bedding should be placed within four hours after inspection and approval of the subgrade to limit such degradation.

As an alternative to the placement of a minimum 300 mm thick layer of Granular A for box culvert extensions, a 100 mm thick concrete working slab could be placed on the subgrade within the culvert footprint, to protect the subgrade from such degradation. In this case, a 75 mm thick layer of OPSS.PROV 1010 Granular A or concrete fine aggregate meeting the gradation requirements set out in OPSS.PROV 1002 should be placed on top of the concrete mat to provide a “levelling pad” for the box culvert replacement. The working slab should be placed within four hours after inspection and approval of the subgrade. A sample NSSP for the concrete working slab is provided in Appendix D.

The clayey subgrade for the rigid frame open footing culvert extension option will also be susceptible to disturbance and degradation on exposure to water and construction traffic. It is recommended that a 100 mm thick concrete working slab be placed within four hours following inspection and approval of the subgrade, to protect the subgrade from softening.

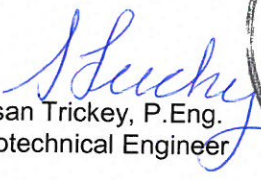


**FOUNDATION REPORT
CULVERT EXTENSION
HIGHWAY 401 - STATION 10+490, KINGSTON, ONTARIO**


7.0 CLOSURE

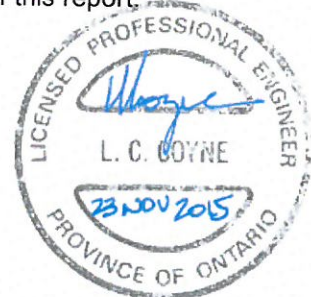
This Foundation Design Report was prepared by Ms. Susan Trickey, P.Eng., and reviewed by Ms. Lisa Coyne, P.Eng., a geotechnical engineer and Principal with Golder. Mr. Fin Heffernan, P.Eng., the Designated MTO Foundations Contact for this assignment, conducted an independent quality review of this report.


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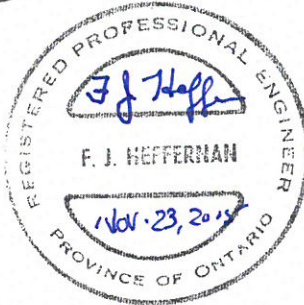

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LIST OF SYMBOLS

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	



**Table 1
Comparison of Foundation Alternatives
G.W.P. 79-99-00**

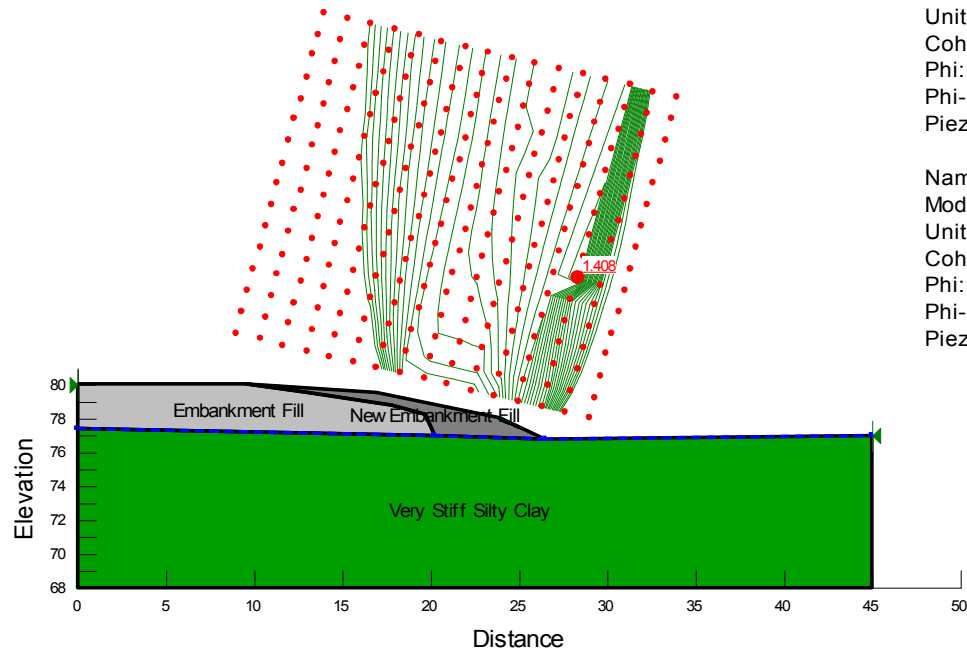
Foundation Option	Feasibility	Advantages	Disadvantages	Constructability	Relative Costs
Precast Box Culvert Extensions founded on the native soils/granular pad on the bedrock	<ul style="list-style-type: none">Feasible – preferred option	<ul style="list-style-type: none">Matches existing foundation typeShallower excavation depthsPrecast sections would be quicker and easier to install	<ul style="list-style-type: none">Could require rock excavation at the north extensionGroundwater control and a temporary protection system may be required	<ul style="list-style-type: none">Conventional excavation and construction techniques and temporary protection system	<ul style="list-style-type: none">Low cost
Cast-In-Place Box Culvert Extensions founded on the native soils/granular pad on the bedrock	<ul style="list-style-type: none">Feasible	<ul style="list-style-type: none">Matches existing foundation typeShallower excavation depths	<ul style="list-style-type: none">Could require rock excavation at the north extensionGroundwater control and a temporary protection system may be requiredCast-In-Place extensions would take longer to install	<ul style="list-style-type: none">Conventional excavation and construction techniques and temporary protection system	<ul style="list-style-type: none">Moderate cost
Precast Rigid Frame Open Footing Culvert Extensions founded on the native soils/bedrock	<ul style="list-style-type: none">Feasible	<ul style="list-style-type: none">Desirable option for culvert flowFootings could be founded on the bedrock for the north extension	<ul style="list-style-type: none">Does not match existing foundation typeDeeper excavation depthsGroundwater control and a temporary protection system may be required	<ul style="list-style-type: none">Conventional excavation and construction techniques and temporary protection system	<ul style="list-style-type: none">Moderate cost
Cast-In-Place Rigid Frame Open Footing Culvert Extensions founded on the native soils/bedrock	<ul style="list-style-type: none">Feasible	<ul style="list-style-type: none">Footings could be poured directly on the bedrock for the north extensionDesirable option for culvert flow	<ul style="list-style-type: none">Does not match existing foundation typeDeeper excavation depthsGroundwater control and a temporary protection system may be requiredCast-In-Place extensions would take longer to install	<ul style="list-style-type: none">Conventional excavation and construction techniques and temporary protection system	<ul style="list-style-type: none">Higher cost
Precast Rigid Frame Open Footing Culvert Extensions with variable height Cast-In-Place Footings founded on the native soils/bedrock	<ul style="list-style-type: none">Feasible	<ul style="list-style-type: none">Footings could be poured directly on the bedrock for the north extensionDesirable option for culvert flow	<ul style="list-style-type: none">Does not match existing foundation typeDeeper excavation depthsGroundwater control and a temporary protection system may be required	<ul style="list-style-type: none">Conventional excavation and construction techniques and temporary protection system	<ul style="list-style-type: none">Moderate cost

Project Number: 1403255-003
 Title: Culvert Extension - Highway 401 - Station 10+490
 File Name: 1403255 Culvert Slope Stability - Static.gsz
 Method: Morgenstern-Price
 PWP Conditions Source: Piezometric Line
 Horz Seismic Load: 0

Name: Embankment Fill
 Model: Mohr-Coulomb
 Unit Weight: 21.5 kN/m³
 Cohesion: 0 kPa
 Phi: 28 °
 Phi-B: 0 °
 Piezometric Line: 1

Name: New Embankment Fill
 Model: Mohr-Coulomb
 Unit Weight: 21.5 kN/m³
 Cohesion: 0 kPa
 Phi: 32 °
 Phi-B: 0 °
 Piezometric Line: 1

Name: Very Stiff Silty Clay
 Model: Mohr-Coulomb
 Unit Weight: 18.5 kN/m³
 Cohesion: 5 kPa
 Phi: 35 °
 Phi-B: 0 °
 Piezometric Line: 1



Directory: N:\Active\2014\1121 - Geotechnical\1403255 MMM Hwy 401 Cataragui River Bridge Kingston\Foundations\6 - Reports\4 - Culvert\

Figure 1

REV. No.	SCALE AS SHOWN
DESIGN	SAT
CADD	
CHECK	LOC
REVIEW	FJH
PROJECT No.	1403255-003

TITLE

STATIC SLOPE STABILITY ANALYSIS

PROJECT

CULVERT EXTENSION
 HIGHWAY 401 - STATION 10+490
 KINGSTON, ONTARIO

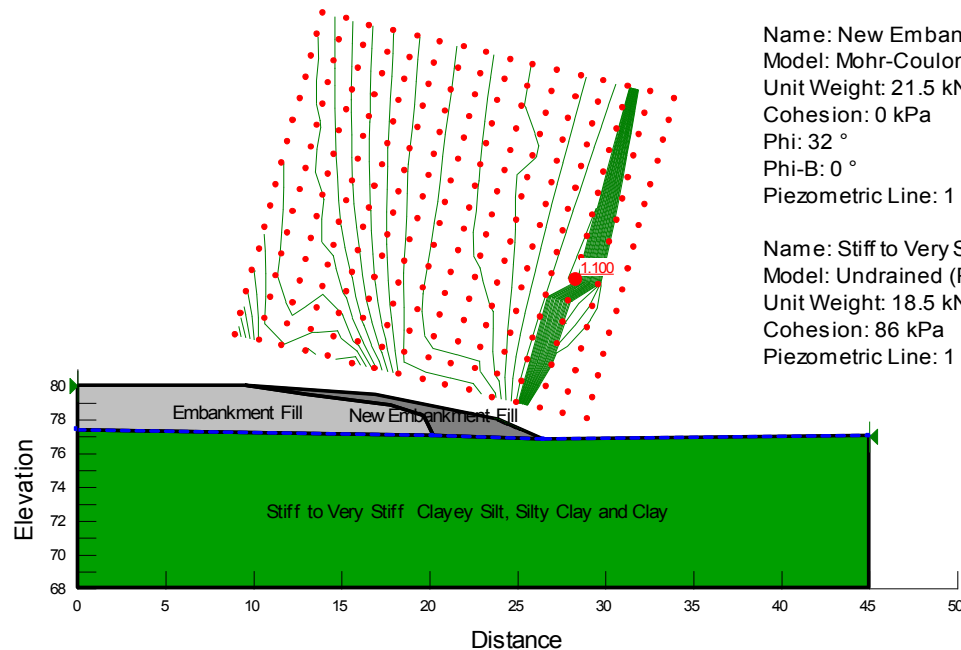


Project Number: 1403255-003
 Title: Culvert Extension - Highway 401 - Station 10+490
 File Name: 1403255 Culvert Slope Stability - Seismic.gsz
 Method: Morgenstern-Price
 PWP Conditions Source: Piezometric Line
 Horz Seismic Load: 0.1

Name: Embankment Fill
 Model: Mohr-Coulomb
 Unit Weight: 21.5 kN/m³
 Cohesion: 0 kPa
 Phi: 28 °
 Phi-B: 0 °
 Piezometric Line: 1

Name: New Embankment Fill
 Model: Mohr-Coulomb
 Unit Weight: 21.5 kN/m³
 Cohesion: 0 kPa
 Phi: 32 °
 Phi-B: 0 °
 Piezometric Line: 1

Name: Stiff to Very Stiff Clayey Silt, Silty Clay and Clay
 Model: Undrained (Phi=0)
 Unit Weight: 18.5 kN/m³
 Cohesion: 86 kPa
 Piezometric Line: 1



Directory: N:\Active\2014\1121 - Geotechnical\1403255 MMM Hwy 401 Cataraqui River Bridge Kingston\Foundations\6 - Reports\4 - Culvert\

Figure 2

PROJECT No.	1403255-003
FILE No.	
REV. 0	SCALE AS SHOWN
DESIGN	SAT 10/21/2015
CADD	
CHECK	LOC 10/21/2015
REVIEW	FJH 10/21/2015

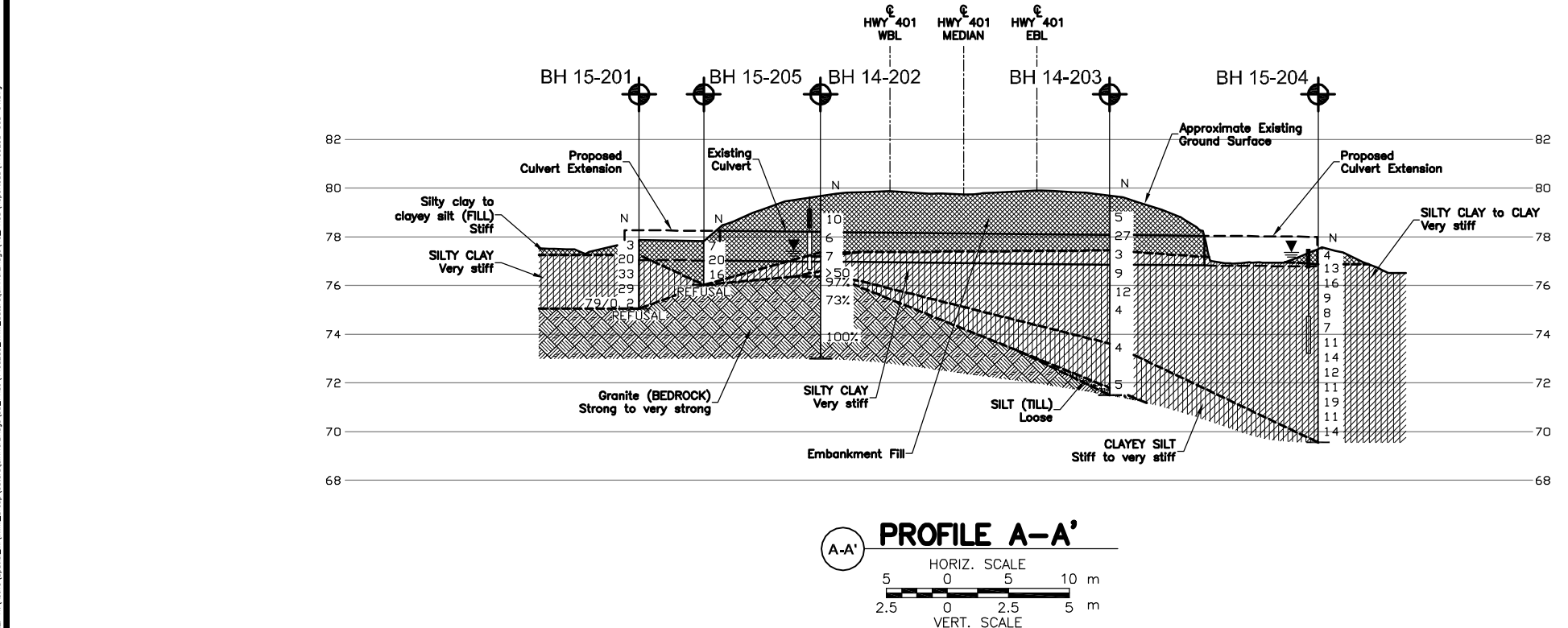
TITLE

SEISMIC SLOPE STABILITY ANALYSIS

PROJECT

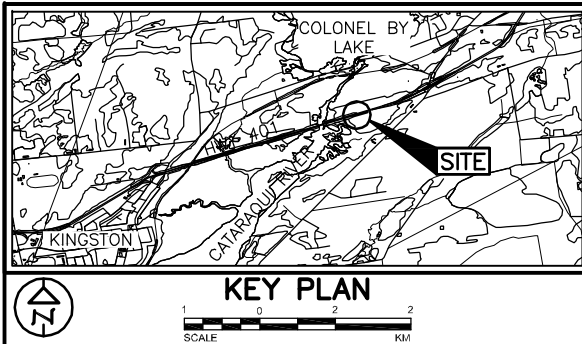
CULVERT EXTENSION
 HIGHWAY 401 - STATION 10+490
 KINGSTON, ONTARIO









CONT No.
WP No. 79-99-00

CULVERT EXTENSION AT STATION 10+490
HIGHWAY 401
BOREHOLE LOCATIONS AND SOIL STRATA



LEGEND

	Borehole – Current Investigation
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
	WL in piezometer
100%	Total Core Recovery (REC)
	Seal
	Piezometer

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
15-201	77.9	4905053.6	309427.4
14-202	79.6	4905039.1	309431.1
14-203	79.7	4905016.6	309439.9
15-204	77.5	4905000.8	309445.5
15-205	77.8	4905049.1	309430.6



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 Contract Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

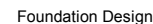
Base plans provided in digital format by MMM Group Limited, drawing file no. 3414034 XN1.dwg, received July 11, 2015.

NO.	DATE	BY	REVISION		
Geocres No. 31C-235					
HWY. 401		PROJECT NO. 1403255-003		DIST. Eastern	
SUBM'D. WAM		CHKD. WAM	DATE: 11/24/2015		SITE: 7-70
DRAWN: JM		CHKD. MJK	APPD. FJH		DWG. 1



APPENDIX A

Record of Borehole/Drillhole Sheets

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMM\GROUP\CATARAQUIR\BRIDGE\02_DATA\GINT\1403255.GPJ GAL-GTA.GDT 10/21/15 JM

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

PROJECT 1403255		RECORD OF BOREHOLE No 14-202		SHEET 1 OF 2		METRIC											
G.W.P. 79-99-00		LOCATION N 4905039.1 ; E 309431.1		ORIGINATED BY DM													
DIST Eastern HWY 401		BOREHOLE TYPE Power Auger 200 mm Diam. (Hollow Stem)		COMPILED BY AM													
DATUM Geodetic		DATE November 13, 2014		CHECKED BY SAT													
SOIL PROFILE			SAMPLES			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	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60 80 100	W _p	W	W _L	γ	GR	SA	SI	CL
79.6	GROUND SURFACE																
0.0	Gravelly sand, angular (FILL) Grey brown																
79.1	Sand, some silt (FILL) Brown Moist						79										
78.7	Silty clay, some gravel and sand, contains organic matter (FILL) Very stiff Grey Moist		1	SS	10												
78.1	Silty clay, some sand, contains cobbles (FILL) Very stiff Brown Moist		2	SS	6		78										
77.3	SILTY SAND Grey brown																
2.4	SILTY CLAY, trace sand, with organic matter Very stiff Grey brown Moist		3	SS	7		77										0 11 43 46
76.6	SILTY SAND, some clay, trace gravel Brown Wet		4	SS	>50												
76.3	Granite (BEDROCK)		1	RC	REC 97%		76										RQD = 97%
3.3	Bedrock cored from depths of 3.3 m to 6.6 m																
	For bedrock coring details refer to Record of Drillhole 14-202		2	RC	REC 100%		75										RQD = 73%
			3	RC	REC 100%		74										RQD = 100%
73.0	END OF BOREHOLE						73										
6.6	NOTES: 1. Water level in standpipe at a depth of 2.2 m below ground surface (Elev. 77.4 m), measured on April 17, 2015.																

[illegible]



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

PROJECT 1403255		RECORD OF BOREHOLE No 15-204		SHEET 1 OF 1		METRIC						
G.W.P. 79-99-00		LOCATION N 4905000.8 ; E 309445.5		ORIGINATED BY DWM								
DIST Eastern HWY 401		BOREHOLE TYPE Portable Drill		COMPILED BY JM								
DATUM Geodetic		DATE March 26, 2015		CHECKED BY WAM								
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID UNIT REMARKS			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)	γ	GR SA SI CL
77.5	GROUND SURFACE											
0.0	Silty clay, trace sand, contains wood fragments (FILL) Stiff Brown Moist		1	SS	4		77					
76.9												
0.6	SILTY CLAY to CLAY, trace sand Very stiff Red-brown Moist		2	SS	13							0 9 29 62
			3	SS	16		76					
75.7												
1.8	SILTY CLAY, trace sand Very stiff Grey Moist		4	SS	9		75					
			5	SS	8							0 3 32 65
			6	SS	7		74					
			7	SS	11							
			8	SS	14		73					
			9	SS	12							0 2 42 56
			10	SS	11		72					
			11	SS	19		71					
			12	SS	11							
			13	SS	14		70					0 6 40 54
69.6												
7.9	END OF BOREHOLE											
NOTES: 1. Water level in well screen at a depth of 0.1 m below ground surface (Elev. 77.4 m), measured on April 17, 2015.												

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMMM_GROUP\CATARAQUIRIVERBRIDGE02_DATA\GINTV1403255.GPJ GAL-GTA.GDT 10/21/15 JM

PROJECT 1403255		RECORD OF BOREHOLE No 15-205				SHEET 1 OF 1		METRIC									
G.W.P. 79-99-00		LOCATION N 4905049.1 ; E 309430.6				ORIGINATED BY DWM											
DIST Eastern HWY 401		BOREHOLE TYPE Power Auger 200 mm Diam. (Hollow Stem)				COMPILED BY JM											
DATUM Geodetic		DATE March 31, 2015				CHECKED BY WAM											
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									
77.8	GROUND SURFACE							20	40	60	80	100					
0.0	Silty clay to clay, trace sand, contains organic matter (FILL) Very stiff Grey-brown Moist		1	SS	7												
			2	SS	20												
			3	SS	16												
76.0	END OF BOREHOLE SAMPLER REFUSAL																
1.8																	

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMMM_GROUP\CATARAQUIRIVERBRIDGE02_DATA\GINTV1403255.GPJ GAL-GTA.GDT 10/21/15 JM



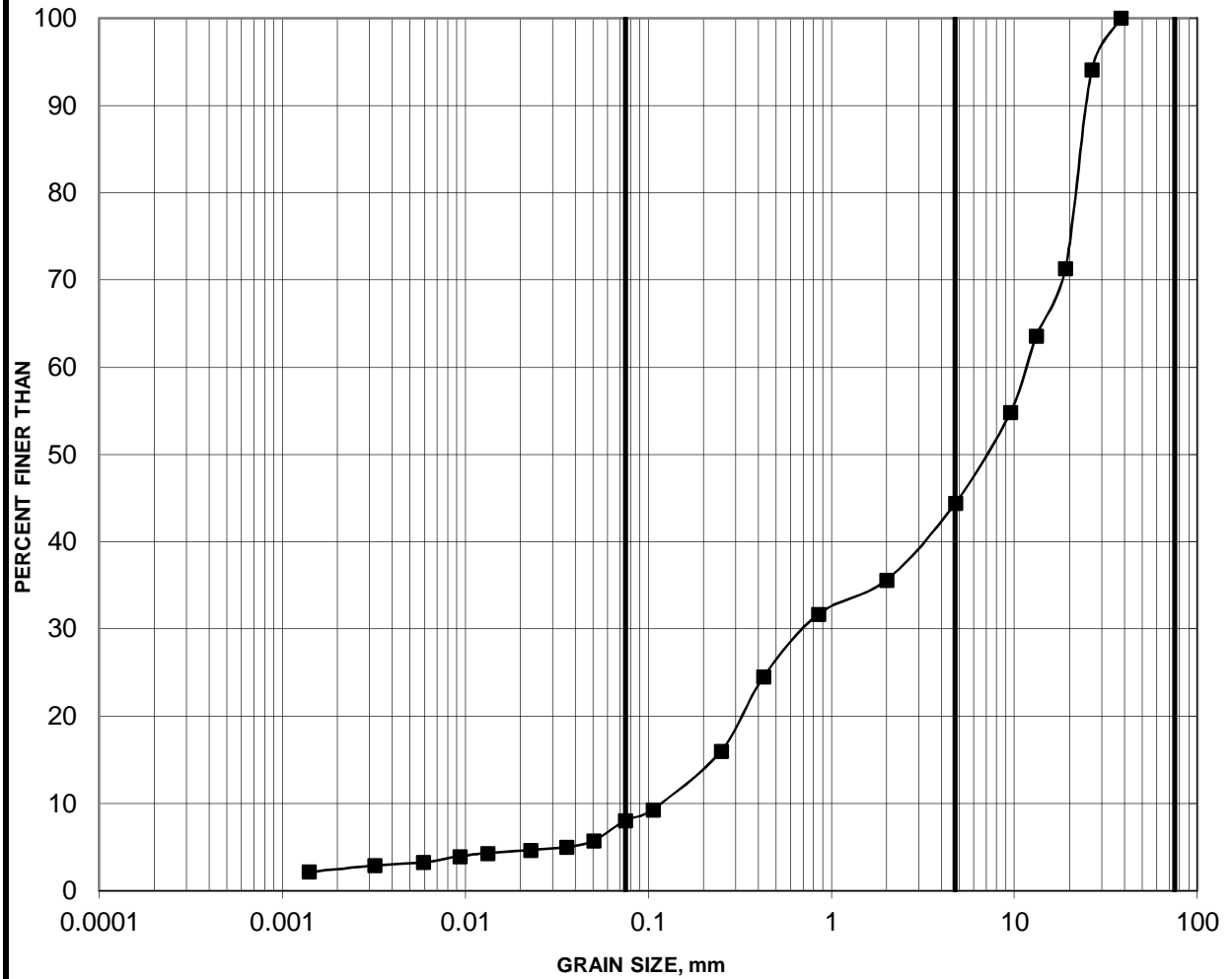
APPENDIX B

Laboratory Test Results

GRAIN SIZE DISTRIBUTION

FIGURE B1

SANDY GRAVEL (FILL)



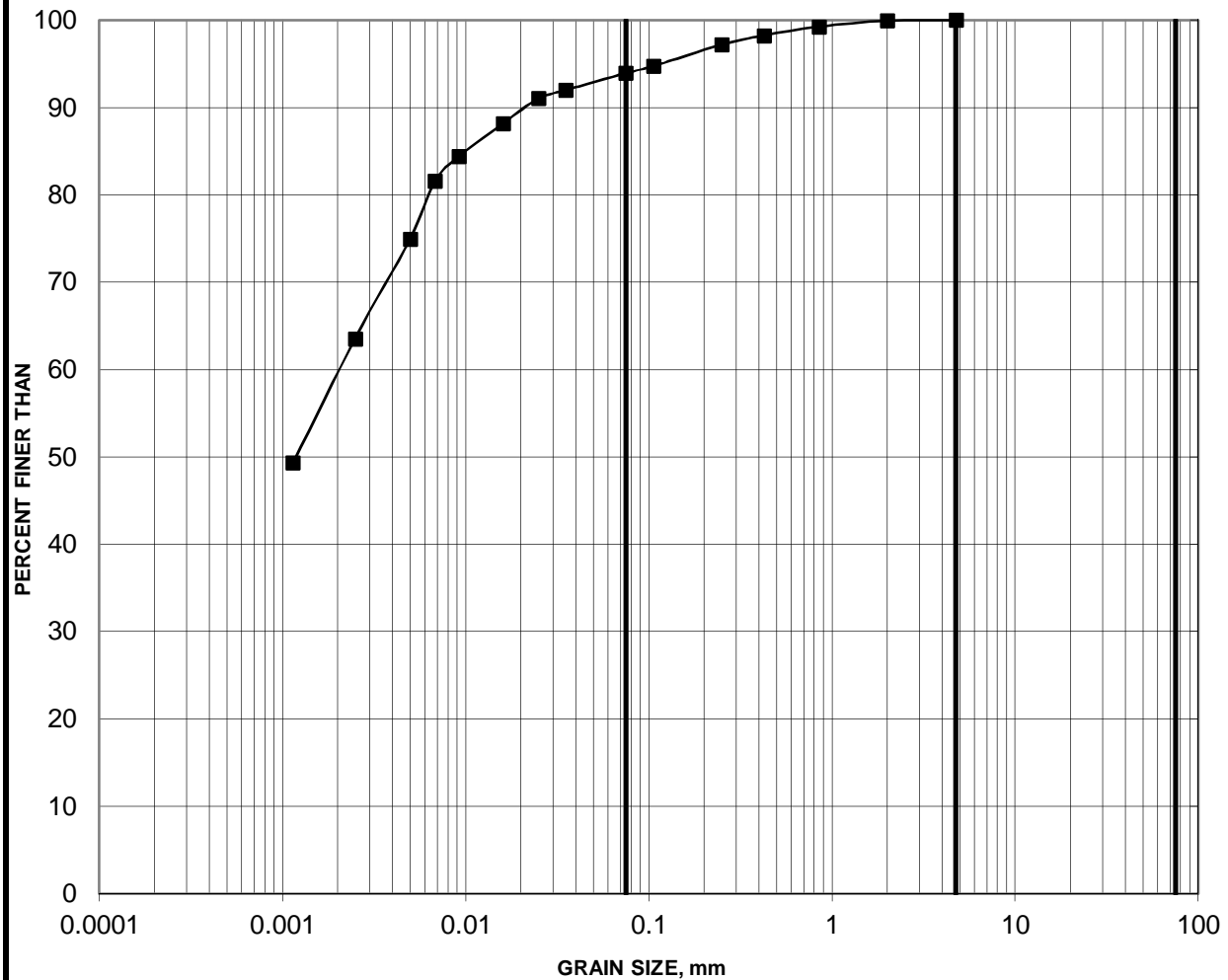
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
—■— 14-203	2	1.52-2.13

GRAIN SIZE DISTRIBUTION

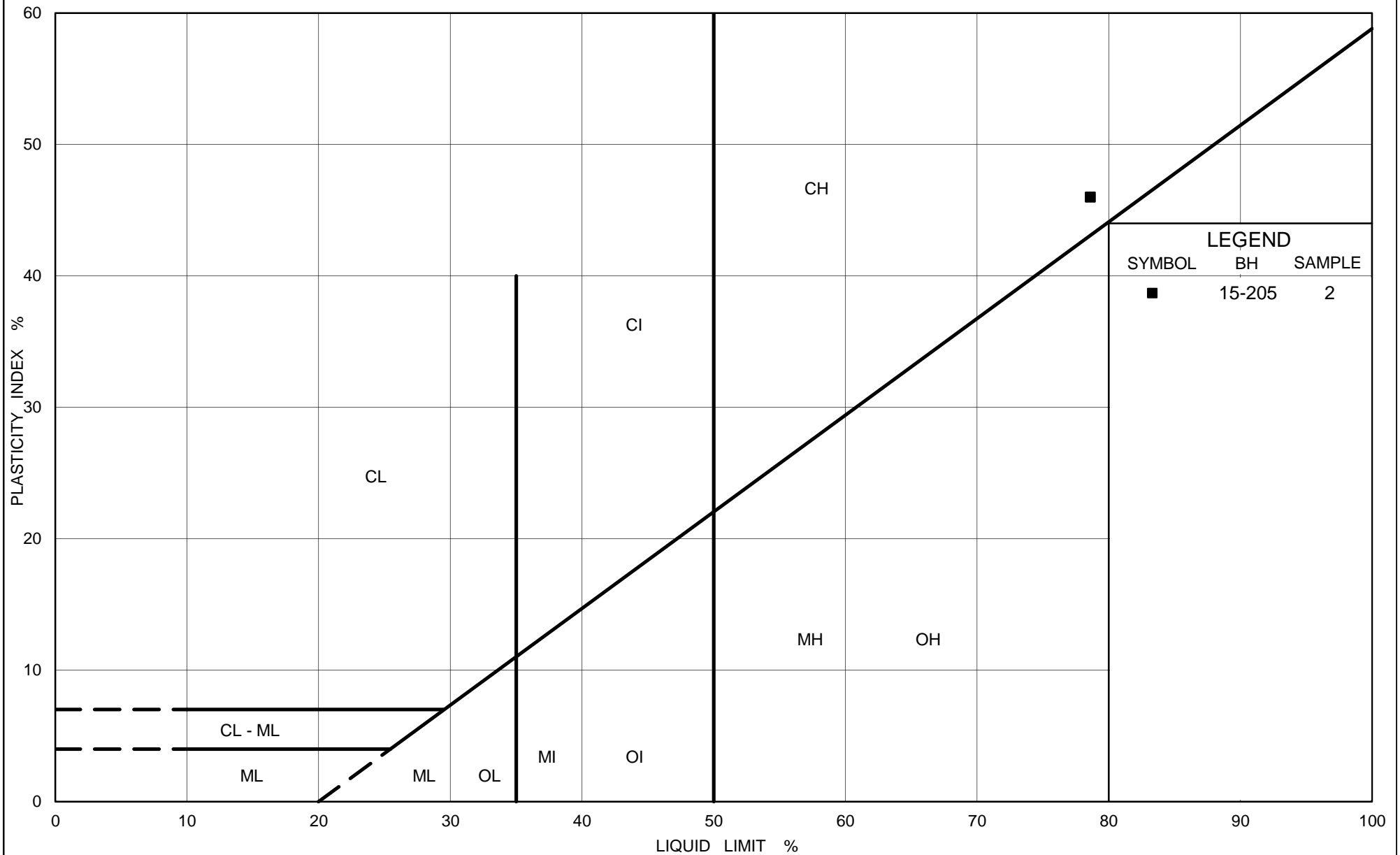
FIGURE B2

SILTY CLAY TO CLAY (FILL)



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

Borehole	Sample	Depth (m)
—■ 15-205	2	0.61-1.22



Ontario

Ministry of Transportation

PLASTICITY CHART

Silty Clay (Fill)

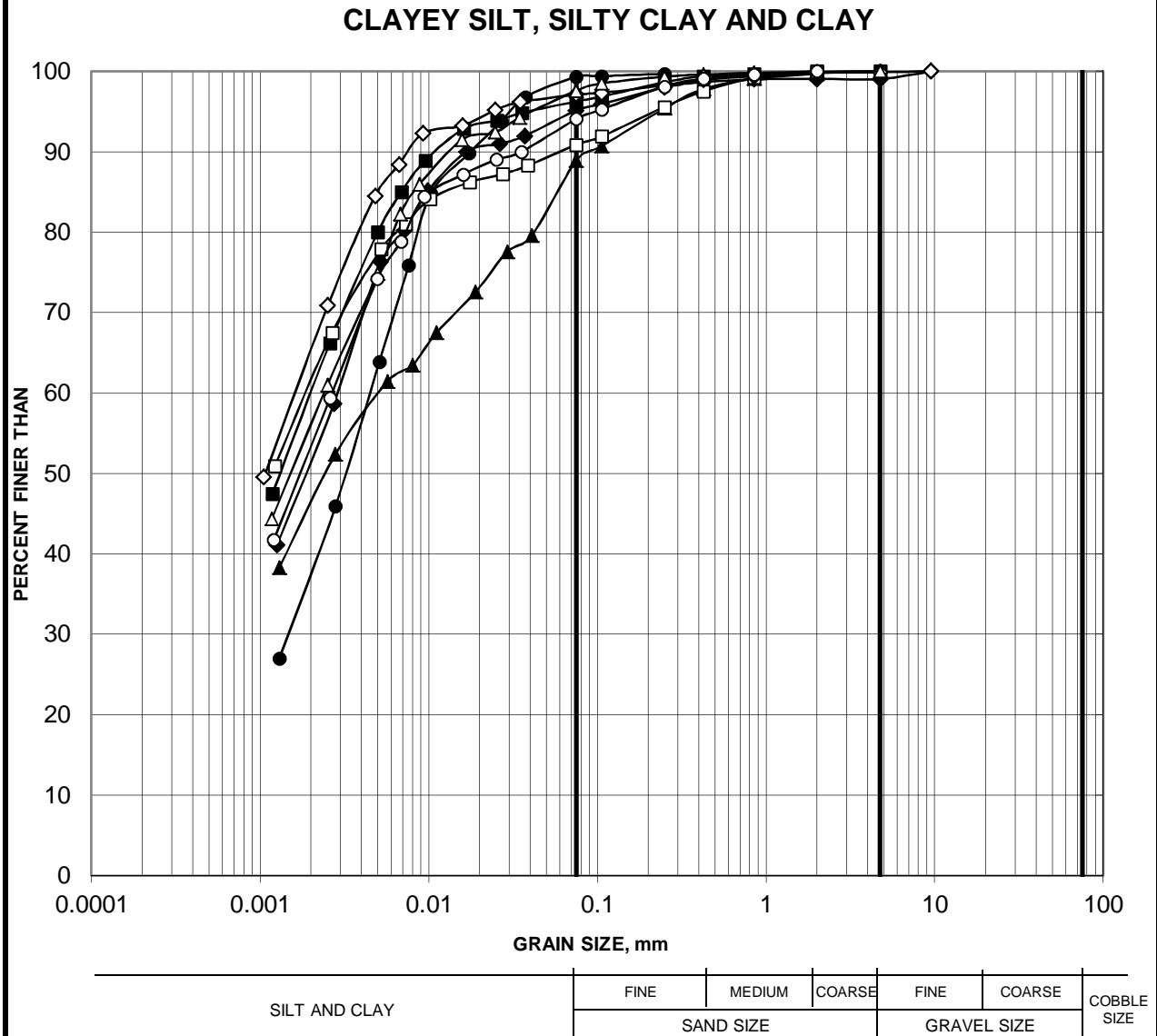
FIG No. B3

Project No. 1403255-003

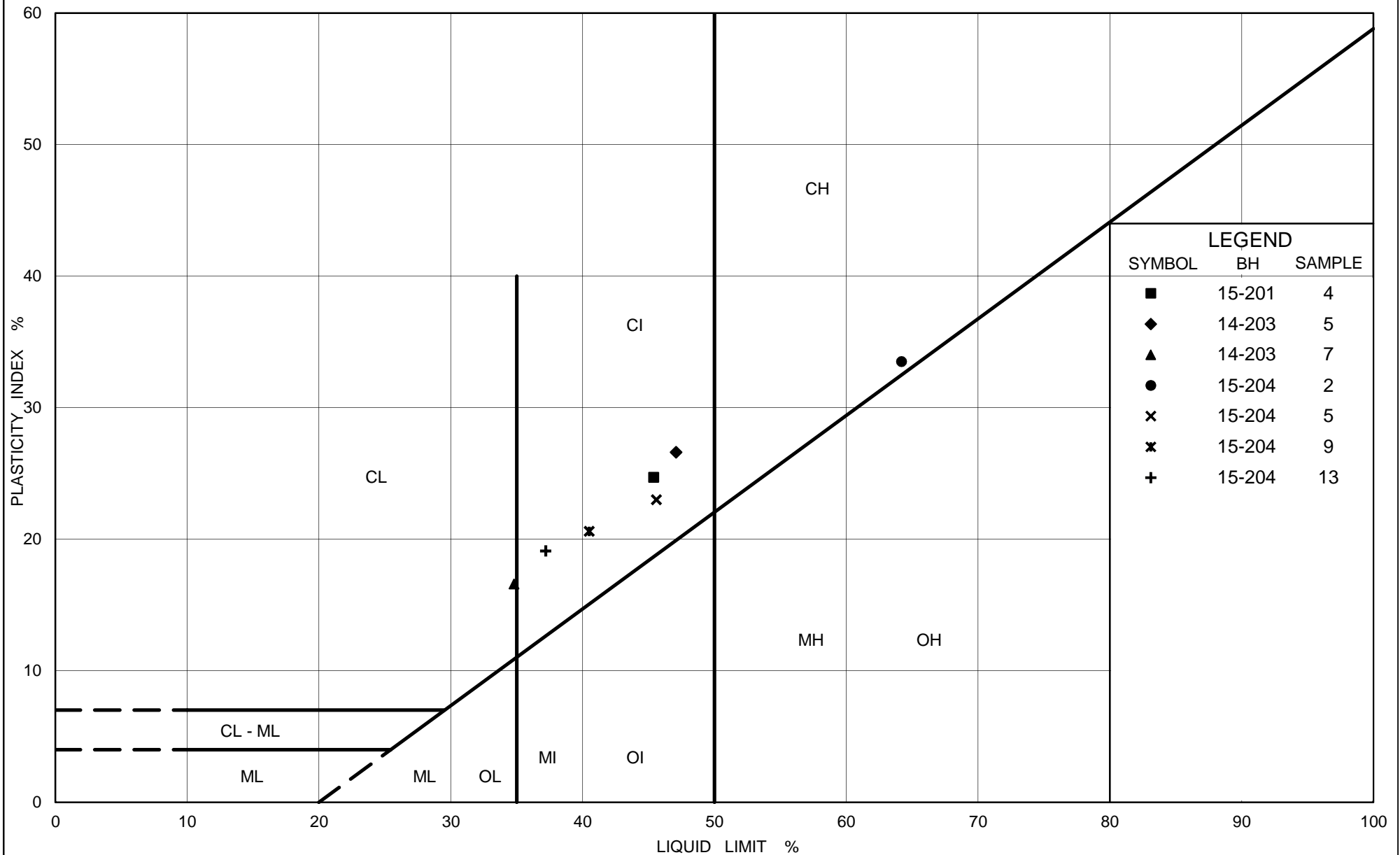
Compiled By : MI Checked By : CNM

GRAIN SIZE DISTRIBUTION

FIGURE B4



Borehole	Sample	Depth (m)
■ 15-201	2	0.61-1.22
◆ 15-201	4	1.83-2.44
▲ 14-202	3	2.29-2.90
● 14-203	7	6.10-6.71
□ 15-204	2	0.61-1.22
◇ 15-204	5	2.43-3.05
△ 15-204	9	4.88-5.49
○ 15-204	13	7.32-7.93



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt to Clay

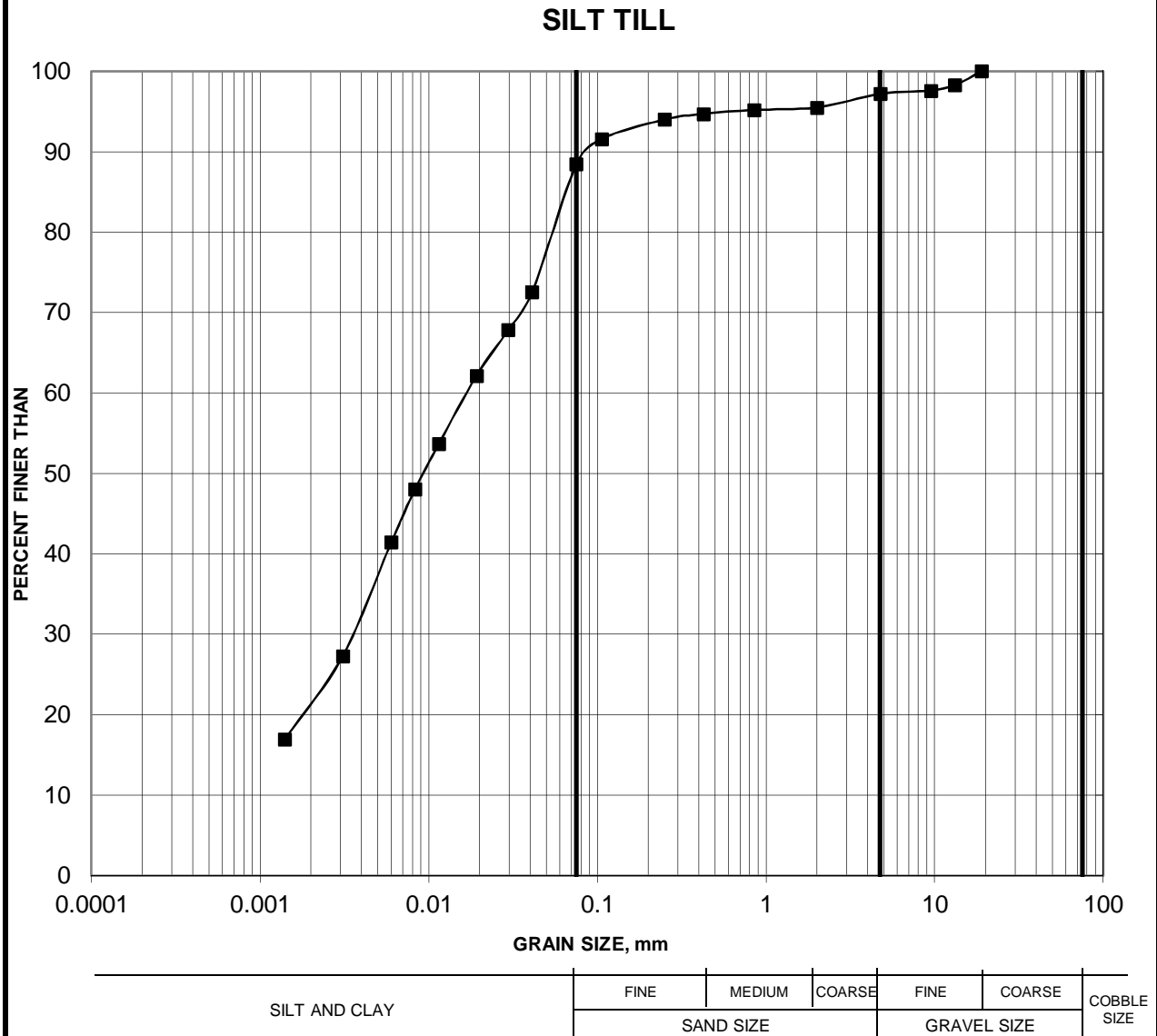
FIG No. B5

Project No. 1403255-003

Compiled By : MI Checked By : CNM

GRAIN SIZE DISTRIBUTION

FIGURE B6



Borehole	Sample	Depth (m)
—■— 14-203	8	7.92-8.23



APPENDIX C

List of Ontario Provincial Standard Drawings and Ontario Provincial Standard Specifications



**FOUNDATION REPORT
CULVERT EXTENSION
HIGHWAY 401 - STATION 10+490, KINGSTON, ONTARIO**

Ontario Provincial Standard Drawings

OPSD 208.010	Benching and Earth Slopes
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal To 3.0 m
OPSD 803.031	Frost Treatment – Pipe Culverts Frost Penetration Line Between Top of Pipe and Bedding Grade
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.101	Foundation, Frost Penetration Depths for Southern Ontario
OPSD 3101.150	Walls, Abutment, Backfill, Minimum Granular Requirement
OPSD 3190.100	Walls, Retaining and Abutment, Wall Drain

Ontario Provincial Standard Specifications

OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 802	Construction Specification for Topsoil
OPSS 803	Construction Specification for Sodding
OPSS 902	Construction Specification for Excavating and Backfilling – Structures
OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 1002	Material Specification for Aggregates – Concrete
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal



APPENDIX D

Non-Standard Special Provisions



CONCRETE WORKING SLAB – Item No.

Non-Standard 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

Within four hours 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

Concrete working slabs are not applicable for granite bedrock.

7.04 Dewatering

Dewatering shall be carried out in accordance with 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.

END OF SECTION

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

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