August 2014

FOUNDATION INVESTIGATION AND DESIGN REPORT

Culvert Replacement, Woods Creek, Site No. 14-444/C
Station 11+732, Highway 21
Contract 2 Structure Replacements and Rehabilitation
GWP 3040-11-00
Ministry of Transportation, West Region

Submitted to:

Mr. Adam Barg, P.Eng.
Stantec Consulting Ltd.
200 - 835 Paramount Drive
Stoney Creek, Ontario
L8J 0B4

REPORT

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MINISTRY OF TRANSPORTATION - WEST REGION

1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Stantec Consulting Ltd. (Stantec) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detail design work for GWP 3040-11-00. The project involves the detail design of the replacement and rehabilitation of several structures along multiple highways in Southern Ontario.

This report addresses the proposed replacement of the culvert at Woods Creek (Site 14-444/C) at Station 11+732 on Highway 21 just north of Forest, Ontario in the Township of Bosanquet, Lambton County.

The purpose of the foundation investigation is to explore the subsurface conditions at the location of the proposed structure replacement by drilling boreholes and carrying out in situ testing and laboratory testing on selected samples. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal and in Golder's proposal P2-1132-0163 dated February 25, 2013. The work was carried out in accordance with our Quality Control Plan for Foundation Engineering dated March 26, 2013.

2.0 SITE DESCRIPTION

The subject culvert is situated at Station 11+732 on Highway 21, approximately 1.9 kilometres north of Townsend Line in the Township of Bosanquet, Lambton County, Ontario. The village of Forest is 1.6 kilometres south of the site. The location of the culvert is shown on the Key Plan, Figure 1.

This section of Highway 21 is currently a two lane undivided highway with paved shoulders. It is generally oriented north-south in the vicinity of the subject site. The creek flow direction in the culvert is from east to west beneath Highway 21. The existing culvert is a concrete rigid frame open (RFO) footing structure with the following characteristics:

Dimensions (m)	Obvert Elevation (m)		Construction
	Lt[1]	Rt[1]	
5.50 x 2.80 x 34.40	214.720	214.721	RFO

NOTE: 1. When facing the direction of increasing chainage, Lt and Rt are defined as Left and Right of centreline, respectively.

The banks of the drainage channel upstream and downstream of the culvert are grass covered and the channel flows through fields adjacent to Highway 21. Site photographs are provided in Appendix B. The culvert is situated in a rural agricultural area with ground surface elevations in the vicinity of the culvert site ranging from about 212 to 220 metres.

2.1 Site Geology

The project area is located within the St. Clair Clay Plains physiographic region. This region is characterized by very deep deposits of clay and silt till plains.[1] The quaternary geological mapping indicates that surficial soils consist of St. Joseph Till which is clayey silt to silty clay till.[2] Geological mapping also indicates that the underlying bedrock consists of black bituminous shale with greenish-grey silty shale interbeds of the Kettle Point Formation of the Port Lambton Group of Upper Devonian age.[3] The bedrock surface at the site is at about elevation 189.0 metres, with the overburden thickness being about 26 to 28 metres.[4]

[1] Chapman, L.J., and Putnam, D.F., 1984: Physiography of Southern Ontario; Ontario Geological Survey, Special Volume 2, 270p. Accompanied by Map. P.2715 (coloured), scale 1:600,000.

[2] Cooper, A.J., and assistants. 1975: Quaternary Geology of Parkhill, Southern Ontario; Ontario Geological Survey, Map 2402, scale 1:50,000.

[3] Sanford B.V., 1969: Geology Toronto-Windsor Area, Ontario; Ontario Geological Survey of Canada Map 1263A, Scale 1:250,000.

[4] Karrow, P.F., and assistants. 1964: Bedrock topography Series. Parkhill Sheet; Ontario Department of Mines. Prelim. Map P.290, scale 1:50,000.

3.0 INVESTIGATION PROCEDURES

The field work for the investigation was carried out on July 8, 2013, during which time three boreholes were drilled at the locations shown on the Borehole Location Plan, Drawing 1. The boreholes were drilled using track-mounted CME 75 drilling equipment supplied and operated by a specialist drilling contractor. Samples of the overburden were typically obtained at depth intervals of 0.75 metres using 50 millimetre outside diameter split spoon sampling equipment in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586).

The recorded SPT N values are noted on the Record of Borehole sheets. The SPT resistance, or N value, is defined as the number of blows required by a 63.5 kilogram hammer dropped from a height of 760 millimetres to drive a split-spoon sampler a distance of 300 millimetres after an initial 150 millimetres of penetration. The results of the SPT testing are presented on the Record of Borehole sheets, Drawing 1 and in Section 4.0 are unmodified (not standardized for hammer efficiency, borehole diameter, rod length, etc.).The samplers used in the investigations limit the maximum particle size that can be sampled and tested to about 40 millimetres. Therefore, particles or objects that may exist within the soils that are larger than this dimension will not be sampled or represented in the grain size distributions.

Groundwater conditions in the boreholes were observed throughout the drilling operations and a standpipe piezometer was installed in borehole 212 as indicated on the corresponding Record of Borehole sheet. The boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 903 (as amended).

The field work was monitored on a full-time basis by experienced members of our staff who located the boreholes in the field, monitored the drilling, sampling, and in situ testing operations and logged the boreholes. The samples were identified in the field, placed in labelled containers, and transported to our London laboratory for further examination and testing. Index and classification tests, consisting of water content determinations, Atterberg limits and grain size distribution analyses, were carried out on selected samples. The results of the testing are shown on the Record of Borehole sheets and in Appendix A.

The as-drilled borehole locations and ground surface elevations are shown on the Record of Borehole sheets and on Drawing 1. The table below summarizes the coordinates, ground surface elevations, and depths of the boreholes.

Borehole	Location (m)		Ground Surface Elevation	Borehole Depth
	Northing	Easting	(m)	(m)
210	4 775 474	346 692	216.71	11.28
211	4 775 475	346 682	216.65	11.28
212	4 775 464	346 679	216.40	11.13

4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the in situ testing and the laboratory testing carried out on selected samples, are given on the attached Record of Borehole sheets following the text of this report and in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous samples and observations of drilling resistance and, therefore, may represent transitions between soil types rather than exact planes of geological change. Further, the subsurface conditions will vary between and beyond the borehole locations.

The boreholes drilled at the site generally encountered the existing pavement structure or topsoil overlying variable embankment fill materials, the embankment fills are underlain by thin layers of silt or silty sand above a more extensive deposits of clayey silt till.

The locations and elevations of the boreholes, together with the interpreted stratigraphic profile, are shown on Drawing 1. A detailed description of the subsurface conditions encountered in the boreholes is provided on the Record of Borehole sheets and is summarized in the following sections.

4.2 Soil Conditions

4.2.1 Pavement Structure

Asphaltic concrete pavement was encountered at ground surface in boreholes 210 and 211 which were advanced through the shoulders of Highway 21. The pavement was 90 and 60 millimetres thick in boreholes 210 and 211, respectively.

Pavement granular base materials 120 and 150 millimetres thick were encountered beneath the asphalt in boreholes 210 and 211, respectively. Pavement granular subbase layers were about 460 and 160 millimetres thick, encountered beneath the granular base in boreholes 210 and 211, respectively.

4.2.2 Topsoil

Topsoil was encountered at the ground surface in borehole 212. The surficial topsoil was about 240 millimetres thick. Materials designated as topsoil in this report were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

4.2.3 Fill

Clayey silt fill materials were encountered beneath the pavement structure in boreholes 210 and 211 from elevations 216.0 to 216.3 metres and beneath the topsoil in borehole 212 at elevation 216.2 metres. The soft to stiff clayey silt fill material was 2.4 to 3.4 metres thick with measured N values ranging from 3 to 10 blows per 0.3 metres. Water contents of the clayey silt fill were from 16 to 25 per cent.

The clayey silt fill is of low plasticity based on the Atterberg limits determination testing carried out on samples obtained during standard penetration testing. The average plastic limit was 18 per cent, the average liquid limit was 31 per cent, and the average plasticity index was 14 per cent. The Atterberg limits data for the clayey silt fill are presented on Figure A-3. Grain size distribution curves for samples of the clayey silt fill materials are provided on Figure A-1.

4.2.4 Silty Sand

A layer of loose silty sand was encountered at elevation 213.7 metres beneath the fill material in borehole 210. The silty sand was 0.4 metres thick. The silty sand had a measured N value of 6 blows per 0.3 metres and a water content of about 20 per cent.

4.2.5 Silt

Compact silt was encountered beneath the fill material in borehole 211 at elevation 213.9 metres. The silt was about 0.9 metres thick with an N value of 11 blows per 0.3 metres. A silt sample had a water content of 21 per cent.

4.2.6 Clayey Silt Glacial Till

A stratum of stiff to very stiff clayey silt glacial till was encountered beneath the silty sand in borehole 210 at elevation 213.3 metres, beneath the silt in borehole 211 at elevation 213.0 metres and beneath the fill in borehole 212 at elevation 212.7 metres. All boreholes were terminated in the clayey silt till after exploring the layer for depths of 7.5 to 7.9 metres. Measured N values for the clayey silt till layers were 11 to 26 blows per 0.3 metres. Water contents of the samples ranged from 12 to 18 per cent. Although cobbles and boulders were not specifically encountered within the clayey silt till layer, their presence should be anticipated due to the depositional history of glacial tills.

The clayey silt till is of low plasticity based on the Atterberg limits determination testing carried out on samples obtained during standard penetration testing. The plastic limits varied between 15 and 16 per cent, the liquid limit between 27 and 28 per cent, and the plasticity indices between 11 and 12 per cent. The Atterberg limits data for the clayey silt till are presented on Figure A-3. Grain size distribution curves for samples of the clayey silt till are provided on Figure A-2.

4.3 Groundwater Conditions

Groundwater conditions were observed during drilling and on completion of drilling and sampling a groundwater observation standpipe was installed in borehole 212. Installation details are provided on the corresponding Record of Borehole sheet following the text of this report. Groundwater was encountered in all boreholes at depths of 3.2 to 3.4 metres or between elevation 213.0 and 213.5 metres during drilling. A summary of the encountered and measured groundwater levels is provided in the table below.

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Elevation (m)	Measured Groundwater Level Elevation (m)		
		July 8, 2013	September 5, 2013	April 30, 2014	July 25, 2014
210	216.71	213.5	-	-	-
211	216.65	213.3	-	-	-
212	216.40	213.0	213.66	214.30	213.66

The above-noted encountered water levels are not considered to be representative of the long-term, stabilized groundwater conditions. The corresponding water level in the watercourse was measured at elevation 212.4 metres on July 8, 2013 and at elevation 212.9 metres on April 30, 2014 following a rainfall event. On September 5, 2013 and July 25, 2014 the water level in the groundwater observation standpipe installed in borehole 212 was about 2.7 metres below ground surface or at about elevation 213.7 metres. On April 30, 2014 the water level in the groundwater observation standpipe installed in borehole 212 was about 2.1 metres below ground surface or at about elevation 214.3 metres.

Based on the observed groundwater levels, the surrounding topography, the soil colour change from brown to grey and water levels in the drain, the inferred groundwater level has been assumed to be elevation 214 metres for design purposes. The groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring snow melt conditions and will be influenced by flows in the watercourse.

5.0 MISCELLANEOUS

The investigation was carried out using equipment supplied and operated by Aardvark Drilling Inc., an Ontario Ministry of Environment licensed well contractor. The field operations were supervised by Mr. Brett Thorner, E.I.T. under the direction of Mr. David J. Mitchell, the Site Investigation Field Manager. The laboratory testing was carried out at Golder Associates' London laboratory under the direction of Mr. Chris M. Sewell. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates. This report was prepared by Mr. Brett Thorner, E.I.T. under direction of the Project Engineer Ms. Dirka U. Prout, P.Eng. and reviewed by Mr. W. Michael Kellestine, P.Eng., a Principal with Golder Associates. Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment conducted an independent quality review of the report.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED   ORIGINAL SIGNED

Dirka Prout, P.Eng.
Project Engineer

Fintan J. Heffernan, P.Eng.
MTO Designed Contact

BT/DUP/WMK/AMH/FJH/cr

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PART B

FOUNDATION DESIGN REPORT

CULVERT REPLACEMENT, WOODS CREEK, SITE NO. 14-444/C
STATION 11+732, HIGHWAY 21
CONTRACT 2 STRUCTURE REPLACEMENTS AND REHABILITATION
GWP 3040-11-00
MINISTRY OF TRANSPORTATION - WEST REGION

6.0 ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides recommendations on the foundation aspects of the design of the replacement culvert at Woods Creek (Site 14-444/C), located at Station 11+732 on Highway 21 in the Township of Bosanquet in Lambton County, Ontario.

The recommendations are based on interpretation of the factual data obtained from the boreholes advanced at this site. The interpretation and recommendations are intended to provide the designers with sufficient information to design the proposed culvert foundations. As such, where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. 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, and scheduling.

The existing culvert is a 34.4 metre long concrete rigid frame open footing (RFO) structure with a 5.5 metre span, a 2.8 metre high opening, and approximate invert elevation of 211.9 metres. The existing culvert has approximately 2.0 metres of fill cover.

6.2 Replacement Culvert

Based on information provided by Stantec Consulting Ltd. (Stantec), it is understood that consideration is being given to replace the existing concrete RFO culvert with a new 6.0 by 3.0 metre concrete box or open footing culvert. It has been indicated by Stantec that the concrete box culvert is the preferred structural alternative and may be pre-cast or cast-in-place (CIP). No grade raise is proposed at this location. A comparison of the various culvert types is presented in Table I following the report text.

It is proposed to replace the existing culvert using open cut installation methods. Traffic staging and temporary roadway protection will be required to facilitate the open trench installation of the replacement culvert to maintain a single lane of traffic during construction.

6.2.1 Foundations

The subsurface conditions encountered during the investigation generally consisted of the existing pavement structure or topsoil overlying variable embankment fill materials to elevations of between 212.7 and 213.9 metres, overlying the primary stratum of stiff to very stiff clayey silt till to elevations of about 205.5 metres. Layers of silt and silty sand were encountered between the fill material and clayey silt till in two of the boreholes. The inferred groundwater level is at elevation 214 metres. The water level in the watercourse was about elevation 212.4 metres at the time of the investigation, and near elevation 212.9 metres on April 30, 2014.

The culvert replacement should be designed to withstand the appropriate vertical weight of fill and traffic loading. It is not necessary to found a box culvert at the standard depth for frost protection purposes as these types of structures are tolerant of small magnitude movements related to freeze-thaw cycles, should these occur. A box or open footing culvert should, however, be founded below any existing fill and surficial organic materials.

Based on the soil conditions encountered at the borehole locations, and assuming that the design culvert invert elevations will be similar to those of the existing culvert, the replacement box or open footing culvert may be founded on the stiff to very stiff clayey silt till. Any observed fill or organic materials should be removed to expose the native soils. Any low areas should be brought to design grade using lean concrete fill or well graded granular materials.

Geotechnical Resistances

The proposed invert elevations will be approximately 0.3 metres below the existing stream bed or at 211.57 metres at the inlet and 211.52 metres at the outlet. Assuming a floor slab thickness of 350 millimetres for a box culvert and allowing for a minimum bedding thickness of 300 millimetres, and a 75 millimetre thick levelling pad, the maximum founding elevation for a box culvert will be near elevation 210.8 metres. Allowing for a frost depth of 1.2 metres for open footing culvert foundations, the maximum founding elevation will be elevation 210.4 metres. A factored geotechnical resistance at Ultimate Limit States (ULS) of 300 kPa and a geotechnical resistance at Serviceability Limit States (SLS) of 200 kPa may be used for design purposes provided that any foundations have a minimum width of 0.5 metres and that the subgrade has been properly prepared (see Section 6.6). The SLS value corresponds to a maximum of 25 millimetres of total settlement for new culvert construction.

Frost Treatment and Scour Protection

Frost treatment in the form of a frost taper symmetrical about the culvert centreline must be provided in accordance with Ontario Provincial Standard Drawing (OPSD) 803.010 for a box or open footing culvert. The design frost penetration depth for this area is 1.2 metres below ground surface. Foundations for open footing culverts must be provided with a minimum frost cover equivalent to the frost depth or thermal alternative using insulating materials. The culvert base should be adequately protected against scour as noted in Section 1.9.5.2 of the Canadian Highway Bridge Design Code (CHBDC). Scour protection for the culvert backfill, bedding, and stream bank should be provided to protect the roadway, approach embankments, and culvert approaches.

Resistance to Lateral Forces/Sliding Resistance

The resistance to lateral forces/sliding resistance between the base of the replacement box culvert and the bedding or concrete open footing and native soils should be calculated in accordance with Section 6.7.5 of the CHBDC.

In accordance with the CHBDC Section 6.7.5, a factor of 0.8 is applied in the equation to calculate the factored horizontal geotechnical resistance, H_{ri} or H_{rs}, as follows:

$$H_{ri} = 0.8A'c' + 0.8V\tan\delta > H_f \text{ (for box culverts)}$$

$$H_{rs} = 0.8A'c' + 0.8V\tan\phi' > H_f \text{ (for open footing culverts)}$$

where:

A'	-	effective contact area, square metres
c'	=	Nil
tan δ	-	coefficient of friction for interface between box culvert base and bedding/levelling pad
tan ϕ'	-	coefficient of internal friction for soil close to the underside of the spread/strip footing
V	-	unfactored vertical force, kilonewtons
H_f	-	unfactored horizontal load, kilonewtons

The factored horizontal resistance may be calculated using the following parameters in the following table:

Structure	Interaction	Angle of Friction, δ (degrees)	Coefficient of Friction, tan δ
CIP Box or Open Footing Culvert	CIP concrete on native clayey silt till	32	0.62
Precast Box Culvert	Pre-cast concrete on Granular A bedding/levelling pad	30	0.58

6.2.2 Bedding

For precast culverts, bedding should be placed above a properly prepared subgrade from which all frozen, soft, uncompacted fill, organic materials, or other deleterious materials have been removed. Subexcavated material below the design subgrade elevation should be replaced with compacted Ontario Provincial Standards Specifications (OPSS) Granular B Type II. It is recommended that the precast box culvert units be placed on a minimum thickness of 300 millimetres of Granular A bedding material and a minimum 75 millimetre thick levelling course consisting of uncompacted Granular A or fine aggregates as specified in MTO Special Provision (SP) 422S01.

6.2.3 Backfill and Cover

Backfill, cover, and construction of the frost taper (backfill transition) should be completed in accordance with OPSD 803.010 for a concrete box or open footing culvert. However, the excavation for the culvert replacement should exceed the culvert dimensions by at least one metre on each side to promote good workmanship and effective compaction of the fill.

The backfill should consist of free-draining, non-frost susceptible granular materials such as OPSS Granular A or Granular B Type II, with less than 5 per cent passing the 0.075 millimetre sieve placed and compacted in accordance with OPSS 501. All bedding, backfill, and cover materials should be placed in accordance with OPSS 501 and 902 and SP422S01.

Heavy compaction equipment should not be used immediately adjacent to the walls and roof of the culvert. The height of backfill adjacent to the culvert walls should be maintained equal on both sides of the structure during all stages of backfill placement with one side not exceeding the other by more than 500 millimetres.

6.2.4 End Treatments and Camber

The culvert invert will be on the native clayey silt till. An outlet filter is not recommended due to the generally cohesive soils that will be present at the outlet, particularly if the head difference between the culvert inlet and outlet is low. Box culverts are to be provided with a cut-off wall at the outlet in accordance with Section 1.9.5 of the CHBDC. No grade raise is proposed as part of the culvert replacement and relatively low cover is proposed for the replacement culvert; therefore it is not necessary to provide a camber.

6.3 Liquefaction Potential and Seismic Analysis

6.3.1 Seismic Parameters

The site is located near the Town of Forest in southern Ontario. According to Table A.3.1.1 of the CHBDC, the zonal acceleration ratio, A, applicable to this site is 0.00. The corresponding acceleration related seismic zone, Z_a, is 0. Based on the site stratigraphy, the soil profile type is categorized as Type I with a seismic site response coefficient, S, of 1.0 based on the CHBDC criteria.

The importance category of the replacement culvert is “other” based on the current version of the CHBDC. The corresponding seismic performance zones (SPZ) to this importance category is 1. Structural culverts situated in SPZ 1 need not be analyzed for seismic loads. However, design forces for restraining elements and support lengths must meet the minimum requirements as outlined in CHDBC Clause 4.4.5.1. It should be noted that the MTO views culverts with spans greater than 3 metres as being similar to bridges. The designer should ensure that the selected culvert design meets the seismic requirements for buried structures as outlined in Clause 7.5.5 of the CHBDC.

6.3.2 Seismic Hazard Assessment

A preliminary screening of the soil stratigraphy was conducted using the procedure outlined in the Federal Highway Administration recommended procedures[5] and Canadian Foundation Engineering Manual (CFEM). The screening results indicated that a detailed evaluation of the liquefaction potential of the foundation soils is not considered warranted.

[5] Federal Highway Administration (FHWA). (1997). “Design Guidance: Geotechnical Earthquake Engineering For Highways. Volume I – Design Principles.” *Geotechnical Engineering Circular No. 3:FHWA-SA-97-076*, Washington, D.C.

6.4 Lateral Earth Pressures for Design

The lateral pressures acting on the proposed culvert will depend on the type and method of placement of the backfill materials, on the nature of the soil behind the backfill, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls.

The following recommendations are made concerning the design of the walls in accordance with the current CHBDC. It should be noted that these design recommendations and parameters assume level backfill and ground surface behind the walls. 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 Granular A or Granular B Type II but with less than 5 per cent passing the 0.075 millimetre sieve should be used as backfill behind the walls. The fill should be compacted in loose lifts not greater than 200 millimetres in thickness. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill.
- A compaction surcharge equal to 12 kPa should be included in the lateral earth pressures for the structural design in accordance with CHBDC Figure 6.6.
- If the wall support does not allow lateral yielding (such is typically the case for a rigid concrete box culvert), at-rest earth pressures should be assumed for geotechnical design. The granular fill should be placed in a zone with a width equal to at least 1.2 metres behind the culvert walls ((Case (a) from commentary on CHBDC Figure C6.20).
- For Case (a), the restrained case, which is typical for box culvert walls, the pressures are based on the existing embankment fill materials, assuming a Select Subgrade Material (SSM) is used, and the following parameters (unfactored) may be used:

Soil unit weight:	19 kN/m³
Coefficients of lateral earth pressure:	
'At rest' or restrained, K_o	0.53

- If the wall support allows lateral yielding (unrestrained structure, such as typically the case for retaining walls), active earth pressures may be used in the geotechnical design of the structure. The granular fill should be placed in a wedged shaped zone with a width equal to at least 1.2 metres at the footing level against a cut slope which begins at the footing level and extends upwards at a maximum inclination of 1 horizontal to 1 vertical (case (b) from commentary on CHBDC Figure C6.20).

- For walls backfilled using granular materials in accordance with case (b), the following parameters (unfactored) may be assumed:

	GRANULAR A	GRANULAR B TYPE II
Fill unit weight:	22 kN/m^3	21 kN/m^3
Coefficients of lateral earth pressure:		
'active' or unrestrained, K_a	0.27	0.27
‘passive’, K_p	3.7	3.7

6.5 Construction Considerations

6.5.1 General

Care should be taken during construction to avoid disturbance of the subgrades prior to constructing foundations for the replacement culvert. All existing fill and any topsoil, organics, and soft or loose soils should be stripped from the proposed founding areas prior to placement of base materials. Subgrade preparation should be performed and monitored in accordance with OPSS 902 and as modified by these recommendations.

It is recommended that the footing excavations be carried out such that the final 0.5 metres of excavation is completed with a Quality Verification Engineer (QVE) experienced in geotechnical engineering on site. The prepared excavation bases should be inspected by the QVE and granular base materials or a working slab should be placed immediately after inspection to protect the founding materials. The clayey silt till subgrade is sensitive to disturbance due to construction traffic and ponded water. If the granular bedding or foundation cannot be placed within 24 hours of inspecting the subgrade then a working slab shall be placed to protect the subgrade. The working slab is to consist of a minimum 100 millimetre thick mat consisting of concrete with a minimum 28 day compressive strength of 20 megapascals. A Non Standard Special Provision (NSSP) should be added to the Contract Documents to provide the working slab requirements. The QVE should assess the foundation conditions to determine if sub-excavation of unsuitable material is required. Sub-excavation and placement and compaction of fill should be carried out under the direction of the QVE.

6.5.2 Erosion and Scour Protection

Erosion and scour protection for the culvert inlet and outlet should be provided, as appropriate. Consideration could be given to using suitable non-woven geotextile and rip-rap, as required, to provide erosion protection based on hydraulic requirements. Temporary erosion protection and sedimentation control measures should be implemented in accordance with OPSS 805. Rip-rap treatment at the culvert outlet should be provided in accordance with OPSD 810.010. In addition, sediment control such as silt fences and erosion control blankets may be required during construction.

6.6 Excavations and Groundwater Control

Excavations will extend into the native silt, silty sand and clayey silt till. It is anticipated that excavation for the culvert replacement will extend approximately 2.5 metres below the inferred groundwater level of elevation 214 metres. Some groundwater seepage from the fill materials and native clayey silt till should be anticipated. It is considered that groundwater can be controlled by pumping from properly constructed and filtered sumps located at the base of the excavations. Sumps should be maintained outside of the actual foundation limits.

Surficial water seepage into the excavations should be expected and will be heavier during periods of sustained precipitation. Surface water runoff should be directed away from the excavations at all times. The existing culvert flows will need to be diverted/piped during construction. The appropriate special provisions should be included in the contract documents to alert the contractor about the need for adequate control of surface and groundwater flows.

Temporary open cut slopes within the fill materials should be maintained no steeper than 1 horizontal to 1 vertical and localized sloughing and ground movements should be expected. All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. The fill materials and silt and silty sand below the groundwater level would be classified as a Type 3 soil and clayey silt till would be classified as Type 2 soils.

6.7 Staging and Temporary Roadway Protection

It is understood that a single lane is to remain open to traffic during construction. Temporary support systems could consist of cantilevered soldier piles and lagging or steel sheet piles. The presence of cobbles and boulders should be anticipated in the clayey silt till. A NSSP should be added to the Contract Documents to alert the contractor to the possibility of sheet pile installation being impeded by cobbles and boulders. Excavation support systems should be designed and constructed in accordance with OPSS 539 and the design should limit the lateral movement of the temporary shoring system to meet Performance Level 2. The contractor is responsible for the complete detailed design of the protection system.

Where cantilevered sheet piles are used, or where the support to the wall is provided by anchors or rakers, the wall design should be based on a triangular earth pressure distribution using the design parameters given below. The raker/anchor support must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line, or point loads as well as the impact of sloping ground behind the system. Passive toe restraint to the soldier piles may be determined using a triangular pressure distribution acting over an equivalent width equal to three times the pile socket diameter.

The unfactored triangular earth pressure distribution (p' in kN/m^2; increasing with depth) can be calculated as follows:

$$p' = K_a (H - h_w) \gamma + K_a (\gamma - \gamma_w) h_w + \gamma_w h_w + K_a q$$

where H = the height of the excavation at any point in metres

K_a = active coefficient of earth pressure

γ = soil unit weight

γ_w = unit weight of water or 9.8 kNm^{-3}

q = surcharge for traffic and other loading

h_w = height of groundwater level above excavation base; water level to be taken as elevation 214 metres

The support systems may be designed using the parameters provided in the table below. These parameters are provided to assist with design for the unfactored ultimate resistance and loading conditions and may not result in a temporary support design that adequately controls ground and structure displacements. Achieving adequate displacement control in accordance with the MTO performance criteria may require designs that result in a system that is stiffer than might otherwise be required based on the soil parameters provided in the table below.

Soil Type	Coefficient of Earth Pressure			Internal Angle of Friction (degrees)	Unit Weight (kN/m^3)
	Active, K_a	At Rest, K_o	Passive, K_p		
Fill	0.36	0.53	2.8	28	19
Silt	0.36	0.53	2.8	28	18
Silty Sand	0.36	0.53	2.8	28	19
Clayey Silt Till	0.31	0.47	3.3	32	20

The earth pressure coefficients identified above may be applied assuming a horizontal ground surface behind the retaining structure. Where the ground surface behind the retaining structure is sloped, the earth pressure coefficients provided in the table above must be increased.

7.0 MISCELLANEOUS

This section of the report was prepared by Mr. Brett Thorner, E.I.T. under the direction of the Project Engineer Ms. Dirka U. Prout, P.Eng. and reviewed by Mr. W. Michael Kellestine, P.Eng., a Principal with Golder Associates. Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment, conducted an independent quality review of the report.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

ORIGINAL SIGNED

Dirka Prout, P.Eng.
Project Engineer

Fintan J. Heffernan, P.Eng.
MTO Designed Contact

BT/DUP/WMK/AMH/FJH/cr

n:\active\2012\1132 - geo\1132-0100\12-1132-0163 stantec-fdns-mega culverts-3011-e-0041\ph 2000-gwp 3040-11-00\rpts\r06 - site 14-444 (woods creek)\1211320163-2000-r06 aug 21 14 (final) part a&b fdns repl clvrt 14-444-c (woodscreek).docx

TABLE I

COMPARISON OF STRUCTURE ALTERNATIVES FOR REPLACEMENT CULVERT

Woods Creek, Site 14-444, Station 11+732, Highway 21
Structure Replacements and Rehabilitation
GWP 3040-11-00

FOUNDATION OPTION	FEASIBILITY	ADVANTAGES	DISADVANTAGES	ESTIMATED COSTS	RISKS/ CONSEQUENCES
Precast box culvert founded on stiff to very stiff clayey silt till	• Feasible • Preferred technical alternative	• Least expensive option due to shallower excavation compared to the open footing option and use of precast elements • Allows for most rapid construction compared to the two other alternatives since there is no wait for concrete to cure • Suitable for corrosive environments • Can be more readily installed during cold weather conditions	• If floor is thin and poorly reinforced, it may crack and heave. • During high flows, the concrete floor can be undermined and removed • Susceptible to defects/leakage at joints	• Low	• Relatively low risk • Improper alignment or transition between stream and culvert may lead to problems with scour
CIP box culvert founded on stiff to very stiff clayey silt till	• Feasible	• Intermediate in cost between a pre-cast box and CIP open footing culvert • Less excavation required compared to an open footing culvert • Suitable for corrosive environments • Culvert design can be customized in the field for high stress or load conditions or other site-	• If floor is thin and poorly reinforced, it may crack and heave. • During high flows, the concrete floor can be undermined and removed • More expensive compared to precast box option due to increased labour associated with concrete formwork	• Low to Moderate	• Relatively low risk • Improper alignment or transition between stream and culvert may lead to problems with scour

COMPARISON OF STRUCTURE ALTERNATIVES FOR REPLACEMENT CULVERT

FOUNDATION OPTION	FEASIBILITY	ADVANTAGES	DISADVANTAGES	ESTIMATED COSTS	RISKS/ CONSEQUENCES
		specific requirements • Can be constructed with far fewer joints than a precast box culvert	• Special curing requirements for cold weather work		
CIP open footing culvert with spread footings founded on stiff to very stiff clayey silt till	• Feasible	• Higher costs compared to box culvert options • Suitable for corrosive environments • Culvert design can be customized in the field for high stress or load conditions or other site-specific requirements • Can be constructed with far fewer joints than a precast box culvert • Most suitable where maintenance of fish and/or wildlife passage and preservation of the natural stream bed is a priority	• More expensive compared to both box culvert options due to increased labour associated with concrete formwork and deeper excavation required to provide frost protection for footings • Footings may be susceptible to scour and undermining especially at entrance • Additional excavation below groundwater level • Additional dewatering effort	• Moderate	• Relatively low to moderate risk • Improper alignment or transition between stream and culvert may lead to problems with scour • Option with foundations most susceptible to damage by scour

NOTES:
1. Qualitative estimates are based on 2014 construction costs and are intended to provide a comparison between alternatives rather than actual construction costs.
2. Table to be read in conjunction with accompanying report.

Prepared By: BT
Checked By: AMH

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
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
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.) split spoon 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, 60º 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 cm^2 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) Cohesionless Soils

Density Index (Relative Density)	N 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	c_u, s_u 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.

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
F	factor of safety
V	volume
W	weight

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
v	poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma$-u)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_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	liquid limit
w_p	plastic limit
l_p	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_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
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 δ
c'	effective cohesion
c_u, s_u	undrained shear strength (ϕ = 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

Notes:
1. $\tau = c' + \sigma' \tan \phi'$
2. shear strength = (compressive strength)/2

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 210

METRIC

PROJECT 12-1132-0163

W.P. 3040-11-00 | LOCATION N 4775474.3 , E 346691.8 | ORIGINATED BY BT

DIST ____ HWY 21 | BOREHOLE TYPE POWER AUGER, HOLLOW STEM | COMPILED BY AMG/LMK

DATUM GEODETIC | DATE July 8, 2013 | CHECKED BY ____

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
216.71	GROUND SURFACE							
0.09	ASPHALT							
0.21	FILL, granular base, Brown					216		
216.04 0.67	FILL, granular subbase, Brown	1	SS	7				
	FILL, clayey silt, some topsoil, some sand, trace gravel, Firm, Dark brown	2	SS	6		215		1 20 45 34
		3	SS	6		214		
213.66 3.05	SILTY SAND, trace topsoil, rootlets, Loose, Brown	4	SS	6	▽			
213.30 3.41	CLAYEY SILT TILL, some sand, trace gravel, Stiff to very stiff, Brown, becoming grey at about elev. 212.29m	5	SS	25		213		
		6	SS	17		212		
		7	SS	14		211		1 13 53 33
		8	SS	11		210		
		9	SS	13		209		
		10	SS	13		208, 207		0 11 54 35
		11	SS	18		206		
205.43 11.28	END OF BOREHOLE							

Groundwater encountered at elev. 213.5m during drilling on July 8, 2013.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 211

METRIC

PROJECT 12-1132-0163
W.P. 3040-11-00 LOCATION N 4775475.0 , E 346681.5 ORIGINATED BY BT
DIST ______ HWY 21 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY AMG/LMK
DATUM GEODETIC DATE July 8, 2013 CHECKED BY ______

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
216.65	GROUND SURFACE					
0.06	ASPHALT					
0.21	FILL, granular base Brown					
0.37	FILL, granular subbase Brown					
	FILL, clayey silt, some sand, trace gravel, trace topsoil, with sandy silt layers Soft to firm Brown	1	SS	7		
		2	SS	4		
		3	SS	3		
213.91 / 2.74	SILT, some clay, trace to some sand Compact Brown	4	SS	11	▽	
212.99 / 3.66	CLAYEY SILT TILL, some sand, trace gravel Stiff to very stiff Grey	5	SS	25		1 12 52 35
		6	SS	18		
		7	SS	16		
		8	SS	17		1 12 52 35
		9	SS	14		
		10	SS	15		1 12 54 34
205.37 / 11.28	END OF BOREHOLE Groundwater encountered at elev. 213.3m during drilling on July 8, 2013.					

Elevation scale: 216, 215, 214, 213, 212, 211, 210, 209, 208, 207, 206

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L
WATER CONTENT (%): 10 20 30
UNIT WEIGHT γ kN/m³

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 212

METRIC

PROJECT 12-1132-0163
W.P. 3040-11-00
LOCATION N 4775464.0 , E 346678.6
ORIGINATED BY BT
DIST ___ HWY 21
BOREHOLE TYPE POWER AUGER, HOLLOW STEM
COMPILED BY AMG/LMK
DATUM GEODETIC
DATE July 8, 2013
CHECKED BY ___

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
216.40	GROUND SURFACE					
0.00	TOPSOIL, sandy Brown					
0.24	FILL, clayey silt, some sand, trace gravel, trace topsoil, with sand layers Soft to stiff Brown to grey	1	SS	9	Backfill	
		2	SS	3		
		3	SS	5		0 27 46 27
		4	SS	10	Filter Sand; Piezometer	
212.74 / 3.66	CLAYEY SILT TILL, some sand, trace gravel Very stiff Brown becoming grey at about elev. 212.3m	5	SS	20		
		6	SS	26	Granular Bentonite	1 10 54 35
		7	SS	20		
		8	SS	20		
		9	SS	19	Backfill	3 13 50 34
		10	SS	25		
		11	SS	19		
205.27 / 11.13	END OF BOREHOLE					

Groundwater encountered at about elev. 213.0m during drilling on July 8, 2013.

Water level measure at elev. 212.59m on July 8, 2013.

Water level measured at elev. 213.66m on September 5, 2013.

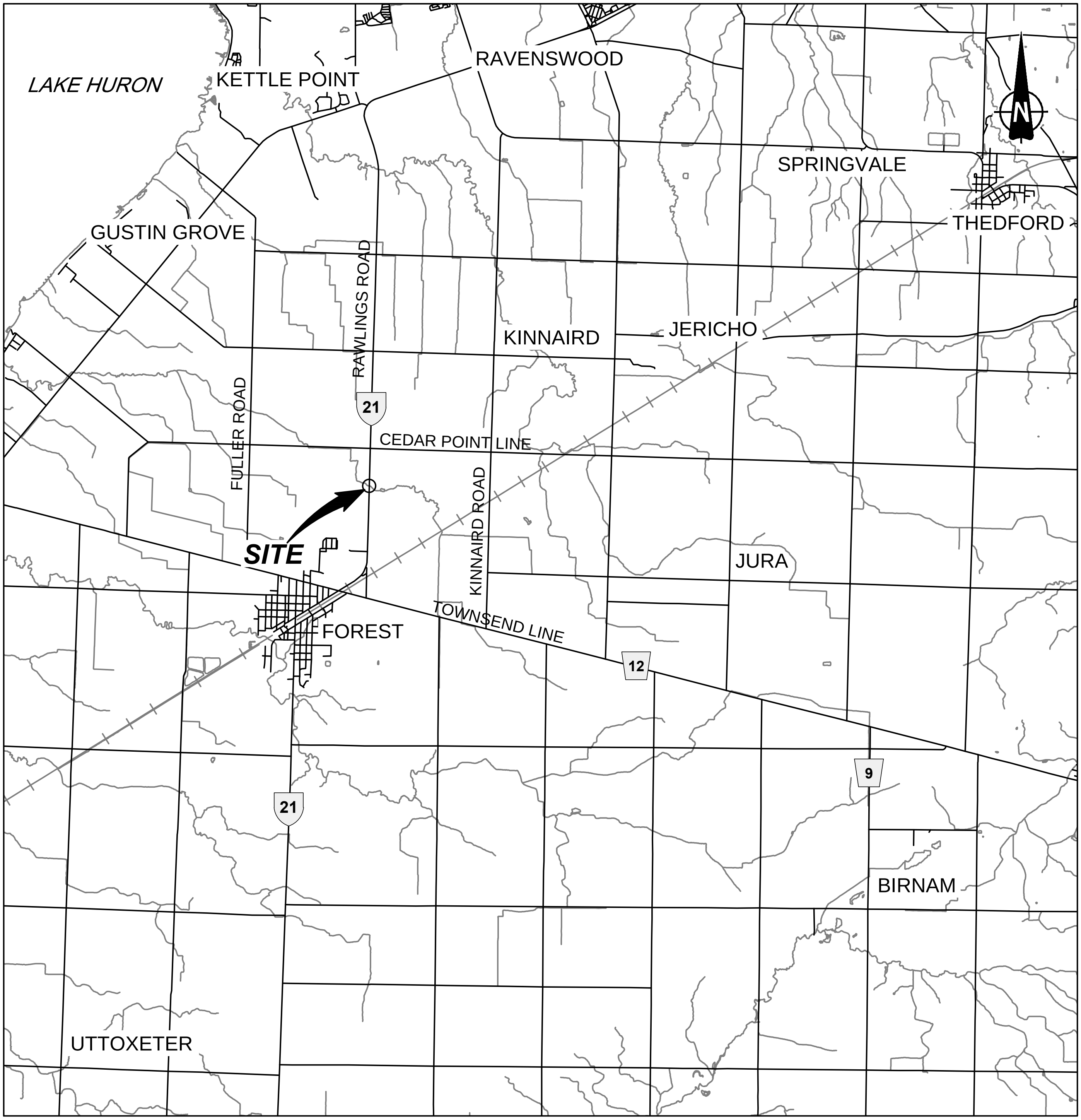
Water level measured at elev. 214.30m on April 30, 2014.

Water level measured at elev. 213.66m on July 25, 2014.

Elevation scale: 216, 215, 214, 213, 212, 211, 210, 209, 208, 207, 206

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³

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



SCALE

0 2000 4000m

1:100,000

REFERENCE

PLAN BASED ON CANMAP STREETFILES V.2008.5.

NOTE

THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

PROJECT

WOODS CREEK, SITE 14-444/C
STATION 11+732, HIGHWAY 21
GWP 3040-11-00

TITLE

KEY PLAN

Golder Associates
LONDON, ONTARIO

PROJECT No.		12-1132-0163	FILE No.	1211320163-2000-F06001
			SCALE AS SHOWN	REV. 0
CADD	LMK	Apr. 4/14	**FIGURE 1**	
CHECK				

Drawing file: 1211320163-2000-F06001.dwg May 13, 2014 - 3:15pm

MINISTRY OF TRANSPORTATION, ONTARIO

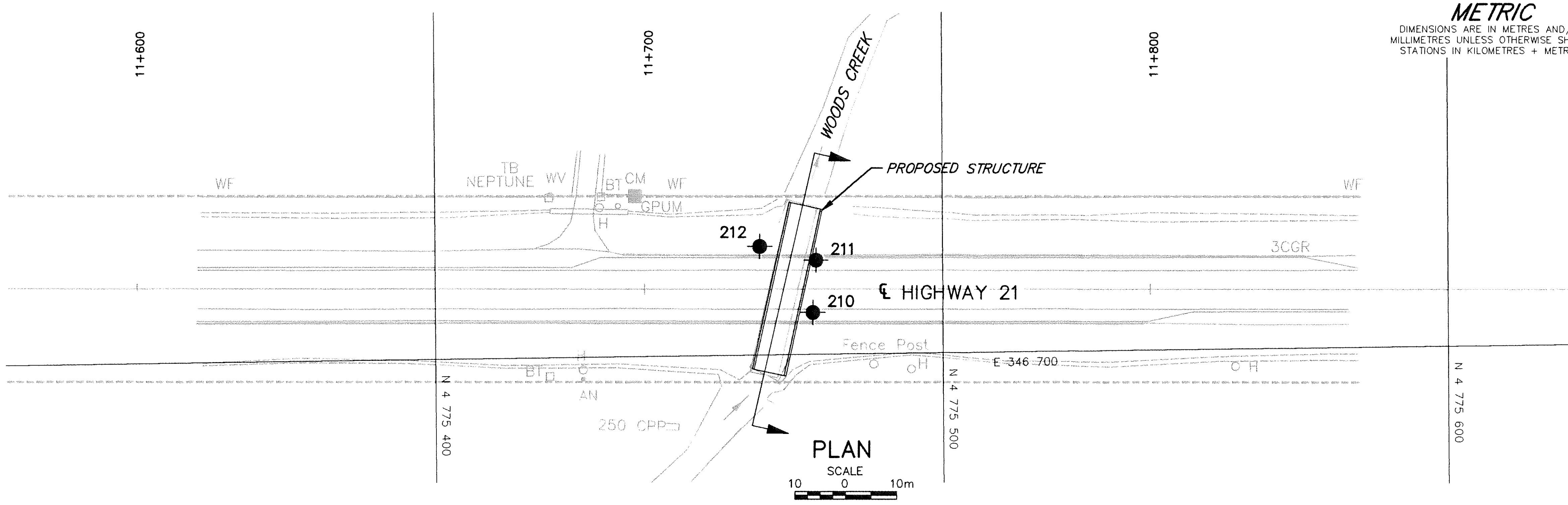
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

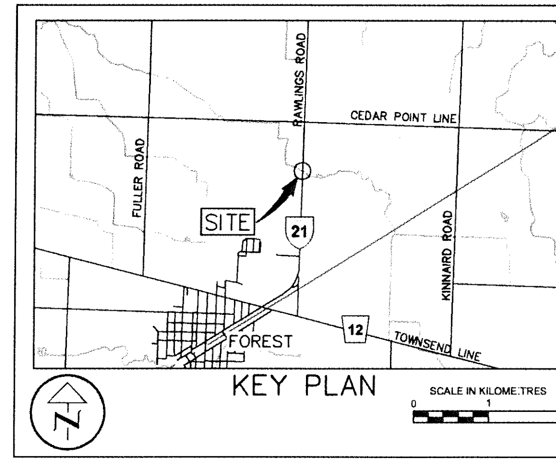
CONT No.
WP No. 3040–11–00

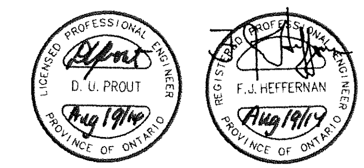
SHEET

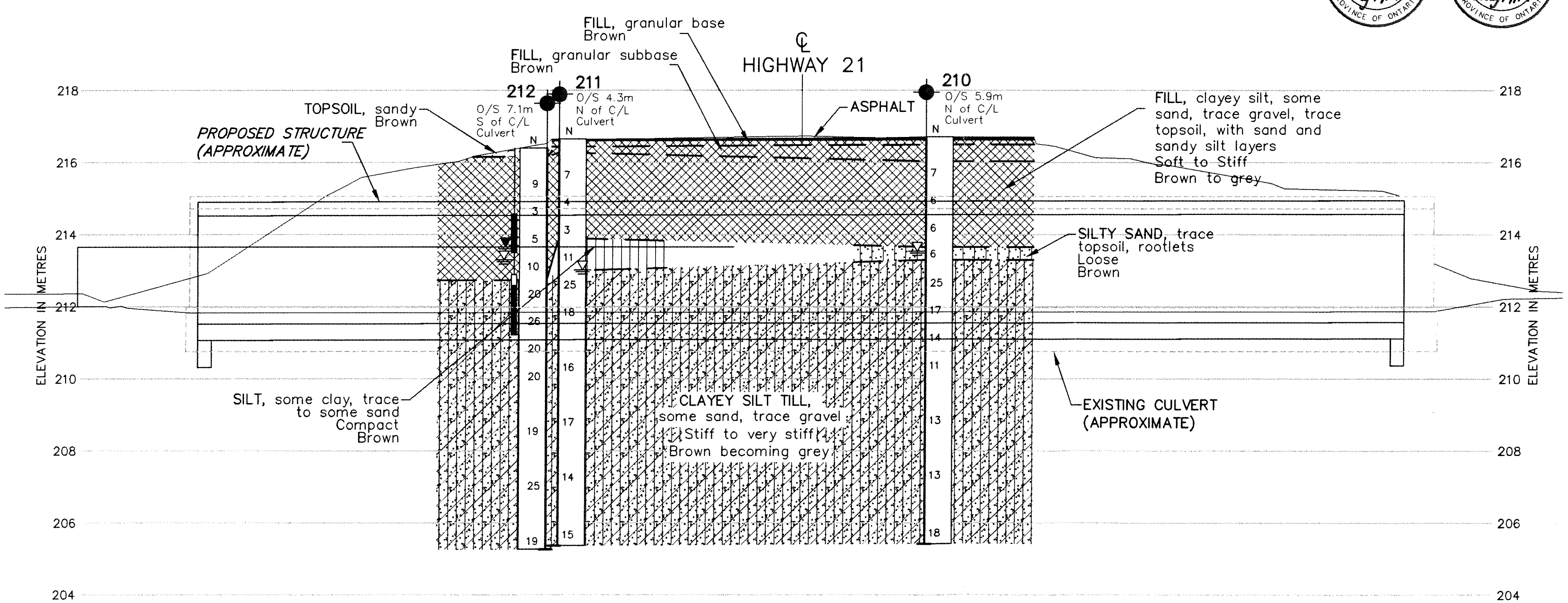
WOODS CREEK
STATION 11+732, HIGHWAY 21
STRUCTURE REPLACEMENTS AND REHABILITATION
BORESHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
LONDON, ONTARIO, CANADA









PROFILE ALONG ℄ CULVERT

HORIZONTAL SCALE 2 0 2 m
VERTICAL SCALE 2 0 2 m

LEGEND

- Borehole – Current Investigation
- Seal
- Standpipe
- N — Standard Penetration Test Value
- 16 — Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL measured on July 25, 2014
- WL encountered during drilling

No.	ELEVATION	CO-ORDINATES (MTM ZONE 11) NORTHING	EASTING
210	216.71	4 775 474.3	346 691.8
211	216.65	4 775 475.0	346 681.5
212	216.40	4 775 464.0	346 678.6

NOTES

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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

REFERENCE

Base plans provided by Stantec.

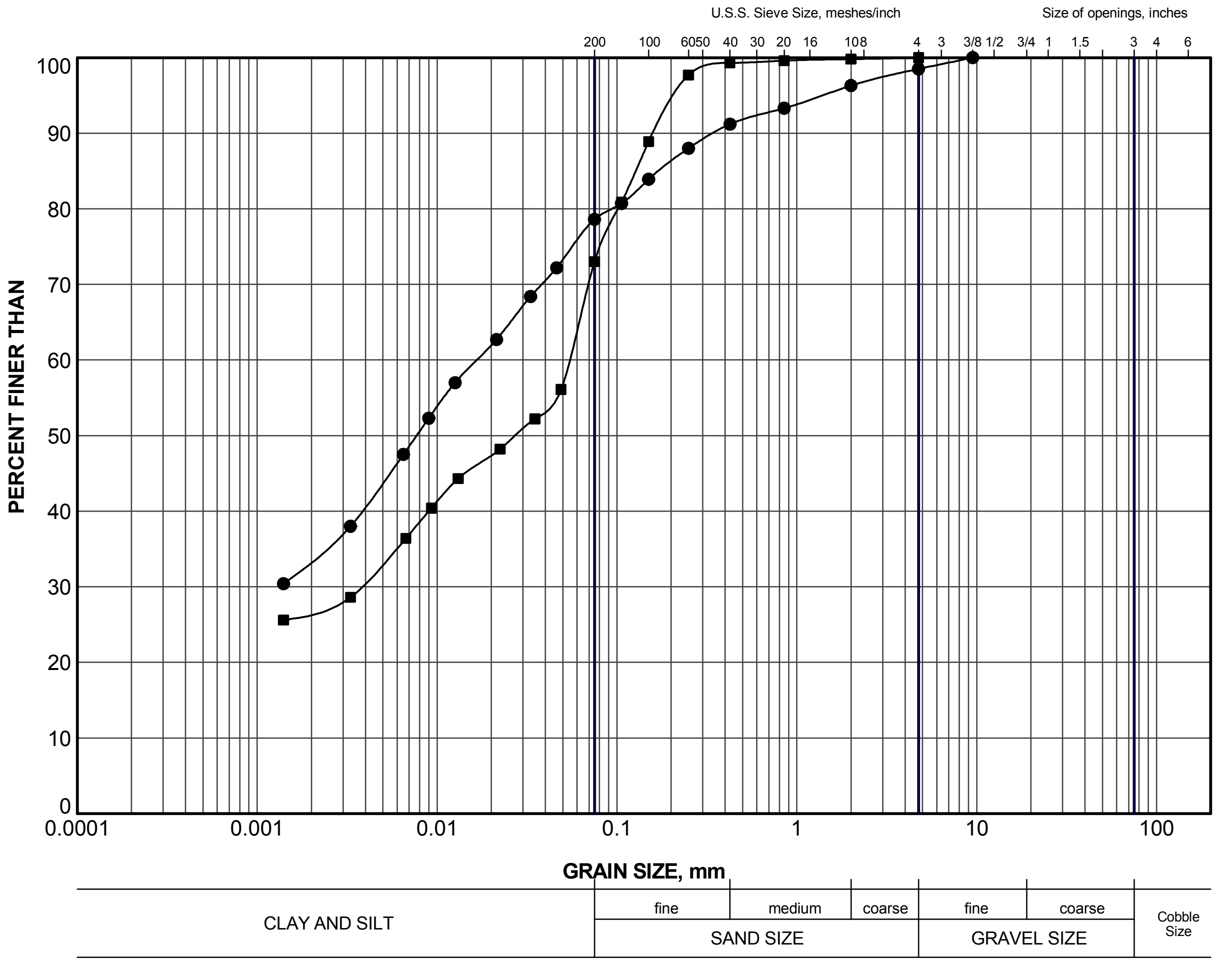
NO.	DATE	BY	REVISION

Geocres No. 40P4–50			
HWY. 21		PROJECT NO. 12–1132–0163	DIST.
SUBM'D. BT	CHKD. DUP	DATE: July 28/14	SITE: 14–444/C
DRAWN: LMK	CHKD. WMK	APPD. FJH	DWG. 1

PLOT DATE: August 19, 2014

APPENDIX A

Laboratory Test Data



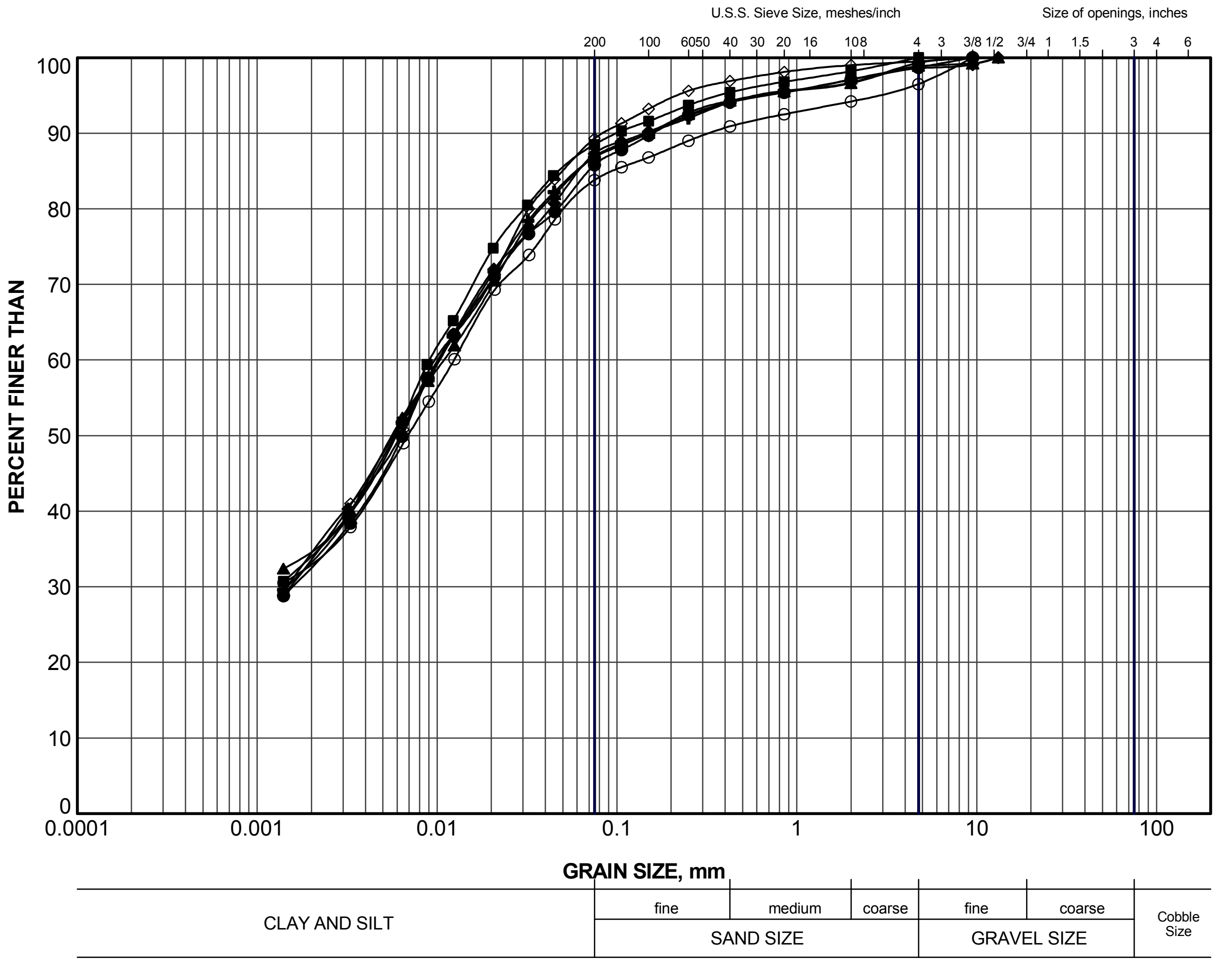
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	210	2	215.0
■	212	3	213.9

PROJECT	WOODS CREEK, SITE 14-444/C STATION 11+732, HIGHWAY 21 GWP 3040-11-00
TITLE	**GRAIN SIZE DISTRIBUTION** **FILL**

Golder Associates LONDON, ONTARIO	PROJECT No. 12-1132-0163		FILE No. 1211320163-2000-F060A1	
			SCALE N/A	REV.
	DRAWN LMK	Apr 4/14	**FIGURE A-1**	
	CHECK			

LDN_MTO_GSD GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	210	7	211.2
■	210	10	207.3
▲	211	5	212.6
✚	211	8	208.8
◆	211	10	205.8
◇	212	6	211.6
○	212	9	208.6

PROJECT

WOODS CREEK, SITE 14-444/C
STATION 11+732, HIGHWAY 21
GWP 3040-11-00

TITLE

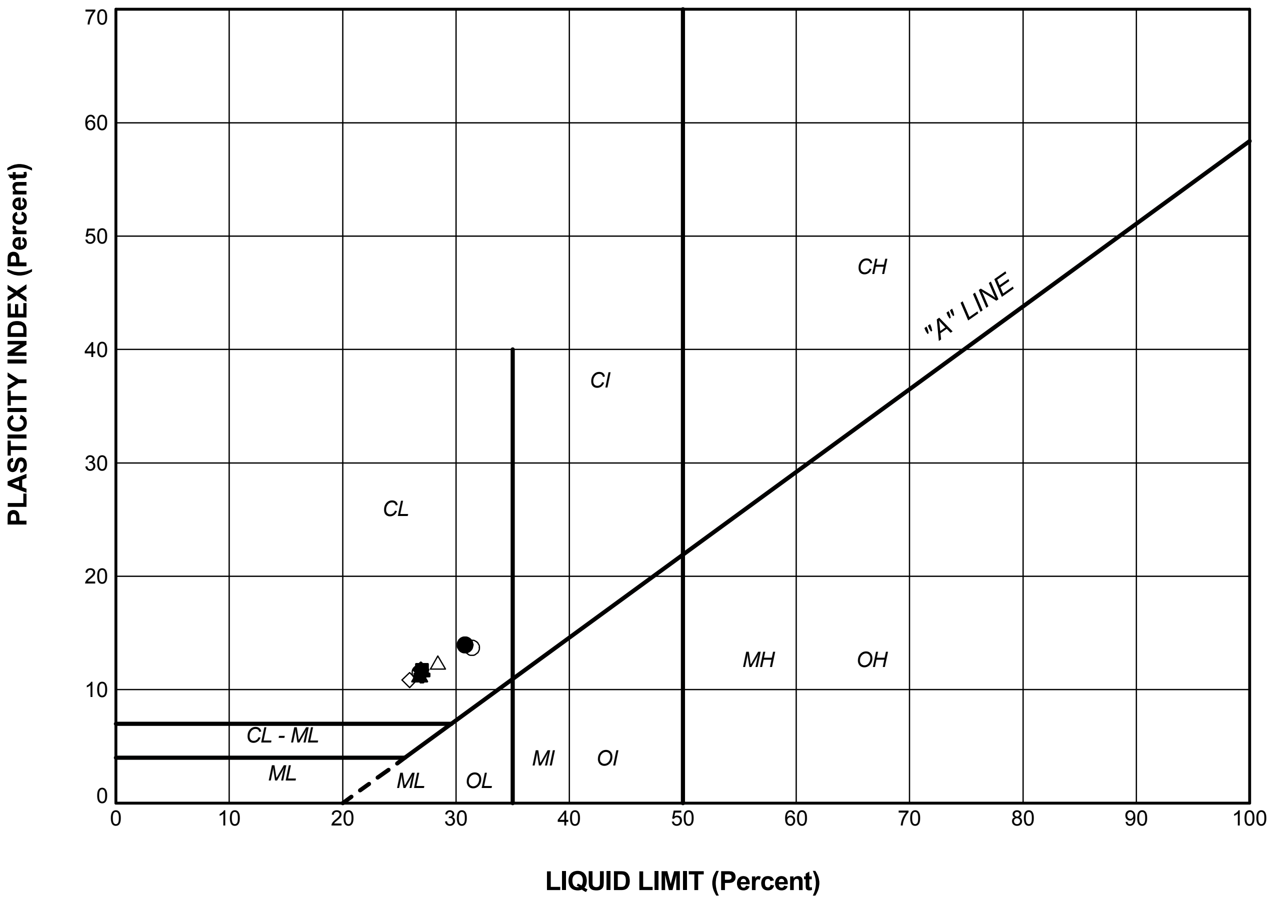
GRAIN SIZE DISTRIBUTION

CLAYEY SILT TILL

Golder Associates
LONDON, ONTARIO

PROJECT No.	12-1132-0163	FILE No. 1211320163-2000-F060A2
		SCALE N/A REV.
DRAWN LMK	Apr 4/14	**FIGURE A-2**
CHECK		

LDN_MTO_GSD GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
FILL					
●	210	2	30.8	16.9	14.0
○	212	3	31.4	17.7	13.7
CLAYEY SILT TILL					
■	210	7	27.0	15.3	11.8
▲	210	10	26.8	15.5	11.3
✚	211	5	27.0	15.7	11.3
◆	211	8	26.9	15.2	11.8
◇	211	10	25.9	15.1	10.9
△	212	6	28.4	16.0	12.4
⊗	212	9	26.8	15.3	11.5

PROJECT
WOODS CREEK, SITE 14-444/C
STATION 11+732, HIGHWAY 21
GWP 3040-11-00

TITLE
PLASTICITY CHART

Golder Associates
LONDON, ONTARIO

PROJECT No.	12-1132-0163	FILE No. 1211320163-2000-F060A3	
		SCALE N/A	REV.
DRAWN	LMK	Apr 4/14	**FIGURE A-3**
CHECK			

LDN_MTO_PI GLDR_LDN.GDT

APPENDIX B

Site Photographs

Photograph 1: West elevation (outlet) of Woods Creek Culvert Site 14-444/C.

Photograph 2: East elevation (inlet).

Photograph 3: Highway 21 looking north from west shoulder at Culvert Site 14-444/C.

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Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

Golder Associates Ltd.
309 Exeter Road, Unit #1
London, Ontario, N6L 1C1
Canada
T: +1 (519) 652 0099

Golder Associates