April 2011

PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

Structural Culvert Site 9-159-C
Rehabilitation of Highway 3 in Canfield
GWP 3507-02-00
Ministry of Transportation, Ontario - West Region

Submitted to:

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REPORT

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PRELIMINARY FOUNDATION INVESTIGATION REPORT

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REHABILITATION OF HIGHWAY 3 IN CANFIELD
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Delcan Corporation (Delcan) on behalf of the Ministry of Transportation, Ontario (MTO) to prepare a preliminary foundation investigation and design report for the structural culvert at Site 9-159-C as part of the preliminary design work for GWP 3507-02-00 which involves the rehabilitation of Highway 3 in Canfield, Ontario.

The purpose of the preliminary foundation investigation was to determine the subsurface conditions at the culvert site. The subsurface conditions have been interpreted based on a literature review of existing information and a field reconnaissance and inspection. A subsurface field exploration was not required for this assignment. The terms of reference for the scope of work are outline in the MTO'S Request for Proposal and Golder Associates' proposal P0-1132-0008 dated March 25, 2010. The work was conducted in accordance with our Quality Control Plan for Foundation Engineering dated June 2010.

Delcan provided Golder Associates with preliminary base plans in digital format showing the culvert location.

2.0 SITE DESCRIPTION

2.1 Location

The project area is located along an approximately 1.1 kilometre stretch of Highway 3 (Talbot Road) in the Community of Canfield, Ontario. The project also includes Structural Culvert Site 9-159-C at Station 31+677. This culvert is approximately 408 metres west of Hald-Dunn Townline Road on Lot 1 Concession 1 NTR near the boundary with Concession 1 Lot 1 STR in the Geographic Township of North Cayuga. The location of the project and Structural Culvert Site 9-159-C are shown on the Key Plan, Figure 1.

Highway 3, in the vicinity of site, is a two lane undivided highway with a rural cross-section which runs approximately east-west. Post and cable guide rails line both sides of the highway in the vicinity of the culvert. Photographs of the site, taken during a site reconnaissance by members of our staff on September 10, 2010, are presented in Appendix C.

2.2 Topography

2.2.1 Topographic Mapping

Topographic information was obtained from the online services Toporama and Niagara Navigator.

The ground surface in the general project area is fairly flat to gently undulating with ground surface elevations ranging from 180 to 190 metres. The unnamed creek meanders through a 275 to 400 metre wide valley area with elevations ranging from 180 metres near to the creek to a high of 185 to 186 metres. Immediately adjacent to the culvert, the ground surface elevation is near 180 metres. The elevation of the paved surface of Highway 3 at the culvert location is approximately 181.8 metres based on recent survey information provided by Delcan.

2.2.2 Aerial Photographs

Aerial photographs taken in 1965, 1976 and 1980 were obtained from the National Air Photo Library. In addition, the 2000 and 2006 aerial photography was obtained from the Niagara Navigator website. Brief summaries of the observations noted after review of each aerial photograph are presented in the following paragraphs.

The 1965 black and white aerial photography was available at a scale of 1:25, 000. The 1976 and 1980 aerial photography was available at a scale of 1:50,000. The aerial photography viewed on the Niagara Navigator website was black and white for 2000 and colour for 2006.

The area is rural residential. A small pond upstream of Structural Culvert Site 9-159-C is visible in the photographs. There are residential structures to the northwest and southwest of the culvert. The channel immediately upstream of the culvert is bordered by trees. At the culvert site, there was no change in land use or the location of Highway 3 since 1965. There appears to have been a reduction in the amount of large trees beside the Oswego Creek tributary from just north of Highway 3 to the Hald-Dunn Townline Road. The former residence northeast of the culvert that was visible in the 1965 aerial photograph appears to have been demolished by 1976. This lot remained vacant until sometime between 1980 and 2000 when a new structure was erected at this site. New structures were also erected on the properties southwest and southeast of the culvert. The ends of the culvert and ponded water at the culvert inlet and outlet are visible in the 2000 and 2006 aerial photography. Between 2000 and 2006, the barn and two neighbouring structures at the rear of Municipal Number (MN) 6701 Talbot Road were demolished and stockpiles of granular material were established on Lot 2, Concession 1 NTR. See Photograph 2 in Appendix C.

2.3 Vegetation

The unnamed creek flows through agricultural lands upstream and downstream of the culvert. The creek banks in the area immediately upstream (north) of the culvert are well vegetated with deciduous trees, shrubs and tall grasses. Although the creek banks downstream (south) of the culvert are also well vegetated, there are sparse trees. The embankment side slopes are well vegetated with grasses, small shrubs and the occasional tree. No evidence of instability was noted on the embankment side slopes.

2.4 Drainage

Regionally, the area is drained by Oswego Creek and its tributaries. The available topographic mapping indicates that the regional drainages are roughly parallel and flow generally in an east-southeast or southeast direction. Structural Culvert Site 9-159-C conveys flows of an unnamed tributary of the Oswego Creek from north to south beneath Highway 3. Several drainages and swales are tributary to this unnamed creek. A small pond is situated approximately 260 metres upstream of the culvert. Oswego Creek discharges to the Welland River, which flows to the east before draining to Lake Ontario via the Niagara River.

2.5 Existing Land Use

Culvert Site 9-159-C is located in an area where the existing land use is agricultural and rural residential. The portion of the creek immediately upstream of the culvert flows through the west side of the residential property at MN 6693 Talbot Road. Immediately downstream, the creek flows through the west and northern parts of MN 6708 Talbot Road.

2.6 Existing Structure

Structural Culvert Site 9-159-C is a rigid frame (RFO) open footed concrete culvert 3.1 metres wide and 1.8 metres high. The original culvert length was 17.7 metres. The culvert is now 22.7 metres long due to 2.5 metre long extensions at each end. The southern extension is clearly visible in Photograph 6. The culvert inlet and outlets are at elevations 178.83 and 178.77 metres, respectively. The culvert has small headwalls at each end such as the one visible in Photograph 6 in Appendix C. According to a condition survey conducted by Delcan on August 26 and November 4, 2010, the culvert roof is cracking, exhibits salt damage and honeycombing. Honeycombing and cracking is also present on the culvert walls. Leaking is occurring in the centre of the culvert along the west wall and 6.3 metres from the outlet along the east wall (see Photograph 3). Delcan's culvert condition survey indicated no problems with the bottom of the culvert. The water level at the time of Delcan's site visit was about elevation 179.8 metres.

Based on our site reconnaissance, the embankment at the culvert has side slopes inclined at approximately 2 horizontal to 1 vertical. The height of fill above the culvert was estimated to be approximately 1.2 metres.

3.0 INVESTIGATION PROCEDURES

The subsurface information at Culvert Site 9-159-C was interpreted based on a review of information from the following sources:

- MTO Geocres Library
- Ontario Geological Survey (OGS) publications
- MOE Water Well Database
- A site reconnaissance conducted by a senior member of our staff.

The subsurface conditions are based on a review and compilation of geological, geotechnical or other subsurface information contained in our library or available from the aforementioned sources. An intrusive foundation investigation was not conducted for this assignment.

Two reports were available from the MTO Geocres Library in relatively close proximity to the site.

i) Geocres Report 30L13-2, [1] a foundation investigation and design report prepared for a proposed Highway 3 bridge over Oswego Creek approximately 3 kilometres east of Culvert Site 9-159-C, and

ii) Geocres No. 30L13-3, a foundation investigation and design report for a proposed overhead structure at the Canfield junction. The site was reported to be approximately 65 metres west of Junction Road and about 805 metres south of Highway 3.[2] The locations of the sites of Geocres Reports Nos. 30L13-2 and 30L13-3 are shown on Figure 1.

[1] Geocres Report No. 30L13-2, 1971: Foundation Investigation Report for the Proposed Bridge of Highway No. 75 over the Oswego Creek, District 4 (Hamilton) W. O. 71-11104-W. P. 456-64-03, dated October 27, 1971.

[2] Geocres Report No. 30L13-3, 1970: Foundation Investigation Report for The C.N.R. & P.C.R. Overhead Structure of the Proposed Connection to Existing Hwy. 3 (Line 'B') at Canfield Junction, North Cayuga Twp. – Haldimand County, District No. 4 (Hamilton), W.O. 70-11068 – W.P. 13-66, dated September 14, 1970.

4.0 SUBSURFACE CONDITIONS

4.1 Site Geology

Structural Culvert Site 9-159-C is situated in a physiographic region known as the Haldimand Clay Plain. This is a plain of stratified clay located in the Niagara Peninsula between the Niagara Escarpment and Lake Erie. The Haldimand Clay Plain is composed of sediments previously submerged under former glacial Lake Warren. The sediments overly till which is occasionally exposed on low morainic ridges.[3]

The surficial materials consist of glaciolacustrine clay and silt deposited during the Pleistocene era.[4] The bedrock surface is near elevation 168 metres or about 14 metres below the surface of Highway 3 at the culvert site.[5] The culvert site is near a northwest to southeast trending geological boundary which is oriented at about 45 degrees to Highway 3 and crosses near the intersection of Highway 3 and Hald-Dunn Townline Road. Within the northwest and southeast quadrants of this intersection, the unnamed creek roughly follows the axis of this geological boundary. The underlying bedrock at the culvert site is reported to be tan dolomite with lenses of anhydrite or gypsum of the E member of the Salina Formation. North and east of the culvert, on the other side of the geological boundary, the bedrock is from the C member of the Salina Formation which is described as grey and olive green shale with lenses of anhydrite or gypsum.

4.2 Site Stratigraphy

The subsurface conditions described in the following sections were inferred based on information from publically available sources including the MTO Geocres Library and our files.

4.2.1 Geocres No. 30L13-2

Three boreholes were advanced for this investigation to depths of 8.3 to 12.3 metres. The ground surface elevations at the borehole locations at the time of the investigation ranged from 174.4 to 178.5 metres. The Records of Boreholes for this investigation are attached in Appendix A.

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

[4] Feenstra, B.H., 1974: Quatery Geology of the Dunnville Area, Southern Ontario; Ontario Division of Mines, Preliminary Map P.981, Geological Series. Scale 1:50,000. Geology 1973.

[5] Feenstra, B.H., 1981: Bedrock Topography of the Dunnville Area, Southern Ontario; Ontario Geological Survey Preliminary Map P.2402, Bedrock Topography Series. Scale 1:50, 000.

Fill

Stiff to very stiff cohesive fill materials were found from the ground surface in borehole 3 to a depth 4.6 metres. The clayey silt fill had N values as determined in the standard penetration test, from 11 to 20 blows per 0.3 metres.

Clayey Silt

Native cohesive deposits of predominantly low plasticity clayey silt interlayered with intermediate to high plasticity silty clay to clay were found from the ground surface in boreholes 1 and 2 and below the fill in borehole 3 from elevation 173.9 metres. The stratification of the clayey materials was variable and pockets of sand were reported in the silty clay to clay found in boreholes 1 and 3. These layers are 2.1 to 3.7 metres in thickness and had N values in the clayey silt ranging from 12 to greater than 100 blows per 0.3 metres indicating a stiff to hard consistency.

Silty Clay to Clay

With the exception of a 0.5 metre thick layer encountered in borehole 1 at elevation 174.7 metres, the silty clay and clay layers were found between elevations 170.0 and 171.4 metres and were 1.5 to 1.8 metres thick. The silty clay to clay was firm to very stiff with N values of 5 and 23 blows per 0.3 metres. The shear strengths of the silty clay to clay layers in borehole 1 were 79 and 50 kilopascals, respectively, based on the results of unconfined compression tests.

Bedrock

The report indicates that all three boreholes were terminated in the clayey silt at elevations 166.0 and 166.3 metres after practical refusal. Since traces of limestone were observed either in the samples or in the soil attached to the augers, it was assumed that either large diameter boulders and/or bedrock are present at these depths.

Groundwater

Groundwater was not established in borehole 1 and grey soils were not encountered. Groundwater was encountered in the remaining boreholes as noted in the following table:

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Level Depth (m)	Encountered Groundwater Level Elevation (m)
1	178.34	Not established	Not established
2	174.38	5.2	169.2
3	178.52	5.9 12.0	172.6 166.5

The groundwater level in the cohesive overburden materials was measured between elevations 166.5 to 172.6 metres during October 7 to 8, 1971. The water level in Oswego Creek was reported at 173.89 metres at the time of the investigation.

4.2.2 Geocres No. 30L13-3

Nine boreholes were advanced for this investigation to depths of 13.7 to 15.7 metres. The ground surface elevations at the borehole locations at the time of the investigation ranged from 186.2 to 188.7 metres. The Records of Boreholes for this investigation are attached in Appendix B.

Topsoil

Topsoil was encountered at the ground surface in boreholes 1 to 4, 6 and 9. The thickness of the topsoil layers ranged from 0.3 to 0.8 metres.

Fill

Granular fill material described as railroad fill was encountered at the ground surface in boreholes 5, 7 and 8. This material is likely railroad ballast and consisted of gravel and cinders. The thickness of the granular fill averaged 1.8 metres. The fill was loose with N values of 4 to 9 blows per 0.3 metres.

Silty Clay to Clay

Layers of silty clay to clay of intermediate to high plasticity were encountered in all boreholes beneath the topsoil or fill layers from elevations 185.4 to 186.9 metres. The silty clay was interlayered with a low plasticity layer which has been classified as clayey silt for the purposes of this report.

The upper silty clay to clay layers were typically 2.5 to 4.9 metres thick but was found to be about 13.7 metres thick at borehole 7. The upper silty clay to clay was firm to hard with N values ranging from 8 to 46 blows per 0.3 metres. The upper silty clay to clay had shear strengths of 34 to greater than 96 kilopascals based on in situ shear vane testing and 83 to 163 kilopascals based on unconfined compressive strength testing.

Layers of lower silty clay to clay were encountered in all boreholes except borehole 7 from elevations 177.8 to 181.0 metres. The lower silty clay to clay layers extended 1.5 to 5.2 metres below the base of the clayey silt. The lower silty clay to clay is stiff to hard with N values of 9 to greater than 100 blows per 0.3 metres. The measured shear strengths were 81 to greater than 96 kilopascals based on in-situ shear vane testing and 54 to 87 kilopascals based on unconfined compressive strength testing.

Clayey Silt

The silty clay to clay layers were underlain by low plasticity layers of clayey silt in all boreholes except borehole 7. The clayey silt contained seams of sand and gravel. The clayey silt layers were encountered from elevations 181.4 to 183.9 metres and were found to be 1.6 to 6.1 metres thick. The clayey silt was very stiff to hard with N values ranging from 24 to 57 blows per 0.3 metres. The shear strength of the clayey silt was found to be greater than 96 kilopascals based on in situ shear vane testing and 184 to 235 kilopascals based on unconfined compressive strength testing.

Sandy Silt to Silty Sand

The cohesive deposits in all boreholes except borehole 1 were underlain by granular materials which ranged in gradation from sandy silt to silty sand. The sandy silt to silty sand layers were 1.4 to 3.4 metres thick. The sandy silt to silty sand was encountered from elevations 174.7 to 177.2 metres. The sandy silt to silty sand is dense to very dense with N values of 40 to greater than 100 blows per 0.3 metres.

Sand

The 2.1 metre thick silty sand and gravel layer in borehole 1 at elevation 175.5 metres has been interpreted to be sand, with some gravel based on the results of a grain size analysis conducted on this material. A 1.4 metre thick sand layer with gypsum was encountered in borehole 6 from elevation 174.0 metres. The sand was very dense with N values of 57 to over 100 blows per 0.3 metres.

Gravel

The sandy silt to silty sand in borehole 9 was underlain by gravel with gypsum from elevation 173.9 metres. The gravel layer was 1.3 metres thick.

Bedrock

The bedrock surface was inferred at elevations 172.7 to 174.3 metres in boreholes 1, 3 to 5, 7 and 8. The bedrock was proven in boreholes 2, 6 and 9 by obtaining 1.5 to 1.7 metres of AXT sized core from elevations 172.5 to 172.9 metres. The bedrock was described as grey limestone with a few irregular seams of hard gypsum up to 75 millimetres in thickness. The reported Rock Quality Designation (RQD) values varied from 31 to 100 per cent with an average of 68 per cent indicating a poor to excellent but generally fair quality rock. The bedrock was weathered and accompanied by softer gypsum to depths of 1.4 and 1.1 metres below the bedrock surface in boreholes 6 and 9, respectively. Sound bedrock was obtained from the bedrock surface at elevation 172.9 metres in borehole 2, from elevation 171.2 metres in borehole 6 and from elevation 171.5 metres in borehole 9.

Groundwater

Groundwater was encountered between elevations 174.3 and 179.1 metres or at depths of 9.1 to 14.4 metres within the lower silty clay to clayey silt or underlying granular layer. The groundwater levels in the granular layers stabilized at depths of 0.2 to 1.9 metres below the ground surface or between elevations 185.3 to 186.7 metres.

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Level Depth (m)	Encountered Groundwater Level Elevation (m)	Stabilized Groundwater Level Depth (m)	Stabilized Groundwater Level Elevation (m)
1	187.06	11.8	175.3	Not reported	Not reported
2	186.81	12.5	174.3	0.9	185.9
3	187.03	10.3	176.7	Not reported	Not reported
4	186.90	11.3	175.6	0.2	186.7
5	188.43	11.4	177.0	1.9	186.5
6	186.17	9.1	177.1	0.9	185.3
7	188.73	14.4	174.3	Not reported	Not reported
8	188.21	9.1	179.1	1.5	186.7
9	186.39	9.6	176.8	0.8	185.6

4.2.3 Review of MOE Water Well Database

Golder submitted a request to the MOE for water well record summaries for all wells located within 500 metres of Structural Culvert Site 9-159-C. On October 25, 2010, the MOE responded that there were no wells within the search area. However a review of a Water Resources Bulletin for Regional Municipality of Haldimand-Norfolk indicated that the closest water well was MOE Well No. 26-01726.[6] This is a 150 millimetres diameter drilled well which is located on Lot 2 of Concession 1 STR, North Cayuga Township. The ground surface elevation at the well is reported to be 185.9 metres.

Well Stratigraphy

The reported stratigraphy was, in sequence, topsoil to elevation 185.3 metres, brown clay to 177.4 metres, blue clay to 172.2 metres then grey shale. Based on the well record, the bedrock surface is at a depth of 13.7 metres. The well was terminated in the shale at elevation 171.0 metres or at a depth of 14.9 metres.

Groundwater

Groundwater was encountered within the shale at a depth of 14.9 metres. The reported static groundwater level was at elevation 182.2 metres or at a depth of 3.7 metres. Well owners surveyed for the Hydrogeological Assessment associated with this project reported that there were water quality issues related to elevated levels of hardness, sulphur and mineral content in bedrock wells.[7]

4.2.4 Inferred Subsurface Conditions at Culvert Site 9-159-C

Site Stratigraphy

Based on our review of the available information, the site stratigraphy is inferred to be:

- Ground level (Highway 3) elevation 182 metres.
- Embankment Fill to elevation 179 metres.
- Stiff to hard silty clay to clayey silt to elevation 170 metres.
- Dolomite rock below elevation 170 metres

The cohesive deposit is expected to be stratified with layers ranging from low to high plasticity. Granular deposits consisting of silty sand to sandy silt, sand and/or gravel may be present between the cohesive deposit and bedrock.

The dominant bedrock in the area is dolomite with lenses of anhydrite or gypsum. The upper 1.0 to 1.5 metres of the bedrock surface may be weathered.

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[6] MOE Water Resources Branch, 1975: Water Resources Bulletin 2-23, Groundwater series. Water Well Records for Ontario, Regional Municipality of Haldimand-Norfolk, 1946-1975.

[7] Golder Associates, 2011: Draft Hydrogeological Assessment, Highway 3 – Canfield, Preliminary Design Study and Class EA, GWP 3507-02-00, Ministry of Transportation, Ontario – West Region, issued February 4, 2011.

Groundwater

The groundwater level is inferred to be at about elevation 182 metres or somewhat above the observed creek water level at approximate elevation 180 metres.

5.0 MISCELLANEOUS

This report was prepared by the Project Engineer, Ms. Dirka U. Prout, P.Eng. under the direction of the Team Leader, Mr. Philip R. Bedell, P.Eng. This report was reviewed by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

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PART B

PRELIMINARY FOUNDATION DESIGN REPORT

STRUCTURAL CULVERT SITE 9-159-C
REHABILITATION OF HIGHWAY 3 IN CANFIELD
GWP 3507-02-00
MINISTRY OF TRANSPORTATION, ONTARIO - WEST REGION

6.0 ENGINEERING RECOMMENDATIONS

This section of the report provides our recommendations on the preliminary foundation design aspects of the preliminary design of the proposed replacement or rehabilitation of Structural Culvert Site 9-159-C conveying an unnamed tributary of Oswego Creek beneath Highway 3. The discussion includes recommendations for a future detailed foundation investigation and preliminary design recommendations. The foundation conditions were assessed based on a review and compilation of all available geological mapping, Geocres reports, the MOE Water well database, preliminary design data provided by Delcan, and a site reconnaissance carried out by Golder.

The interpretation and recommendations are intended to provide the designers with sufficient information for preliminary assessment of the feasible foundation alternatives and to design the foundations of the proposed culvert replacement/rehabilitation. 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 consists of a rigid open footed concrete culvert 3.10 metres wide and 1.80 metres high with a main body that is 17.68 metres long. Concrete extensions 2.5 metres in length were added to each end at an unknown date. The invert elevations are 178.83 metres at the inlet and 178.77 metres at the outlet. The culvert conveys flows of an unnamed tributary of Oswego Creek from north to south below Highway 3. Both replacement and rehabilitation of the culvert is being considered at this time. There will be no grade or alignment changes along Highway 3 in the vicinity of this culvert.

The preferred culvert type, for the culvert replacement scenario will be made by the TPM team based on the hydraulic conditions prevailing at this site. At the time of preparation of this report, the preliminary design of the culvert was still underway and decisions on whether or not the culvert will be replaced, the range of suitable culvert replacement and rehabilitation options have not yet been arrived at. However, from a foundations engineering perspective, pre-cast box culverts, cast-in-place open footed culverts, pre-cast concrete pipe and corrugated steel pipe (CSP) culverts are all suitable replacement alternatives.

6.1 Foundations

The subsurface conditions based on a review of the compiled data have been inferred to be:

- Ground level (Highway 3) elevation 182 metres.
- Embankment Fill to elevation 179 metres.
- Firm to hard silty clay to clayey silt to elevation 170 metres.
- Dolomite rock below elevation 170 metres.

Competent cohesive materials are expected to be present near the original ground surface at the culvert location. No changes in grade or alignment have been proposed for this section of Highway 3. As such, shallow foundations are considered to be most cost-effective and more readily constructed foundation type from a foundation engineering perspective. Deep foundations such as steel H or tube piles driven to bedrock, are not considered warranted primarily because competent soils are expected to be present near the ground surface. The use of shallow foundations is the preferred technical alternative. The advantages/disadvantages, costs, risks/consequences for these two options are summarized in Table I following the text of this report.

6.1.1 Anticipated Geotechnical Resistances

Shallow Foundations

A cast-in-place open footing culvert can be founded 1.2 metres below the culvert invert or at approximate elevation 178 metres. If a pipe or box culvert is installed, the levelling and/or bedding course can be placed at or below elevation 178.8 metres. A factored geotechnical resistance at Ultimate Limit States (ULS) of 225 kilopascals (kPa) and a geotechnical resistance of 150 kPa at Serviceability Limit States (SLS) may be used for the purposes of preliminary design. The SLS value corresponds to 25 millimetres of settlement. The proposed founding depths and associated geotechnical resistances assume that competent native materials are present at these elevations.

Footing excavations should penetrate all existing topsoil and fill so that foundations bear directly on the native cohesive strata. Any low areas should be brought to grade using granular engineered fill or lean concrete. The footing excavations should be inspected in accordance with Ontario Provincial Standard Specifications (OPSS) 902.

Deep Foundations – Geotechnical Axial Resistance

Deep foundations will be required if the shear strength of the near surface soils are insufficient for support of the culvert using shallow foundations. Steel H-piles or tube piles can be driven to refusal into the underlying bedrock near elevation 170 metres. The culvert can be supported on driven HP 310 x 110 steel H-piles or 323 millimetre outer diameter (O.D.), concrete filled steel tube piles with a nominal 9.5 millimetre thick wall thickness.

For preliminary design, the factored axial geotechnical resistance at Ultimate Limit States (ULS) for HP 310 x 110 piles or 323 millimetre O.D. steel tube driven to refusal into the dolomite bedrock is 2000 kilonewtons. A Serviceability Limit States (SLS) value is not given since bedrock is considered to be an unyielding medium. For the purposes of preliminary design, it was assumed that the cut-off elevation will be near elevation 179 metres. Therefore, piles at this site will be approximately 9 metres long.

The driven piles should be installed and monitored in accordance with OPSS 903 and Ontario Provincial Standard Drawing (OPSD) 3000.150 or OPSD 3001.150 as applicable. The H-piles are to be equipped with reinforced flanges as shown in OPSD 3000.100.

A pile note is to be added to the foundation drawing that states that piles are to be driven to bedrock.

6.1.2 Frost Protection and Frost Treatment

Pile caps and shallow foundations for a cast-in-place open footing culvert should be provided with 1.4 metres of soil cover or thermal equivalent for frost protection. Frost treatment for all culverts is to be symmetrical about the culvert centreline. Frost treatment is to be provided in accordance with Ontario Provincial Standard Drawing (OPSD) 803.010 for concrete cast-in-place open footing or pre-cast box culverts, and OPSD 803.030 or OPSD 803.031 as applicable for concrete pipe or CSP culverts.

6.2 Backfill and Bedding

Concrete cast-in-place open footing and pre-cast box culverts are to be backfilled in accordance with OPSS 422 and OPSD 803.010. Bedding and backfilling to be carried out in conformance with OPSS 421 and OPSD 802.010 for CSP culverts and OPSD 802.030 for concrete pipe culverts. The appropriate frost tapers must be constructed within the backfill. Backfill materials should consist of free-draining, non-frost susceptible granular materials such as OPSS Granular A or Granular B, Type II.

Heavy compaction equipment should not be used immediately adjacent to the walls of the culvert. The height of backfill adjacent to the culvert walls should be maintained as equal as possible on both sides of the walls during all stages of backfill placement.

6.3 Lateral Earth Pressures For Design

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

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.

- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the walls in accordance with CHBDC Figure 6.6. Compaction equipment should be used in accordance with Special Provision 105S10. Other surcharge loadings should be accounted for in the design, as required.

- The granular fill may be placed either in a zone with a width equal to at least 1.4 metres behind the back of the stem (Case (a) from Commentary on CHBDC Figure C6.20 or within the wedge-shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical extending up and back from the rear face of the foundation (Case (b) from Commentary on CHBDC Figure C6.20.
- The pressures are based on the granular fill as placed and 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 static lateral earth pressure:		
'active' or unrestrained, K_a	0.27	0.27
'at rest' or restrained, K_o	0.43	0.43

- If the wall support allows lateral yielding (unrestrained structure), active earth pressures may be used in the geotechnical design of the structure. If the wall support does not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design.

The resistance to sliding between the base of the culvert footing and the cohesive subgrade soils should be calculated in accordance with Section 6.7.5 of the CHBDC. Assuming that the founding soils are not loosened/disturbed during excavation and wall construction, the following unfactored angle of friction and corresponding unfactored coefficients of friction, tan δ, may be used for the interaction between the culvert footing and the founding soil:

Footings on firm to hard silty clay to clayey silt:

effective angle of friction, φ'	28 degrees
tan δ	0.53

In accordance with the CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistance. The factored horizontal geotechnical resistance, H_{ri}, should be based on CHBDC 6.7.5 as follows:

$$H_{ri} = 0.8A'c' + 0.8V\tan\delta > H_f$$

Where:

A'	-	effective contact area, square metres
c'	=	0
δ	=	28 degrees
V	-	unfactored vertical force, kilonewtons
H_f	-	factored horizontal load, kilonewtons

The unfactored coefficient of passive pressure for the portion of the culvert wall and footing below the invert may be taken as 2.8 based on an unfactored effective angle of internal friction, φ', of 28 degrees for the silty clay to clayey silt.

6.4 Embankment Stability and Settlement

There will be no changes to the existing grade of Highway 3 in the vicinity of Culvert Site 9-159-C. Therefore a conventional slope geometry of 2 horizontal to 1 vertical can be established for the sideslopes of the reconstructed embankment. Negligible settlement is anticipated due to the proposed works.

6.5 Construction Considerations

Our review of the information compiled for this project has indicated that there are no construction concerns that may affect the construction of embankments. Saturated granular materials may be present between the silty clay to clayey silt layers and the bedrock.

The near surface soils are expected to consist of cohesive deposits. Although excavations for shallow foundations will extend below the inferred groundwater level at elevation 182 metres, proactive dewatering will not be required. Any seepage can be controlled through use of properly filtered sumps. Topsoil, organics and soft or loose soils, if found within the foundation area, should be removed and wasted or reused as landscaping fill, as required. Subgrade preparation should be performed and monitored in accordance with OPSS 902. Shallow foundations will likely be constructed on fine-grained materials that are sensitive to disturbance and softening due to water seepage and/or ponding. Placement of a working slab of lean concrete will be required at the base of the excavations for the footing area. Exposure without the protection of the working slab will result in softening of the founding soils. The cleaned excavation base should be inspected by a Quality Verification Engineer (QVE) qualified in geotechnical engineering prior to placing the working slab. It is recommended that the footing excavation be carried out such that the final 0.5 metres of excavation is completed with the geotechnical QVE on site and the working slab placed immediately after footing inspection.

Erosion and scour protection for the culvert backfill 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. Rip-rap treatment at the culvert outlet should be provided in accordance with Ontario Provincial Standard Drawing 810.010. In addition, sediment control such as silt fences and erosion control blankets may be required during construction and diversion/piping of the watercourse to mitigate migration of fine soil particles.

If the highway can be closed to traffic during rehabilitation/replacement of the existing culvert, the work can be carried out in an open excavation without the use of shoring. If it is necessary to maintain one lane of traffic during staged construction then temporary roadway protection will be required to support the sides of the excavation and permit the use of vertical cuts. The temporary excavation support system should be designed and constructed in accordance with OPSS 539. The lateral movement of the temporary shoring system should meet Performance Level 2.

7.0 COMMENTS FOR DETAIL DESIGN

Shallow foundations have been identified as the preferred foundation type. There is no site-specific foundation investigation for Structural Culvert Site 9-159-C. Therefore, it is recommended that a Foundation Investigation and Foundation Design Report be prepared to provide appropriate information for future Detail Design. A standard MTO foundation investigation for replacement of a culvert is considered appropriate for this site. Specifically, a minimum of three boreholes should be advanced to at least 6 metres below the culvert invert elevation of 179 metres or to the inferred rock surface, whichever is closer. A schematic plan illustrating potential borehole locations is shown on Figure 2.

Sampling should be conducted at intervals of 0.75 metres and include in-situ shear vane testing in the softer cohesive layers. Routine soil testing consisting of grain size analyses, water contents and Atterberg limits is considered appropriate since there will be no increase in the road grade or change in alignment. The preliminary recommendations given in this Preliminary Foundation Design report should be revised and updated and presented in a Foundation Design Report once the foundation investigation for detail design is completed.

8.0 MISCELLANEOUS

This report was prepared by the Project Engineer, Ms. Dirka U. Prout, P.Eng. under the direction of the Team Leader, Mr. Philip R. Bedell, P.Eng. This report was reviewed by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

ORIGINAL SIGNED

Dirka U. Prout, P.Eng.
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DUP/PRB/FJH/ly

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TABLE I

COMPARISON OF FOUNDATION ALTERNATIVES

Site 9-159-C
Rehabilitation of Highway 3 in Canfield
GWP 3507-02-00

FOUNDATION OPTION	FEASIBILITY	ADVANTAGES	DISADVANTAGES	RELATIVE COSTS	RISKS/ CONSEQUENCES
Spread footings supported on firm to hard cohesive soils	• Feasible • Preferred technical alternative	• Least expensive option • Ease of construction • Option with least construction time	• Potential for differential settlement or low geotechnical resistance if soft layers are present near surface • Possibility of differential settlement between widened and pre-existing areas if used for abutment foundations	• Low with lower costs anticipated if pipe or pre-cast box culverts are installed • Less expensive than deep foundation options	• Relatively low risk
End bearing steel H-pile or tube pile foundations driven to refusal into underlying bedrock	• Feasible	• High bearing resistance • Negligible settlement	• More expensive option • Special precautions required to control seepage if saturated granular layer present between cohesive deposits and bedrock • Specialized equipment required • Improved differential performance compared to existing spread footings	• Medium to high • More expensive than shallow foundations	• Low to moderate risk

NOTES:
1. Costs are very preliminary estimates 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: DUP
Checked By: PRB

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	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
I_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)

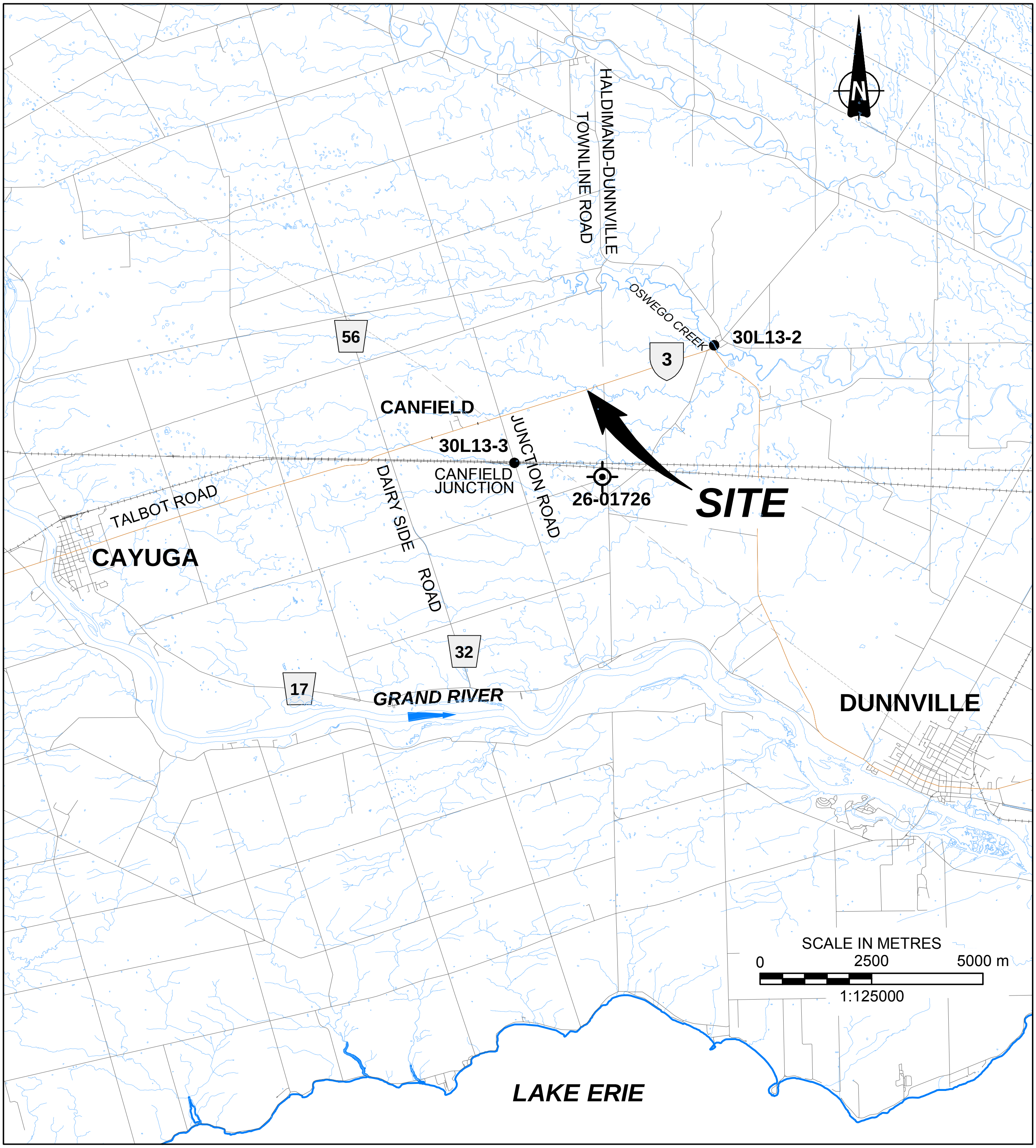
C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation 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)



LEGEND

- MTO GEOCRES No.
- WATER WELL (MOE RECORDS)

REFERENCE

CANMAP STREETFILES V2008.4.

NOTE

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

PROJECT

CULVERT SITE 9-159-C
REHABILITATION OF HIGHWAY 3 IN CANFIELD
GWP 3507-02-00

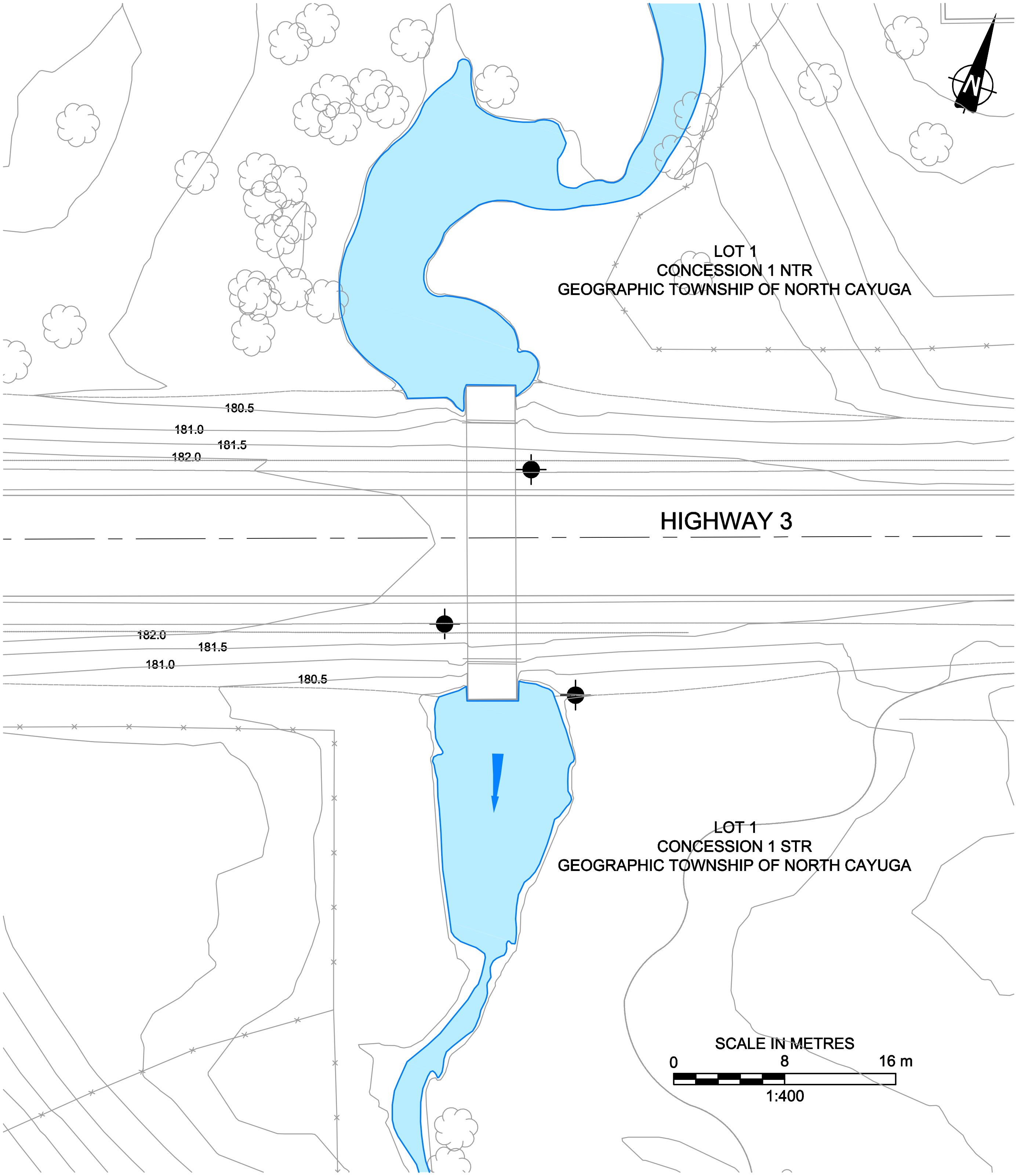
TITLE

KEY PLAN

Golder Associates
LONDON, ONTARIO

PROJECT No.	10-1132-0008	FILE No.	1011320008-5000-R01001
		SCALE	AS SHOWN	REV. 0
CADD	WDF	FEB. 8/11	
CHECK			**FIGURE 1**

Drawing file: 1011320008-5000-R01001.dwg Feb 11, 2011 - 10:39am



LEGEND

PROPOSED BOREHOLE

REFERENCE

CANMAP STREETFILES V2008.4.

NOTE

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

PROJECT

CULVERT SITE 9-159-C
REHABILITATION OF HIGHWAY 3 IN CANFIELD
GWP 3507-02-00

TITLE

SCHEMATIC BOREHOLE LOCATIONS

Golder Associates
LONDON, ONTARIO

PROJECT No.	10-1132-0008		FILE No.	1011320008-5000-R01001
			SCALE AS SHOWN	REV. 0
CADD	WDF/AMG	FEB. 8/11		
CHECK				

FIGURE 2

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APPENDIX A

Records of Previous Boreholes
(Geocres Report No. 30L13-2)

FORM OD-MT - 126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 1

FOUNDATION SECTION

JOB 71-11104 LOCATION Sta. 312 + 64 3' Lt. ORIGINATED BY FK

W.P. 456-64-03 BORING DATE Oct. 8, 1971 COMPILED BY AKB.

DATUM Geodetic BOREHOLE TYPE Auger CHECKED BY [illegible]

SOIL PROFILE: ELEV. DEPTH	DESCRIPTION	SAMPLES: NUMBER	TYPE	BLOWS/FOOT	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL.
585.1	Ground Level					
0.0	Clayey silt, some sand and gravel. Hard. Brown	1	SS	40		W.L. not established
		2	SS	40		
		3	SS	28		
573.1 / 12.0	Silty Clay. Stiff	4	TW	PM	127	
13.6	Clayey silt, some sand and gravel. Hard. Brown	5	SS	118		
		6	SS	64		
561.1 / 24.0	Clay, occasional sand pockets. Stiff	7	TW	PM	115	
555.1 / 30.0	Clayey silt, some sand Hard. Brown	8	SS	102		
544.6		9	SS	50/4"		
40.5	End of Borehole					

STRAT. PLOT

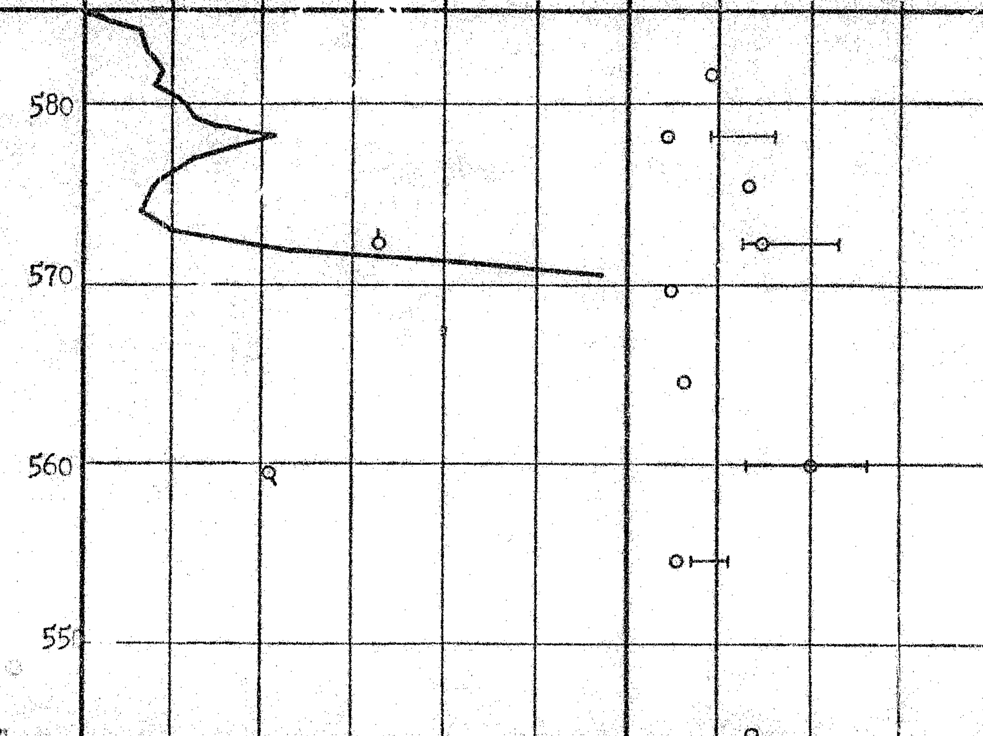
ELEV. SCALE

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100

SHEAR STRENGTH P.S.F.
o UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB. VANE
1000 2000

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_P
WATER CONTENT —— w

WATER CONTENT % 20 40 60



FORM OD-MT-126 (REV. 1969)

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 2

FOUNDATION SECTION

JOB 71-11104 LOCATION Sta. 312 + 31 24' Lt. ORIGINATED BY FK
W.P. 456-64-03 BORING DATE Oct. 7 - 8, 1971 COMPILED BY AKB
DATUM Geodetic BOREHOLE TYPE Auger CHECKED BY

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS/FOOT; SHEAR STRENGTH P.S.F. (O UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB. VANE) 1000 2000	LIQUID LIMIT w_L, PLASTIC LIMIT w_P, WATER CONTENT w; WATER CONTENT % 20 40 60	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL.
572.1	Ground Level									
0.0	Clayey silt, some sand and gravel.		1	SS	12	570				
			2	AS	-					
	Stiff to Hard		3	SS	61					
562.3			4	SS	23					
9.8	Silty clay to clay. Firm to Stiff		5	SS	5	560				
557.1			6	TW	PM		4370			
15.0	Clayey silt, some sand.		7	SS	80					
	Hard. Brown		8	SS	100/5"	550				
545.0			9	SS	100/1"					
27.1	End of Borehole					540				

FORM OD-MT-126 (REV. 1969)

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO

MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 3

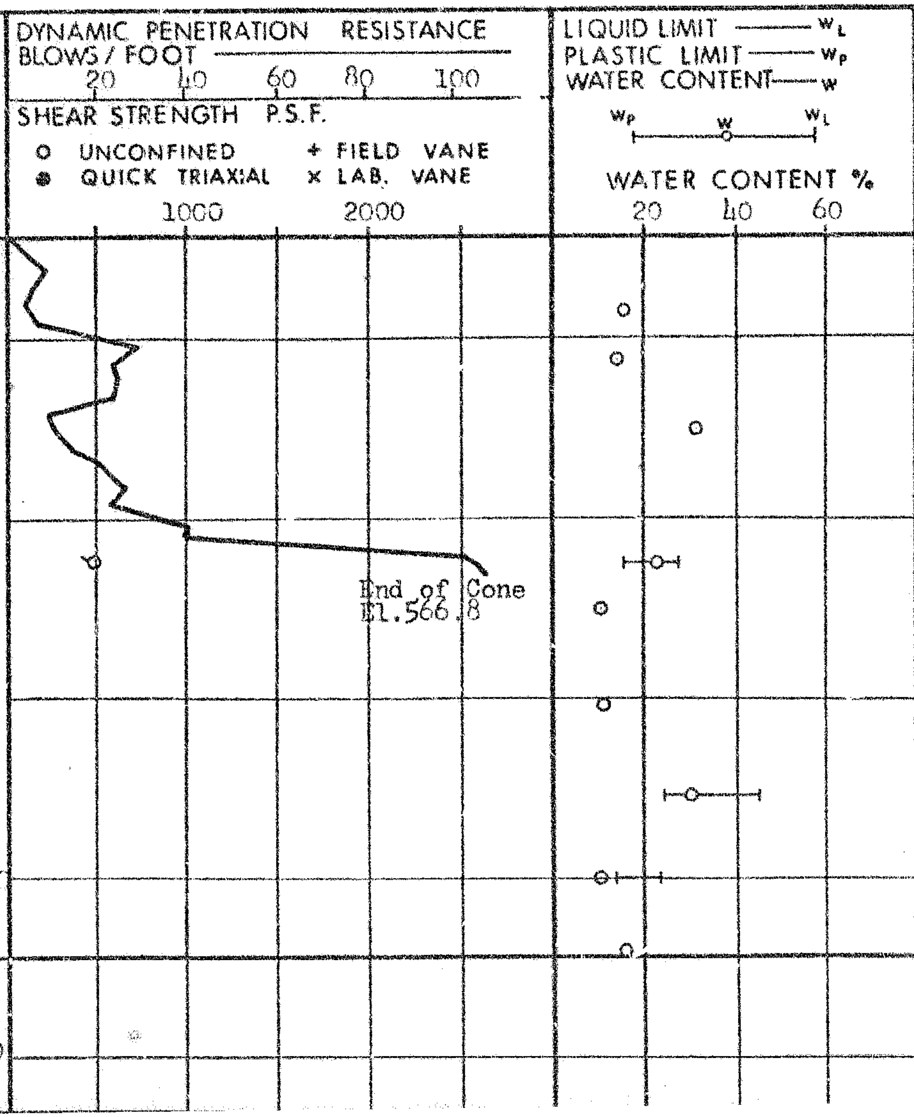
FOUNDATION SECTION

JOB 71-11104 LOCATION Sta. 311 + 43 17' Rt. ORIGINATED BY PK

W.P. 456-64-03 BORING DATE Oct. 7, 19 COMPILED BY AKB

DATUM Geodetic BOREHOLE TYPE Auger CHECKED BY

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL.
585.7	Ground Level							
0.0	Clayey silt, some sand and gravel and mixed fill (down to 15 ft.) Stiff to Hard. Brown		1	SS	20			
			2	SS	11	580		
			3	SS	16			
						570		
			4	TW	PH		126	
			5	SS	73			
			6	SS	52	560		
557.7								
28.0	Silty clay, pockets of sand. Very Stiff		7	SS	25			
552.7								
33.0	Clayey silt, some sand and gravel. Hard		8	SS	66	550		
545.7			9	AS	-			
40.0	End of Borehole					540		



APPENDIX B

Records of Previous Boreholes (Geocres Report No. 30L13-3)

FORM OB-MT-126 (REV. 1969)

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO

MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 1

FOUNDATION SECTION

JOB 70-11058

W.P. 13-66

DATUM Geodetic

LOCATION Canfield Junction Sta. 127 + 54 o/s 20' Lt.

BORING DATE Aug. 14 & 17, 1970

BOREHOLE TYPE Auger

ORIGINATED BY GC

COMPILED BY GC

CHECKED BY [signature]

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	SHEAR STRENGTH P.S.F.	WATER CONTENT %	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL
613.7	Ground Level									
611.2	Topsoil Brown									
2.5	Silty clay to clay		1	TW	PH	610	+>2000			
			2	TW	PH		+ 2000		128	
	Very Stiff		3A	SS	-					
			4	TW	PH					
	Brown		5	TW	PH	600	+>2000		122	
597.8			6	TW	PH		3840		126	
15.9	Clayey silt with some sand & gravel in random seams		7	SS	36				133	
	Hard		8	TW	PH	590				
587.7	Brown									
26.0	Silty clay to clay		9	TW	PH		+ 2000		121	
	Stiff									
	Grey		10	TW	PH	580	+84		117	
									117	
575.8			11	TW	PH				129	
37.9	Silty sand with gravel & clay.		11A	SS	57					
	Very Dense Grey		12	SS	65/4"					
568.8	Probable Bedrock					570				11 83 (6)
44.9	End of Borehole									

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 2

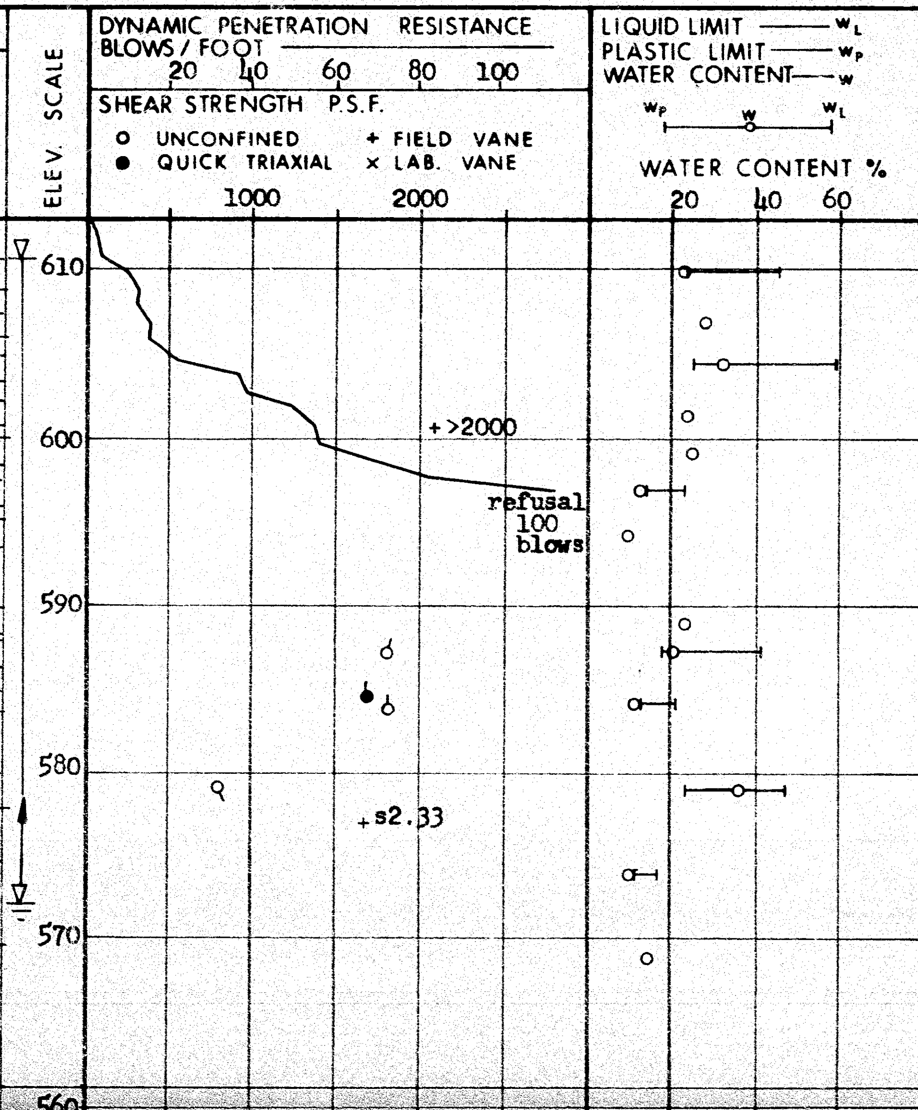
FOUNDATION SECTION

JOB 70-11068 LOCATION Canfield Jct. Sta. 127 + 14 o/s 22' Rt. ORIGINATED BY GC

W.P. 13-66 BORING DATE August 4 & 17, 1970 COMPILED BY GC

DATUM Geodetic BOREHOLE TYPE Auger CHECKED BY [signature]

ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	TYPE	BLOWS / FOOT	BULK DENSITY γ P.C.F.	REMARKS GR. SA. SI. CL.
612.9	Ground Level					
0.0	Brown Topsoil					
2.0	Silty clay to clay	1	SS	20		
		2	SS	23		
	Very Stiff	3	SS	20		
	Brown (Mottled near Surface)	4	SS	16		
599.9 / 13.0	Clayey silt to silty clay, some sand & grav. in random seams	5	SS	18		
		6	SS	29		
	Very Stiff to Hard Brown	7	SS	46		
591.4 / 21.5	Silty clay to clayey silt	8	SS	24		
		9	TW	PH	127	
	Firm to Very Stiff	10	TW	PH	145 143	
	Grey	11	TW	PH	115	0 0 38 62
574.4 / 38.5	Sandy silt with gravel and clay	12	SS	40		12 37 42 9
	Hard Grey	13	SS	-		17 56 26 1
567.4 / 45.5	Sound Limestone Bedrock	14	AXT	80%		
		15	AXT	91%		
		16	AXT	60%		
		17	AXT	92%		
561.3 / 51.6	End of Borehole					



FORM OB-MT-126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 3

FOUNDATION SECTION

JOB	70-110-68	LOCATION	Canfield Jct. Sta. 126 + 59 o/s 20' Lt.	ORIGINATED BY	GC
W.P.	13-66	BORING DATE	August 13 - 14, 1970	COMPILED BY	GC
DATUM	Geodetic	BOREHOLE TYPE	Auger	CHECKED BY	[illegible]

SOIL PROFILE | SAMPLES | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT | SHEAR STRENGTH P.S.F. (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB. VANE; 1000, 2000) | LIQUID LIMIT — w_L, PLASTIC LIMIT — w_P, WATER CONTENT — w; WATER CONTENT % (20, 40, 60) | BULK DENSITY γ P.C.F. | REMARKS GR.SA.SI.CL.

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	SHEAR STRENGTH P.S.F.	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL.
613.6	Ground Level								
	Brown Topsoil								
1.0	Silty clay to clay		1	TW	PH	610		126	
	Stiff to Very Stiff		2	TW	PH		+ >2000	125 124	
			3	TW	PH		+ > 2000		
	Brown		4	TW	PH			123 121	
			5	TW	PH	600			
596.6			6	TW	PH			141	
17.0	Clayey silt, some sand and gravel in random seams		7	SS	55				
	Hard		8	TW	PH	590			
583.6	Brown		9	SS	42				
30.0	Silty clay to clay,		10	SS	15	580		119	
	Trace of gravel		11	TW	PH		+ > 2000	118	
573.6	Stiff Grey		12	TW	PH				
40.0	Sandy silt with gravel & clay. Hard Brown		13	SS	152	570			
567.6	Probable Bedrock								
46.0	End of Borehole								

FORM OB-MT-126 (REV. 1969)

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 4

FOUNDATION SECTION

JOB 70-11068 LOCATION Canfield Jct. Sta. 126 + 24 ℄ ORIGINATED BY GC

W.P. 13-66 BORING DATE August 12-13, 1970 COMPILED BY GC

DATUM Geodetic BOREHOLE TYPE Auger CHECKED BY [signature]

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT

SHEAR STRENGTH P.S.F.: o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB. VANE (scale 1000, 2000)

LIQUID LIMIT — w_L; PLASTIC LIMIT — w_P; WATER CONTENT — w (WATER CONTENT %: 20, 40, 60)

ELEV. DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	SHEAR STRENGTH P.S.F.	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL.
613.2	Ground Level							
0.0	Black Topsoil							
1.0	Silty clay to clay	1	TW	PH	610		126	
		2	TW	PH		+>2000		
	Stiff	3	TW	PH		+>2000		
		4	TW	PH			123 122	
	Brown	5	TW	PH	600	+>2000		
598.2								
15.0	Clayey silt, trace of sand & gravel in random seams	6	TW	PH			136	
		7	TW	PH				
	Stiff							
		8	TW	PH	590	+>2000		
	Grey-Brown							
		9	TW	PH				
583.2								
30.0	Silty clay to clay							
		10	TW	PH	580	+>2000		
	Stiff Grey							
		11	TW	PH			122	
573.2								
40.0	Silty sand with gravel & clay. Very Dense	12A	SS	65	570			16 62 (22)
566.7	Probable Bedrock							
46.5	End of Borehole							

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 5

FOUNDATION SECTION

JOB 70-11068 LOCATION Canfield Jct. Sta. 125 + 49 ℄ ORIGINATED BY GC
W.P. 13-66 BORING DATE August 11, 1970 COMPILED BY GC
DATUM Geodetic BOREHOLE TYPE Auger CHECKED BY

ELEV. DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS / FOOT	SHEAR STRENGTH P.S.F.	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL.
618.2	Ground Level						
0.0	Railroad Fill Gravel & Organic cinders Loose	1	SS	5			
612.3		2	SS	8	+ s2.57		
5.9	Silty clay to clay Firm to very stiff Brown(mottled near top)	3	TW	PH	+2000	130	
		4	TW	PH			
604.2		5	SS	28			
14.0	Silty clay to clayey silt, trace gravel in random seams Very Stiff to Hard Brown	6	TW	PH	3030; +>2000; 4000	120; 124	
		7	TW	PH			
		8	TW	PH	4900	134	
583.2		9	SS	31			
35.0	Silty clay to clay Stiff Grey	10	SS	17			
		11	TW	PH	+s3.28	122	
573.2		12	TW	PH	+>2000	119	
45.0	Sandy silt with clay and gravel. Hard. Brown	13	SS	84/8"			
568.7	Probable Bedrock						
49.5	End of Borehole						

STRAT. PLOT

ELEV. SCALE: 610, 600, 590, 580, 570

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT

SHEAR STRENGTH P.S.F.
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB. VANE
1000 2000

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_P
WATER CONTENT —— w

WATER CONTENT %
20 40 60

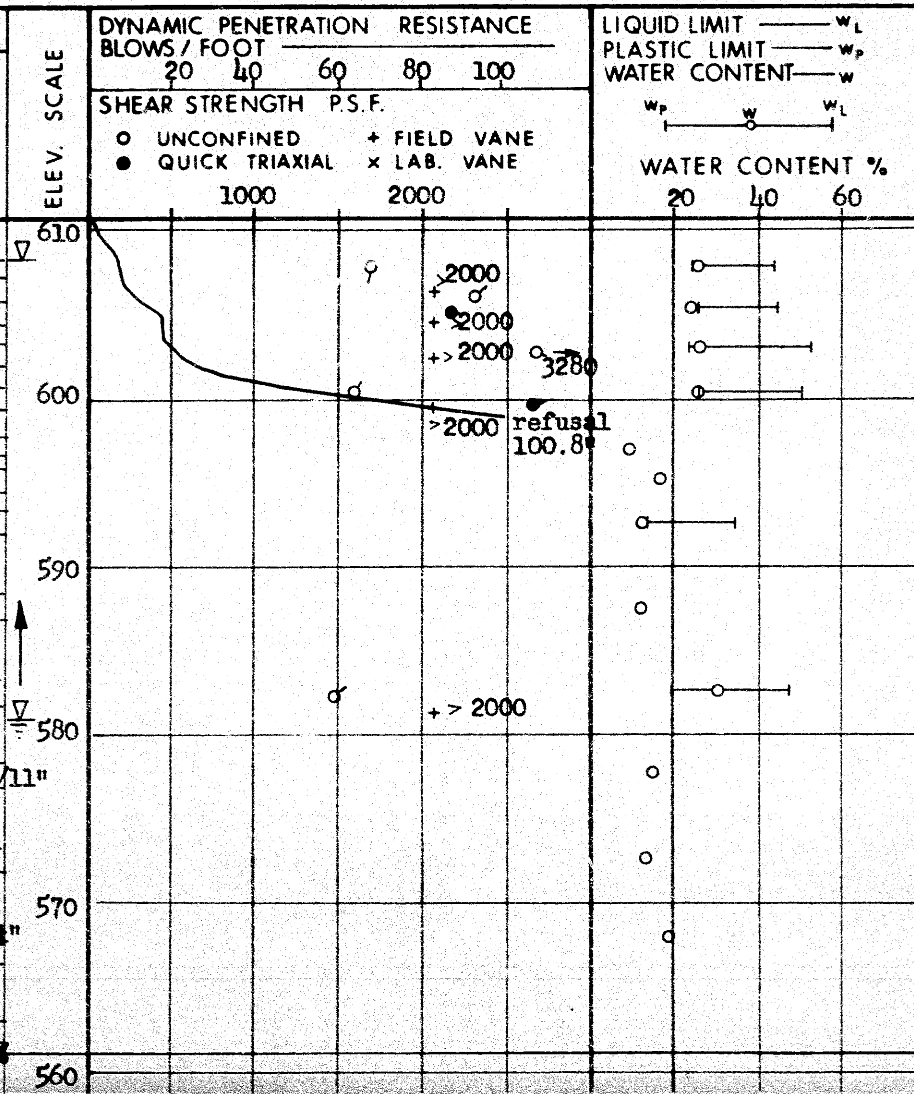
DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 6

FOUNDATION SECTION

JOB 70-11068 LOCATION Canfield Jct. Sta. 123 + 14 o/s 20' Rt. ORIGINATED BY GC
W.P. 13-66 BORING DATE August 7, 10, 11, 1970 COMPILED BY GC
DATUM Geodetic BOREHOLE TYPE Auger CHECKED BY [signature]

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	BLOWS / FOOT	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL
610.8	Ground Level					
608.3	Black Topsoil					
2.5	Silty clay to clay	1	TW	PH	124.5	
	Stiff to Very Stiff	2	TW	PH	127 126	
	Brown	3	TW	PH	126	
598.2		4	TW	PH	125 126.5	
12.6	Clayey silt to silty clay, some sand and gravel in random seams	5A	SS	57		
		6	SS	50		
	Hard	7	SS	53		
585.8	Brown	8	SS	32		
25.0	Silty clay to clay Stiff	9	TW	PH	120.5	
575.8	Grey	10A	SS	100/11"		
35.0	Sandy silt with clay & gravel					
570.8	Hard Grey	11	SS	90		
40.0	Sand, gravel & gypsum	12	SS	20/1"		
566.3	S Dense					
44.5	Weathered Limestone Bedrock	13	AXT	38%		
661.6		14	AXT	38%		
49.2	Sound Bedrock	15	AXT	100%		
49.5	End of Borehole					



DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 7

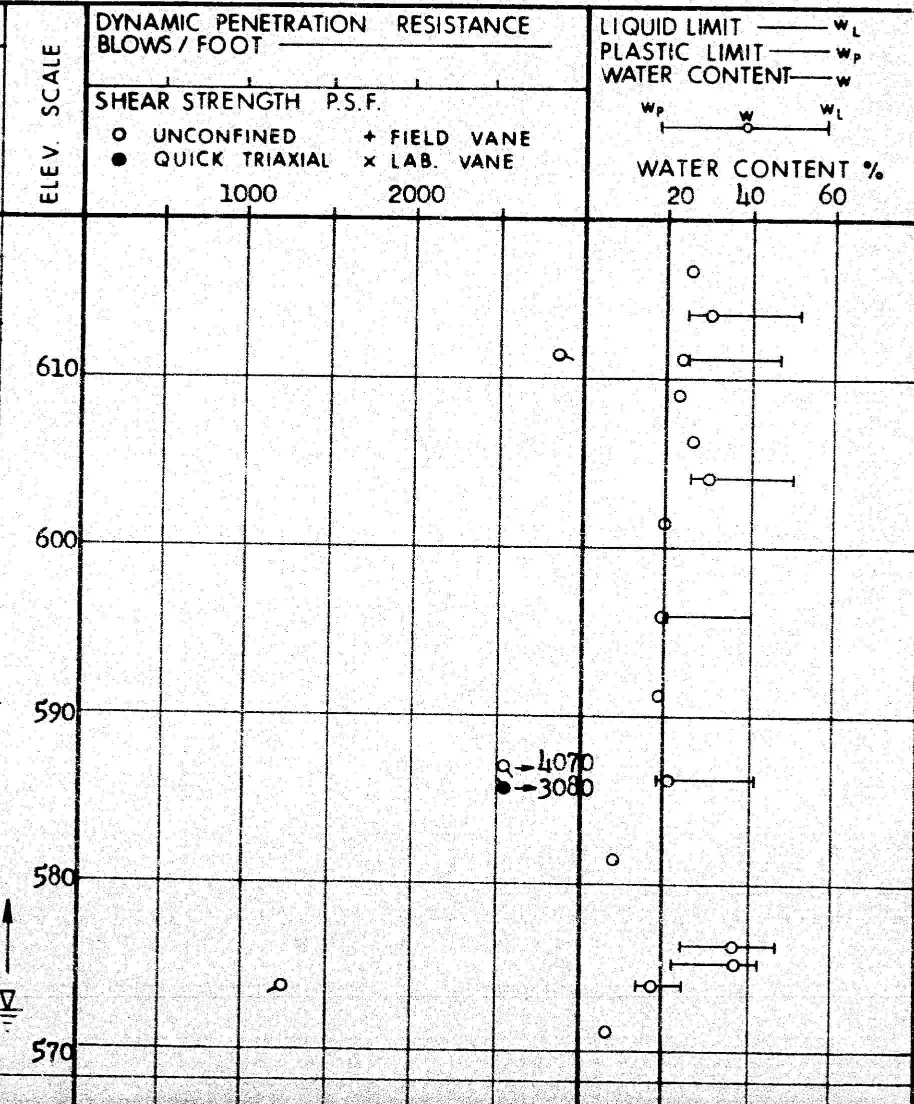
FOUNDATION SECTION

JOB 70-11068
W.P. 13-66
DATUM Geodetic

LOCATION Canfield Jct. Sta. 124 + 40 o/s 20' Lt.
BORING DATE August 5, 1970
BOREHOLE TYPE Auger

ORIGINATED BY GC
COMPILED BY GC
CHECKED BY

ELEV. / DEPTH	SOIL PROFILE — DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS / FOOT	BULK DENSITY γ P.C.F.	REMARKS GR. SA. SI. CL.
619.2	Ground Level					
0.0	Railroad Fill, Organic Cinders, Loose	1	SS	4		
613.2		2	SS	9		
6.0	Silty clay to clay, Very Stiff to Hard, Brown (mottled at top)	3	TW	PH	126	
		4	SS	35		
		5	SS	30		
602.7		6	SS	24		
16.5	Silty clay to clayey silt, trace sand and gravel in random seams, Hard, Grey Brown	7	SS	32		
		8	SS	44		
		9	SS	32		
		10	TW	PH	129 / 140.5	
579.2		11	SS	37		
40.0	Silty clay to clayey silt, Firm, Grey	12	SS	9		
574.2		13	TW	PH		
45.0	Silty sand & gravel, Very Dense. Brown, Probable Bedrock				119	2 24 45 29
568.2		14	SS	56		
51.0	End of Borehole					



FORM OB-MT-126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

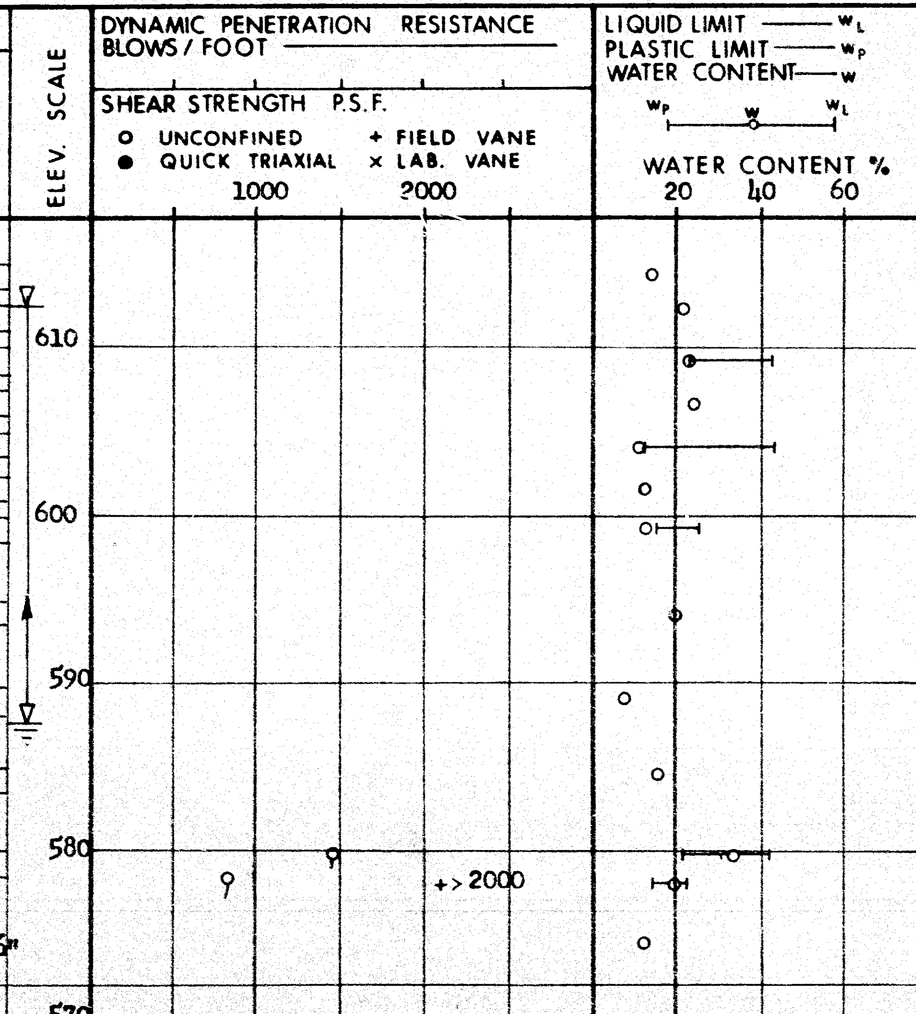
DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 8

FOUNDATION SECTION

JOB 70-11068	LOCATION Canfield Jct. Sta. 123 + 85 o/s 21' Rt.	ORIGINATED BY GC
W.P. 13-66	BORING DATE August 5 - 6, 1970	COMPILED BY GC
DATUM Geodetic	BOREHOLE TYPE Auger	CHECKED BY [illegible]

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	BLOWS/FOOT	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL
617.5	Ground Level					
0.0	Railroad Fill Organic Cinders	1	SS	5		
611.6	Loose					
5.9	Silty clay to clayey silt	2	SS	22		
		3	SS	46		
	Hard. Brown	4	SS	32		
603.5	(mottled at top)	5	SS	34		
14.0	Clayey silt, trace sand & gravel in random seams	6	SS	42		
		7	SS	43		
	Very stiff to hard Brown	8A	SS	34		
		9A	SS	24		27 29 37 7
583.5		10	SS	44		
34.0	Clayey silt to silty clay, trace sand.					
578.5	Firm. Grey	11	TW	PH	136.5 118	
39.0	Silty sand & clay & gravel. Very Dense. Brown	12	SS	78/6"		
572.0	Probable Bedrock					
45.5	End of Borehole					



DEPARTMENT OF HIGHWAYS- ONTARIO

MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 9

FOUNDATION SECTION

JOB 70-11068 LOCATION Canfield Jct. Sta. 123 + 43 o/s 20' Lt. ORIGINATED BY GC

W.P. 13-66 BORING DATE August 6 - 7, 1970 COMPILED BY GC

DATUM Geodetic BOREHOLE TYPE Auger CHECKED BY

SOIL PROFILE: ELEV. DEPTH	DESCRIPTION	SAMPLES: NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	SHEAR STRENGTH P.S.F. (O UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB. VANE)	WATER CONTENT %	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL.
611.5	Ground Level								
609.0	Black Topsoil				610				
2.5	Silty clay to clay	1	TW	PH		+ > 2000		125	
		2	TW	PH		3400		126.5	
	Stiff	3	TW	PH		+ > 2000			
599.0	Brown	4	TW	PH	600			120	
12.5	Clayey silt, trace sand & gravel in random seams.	5A	SS	57					
593.7	Hard Brown	6	SS	34					
17.8	Silty Clay	7	SS	25	590				
	Stiff								
581.5	Grey	8	TW	PH		+ s2.6			
30.0	Sandy silt with gravel & clay, trace gypsum				580				
		9A	SS	100/6"					20 30 49 1
	Hard	10	SS	75/4"					
570.5	Brown				570				
41.0	Gravel & soft gypsum.								
566.1	Very Dense								
45.4 / 562.5	Weathered Limestone Bedrock	11	AXT	31%					
49.0 / 560.4	Sound Limestone Bedrock	12	AXT	81%					
51.1	End of Borehole				560				

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT

LIQUID LIMIT w_L, PLASTIC LIMIT w_P, WATER CONTENT w

Shear strength scale: 1000, 2000. Water content scale: 20, 40, 60.

APPENDIX C

Site Photographs

Photograph 1 - Highway 3 looking east from Structural Culvert 9-159-C.

Photograph 2 - Highway 3 looking west of Structural Culvert 9-159-C.

Photograph 3 - Interior of culvert, looking downstream from inlet (north end). Leakage is evident near centre of culvert.

Photograph 4 - Culvert inlet (north end), looking southwest.

Photograph 5 - Looking upstream (northwest) from inlet.

Photograph 6 - Culvert outlet (south end), looking northwest.

Photograph 7 - Looking downstream (south) from outlet.

Photograph 8 - Culvert outlet (south end), looking west.

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