FOUNDATION INVESTIGATION AND DESIGN REPORT

CULVERT REPLACEMENT
STATION 13+537, HIGHWAY 401
TOWNSHIP OF ROCHESTER

HIGHWAY 401 RECONSTRUCTION

GWP 63-00-00, AGREEMENT NO. 3004-E-0006

Submitted to:

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TABLE OF CONTENTS

APPENDIX A - Laboratory Test Data (Figures A-1 and A-2)

PART A

FOUNDATION INVESTIGATION REPORT

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MINISTRY OF TRANSPORTATION – SOUTHWESTERN REGION

introduction

Golder Associates Ltd. (Golder Associates) has been retained by Dillon Consulting Limited on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundations engineering services as part of the detail design work for the section of Highway 401 described by GWP 63-00-00. This section of Highway 401 is some 9.9 kilometres in length and extends from 2.5 kilometres east of Essex Road 27 easterly to 1.2 kilometres west of Highway 77 in the Township of Lakeshore, County of Essex, Ontario.

The purpose of this portion of the foundation investigation was to determine the subsurface conditions for the replacement of the culvert located at Station 13+537, Highway 401, Township of Rochester, by drilling boreholes, carrying out in-situ tests and laboratory tests on selected samples. The terms of reference for the scope of work are outlined in the MTO’s request for proposal and Golder Associates proposal P41-3106, dated December 24, 2004. The work was carried out in accordance with our Quality Control Plan for Foundation Engineering Detail Design Services dated March 9, 2005.

site description

General

GWP 63-00-00 comprises the reconstruction and widening of some 9.9 kilometres of Highway 401 extending from 2.5 kilometres east of Essex Road 27 in the Township of Rochester easterly to 1.2 kilometres west of Highway 77 in the Township of Tilbury West, County of Essex, Ontario. The location of the project is shown on the Key Plan, Figure 1. The project chainage extends from Highway 401 Station 13+000, Township of Rochester to Station 12+700, Township of Tilbury West.

This report addresses the subsurface conditions for the proposed culvert replacement at Station 13+537, Highway 401 in the Township of Rochester. The location of the subject culvert is shown on the Key Plan, Figure 1. The existing culvert a non-rigid frame, open footing culvert. The culvert has a span of 6.10 metres, a height of 1.83 metres and a length of 50.70 metres.

This section of Highway 401 is currently a four lane divided freeway with a depressed grass median. In each direction, two 3.35 metre wide lanes with 3.58 metre outer shoulders and 4.57 metre wide inner shoulders are present.

The topography in the area of the site is generally flat. The areas outside of the Highway 401 paved surfaces are well vegetated with grasses. The primary land use in the area is agricultural with some residential areas along French Line Road.

Site Geology

The project lies within the Essex Clay Plain, a subregion of the physiographic region of southern Ontario known as the St. Clair Clay Plains, identified in “The Physiography of Southern Ontario” by Chapman and Putnam (1984). The clay plain is described as a till plain that has been smoothed by shallow deposits of lacustrine clay which settled in the depressions of the till. The prevailing soil type is reportedly the Brookston clay.

Based on the Ontario Department of Mines and Northern Affairs Preliminary Maps P.749 and P.750 entitled “Quaternary Geology of the Windsor-Essex Area” Western and Eastern Parts, respectively, the project area is reportedly located in predominantly clayey silt till.

Based on the available bedrock geology mapping, the subcropping bedrock consists of limestone of the Dundee formation of Middle Devonian age.

investigation procedures

The field work for this investigation was carried out on August 10, 2005 at which time three boreholes were drilled at the locations indicated on Drawing 1.

The as-drilled borehole locations, ground surface elevations and borehole depths are as follows:

BOREHOLE	LOCATIONS (m)		GROUND SURFACE ELEVATION (m)	BOREHOLE DEPTH (m)
	Northing	Easting		
217	4677317	290295	182.07	8.84
218	4677271	290306	181.73	8.23
219	4677261	290285	180.72	8.08

The soil stratigraphy encountered in the boreholes is shown on the attached Record of Borehole sheets and on Drawing 1.

The boreholes were advanced using an all terrain vehicle mounted power auger supplied and operated by a specialist drilling contractor. Samples of the overburden were obtained at suitable intervals of depth using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures. Groundwater conditions were observed in the boreholes throughout the drilling operations. All of the boreholes were backfilled in accordance with current regulations and MTO recommended procedures.

The field work was supervised on a full-time basis by experienced members of our engineering staff who arranged for underground utility locates, directed the drilling, sampling and in situ testing operations, logged the boreholes and cared for the samples obtained. The soil samples were identified in the field, placed in labeled containers and transported to Golder Associates' London laboratory for further examination and routine testing. Index and classification tests consisting of water content determinations, grain size distribution analyses and Atterberg limits determinations were carried out on selected samples. The results of the field and laboratory testing are given on the Record of Borehole sheets and in Appendix A.

Temporary traffic control was provided in accordance with the Ontario Traffic Manual, Book 7, dated March 2001.

subsurface conditions

Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of the in situ and laboratory testing are provided 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 sampling and observations of drilling resistance and may represent transitions between soil types rather than exact planes of geological change. Further, the subsurface conditions may vary significantly between and beyond the borehole locations.

In summary, the boreholes drilled for the proposed culvert replacement encountered topsoil and fill materials overlying stiff to hard silty clay till. In borehole 217, a layer of stiff to very stiff clayey silt till was also present and dense silt was encountered at depth.

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.

Topsoil and Fill Materials

Topsoil layers 0.1 to 0.2 metres thick were encountered at ground surface in all of the boreholes.

Beneath the surficial topsoil layers, firm to stiff clayey fill materials were encountered in boreholes 217 and 218. The fill materials were 0.8 and 2.0 metres thick in boreholes 217 and 218, respectively. The fill had N values, as determined in the standard penetration testing, of 6 to 9 blows per 0.3 metres with water contents of 15 to 25 per cent.

Clayey Silt Till

Stiff to very stiff clayey silt till was encountered beneath the fill materials in borehole 217 at elevation 181.2 metres. The clayey silt till was 2.8 metres thick at the borehole location. The clayey silt till had N values of 9 to 27 blows per 0.3 metres with natural water contents of 16 to 19 per cent.

Silty Clay Till

Beneath the clayey silt till in borehole 217 and beneath the fill materials in boreholes 218 and 219, stiff to hard silty clay till was encountered. The surface of the till was encountered between elevation 178.4 and 180.5 metres. Boreholes 218 and 219 were terminated in the silty clay till after exploring it for 6.1 to 7.9 metres. Where fully penetrated in borehole 217, the silty clay till was 4.9 metres thick. The silty clay till had N values of 7 to 34 blows per 0.3 metres with natural water contents of 16 to 22 per cent and an average of 19 per cent. The silty clay till had corresponding average plastic and liquid limits of 16 and 33 per cent, respectively, based on four Atterberg limits determinations indicating an inorganic clay of low plasticity.

Grain size distribution curves for samples of the silty clay till recovered from the standard penetration testing are provided on Figure A-1. The Atterberg limits data are provided on Figure A-2.

Silt

Beneath the silty clay till in borehole 217, dense silt was encountered at elevation 173.5 metres. Borehole 217 was terminated in the silt after exploring it for about 0.3 metres. The silt had a measured N value of 37 blows per 0.3 metres with a natural water content of 11 per cent.

Groundwater Conditions

Groundwater conditions were observed in the boreholes during drilling. All of the boreholes were dry during drilling. This information is summarized below:

BOREHOLE	GROUND SURFACE ELEVATION (m)	ENCOUNTERED GROUNDWATER ELEVATION (m)
217	182.07	Dry
218	181.73	Dry
219	180.72	Dry

Based on the conditions encountered in the boreholes, the long-term groundwater level is estimated to be at approximately elevation 178 metres. Seasonal variation in groundwater levels should be expected.

The water level in the watercourse was at elevation 179.6 metres on August 10, 2005.

MISCELLANEOUS

This investigation was carried out using equipment supplied and operated by Lantech Drilling Services Inc., an Ontario Ministry of Environment licensed well contractor. The field operations were supervised by Mr. Michael Arthur and Mr. Dan Babcock under the direction of Mr. David J. Mitchell. 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. Michael E. Beadle, P. Eng. under the direction of the Project Manager, 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

FOUNDATION DESIGN REPORT

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engineering recommendations

General

This section of the report provides our recommendations on the foundation aspects of the design of the proposed culvert replacement at Station 13+537, Highway 401, Township of Rochester. The recommendations are based on our interpretation of the factual information obtained during the investigation. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. 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 has a span of 6.10 metres, a height of 1.83 metres and a length of 50.70 metres. It is proposed to replace this culvert with a new, non-rigid frame, open footing culvert with a span of 6.00 metres and a height of 2.00 metres.

Foundations

The subsurface conditions encountered in the boreholes drilled for this investigation typically consist of fill overlying clayey silt till and silty clay till.

Based on the information provided, the proposed new culvert will be founded as follows:

PROPOSED DIMENSIONS (m)	MEASURED GROUNDWATER LEVEL (m)	ANTICIPATED FOUNDING ELEVATION (m)	FOUNDING SOIL
6.00 x 2.00	-	178.8	Clayey silt till and silty clay till

The proposed culvert excavation should penetrate the existing fill materials and be terminated in the stiff to very stiff clayey silt till and stiff to hard silty clay till at about elevation 178.8 metres. Assuming a maximum allowable settlement of 25 millimetres and a footing width of 1.5 metres, culvert foundations constructed at this level may be designed using a factored geotechnical resistance at ultimate limit states (ULS) of 225 kilopascals (kPa) and a geotechnical resistance at serviceability limit states (SLS) of 150 kPa.

Temporary diversion of surface water flow may be required during installation depending on the prevailing weather conditions at the time of construction.

Lateral Earth Pressures for Design

The lateral pressures acting on the proposed culvert will depend on the backfill soils and, where used, the type and method of placement of the backfill materials behind the wall, as well as the subsequent lateral movement of the structure. The following recommendations are made concerning the design of the culvert walls in accordance with the Canadian Highway Bridge Design Code (CHBDC).

Backfill behind the culvert should be carried out as per Ontario Provincial Standard Drawing (OPSD) 802.02. Backfill behind the culvert walls should consist of select, free draining granular fill meeting the requirements of Granular A or Granular B Type III but with less than 5 per cent passing the 0.075 millimetre sieve.

Where backfill soils are placed and compacted behind the walls, a compaction surcharge equal to 12 kPa should be included in the lateral earth pressures for structural design in accordance with Section 6.9.3 of the CHBDC. Compaction equipment should be used in accordance with OPSS 501.06.

Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert sections. 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.

The granular fill should be placed in a zone with a width equal to at least 1.2 metres behind the culvert walls. For walls backfilled as noted above, the following unfactored parameters may be assumed:

	GRANULAR A	GRANULAR B TYPE III
Fill unit weight:	22 kN/m^3	21 kN/m^3

Coefficients of lateral earth pressure:		
'active', K_a	0.31	0.27
'at-rest', K_o	0.47	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 culvert wall support does not allow lateral yielding (restrained structure), at-rest pressures should be assumed for geotechnical design. The unfactored coefficient of passive pressure for the portion of the culvert wall and footing below invert may be taken as 3.1. Resistance to sliding may be based on an angle of internal friction of 30 degrees between the concrete footings and the silty clay till subgrade materials.

Construction Considerations

The founding soils are sensitive to disturbance and softening due to water seepage and/or ponding. If cast-in-place culverts are to be constructed, placement of a working slab of lean concrete will be required at the base of the culvert excavations for the footing area. Exposure without protection of the working slab will result in softening of the founding soils. The cleaned base of the excavation should be inspected by qualified geotechnical personnel prior to placing the lean concrete. It is recommended that the footing excavation be carried out such that the final 0.5 metres of excavation is completed with the geotechnical personnel on site and the lean concrete be placed immediately after footing inspection.

Erosion protection for the culvert/wing wall backfill should be provided, as appropriate to the high water level. Consideration could be given to using suitable non-woven geotextile and rip rap, as required, provide erosion protection based on hydraulic requirements. In addition, sediment control such as silt fences and erosion control blankets may be required during construction as well as diversion of the water to mitigate migration of fine soil particles into the water course.

Excavations and Temporary Cut Slopes

Based on the subsurface conditions encountered in the boreholes, the base of excavations will be above the measured groundwater level. Temporary open cut slopes should be maintained no steeper than 1 horizontal to 1 vertical, but may need to be locally flattened, as required, in the fill materials.

Surficial water seepage into the excavations should be expected at the culvert site, and will be heavier during periods of sustained precipitation. In addition to diverting any culvert flows, pumping from well filtered sumps located at the base of the excavations may be required to provide groundwater control during foundation excavations.

The consideration with respect to protection of the founding soils, however, as given in Section 6.2.2 under the heading Construction Considerations must be recognized. Sumps should be maintained outside of the actual footing limits. Surface water runoff should be directed away from the excavations at all times. The appropriate Non Standard Special Provision (NSSP) should be included in the contract documents to address these issues.

Where space is restricted and will not permit open cuts, a temporary support system should be installed to support the sides of the excavation and permit the use of vertical cuts. The temporary support system could consist of soldier piles and lagging where H-piles would be driven to a suitable depth and horizontal lagging installed as the excavation proceeds. Support to the soldier pile and lagging wall system could be in the form of struts and walers in the case of footing excavations or rakers and anchors in the case of roadway protection excavations.

The design of braced soldier pile and lagging walls should be based on a rectangular earth pressure distribution using the design parameters given below. 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 earth pressures and surcharge pressures from area, line or point loads as well as the impact of sloping ground behind the system.

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

$$p = K_a \gamma H$$

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

K_a = 0.3 for level ground behind excavation

γ = soil unit weight = 20 kN/m^3

Unfactored rectangular earth pressure distribution (p in kN/m^2; constant with depth), can be calculated as follows:

$$p = K \gamma H$$

where H = the height of the excavation

K = 0.3 for level ground behind excavation

γ = soil unit weight = 20 kN/m³

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 coefficient of passive lateral earth pressure, K_p, for the socket within the very stiff to hard silty clay till may be taken as 3.5. The soil unit weight should be taken as 20 kN/m³ and the unit weight of water should be taken as 9.8 kN/m³.

The temporary excavation support system should be designed and constructed in accordance with MTO Special Provision 539S01. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SP 539S01.

Inlet and Outlet Seals and Camber

Based on our understanding that an open footing culvert will be constructed, inlet and outlet seals are not considered necessary. Based on the anticipated height of fill over the culvert, camber is not necessary.

miscellaneous

This report was prepared by Mr. Michael E. Beadle, P.Eng. under the direction of the Project Manager, 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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APPENDIX A

LABORATORY TEST DATA (FIGURES A-1 AND A-2)