

**FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT REPLACEMENT AT HOLLAND CREEK
SITE NO. 39W-129
HIGHWAY 11
WEST OF HEARST, ONTARIO
G.W.P. No. 5195-13-00**

GEOCRES Number: 42G-50

Report to

AECOM

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) in the immediate vicinity of the box culvert carrying Holland Creek under Highway 11, located in the township of Hanlan near Hearst, Ontario.

The purpose of this investigation was to obtain subsurface information at the culvert location and, based on the data obtained, to provide a borehole location plan, stratigraphic profiles, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber was retained by URS Canada Inc. (URS) to carry out this foundation investigation under the MTO Agreement Number 5012-E-0033. There is no record available of any previous foundation investigation carried out at or near the subject culvert.

2 SITE DESCRIPTION

The culvert site is located on Highway 11 in the Township of Hanlan, approximately 12.8 kilometres west of Highway 583 near Hearst, Ontario. The culvert allows Holland Creek to flow from south to north under Highway 11.

The existing culvert, constructed in 1938, consists of a single 3.0 m span by 1.5 m high by 30 m long concrete rigid frame culvert. It is understood that the culvert is in poor condition with deterioration of the barrel. The grade of the existing Highway 11 in the vicinity of the culvert is at approximately Elevation 247.5 m. The embankment fill height above the culvert ranges between 3 and 4 m.

The site is located in a rural area with swamps, creeks and other watercourses nearby. The surrounding areas are covered by trees, low shrubs and bushes with no visible bedrock outcrops. Local relief is relatively flat with poor drainage resulting in low-lying swampy areas. There are a few residential properties in the vicinity of the culvert crossing. Selected photographs of the site are included in Appendix E.

Based on published geological information, the general area of the project is covered by glacial outwash deposits of silts, sands, and gravel, all underlain by Early Precambrian (Superior Province) granitic rock.

3 SITE INVESTIGATION AND FIELD TESTING

The first phase of borehole investigation and field testing program was carried out on November 5, 2013. The program consisted of drilling and sampling two boreholes identified as HC13-01 and HC13-02 to depths of 4.1 and 4.3 m (Elevations 240.1 and 240.6 m), respectively. Both boreholes were located in the vicinity of the culvert inlet. The second phase of borehole investigation and field testing program was carried out from September 8 to September 10, 2014. The program consisted of drilling and sampling five boreholes identified as HC14-03 to HC14-07. The boreholes were drilled to depths ranging from 3.4 to 6.9 m (Elevations 237.8 to 242.5 m). The Record of Borehole sheets are included in Appendix A.

The borehole locations were marked in the field and utility clearances were obtained prior to commencement of the drilling operations. The co-ordinates and elevation of the as-drilled boreholes were subsequently provided by Callon Dietz utilizing Digital Terrain Model (DTM), based on borehole location sketches provided by Thurber. The approximate locations and elevations of the boreholes are shown on the attached Borehole Locations and Soil Strata Drawing included in Appendix C.

The drilling was carried out using a track-mounted CME45 drill rig using hollow stem auger drilling techniques until refusal to further auger advance. Soil samples were obtained at select intervals using a 50 mm diameter split spoon sampler in conjunction with the Standard Penetration Testing (SPT).

The drilling and sampling operations were supervised on a full time basis by an experienced member of Thurber's technical staff. The recovered soil samples were logged in the field and processed for transportation to Thurber's geotechnical laboratory in Oakville, Ontario for further examinations and testing.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. The details of standpipe piezometer installation and borehole completion are summarized in Table 3-1.

Table 3-1. Borehole Completion and Standpipe Piezometer Installation Details

Borehole Number	Tip Location (Depth / Elevation)	Monitoring Well Installations			Completion Details
		Sand Screen Depth (m)	Sand Screen Elevation (m)	Sand Filter Stratum	
HC13-01	4.1 / 240.1	2.1 – 4.1	242.1 – 240.1	Sand	Bentonite holeplug above sand screen to surface
HC13-02	None Installed				Bentonite holeplug and cuttings to surface

HC14-03	None Installed				Bentonite holeplug and cuttings to surface
HC14-04	None Installed				Bentonite holeplug and cuttings to surface
HC14-05	2.4 / 240.9	0.2 – 2.4	243.1 – 240.9	Sand	Bentonite holeplug above sand screen to surface
HC14-06	3.4 / 242.5	0.9 – 3.4	245.0 – 242.5	Sand	Bentonite holeplug above sand screen to surface
HC14-07	5.6 / 240.2	3.2 – 5.6	242.6 - 240.2	Sand	Bentonite holeplug above sand screen to surface

Results of field drilling and sampling are presented on the Record of Borehole sheets in Appendix A.

4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected soil samples were subjected to grain size distribution analyses (sieve and hydrometer) and Atterberg Limits testing. The results of this laboratory testing program are included on the Record of Borehole sheets in Appendix A and on the figures in Appendix B.

A sample of surface water was submitted to AGAT Laboratories in Mississauga, a qualified analytical laboratory, for testing against selected corrosivity parameters.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

5.1 General

Reference is made to the Record of Borehole sheets in Appendix A and the Borehole Locations and Soil Strata Drawing included in Appendix C for details of the soil stratigraphy encountered in the boreholes. An overall description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions.

In general, the subsurface stratigraphy encountered in the boreholes, located in the vicinity of the culvert consists of a thin, surficial layer of topsoil overlying a deposit of silty clay containing some sand which is underlain by silty sand containing trace to some gravel. Probable bedrock is inferred below the silty sand layer. Bedrock was confirmed by coring in Borehole 14-05. More detailed descriptions of the individual strata encountered within the boreholes are presented below.

5.2 Asphalt and Topsoil

A layer of asphalt between 200 and 225 mm in thickness was encountered at ground surface in Boreholes HC14-03 and HC14-04 located on the road embankment, respectively.

Topsoil 50 to 150 mm in thickness was encountered at ground surface in Boreholes HC14-05, HC14-06, HC13-01 and HC13-02. The topsoil thickness may vary between and beyond the borehole locations, and the limited data is not intended for the purpose of estimating quantities.

5.3 Fill

Embankment fill was encountered below the asphalt in Boreholes HC14-03 and HC14-04. This fill typically consists of layers of grey to brown gravelly sand. In these boreholes, the fill was found extending to depths of 1.3 m to 2.8 m (Elevations 246.1 to 244.7 m).

SPT N-values measured in the cohesionless fill ranged from 13 to 93 blows per 0.3 m penetration, indicating a compact to very dense state. A loose zone indicated by an N-value of 8 blows for 0.3 m penetration was encountered in Borehole HC14-04. Measured moisture contents of the recovered fill samples ranged between 4% and 10%.

Results of grain size analyses conducted on a sample of the fill are presented on Figure B1 in Appendix B and are summarized in the following table:

Soil Particles	%
Gravel	21
Sand	73
Silt and Clay	6

5.4 Silty Clay

Silty clay, trace to some sand was encountered beneath the topsoil or fill in all boreholes except for Borehole HC14-05. The silty clay was brown to grey in colour and contained trace gravel and the upper zone included trace to some organics. The silty clay layer ranged from 2.3 to 4.5 m in thickness (base Elevation 241.2 to 242.9 m). A 1 m thick layer of sand and gravel was observed in borehole HC14-03 within the silty clay.

SPT N-values measured in the silty clay typically ranged from 3 to 12 blows per 0.3 m penetration, indicating soft to stiff consistency. Higher values of 16 to 27 blows per 0.3 m and 50 blows for less than 0.3 m penetration recorded in Borehole HC13-01 and HC14-03 indicated very stiff to hard zones. The moisture contents typically ranged between 15% and 56% with a single moisture content recorded at 79% for a sample containing organics in Borehole HC13-02.

Laboratory grain size distribution analyses were performed on samples of the silty clay. The results of these tests are presented on the corresponding Record of Borehole Sheets in Appendix A and the grain size distribution curves are plotted in Figures B2 to B3 of Appendix B. The results are summarized in the following tables.

Soil Particles	(%)
Gravel	0 to 3
Sand	3 to 30
Silt	25 to 78
Clay	17 to 56

Atterberg Limits tests were performed on samples of the silty clay. Liquid limits were in the range of 42 to 46. The plasticity index ranged from 21 to 23 indicating a medium plasticity. The results of these tests are plotted in Figure B7 of Appendix B and summarized below.

Soil Particles	(%)
Liquid Limit	42 to 45
Plasticity Index	21 to 23

5.5 Sand and Gravel

A layer of sand and gravel with silt and clay was encountered below the silty clay in Boreholes HC14-04 and HC14-06 and within the silty clay in Borehole HC14-03. In Boreholes HC14-04 and HC-14-06, the sand and gravel layer was 0.4 to 0.7 m in thickness with an underside depth of 3.4 to 6.8 m (Elevation 240.7 to 242.5). The sand and gravel layer within the silty clay in Borehole HC14-03 was 1.0 m thick and was encountered at a depth of 1.8 m (Elevation 245.7).

The sand and gravel layer was compact in Borehole 14-03 as indicated by an SPT N-value of 17 blows per 0.3 m penetration. An SPT N-value of 74 blows per 0.3 m of penetration to greater than 100 blows for less than 0.3 m penetration indicated a very dense condition in Boreholes 14-04 and 14-06. A high blow count was likely due to the presence of probable bedrock immediately below the soil. The moisture contents of samples ranged from 4% to 18%.

One laboratory grain size distribution analysis was performed on a sample of the sand and gravel. The results of this test are presented on the corresponding Record of Borehole Sheet in Appendix A and the grain size distribution curves are plotted in Figure B4 of Appendix B. The results are summarized in the following table.

Soil Particles	(%)
Gravel	36
Sand	35
Silt and Clay	29

5.6 Sandy Silt

A layer of sandy silt with trace clay and some organics was encountered below the topsoil in borehole HC14-05. The sandy silt layer was 2.3 m in thickness with an underside depth of 2.4m (Elevation 240.9).

The SPT N-values of 3 to 23 blows per 0.3 m of penetration indicated a very loose to compact condition. A higher value of greater than 50 blows for less than 0.3 m of penetration was encountered at the bedrock surface. The moisture contents of samples ranged from 21% to 32%.

One laboratory grain size distribution analysis was performed on a sample of the sandy silt. The results of this test are presented on the corresponding Record of Borehole Sheet in Appendix A and the grain size distribution curves are plotted in Figure B5 of Appendix B. The results are summarized in the following table.

Soil Particles	(%)
Gravel	0
Sand	33
Silt	62
Clay	5

5.7 Silty Sand

A layer of silty sand with gravel and trace to some clay was encountered below the silty clay in Boreholes HC13-01, HC13-02, HC14-03 and HC14-07. The sand layer ranged from 0.8 to 1.8 m in thickness with an underside depth of 4.1 to 6.9 m (Elevations 240.1 to 240.6 m).

The SPT N-values of 3 to 86 blows per 0.3 m of penetration indicated a very loose to very dense condition. Higher values of 50 blows for less than 0.3 m penetration in Borehole HC13-01 and HC13-02 indicate the presence of probable bedrock, cobbles or boulders. The moisture contents of samples ranged from 5% to 21%.

Three laboratory grain size distribution analyses were performed on samples of the silty sand. The results of these tests are presented on the corresponding Record of Borehole Sheets in Appendix A and the grain size distribution curves are plotted in Figure B6 of Appendix B. The results are summarized in the following table.

Soil Particles	(%)	
Gravel	4 to 26	
Sand	33 to 81	
Silt	24	15 to 20
Clay	17	

5.8 Bedrock

Boreholes were terminated upon refusal to auger advance on inferred bedrock or boulders in most boreholes. Bedrock was proven by coring in Borehole 14-05. In Borehole HC14-06, auger refusal was probably met on obstructions such as cobbles or boulders. The depths and elevations of auger refusal encountered at the borehole locations are summarized below in Table 5-1.

Table 5-1. Depths and Elevation of Auger Refusal

Borehole	Probable Bedrock or Boulders (unless otherwise noted)	
	Depth (m)	Elevation(m)
HC13-01	4.1	240.1
HC13-02	4.3	240.6
HC14-03	6.9	240.6
HC14-04	6.8	240.7
HC14-05	2.4*	240.9*
HC14-06	3.4**	242.5**
HC14-07	5.6	240.2

* Bedrock proven by coring

** Possibly cobbles or boulders

Bedrock was encountered and proven by coring in Borehole HC14-05 at a depth of 2.4 m, or Elevation 240.9 m. The rock is identified as granite of the Archean Formation occurring as a felsic intrusive contact as part of the Pre-Cambrian Canadian Shield. The rock cores are generally in a fresh state with slight weathering at the joints. No exposed bedrock was observed in the general vicinity of the site.

The measured Total Core Recovery (TCR) was 100% in all three runs of the granite. The Rock Quality Designation (RQD) values ranged from 87 to 100% indicating good to excellent rock quality. The Fracture Indices (FI) were typically between 0 and 3 fractures per 0.3 m core run.

The estimated Unconfined Compressive Strength (UCS) for the cores ranged from 109 to 145 MPa indicating a very strong rock. These estimated rock strength values are based on point load tests that were conducted on selected rock cores recovered from Borehole BH-05.

5.9 Groundwater Conditions

Free water was observed in borehole HC14-04. Standpipe piezometers were installed in Boreholes HC14-07, HC14-05, HC14-06 and HC13-01. The short term water levels measured in the piezometers are summarized in the following table.

Borehole (screen location)	Date of Reading	Water Level Depth (m)	Water Level Elevation (m)
HC13-01 (Silty Sand)	November 7, 2013	0.5	243.7
HC14-05 (Sandy Silt)	September 9, 2014	1.2	242.1
	September 10, 2014	1.1	242.2
HC14-06 (Sand and Gravel)	September 9, 2014	Dry	Dry
	September 10, 2014	2.8	243.1
HC14-07 (Silty Sand)	September 9, 2014	2.9	242.8
	September 10, 2014	4.4	241.3

The localized groundwater level is expected to be governed by the creek water level. Local high water levels, spring snowmelt and periods of significant and/or prolonged precipitation events must also be taken into consideration.

6 MISCELLANEOUS

The drilling and sampling operations in the field were supervised on a full time basis by Mr. Joe Gurzanski, and Mr. Alistair Hall of Thurber Engineering Ltd. Routine laboratory testing was carried out by Thurber Engineering Ltd. geotechnical laboratory in Oakville, Ontario. A sample of surface water was submitted to AGAT Laboratories in Mississauga, Ontario for testing against corrosivity parameters. Sulphate concentration in the creek water is less than 1 mg/L which is considered negligible in terms of sulphate attack on concrete.

Borehole locations were selected by Thurber. Callon Dietz provided the northing and easting coordinates and ground surface elevations utilizing their DTM based on a borehole location sketch provided by Thurber.

Eastern Ontario Diamond Drilling of Hawkesbury, Ontario supplied and operated the track-mounted drill rig to carry out the drilling, sampling, in-situ testing operations and standpipe installation.

Overall project management was provided by Dr. Sydney Pang, P.Eng. Direction of the field and laboratory programs was provided by Mr. Lukasz Gilarski, P.Eng. Interpretation of the field data and preparation of this report was completed by Mr. Lukasz Gilarski, P.Eng and Dr. Pang. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and provides foundation recommendations for the design of the replacement of the existing culvert at Holland Creek on Highway 11, located approximately 12.8 kilometres west of Highway 583 near Hearst, Ontario within the Township of Hanlan.

Based on the terms of reference, the existing culvert, constructed in 1938, consists of a single 3.0 m span by 1.5 m high by 30 m long concrete, open footing, rigid frame culvert. It is understood that the culvert is in poor condition with deterioration of the barrel. The existing embankment fill height above the culvert is in the order of 3 to 4 m.

The discussions and recommendations presented in this report are based on information provided by URS and on the factual data obtained during the course of this investigation.

An archived drawing shows the general topography of the subject area prior to construction of the culvert and the highway. Selected photographs showing the culvert area are included in Appendix E for reference.

8 CULVERT FOUNDATIONS

8.1 General

Information from URS indicates that current project requirements involve the construction of a new concrete box culvert along a parallel alignment to replace the existing concrete open footing culvert. Temporary pavement widening generally within the existing highway platform will be required during construction. Based on staging drawings, the widening at this site involves construction of wedges of Granular A fill in the order of 2 to 3 m in width. Physical dimensions of the proposed culvert obtained from a General Arrangement (GA) drawing and other design information provided by URS are presented in Table 8.1. Boreholes drilled at the culvert site are also identified in this table for reference.

Table 8.1 - Physical Data of Proposed Replacement Culverts

Culvert I.D.	Borehole Numbers	Approx. Invert Elevations (m)		Length (m)	Width (m)	Height (m)
		Inlet	Outlet			
Holland Creek	HC14-05 near outlet	242.140	242.110	31.7	3.5	2.6
	HC14-03 and HC14-04 through embankment adjacent to existing culvert					
	HC14-06 and HC14-07 for widening					
	HC13-01 and HC13-02 near inlet					

Note: All dimensions are preliminary and subject to changes

8.2 Foundation Alternatives

This section presents discussions on alternate types of replacement culverts and foundation alternatives, and provides recommendations on a feasible and/or preferred foundation option.

Several culvert types that may be considered for this site are listed as follows:

- Concrete box (closed) culvert
- Concrete, open footing, culvert
- Circular pipes (concrete, steel, HDPE)

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix D.

The existing culvert is a Concrete Open Footing culvert (COF). Preliminary design information indicates that consideration is being given to using a precast closed box culvert as replacement. Given the subsurface conditions and anticipated construction sequencing, we consider the box culvert to be the preferred option from a foundation engineering standpoint. Precast sections can be installed rapidly with less potential for disturbance of the founding soils during installation.

From a foundation engineering standpoint, concrete open footing culverts as well as concrete, steel and HDPE pipes are also technically feasible alternatives, provided that other design issues including flow capacity, hydraulic properties and durability can also be satisfied.

The report herein focuses on providing foundation recommendations on the design and construction of the box culvert and the associated retaining walls. Recommendations for other culvert options will be provided upon request.

8.3 Foundation Design for Culverts

It is understood that the invert level of the replacement culvert is approximately the same as that of the existing culvert. Foundation design aspects for the replacement culvert include subgrade conditions, geotechnical resistances below the culvert subgrade and for the retaining wall foundation soils, settlement of founding soils, lateral earth pressures, erosion control, protection system design, groundwater control and staged excavation.

8.3.1 Concrete Box Culverts

Since the replacement culvert will be installed along a new alignment parallel to the existing culvert, it is anticipated that the subgrade soils will be subject to “unloading” conditions within the new culvert footprint. Along the existing culvert footprint, compacted granular backfill will be used to reconstruct the road embankment. The subgrade soils along the existing culvert footprint will be subjected to additional loading.

In order to provide a more uniform foundation subgrade condition, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A requirements should be provided under the base of the box culvert as per OPSD 803.010. The bedding material should be placed as soon as practical for protecting the subgrade from disturbance during construction following its inspection and approval. Construction equipment must not be allowed to travel on the bedding or the prepared subgrade.

Information from URS indicates that the underside of the Granular A pad is to be founded on the undisturbed, firm silty clay overlying typically compact to very dense silty sand at or below Elevation 242 m. The recommended geotechnical resistances for this founding elevation are as follows:

- Factored Geotechnical Resistance at ULS of 225 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 150 kPa

In the vicinity of Borehole HC14-06 and possibly at other locations, boulders and/or bedrock may be encountered at or above the culvert founding elevation. An NSSP should be included in the contract to alert the Contractor of such possibility. If boulder and bedrock excavation is required, the sub-excavation should extend to 0.5 m below the design culvert founding level that would allow construction of the Granular A pad of 300 mm minimum thickness. Suggested wording of an NSSP to this effect is included in Appendix F.

Resistance to lateral forces / sliding resistance between the concrete slab and the underlying Granular A should be calculated assuming an ultimate coefficient of friction of 0.4.

It is recommended that the culvert be designed to resist external loadings including frost forces, lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

8.3.2 Retaining Walls

Retaining walls are required at all four quadrants of the new culvert. Consideration may be given to using Retained Soil Systems (RSS) walls or cantilevered concrete walls.

Borehole information indicates that the founding condition at the wall locations generally consist of firm to very stiff silty clay overlying typically compact to very dense silty sand.

8.3.2.1 RSS walls

The soil conditions encountered on site are generally suitable for the support of RSS walls. RSS walls should be specified as “Medium Performance” and “High Appearance”. The contract drawings should include information on the longitudinal alignment of the wall in plan, the top and base elevations of the wall in profile, cross-sectional space constraints and an NSSP for the RSS wall.

The performance of a RSS is dependent on, among other factors, the characteristics of its foundation. Failure to provide an adequate foundation may lead to settlement and distortion of the RSS and, in severe cases, to possible failure of the system. The foundation of the entire RSS mass must be considered, i.e. from the face of the wall to the furthest extent of the reinforcement.

To provide an acceptable foundation performance, the RSS mass should be founded on the undisturbed native silty clay or silty sand. The highest recommended base level for the underside of the walls is at Elevation 242 m. An RSS wall founded at this level may be designed using a factored geotechnical resistance at ULS of 225 kPa and a geotechnical resistance at SLS of 150 kPa. The RSS may be founded on engineered fill resting on the native subgrade. Engineered fill pads placed under the RSS mass must consist of OPSS Granular “A” compacted to 100% of its SPMDD at a moisture content within 2% of optimum. The engineered pad must extend at least 500 mm beyond the limits of the RSS mass and levelling strip.

The geotechnical resistances provided above are for concentric, vertical loading. The effects of load inclination and eccentricity need to be taken into account according to the CHBDC (2010) Clauses 6.7.3 and 6.7.4.

The entire block of reinforced earth must be designed against various modes of failure including sliding and overturning. Sliding resistance along the base of the wall may be estimated using an ultimate friction coefficient of 0.55 for an engineered granular fill subgrade and 0.4 for a silty clay subgrade.

Topsoil, loose fill, and any soft/wet material must be stripped from the footprint of the RSS. The subgrade under the RSS foundation should be inspected and any soft or loose spots sub-excavated and replaced with compacted granular materials prior to placing fill.

The proprietary RSS system must meet the Ministry's specifications for performance and appearance. The RSS supplier/designer may specify more stringent criteria or other requirements related to the particular design. The internal stability of the RSS wall should be analyzed by the supplier/designer of the proprietary product selected for this site.

Global stability of the RSS walls will be analyzed by Thurber once the detailed configurations of the walls are known. Preliminary analyses based on the schematic geometric configuration shown on the GA drawing indicate that RSS walls with an average retained height of not more than 2 m are expected to satisfy global stability requirements.

8.3.2.2 Foundation slabs

From a foundation standpoint, the retaining walls may be supported on foundation slabs founded on undisturbed, native silty clay or silty sand. For a founding elevation of Elevation 242 m or lower, the recommended geotechnical resistances recommended above for the RSS walls may be used for design. Load inclination and eccentricity should also be taken into account as outlined above.

Resistance to lateral forces / sliding resistance between precast concrete and the underlying undisturbed, native silty clay or silty sand should be evaluated in accordance with the CHBDC (2010) assuming an ultimate coefficient of friction of 0.35.

8.3.3 Settlements

It is understood that there is no grade raise at this site. The new box culvert is to be constructed at a new alignment parallel to the existing COF culvert. The opening sizes of the new and existing culverts are similar. Taking into consideration the proposed construction sequencing for this site, it is anticipated that there will be negligible settlement associated with the subgrade under the new culvert footprint due to the net unloading condition. After the removal of the existing culvert, granular backfill is to be placed for backfilling the excavation. Given the firm silty clay and/or compact silty sand subgrade, any foundation settlement would be completed by the end of construction.

An abrupt change of subgrade conditions from one with a granular cover above a concrete culvert (new alignment) at shallow depth to one with newly compacted granular materials extending to the culvert founding level (old alignment) could result in post construction differential settlement over a relatively short distance. The estimated differential settlement could be up to the order of 10 to 15 mm. Should it be required to maintain the top of pavement profile, consideration may be given to resurfacing the pavement within a few years after completion of construction.

8.3.4 Subgrade Preparation

After the excavation reaches the design elevation and removal of the existing culvert, any

remaining fill, topsoil, loose creekbed deposits, disturbed soils and any deleterious materials within the culvert replacement footprint must be sub-excavated to the undisturbed native firm to stiff silty clay or compact silty sand. The exposed surface must be inspected to confirm that the subgrade is suitable and uniformly competent. The sub-excavated areas should be backfilled with well compacted Granular A or Granular B Type II material.

Construction of the culvert replacement must be carried out in the dry. This work should be carried out in accordance with OPSS 902.

8.3.5 Frost Depth

The frost penetration depth for this site is 2.6 m.

8.4 Construction Considerations

Staged open cutting will be employed to construct the replacement culvert at the Holland Creek site. The pavement will be temporarily widened on the north side with the placement of a small wedge of fill within the upper slope of the embankment. In general, the works are to be carried out within the existing highway platform.

Detailed construction sequencing is not available at the time of preparation of this draft report. It is anticipated that the following features will be included in the staging plans:

- Two-way traffic will be maintained at all times during construction
- Temporary widening of the pavement will be carried out on the north side
- Cofferdams are required to be installed at the inlet and outlet areas to facilitate diversion of creek flow and surface water
- Sump pumping may be required within the cofferdams
- Creek flow will be maintained in one culvert at all times
- Roadway protection will be required during various stages of construction
- Excavation and removal of the existing culvert, installation of the new culvert and backfilling will be carried out within the protection systems.
- All works to be carried out in the dry.

Protection systems (temporary shoring) such as the use of soldier pile and lagging will be required. Foundation recommendations for design of such a system are provided in a subsequent section of this report. Sump pumping will be required at all locations to maintain reasonably dry excavations. Positive dewatering such as the use of vacuum well points may be required at some locations where the silty sand is present at the subgrade level. Other unwatering methods such as temporary diversion of creek and surface water, sandbagging and/or a properly designed cofferdam will be required.

A Permit To Take Water (PTTW) should be obtained for this project.

9 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

It is recommended that backfill to the culvert and retaining walls consists of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS.PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 803.01 as appropriate.

All fills must be placed in regular lifts and be compacted in accordance with OPSS.PROV 501. The backfill must be placed and compacted in simultaneous lifts on both sides of a culvert, and the top of backfill elevation should be the same on both sides of the culvert at all times. Heavy compaction equipment must not be used adjacent to the walls and roofs of the culverts.

Earth pressures acting on the culvert walls may be assumed to impose a triangular distribution. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2010 but are generally given by the expression:

$$p_h = K (\gamma h + q)$$

where	p_h	=	horizontal pressure on the culvert wall at depth h (kPa)
	K	=	earth pressure coefficient (see table below)
	γ	=	bulk unit weight of retained soil (see table below)
	h	=	depth below top of fill where pressure is computed (m)
	q	=	value of any surcharge (kPa)

If full drainage is not achievable, the culvert walls must be designed to withstand full hydrostatic pressure assuming a water level at least equal to the design creek water level.

Earth pressure coefficients for backfill to the retaining walls are dependent on the material used as backfill. Recommended unfactored values are shown in the following Table 9.1. Active pressures should be used for retaining walls adjacent to the culvert inlet and outlet.

Table 9.1
Earth Pressure Coefficients (K)

Wall Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ$; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (modified) $\phi = 32^\circ$; $\gamma = 21.2 \text{ kN/m}^3$		Embankment Fill $\phi = 30^\circ$; $\gamma = 20.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54

At rest (Restrained Wall)	0.43	0.62	0.47	0.70	0.50	0.76
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	3.0	-

For rigid structures such as concrete box culverts, it is recommended that at-rest horizontal earth pressures be used for design.

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I, or at a depth of 1.7 m for Granular A or Granular B Type II.

10 EMBANKMENT DESIGN AND RECONSTRUCTION

The existing embankment beyond the culvert along this section of the highway is approximately 4.5 to 5 m in height. The fill cover above the crown of the new culvert is up to the order of 2.8 m. It is understood that there is no planned grade raise at this site.

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment material should consist of imported Granular A or B Type II material. Excavated granular fill may be considered for reuse if they meet the moisture and gradation requirements of OPSS.PROV 1010. The reused fill must satisfy all environmental requirements.

Provided that the granular material is placed and compacted as recommended, it is anticipated that a slope inclination of 2H : 1V or flatter should remain stable. Where applicable, benching of the existing earth slope surface should be carried out as per OPSD 208.010 in order to enhance the keying in of the new fill. Selected stability analysis results are included in Appendix G.

In general, surface vegetation, peat, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlet and outlet, and within the embankment footprints. Inspection and approval of the foundation surfaces by qualified geotechnical personnel is recommended.

11 EROSION CONTROL

Erosion protection should be provided at the culvert inlet and/or outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field.

Typically, rock protection should be provided over all surfaces with which creek water is likely to be in contact including the retaining walls. Treatment at the outlets should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

A clay seal or a concrete cut-off wall may be used to minimize the potential for erosion or piping around the culvert. The clay seal must extend to the order of 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS.PROV 1205. A geosynthetic clay liner may be used as a clay seal.

12 EXCAVATION, BACKFILLING AND GROUNDWATER CONTROL

12.1 General

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill, native silty clay and silty sand at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Surficial alluvial deposits that are anticipated in the inlet and outlet areas are classified as Type 4 soils.

12.2 Foundations

Excavation and backfilling for culvert construction must be carried out in accordance with OPSS 902.

Excavated gravelly sand fill may be reused as backfill provided the following conditions are satisfied.

- There is sufficient space to stockpile on site and control the moisture content within acceptable limits for compaction
- Gradation (OPSS Granular A or B Type II requirements) and compaction characteristics are confirmed prior to reuse as backfill

Excavated silty clay, organics and debris such as wood fibres should not be reused and should be segregated and removed from site.

12.3 Excavations

Excavations for culvert replacement will typically be carried out through the existing embankment fill and silty clay, and extended into the underlying silty sand. The work will be carried out within a protection system.

Any protection system should be designed by the Contractor who must retain a licensed Professional Engineer experienced in such designs. OPSS.PROV 539 “Construction Specification for Protection Systems” will have to be included in the contract documents. It is recommended that Performance Level 2 as per Clause 539.04.02.01 (maximum horizontal displacement of 25 mm) be specified for this culvert replacement site.

12.4 Groundwater Control

The subgrade of the new culvert will be below the groundwater level which is expected to be largely governed by the water level in the creek. In addition, groundwater perched within the embankment fill will seep into the excavations during culvert replacement. Surface runoff will also tend to accumulate in these excavations. A combination of creek diversion with piping, sandbagging in conjunction with sump pumping will be required to maintain reasonably dry excavations during the course of staged construction. Dewatering is the responsibility of the Contractor who should retain a specialist to design the dewatering system.

13 ROADWAY PROTECTION SYSTEMS

Roadway protection will be required during various stages of construction. The design of roadway protection should be the responsibility of the Contractor. The presence of bedrock at shallow depth below the culvert will impact the design of roadway protection. An option that may be considered is a soldier pile and lagging system with the piles socketed into bedrock used in conjunction with a dewatering system. Interlocking sheetpiles may not be a cost effective option at this site. It is anticipated that the shoring system may be stiffened by corner and cross bracings, where applicable.

A roadway protection system may be designed using the parameters given below:

γ	=	20 kN/m ³
γ_w	=	10 kN/m ³
K_a	=	0.33 (road embankment fill)
K_p	=	3.0 (road embankment fill/native silty sand)
	=	5.8 (bedrock)

If a permeable soldier pile and lagging wall is used, hydrostatic pressure does not need to be considered in the design.

The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors must be considered when designing the shoring system. Typically, a triangular earth pressure distribution similar to the one used for culvert lateral pressure design should be used.

The designer of the roadway protection system should check whether the penetration depth is sufficiently deep to provide base fixity.

All shoring systems should be designed by a Professional Engineer experienced in such designs.

14 CONSTRUCTION CONCERNS

During construction, the Contract Administrator should employ experienced geotechnical staff to observe construction activities related to foundation construction, and to inspect and approve the culvert subgrade.

Potential construction concerns include, but are not necessarily limited to, the following:

- Impact of excavation on the existing pavement surface

Daily visual inspection of the pavement surface must be carried out in the vicinity of the culvert replacement. If cracks form in the pavement or settlement is observed to occur, these matters must immediately be brought to the attention of the C.A. for determining as to whether remedial action is required.

- Occurrence of bedrock within the culvert construction envelop

The site is underlain by bedrock which characteristically has an uneven surface. Although bedrock was not encountered or inferred in the boreholes at elevations above the proposed culvert invert, consideration may be given to alerting the bidders of this possibility and the contract should contain provisional items to cover payment of small quantities of rock excavation,

- Adequate dewatering of the temporary excavations to install the new culvert,
- Removal of peat, organics, soft soils and alluvial deposits near the creek channel,
- Disturbance of the soil subgrade within the culvert foundation footprint,
- Confirmation that the culvert and retaining wall backfill are adequately placed and compacted to specifications.

It is recommended that provision(s) be included in the contract requiring the QVE to confirm that the above issues are adequately addressed. Should there be any doubts about issues such as depth of sub-excavation, these provisions should require the QVE to alert the CA.

15 CLOSURE

Preparation of this foundation design report was carried out by Lukasz Gilarski, P.Eng. and Dr. Sydney Pang, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng.

THURBER ENGINEERING LTD.



Sydney Pang, P.Eng.
Associate, Senior Foundations Engineer



P.K. Chatterji, P.Eng.
Principal, Designated MTO Contact

Appendix A

Record of Borehole Sheets

19-4406-9

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample		TP Thin Wall Piston Sample
	PH Sampler Advanced by Hydraulic Pressure		PM Sampler Advanced by Manual Pressure
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$






 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION		SYMBOLS	
Fresh (FR)	No visible signs of weathering.		
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		CLAYSTONE
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

DISCONTINUITY SPACING		STRENGTH CLASSIFICATION			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m				
Very thinly bedded	20 to 60mm	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Laminated	6 to 20mm				
Thinly Laminated	Less than 6mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.

TERMS					
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				

RECORD OF BOREHOLE No HC13-01

1 OF 1

METRIC

GWP# 5195-13-00 LOCATION Holland Creek N 5 508 822.3 E 316 685.9 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.11.05 - 2013.11.05 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _P W W _L							
244.2	GROUND SURFACE																
0.0	TOPSOIL: (50mm)																
	Silty CLAY , with sand, trace gravel, some organics Soft to Hard Brown Moist		1	SS	4		244										
			2	SS	50/ 0.150		243										0 25 42 33
			3	SS	27												
241.9							242										
2.3	Silty SAND , trace to some gravel, trace clay Very Loose to Compact Brown Wet		4	SS	3												
			5	SS	19		241										18 62 20 (SI+CL)
			6	SS	50/ 0.150												
240.1																	
4.1	END OF BOREHOLE AT 4.1m UPON AUGER REFUSAL ON PROBABLE BEDROCK Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Nov. 7/13 0.5 243.7																

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No HC13-02

1 OF 1

METRIC

GWP# 5195-13-00 LOCATION Holland Creek N 5 508 826.0 E 316 671.3 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE Hollow Setm Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.11.05 - 2013.11.05 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT							UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa																	
								20 40 60 80 100												PLASTIC LIMIT w _p		NATURAL MOISTURE CONTENT w		LIQUID LIMIT w _L	
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												WATER CONTENT (%)					
244.9	GROUND SURFACE																								
0.0	TOPSOIL: (50mm)																								
	Silty CLAY , with sand, trace gravel, some organics Soft to Firm Brown Moist		1	SS	4														3 29 25 43						
			2	SS	5		244																		
			3	SS	3		243																		
	Organics		4	SS	5		242																		
241.9			5	SS	50/ 0.127														26 33 24 17						
3.0	Silty SAND , with gravel, some clay Very Dense Brown Moist																								
			6	SS	50/ 0.025		241																		
240.6																									
4.3	END OF BOREHOLE AT 4.3m UPON AUGER REFUSAL ON PROBABLE BEDROCK BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																								

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No HC14-03

1 OF 1

METRIC

GWP# 5195-13-00 LOCATION Holland Creek N 5 508 839.4 E 316 692.3 ORIGINATED BY ADH
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.09.08 - 2014.09.08 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20 40 60 80 100								
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) 20 40 60						
247.5	GROUND SURFACE															
0.0	ASPHALT: (200mm)															
0.2	Gravelly SAND Very Dense to Dense Grey Moist (FILL)		1	SS	93		247									21 73 6 (SI+CL)
246.1			2	SS	37											
1.3	Silty CLAY Grey Moist						246									
245.7			3	SS	32											
1.8	SAND and GRAVEL Compact Moist															
244.7			4	SS	17		245									
2.8	Silty CLAY, trace sand Very Stiff to Stiff Grey Moist		5	SS	22		244									
			6	SS	12											0 3 41 56
			7	SS	19		243									
	Occasional cobbles						242									
241.4																
6.1	Silty SAND, some gravel Very Dense Grey Wet		8	SS	86		241									
240.6																
6.9	END OF BOREHOLE AT 6.9m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.															

ONTMT4S 4069.GPJ 2012TEMPLATE(MTO).GDT 11/12/14

RECORD OF BOREHOLE No HC14-04

1 OF 1

METRIC

GWP# 5195-13-00 LOCATION Holland Creek N 5 508 839.7 E 316 672.3 ORIGINATED BY ADH
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.09.08 - 2014.09.08 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
247.5	GROUND SURFACE																
0.0	ASPHALT: (225mm)																
0.2	Gravelly SAND Very Dense to Compact Brown Moist (FILL)		1	SS	88												
			2	SS	25												
			3	SS	13												
245.3																	
2.2	Loose		4	SS	8												
244.7																	
2.8	Silty CLAY, trace sand Stiff Grey Moist		5	SS	12												
			6	SS	11												
	Organic inclusion		7	SS	10												
241.4																	
6.1	SAND and GRAVEL, with silt and clay Very Dense Grey Wet		8	SS	74												
240.7																	
6.8	END OF BOREHOLE AT 6.8m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE OPEN AND WATER LEVEL AT 6.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

ONTMT4S 4069.GPJ 2012TEMPLATE(MTO).GDT 11/12/14

RECORD OF BOREHOLE No HC14-05

1 OF 1

METRIC

GWP# 5195-13-00 LOCATION Holland Creek N 5 508 860.7 E 316 679.6 ORIGINATED BY ADH
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.09.09 - 2014.09.09 CHECKED BY JPL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	WATER CONTENT (%)							
243.3	GROUND SURFACE						20	40	60	80	100						GR SA SI CL		
0.0	TOPSOIL, some organics: (100mm) Sandy SILT, trace clay, some organics Very Loose to Compact Grey Wet																		
0.1																			
			1	SS	5														
			2	SS	3														
			3	SS	23														0 33 62 5
240.9	GRANITE, fresh, slightly weathered at joints, medium grained, very strong, grey Horizontal fracture at 2.8m		4	SS	52/														
2.4																			
			1	RUN	0.125														RUN #1 TCR=100% SCR=79% RQD=87% UCS=109MPa
			2	RUN															RUN #2 TCR=100% SCR=100% RQD=100% UCS=145MPa
			3	RUN															RUN #3 TCR=100% SCR=100% RQD=97% UCS=117MPa
237.8	END OF BOREHOLE AT 5.5m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Sep. 9/14 1.2 242.1 Sep. 10/14 1.1 242.2																		
5.5																			

ONTMT4S 4069.GPJ 2012TEMPLATE(MTO).GDT 11/12/14

RECORD OF BOREHOLE No HC14-06

1 OF 1

METRIC

GWP# 5195-13-00 LOCATION Holland Creek N 5 508 863.5 E 316 645.4 ORIGINATED BY ADH
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.09.08 - 2014.09.08 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
245.9	GROUND SURFACE							20	40	60	80	100		
0.0	TOPSOIL: (150mm)													
0.2	Silty CLAY , trace sand		1	SS	10									
245.3	Stiff													
0.7	Brown													
	Moist													
	Very Stiff		2	SS	16		245							0 8 64 28
244.5														
1.4			3	SS	11		244							
			4	SS	11									0 4 78 18
242.9							243							
3.0	SAND and GRAVEL , with silt and clay		5	SS	46/									
242.5	Loose													
3.4	Brown													
	Wet													
	END OF BOREHOLE AT 3.4m UPON AUGER REFUSAL ON COBBLES OR BOULDERS. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.													
	WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Sep. 9/14 Dry Sep. 10/14 2.8 243.1													

RECORD OF BOREHOLE No HC14-07

1 OF 1

METRIC

GWP# 5195-13-00 LOCATION Holland Creek N 5 508 835.3 E 316 750.0 ORIGINATED BY ADH
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.09.09 - 2014.09.09 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
245.7	GROUND SURFACE							20 40 60 80 100					
0.0	TOPSOIL: (75mm) Silty CLAY , trace sand, trace organics Stiff to Firm Brown Moist 												

ONTMT4S 4069.GPJ 2012TEMPLATE(MTO).GDT 11/12/14

Appendix B

Laboratory Test Results

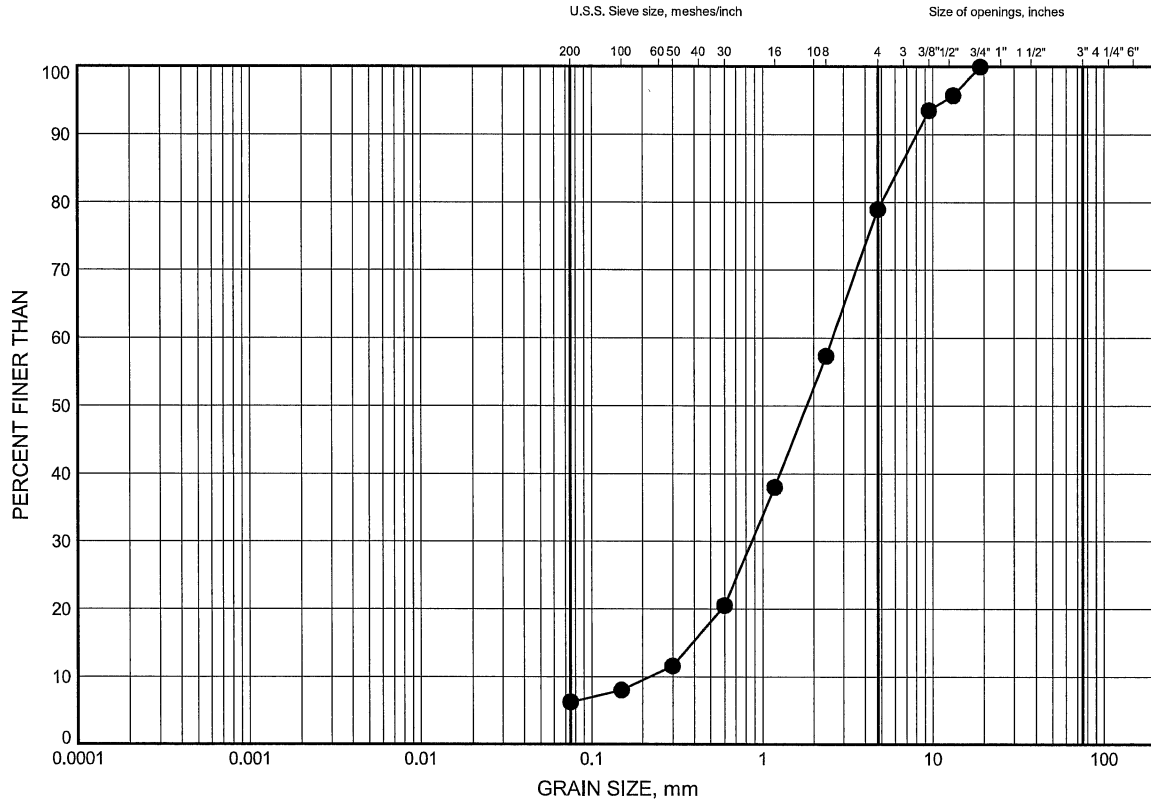
19-4406-9

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B1

GRAVELLY SAND FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	HC14-03	1.12	246.37

Date ..October 2014.....
GWP# ..5195-13-00.....



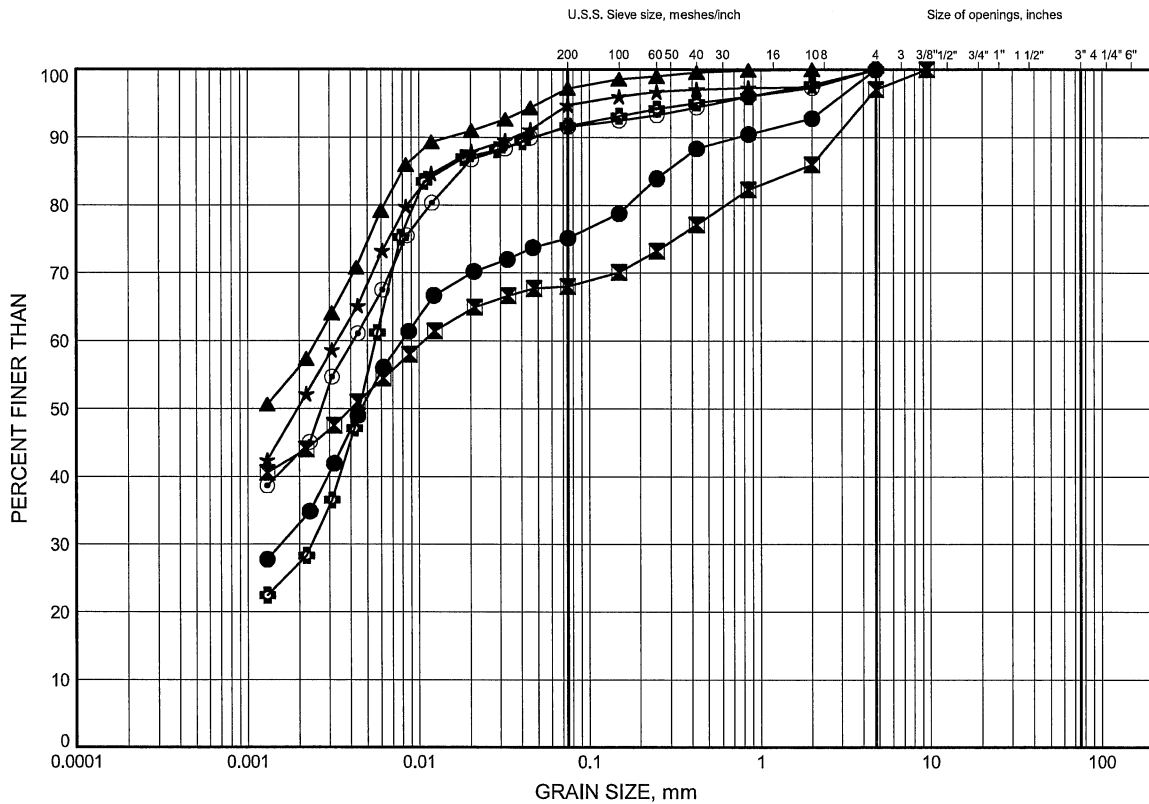
Prep'dAN.....
Chkd.LPG.....

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B2

SILTY CLAY



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	HC13-01	0.91	243.29
⊠	HC13-02	0.30	244.60
▲	HC14-03	4.11	243.37
★	HC14-04	3.28	244.21
⊙	HC14-04	4.88	242.61
⊞	HC14-06	0.99	244.96

Date ..October 2014.....

GWP# ..5195-13-00.....



Prep'dAN.....

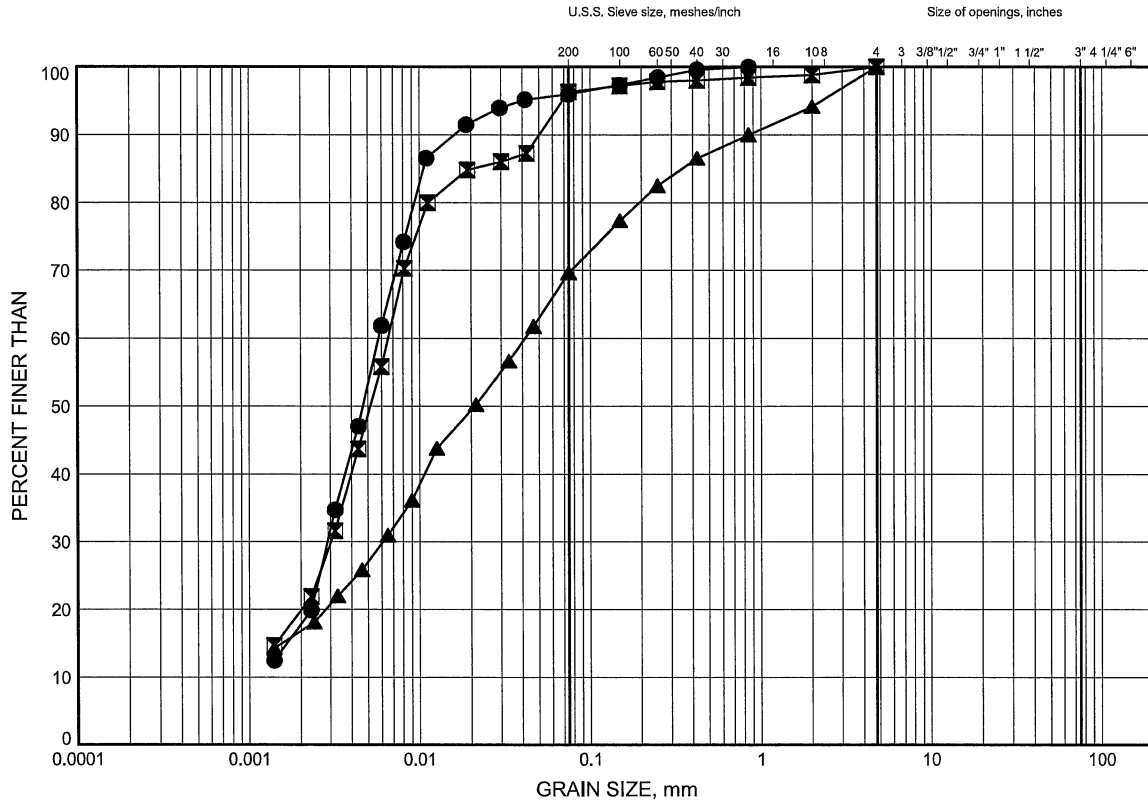
Chkd.LPG.....

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILTY CLAY



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	HC14-06	2.59	243.36
⊠	HC14-07	1.07	244.68
▲	HC14-07	3.35	242.39

GRAIN SIZE DISTRIBUTION - THURBER 4069.GPJ 10/27/14

Date ..October 2014.....
GWP# ..5195-13-00.....



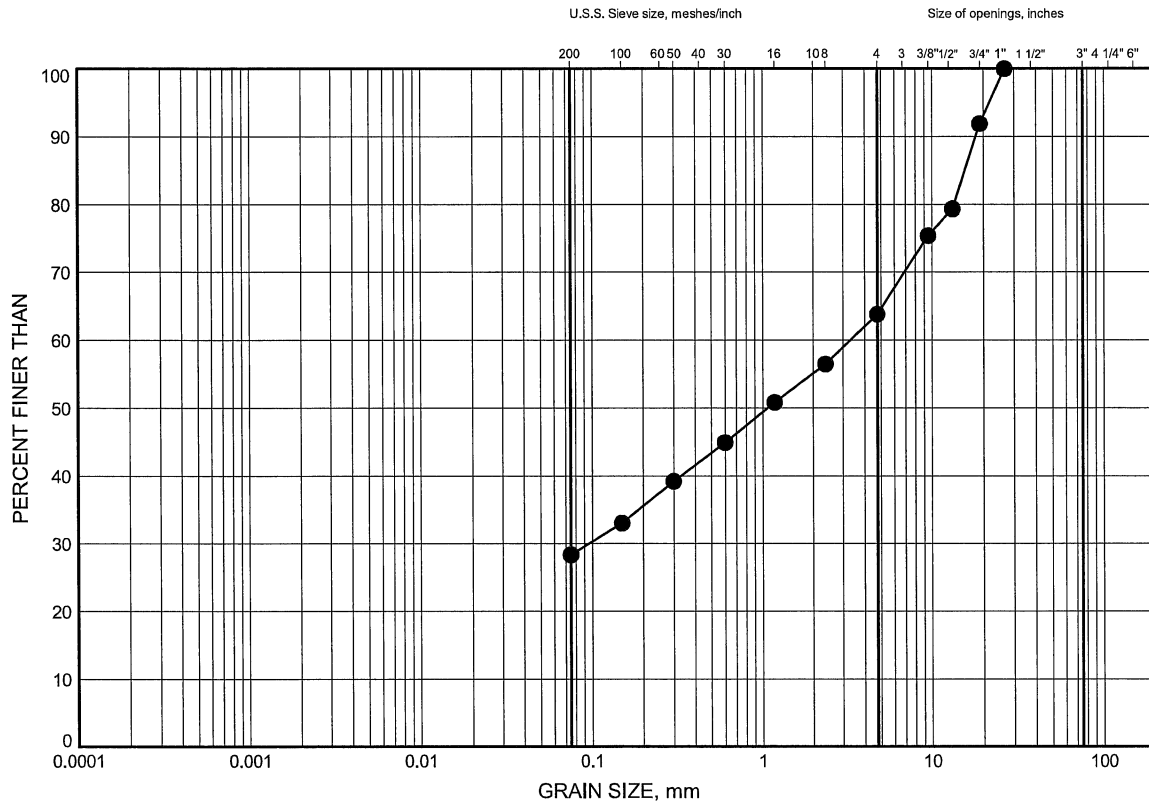
Prep'dAN.....
Chkd.LPG.....

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B4

SAND & GRAVEL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	HC14-04	6.39	241.10

Date ..October 2014.....

GWP# 5195-13-00



Prep'dAN.....

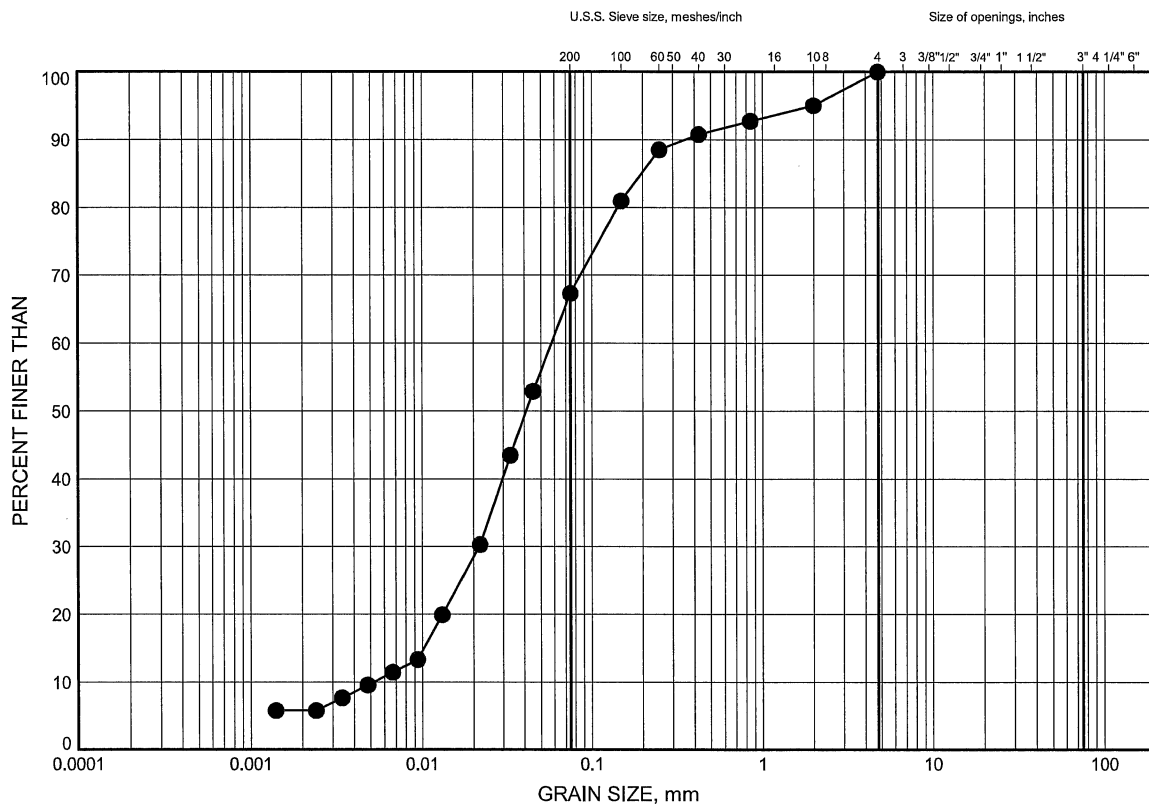
Chkd.LPG.....

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B5

SANDY SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	HC14-05	1.68	241.66

GRAIN SIZE DISTRIBUTION - THURBER 4069.GPJ 10/27/14

Date ..October 2014.....
GWP# ..5195-13-00.....



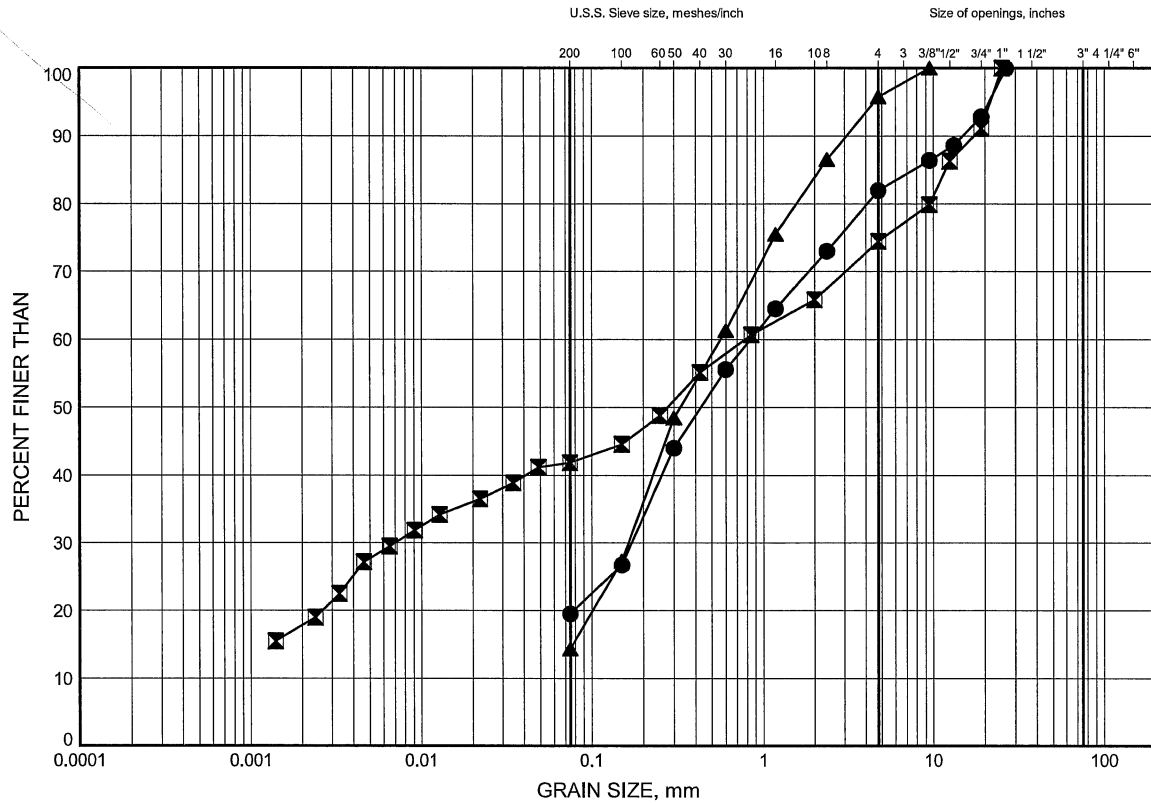
Prep'dAN.....
Chkd.LPG.....

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B6

SILTY SAND



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	HC13-01	3.35	240.85
■	HC13-02	3.12	241.78
▲	HC14-07	4.88	240.87

Date ..October 2014.....

GWP# ..5195-13-00.....



Prep'dAN.....

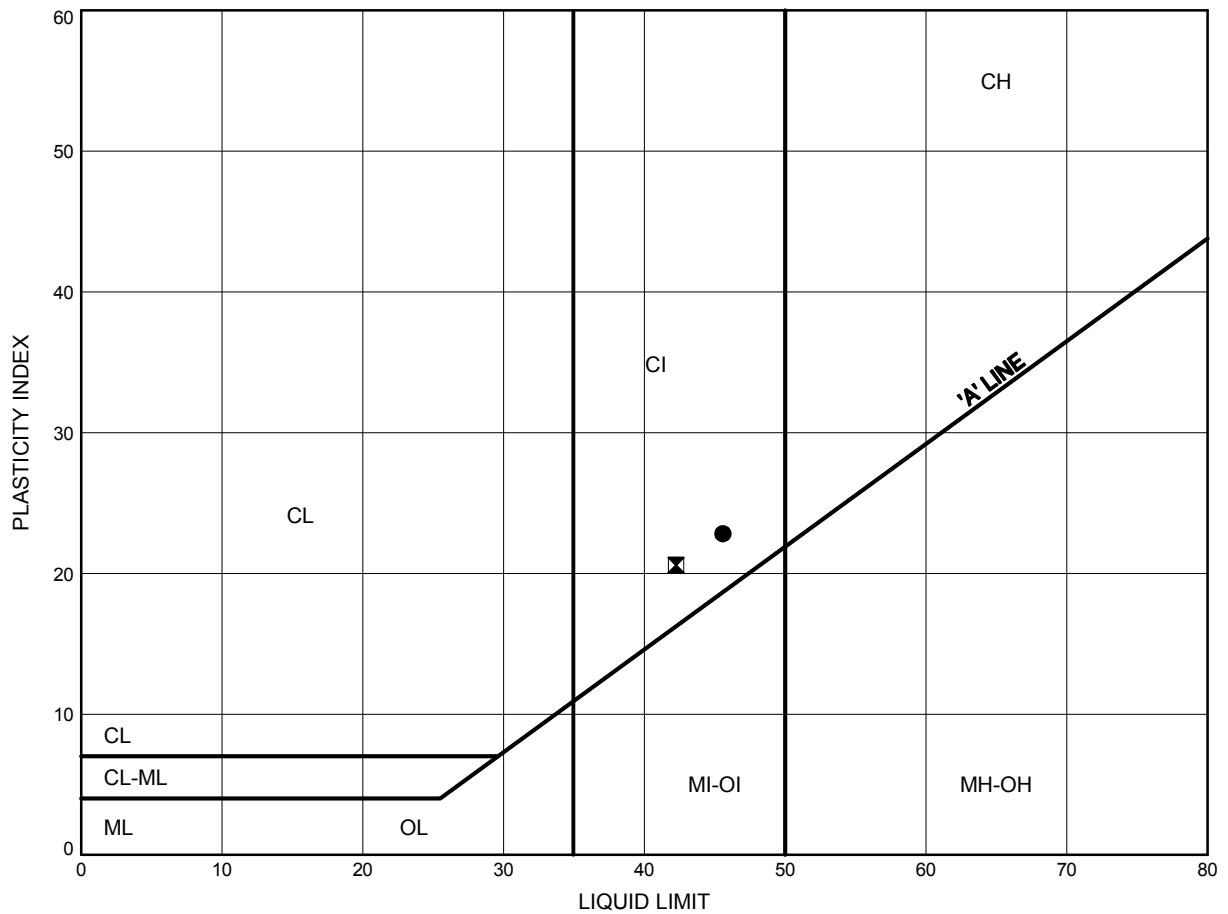
Chkd.LPG.....

Hwys 11, 583, 652 Culverts - Foundations

ATTERBERG LIMITS TEST RESULTS

FIGURE B7

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BH-04	4.11	243.37
⊠	BH-06	3.28	244.21

Date October 2014
GWP# 5195-13-00

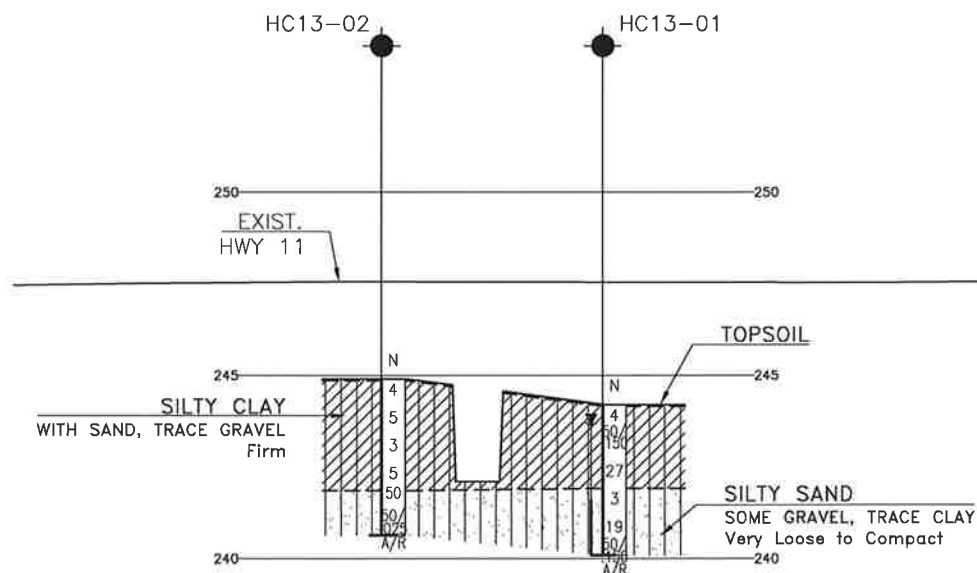
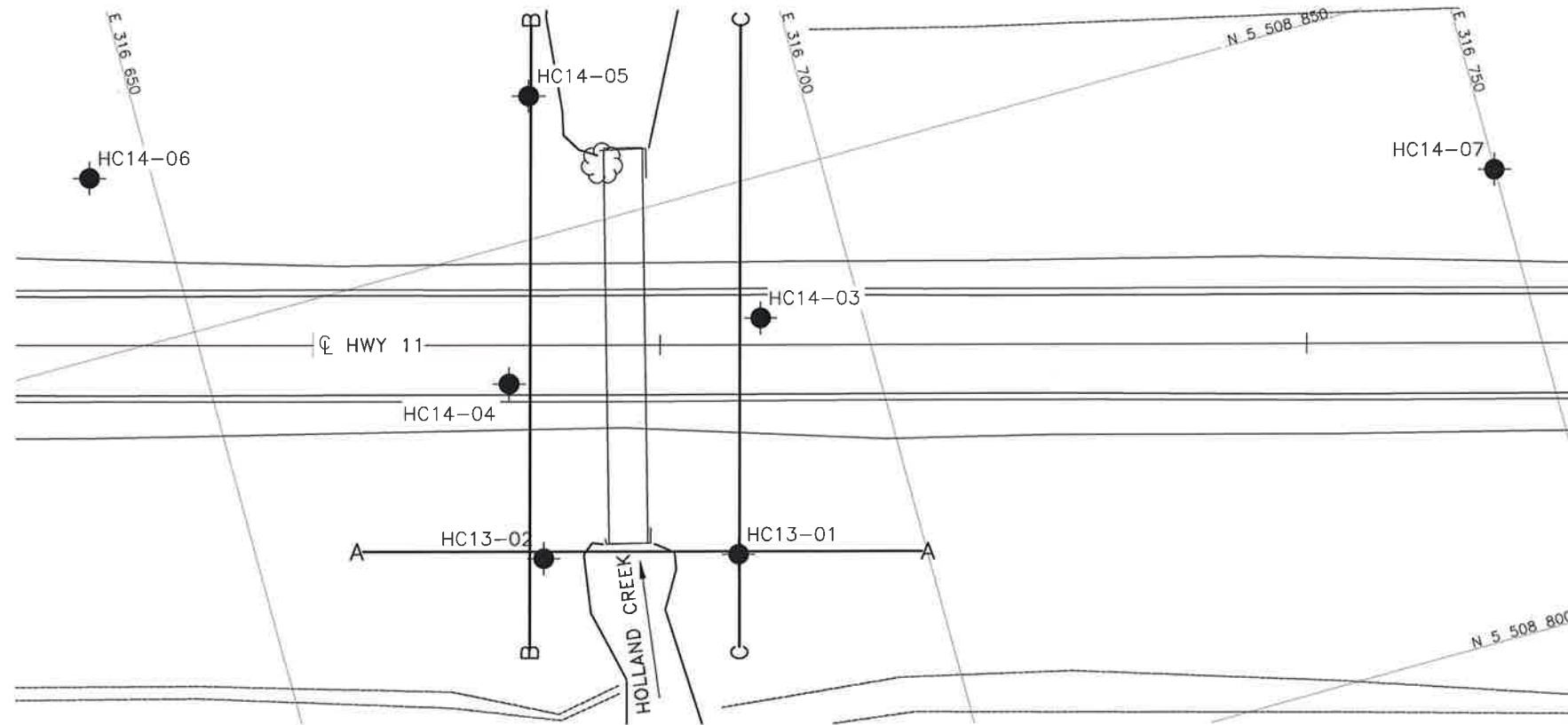


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Chkd. LPG

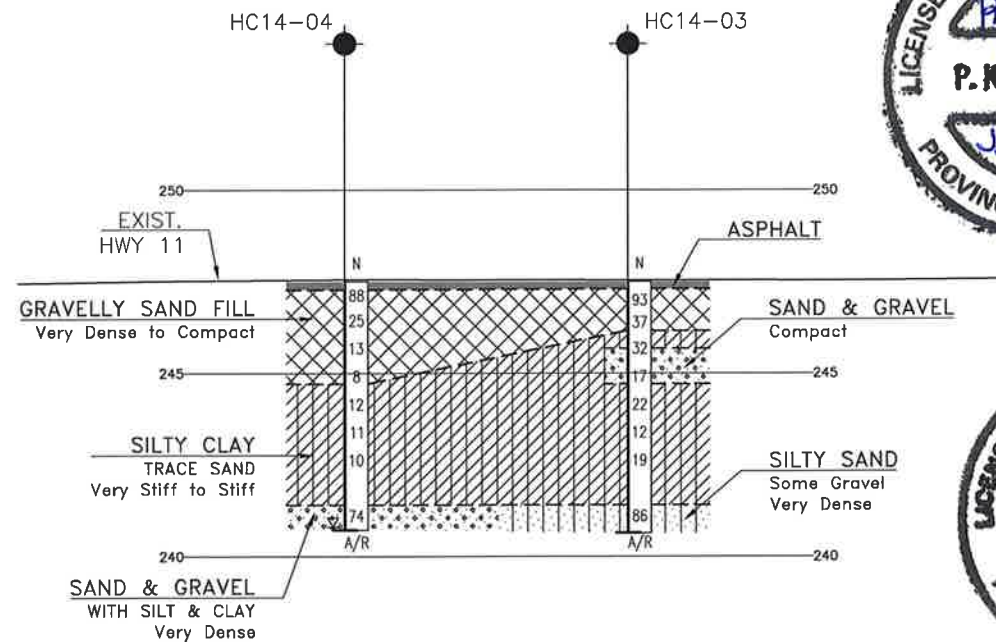
Appendix C

Borehole Locations and Soil Strata Drawings

19-4406-9



SECTION ALONG A-A



SECTION ALONG Q HWY 11

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



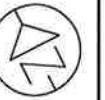
CONT No
GWP No 5195-13-00

HIGHWAY 11
HOLLAND CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

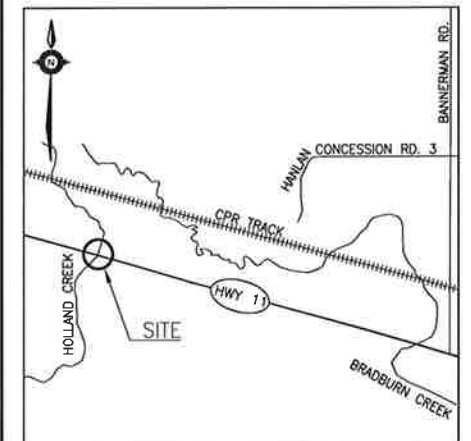
AECOM



THURBER ENGINEERING LTD.



SHEET



KEYPLAN

LEGEND

●	Borehole
⊕	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
⊕	Head Artesian Water
⊕	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
HC13-01	244.2	5 508 822.3	316 685.9
HC13-02	244.9	5 508 826.0	316 671.3
HC14-03	247.5	5 508 839.4	316 692.3
HC14-04	247.5	5 508 839.7	316 672.3
HC14-05	243.3	5 508 860.7	316 679.5
HC14-06	245.9	5 508 863.5	316 645.4
HC14-07	245.7	5 508 835.3	316 750.0

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Embankment outline is approximate.

GEOCRES No. 42G-50

REVISIONS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
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METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

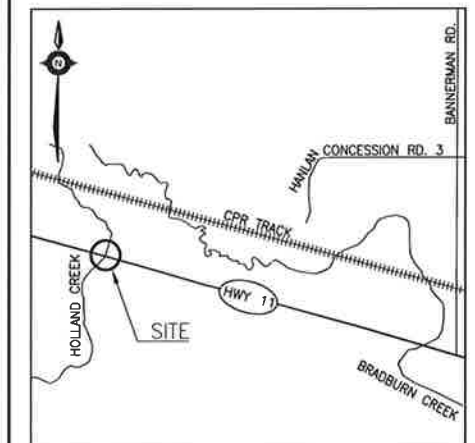
CONT No	
GWP No	5195-13-00

HIGHWAY 11
HOLLAND CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA






SHEET



THURBER ENGINEERING LTD.



KEYPLAN
LEGEND

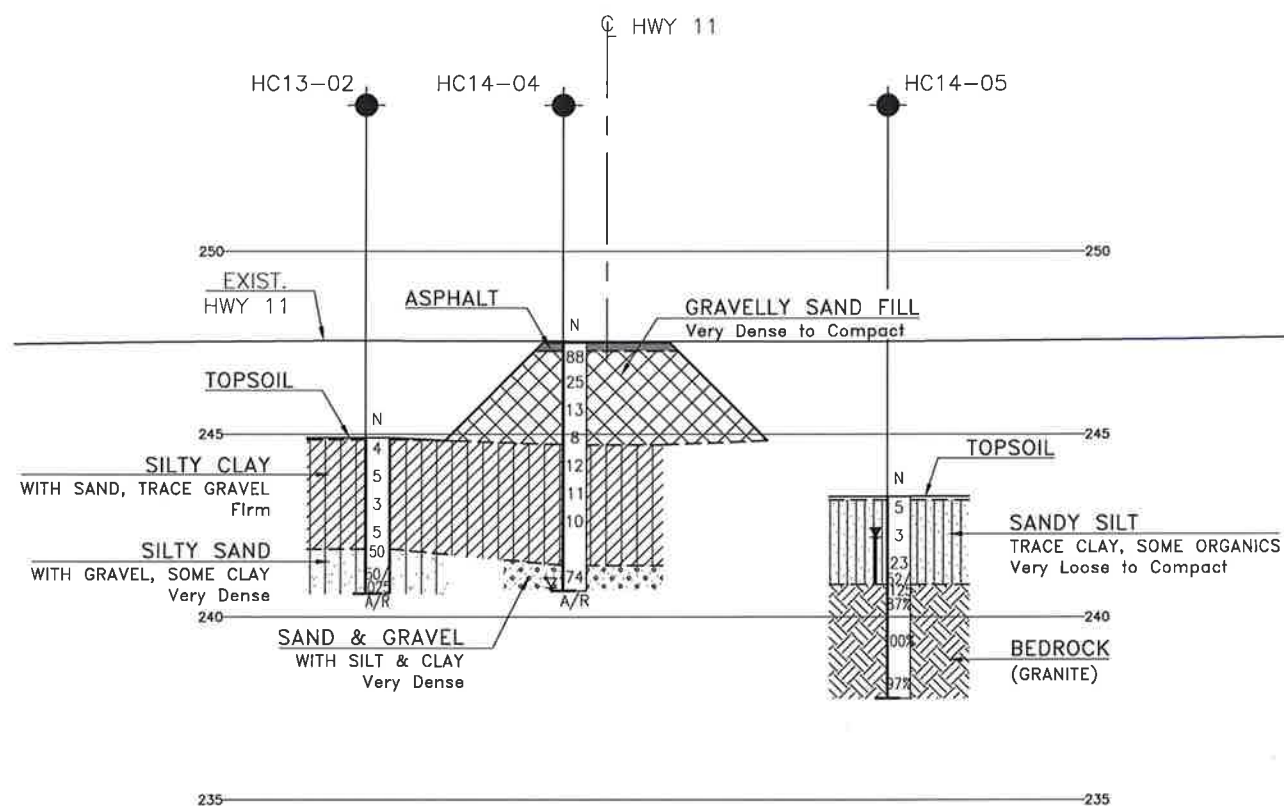
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
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HC13-02	244.9	5 508 826.0	316 671.3
HC14-03	247.5	5 508 839.4	316 692.3
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HC14-05	243.3	5 508 860.7	316 679.5
HC14-06	245.9	5 508 863.5	316 645.4
HC14-07	245.7	5 508 835.3	316 750.0

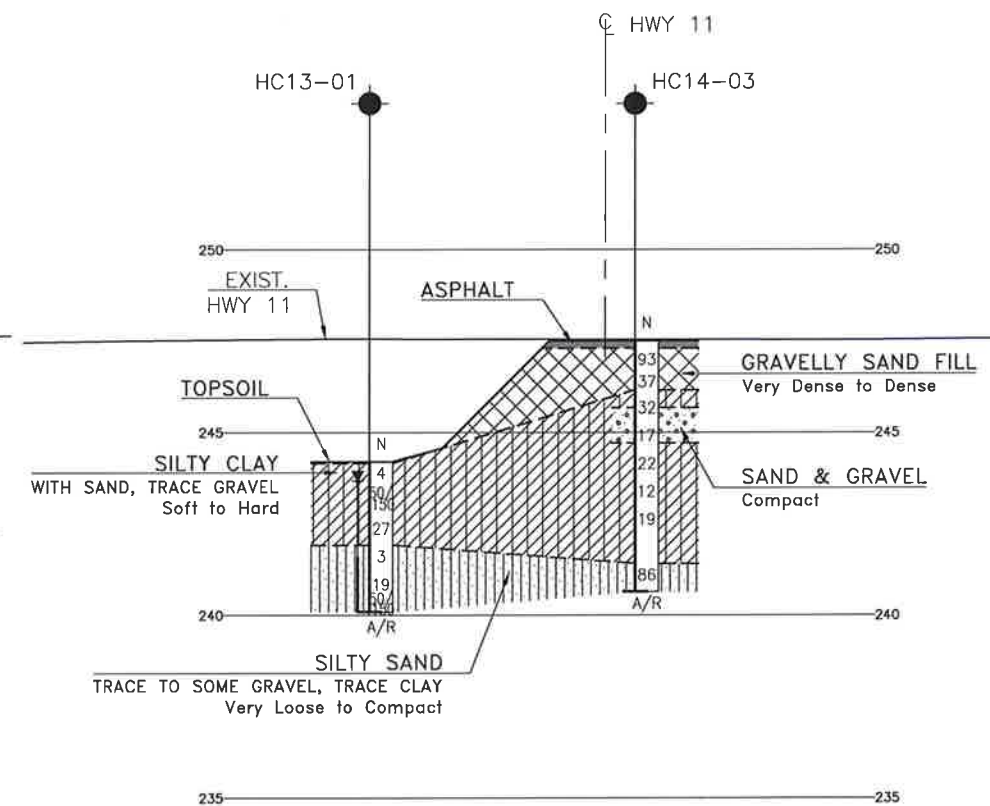
-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Embankment outline is approximate.

GEOCRES No. 42G-50



SECTION ALONG B-B



SECTION ALONG C-C

[illegible]

FILENAME: H:\Uprating\19\4406\9\red+ubs - BoreholePlan&Profile\HolladaCreek.awg
PLOTDATE: 6/15/2015 8:55 AM

Appendix D

Foundation Alternatives Comparison

19-4406-9

COMPARISON OF ALTERNATIVE CULVERT TYPES

Location	Concrete Open Footing Culvert	Concrete Rigid Box Culvert	Circular Pipe Culvert (concrete, CSP, HDPE)
Culvert Replacement	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Relatively expedient installation if precast units are used. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Requires deeper sub-excavation than box culverts. ii. Relatively higher post construction settlement than box culverts. 	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade. ii. Relatively expedient installation if precast units are used. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Requires compacted granular pad on subgrade. 	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts. ii. Lower cost than concrete (rigid frame) culverts. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. CSP and HDPE pipes not as durable as concrete culverts. ii. Feasibility also depends on flow capacity and other hydraulic properties.
	FEASIBLE	RECOMMENDED	GENERALLY FEASIBLE

Appendix E

Selected Photographs of Existing Culvert Area



Photo 1: Holland Creek Culvert Inlet



Photo 2: Holland Creek Culvert Outlet

Appendix F

List of OPS Specifications and Suggested Wording for NSSP

1. List of OPSS Documents Relevant this Project

- OPSS.PROV 206
- OPSS.PROV 501
- OPSS.PROV 539
- OPSS.PROV 804
- OPSS 902
- OPSS.PROV 1010
- OPSS.PROV 1205
- OPSD 803.010
- OPSD 810.010

2. Suggested Wording for NSSP on “Rock Excavation at Culvert Subgrade”

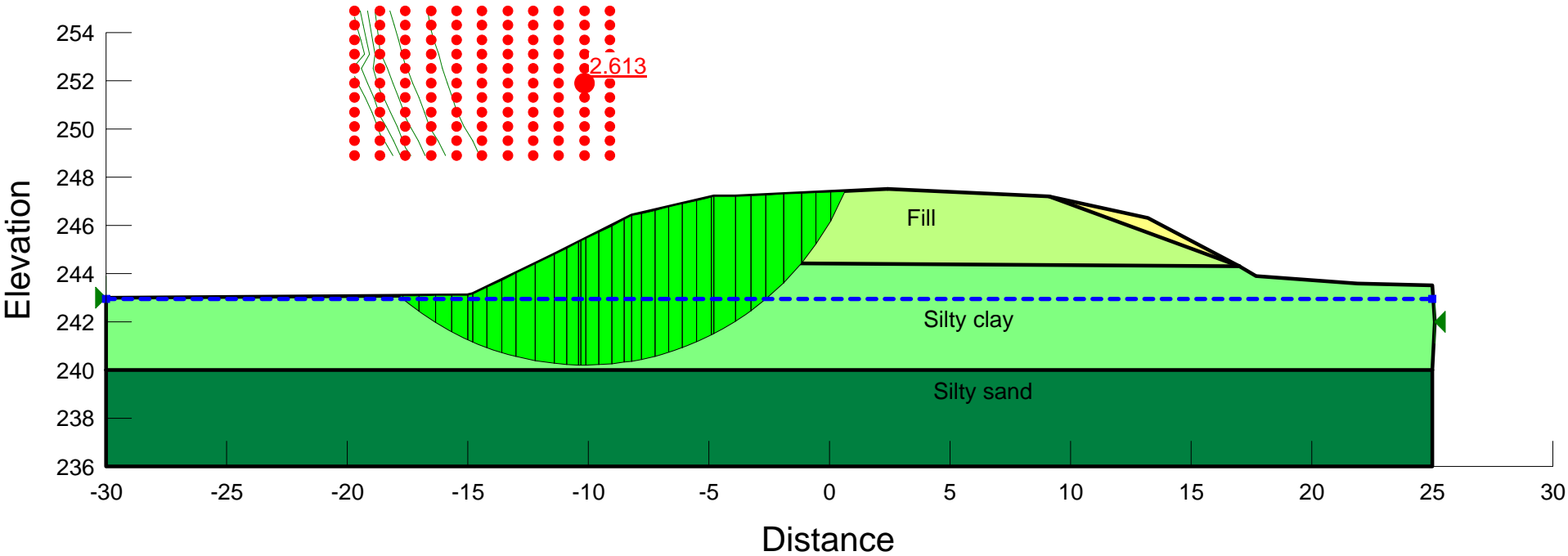
The Contractor is advised that boulders and/or bedrock may be encountered at or above the culvert founding elevation at some locations. Should removal of small quantities of boulder and/or bedrock be required, the sub-excavation should extend to 0.5 m below the design culvert founding level that would allow construction of the Granular A pad of 300 mm minimum thickness. Rock excavation, where required, shall be carried out using breakers.

Appendix G

Selected Stability Analysis Results

Holland Creek Culvert
Highway 11
Undrained Analysis
Method: Morgenstern-Price, Half sine

New fill	21 kN/m ³	0 kPa	32 °	1
Existing fill	21 kN/m ³	0 kPa	32 °	1
Silty clay	19 kN/m ³	40 kPa	1	
Silty Sand	20 kN/m ³	0 kPa	31 °	1



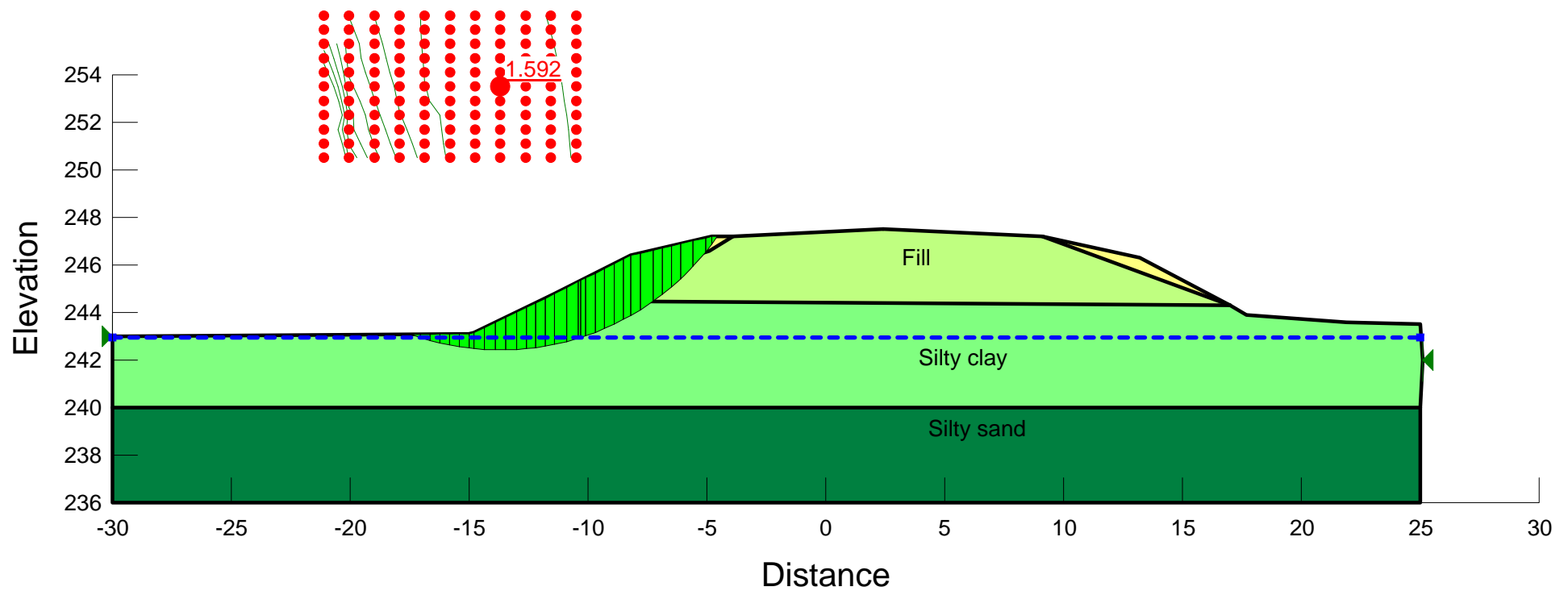
Holland Creek Culvert

Highway 11

Drained Analysis

Method: Morgenstern-Price, Half sine

New fill	21 kN/m ³	0 kPa	32 °	1
Existing fill	21 kN/m ³	0 kPa	32 °	1
Silty clay	19 kN/m ³	0 kPa	30 °	1
Silty Sand	20 kN/m ³	0 kPa	31 °	1



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Figure G2