

**FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT REPLACEMENT AT WALLY CREEK
SITE NO. 39E-227
HIGHWAY 652
COCHRANE AREA, ONTARIO
G.W.P. No. 5193-13-00**

GEOCRES Number: 42H-57

Report to

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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) at the twin culverts where replacement is proposed on Highway 652 over Wally Creek, located in the Township of Stimson, in the Cochrane Area, Ontario.

The purpose of this investigation was to obtain subsurface information at the location of the culverts and, based on the data obtained, to provide a borehole location plan, a stratigraphic profile, cross-sections, 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. The foundations terms of reference indicate that 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 652, in the Township of Stimson, approximately 28 kilometres east of Highway 11/579. The culvert allows Wally Creek to flow from north to south under Highway 652.

The existing structure, constructed in 1964, consists of twin Structural Steel Plate Pipe (SPP) culvert each with a 2.0 m span and 20.0 m long. It is understood that the structure is in poor condition with deterioration of several elements. The grade of the existing Highway 652 in the vicinity of the culvert is at approximate Elevation 300.1 m resulting in an embankment height above the culvert in the order of 1.7 to 1.8 m.

Naturally low-lying, swampy areas are present near the inlet and outlet of the culvert, with vegetation consisting of tall grass and shrubs with occasional trees. Local topography is of low relief with no visible bedrock outcrops. Areas surrounding the properties are heavily forested. The area in the

immediate vicinity of the culvert is undulating and generally sloping from the highway grade to the creek. There is a parking area located north-east of the existing culvert.

The site is located in a rural area with swamps, creeks and other watercourses nearby. The surrounding areas are covered by forests and low shrubs and bushes with no visible bedrock outcrops. Local topography is generally flat with some low sloping hills. This particular site is adjacent to a turnaround point which provides access to a hiking path in the woods.

Based on published geological information, the general area of the project is covered by glacio-lacustrine sediments of clays and silts laid down by the Glacial Lake Barlow-Ojibway. These deposits are mostly varved clays, but massive clays are also present in some areas. Due to the different rates of seasonal deposition during various periods of glaciation, the lower zones of the deposits display much thicker varves than in the upper zones. Below the varved clays are glacial outwash deposits of silts, sands and gravel underlain by Early Precambrian (Superior Province) metasedimentary rocks.

3 SITE INVESTIGATION AND FIELD TESTING

This borehole investigation and field testing program was carried out on October 4, 5, 6 and 9, 2013. The program consisted of drilling and sampling eight boreholes (identified as WC13-01 through 08) to depths ranging from 6.7 to 17.2 m (Elev. 292.0 to 282.7 m) with Dynamic Cone Penetration Tests (DCPT's) continuing below the base of selected boreholes to depths ranging from 22.3 to 25.0 m (Elevations 277.7 to 274.9 m). Of the eight total boreholes, two were located in the vicinity of the culvert inlet (WC13-01 and 02), two were located in the vicinity of the culvert outlet (WC13-07 and 08), and the remaining four boreholes (WC13-03 through 06) were located at the highway embankment level.

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

A truck mounted CME75 drill rig was used to drill and sample boreholes WC13-03, 04 and 06 using NW casing drilling techniques. A track mounted drill rig was used to drill and sample boreholes WC13-01, 02 and 05 using hollow stem auger drilling techniques. The remaining two boreholes (WC13-07 and 08), drilled near the culvert inlet, were advanced with tri-pod rig using NW casing. DCPT's were conducted below the last samples in Boreholes WC13-04, 05 and 06 until blow count refusal was met.

Soil samples were obtained at select intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Field vane testing was carried out to measure in-situ, undrained shear strength of the cohesive soils at selected locations.

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 examination and testing.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Two standpipe piezometers were installed in Borehole WC13-01 and WC13-08 for monitoring of the groundwater level. The details of piezometer installations and borehole completion are summarized in Table 3-1.

Table 3-1. Borehole Completion and Piezometer Installation Details

Borehole Number	Piezometer Installations			Completion Details
	Screen Depth (m)	Screen Elevation (m)	Sand Filter Stratum	
WC13-01	4.3 – 5.9	294.3 -292.7	Silty Clay	Bentonite hole plug and cuttings
WC13-02	None Installed			Bentonite holeplug and cuttings to surface
WC13-03	None Installed			Sand and Holeplug to 0.1 m and asphalt cold patch at surface
WC13-04	None Installed			Bentonite holeplug to 0.2 m and cuttings to surface
WC13-05	None Installed			Bentonite holeplug to surface.
WC13-06	None Installed			Bentonite holeplug to 0.1 m and a mixture of cuttings and bentonite holeplug to surface.
WC13-07	None Installed			Bentonite holeplug to 5.8 m and cuttings to surface.
WC13-08	4.6 – 6.7	293.6-291.5	Silty Clay	Bentonite to surface

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

A member of Thurber's technical staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes, secured the recovered soil samples in labelled containers, and transported the samples to Thurber's laboratory for further examination and testing.

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 plasticity testing (Atterberg Limits). The results of this laboratory testing program are shown on the Record of Borehole sheets in Appendix A and on the figures in Appendix B.

A sample of surface water was submitted to 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 Drawings 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 boreholes governs any interpretation of the site conditions.

In general, the subsurface conditions encountered in the boreholes located at the highway level consists of embankment fill overlying a deposit of native silty clay. Boreholes located at the culvert inlet and outlet encountered topsoil overlying a native clay deposit. More detailed descriptions of the individual stratum are presented below.

5.2 Topsoil and Peat

Topsoil, ranging from 50 to 100 mm in thickness, was encountered at the surface in Boreholes WC13-01, 02, 07, and 08. A 1.0 m thick layer of buried peat with pieces of wood was encountered below the sand fill in Borehole WC13-04. The peat was firm in consistency with a moisture content of 491%.

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 Asphalt

A 20 to 75 mm thick layer of asphalt was encountered at the surface in Boreholes WC13-03 through 06 drilled from the highway level.

5.4 Fill

Embankment fill was encountered below the asphalt in Boreholes WC13-03 through 06. The fill layer typically consists of brown sand with some gravel to gravelly, trace silt underlain by sand, trace to some silt, trace gravel. Where encountered, the embankment fill extended to depth of 1.4 to 3.7 m (Elev. 298.6 to 296.2 m).

SPT N-values measured in the embankment fill typically ranged from 4 to 59 blows per 300 mm of penetration indicating a loose to very dense relative density, to as high as 50 blows per 150 mm penetration. The moisture contents of the recovered samples ranged from 2 to 21%.

Three laboratory grain size analyses were performed on samples of the fill. 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 on Figure B1 of Appendix B. These results are summarized in the following table.

Soil Particles	%
Gravel	1 to 17
Sand	80 to 96
Silt and Clay	3 to 10

5.5 Sand

A layer of sand, trace silt to silty was encountered below the topsoil in Boreholes WC13-01, 07 and 08. The thickness of the sand ranged from 0.7 to 1.5 m with a corresponding underside depth of 0.8 to 1.6 m (Elev. 297.7 to 297.0 m).

SPT N-values measured in the sand ranged from 1 to 4 blows per 300 mm of penetration, indicating very loose relative density. The moisture contents of the recovered soil samples ranged from 13 to 53%.

The gradation of the sand layer is summarized below and in the grain size distribution curves plotted on Figure B4 of Appendix B.

Soil Particles	%
Gravel	3
Sand	94
Silt and Clay	3

5.6 Silty Clay

A layer of silty clay, trace to some sand, trace gravel was encountered below the layers noted above in all boreholes. The investigated thicknesses of the silty clay ranged from 2.4 to 14.0 m with a corresponding underside depth of 7.0 to 17.2 m (Elev. 292.0 to 282.7 m). All borehole sampling was terminated within the silty clay.

SPT N-values measured within the silty clay typically ranged from 0 (static weight of hammer) to 12 blows per 300 mm of penetration, indicating very soft to stiff consistency. A firm crust was noted in the upper 1 to 1.5 m. An N-value of 35 blows per 300 mm of penetration was recorded in Borehole WC13-08, indicating a localized hard zone. The vane tests indicate a range of undrained shear strengths of 18 to 50 kPa. The measured moisture contents of the recovered samples typically ranged from 19% to 67%.

Fourteen grain size analyses were performed on samples of the silty clay. The results are presented on the corresponding Record of Borehole sheets in Appendix A and the grain size distribution curves are plotted on Figures B2, B3 and B4 of Appendix B. These results are summarized in the following table.

Soil Particles	%
Gravel	0 to 4
Sand	0 to 15
Silt	19 to 77
Clay	23 to 80
Soil Property	%
Liquid Limit	29 - 65
Plasticity Index	14 - 36

The results of the Atterberg Limits tests performed on 16 samples of the silty clay are plotted in Figure B5 through B7 of Appendix B. The results of the tests are summarized above and indicate that the silty clay ranges from low to high plasticity, but predominately exhibits intermediate plasticity.

5.7 Groundwater Conditions

Water levels were observed in the open boreholes during and upon completion of drilling. Standpipe piezometers were installed in Boreholes WC13-01 and 08 to permit longer term monitoring. The water levels observed in the open boreholes and measured in the piezometer are as follows:

Table 5-1 Groundwater Elevations

Borehole	Date of Reading	Water Level Depth (m)	Water Level Elevation (m)	Comments
13-01	November 1, 2013	0.2	298.4	Piezometer
	November 7, 2013	0.2	298.4	Piezometer
13-08	November 1, 2013	0.2	298.0	Piezometer
	November 7, 2013	0.2	298.0	Piezometer

Where surface water is present, the groundwater level should be assumed to coincide with the local surface or 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

Borehole locations were selected by Thurber. Callon Dietz provided northing and easting coordinates and ground surface elevation for the as-drilled locations utilizing DTM, based on borehole location sketches provided by Thurber.

Downing Drilling of Hawkesbury, Ontario supplied and operated a truck-mounted drill rig, a track-mounted drill rig, and a tri-pod drill to carry out the drilling, sampling, in-situ testing operations and standpipe installations.

The drilling and sampling operations in the field were supervised on a full time basis by Mr. Stephane Loranger and Ms. Kathrine Young of Thurber. Routine laboratory testing was carried out by Thurber's geotechnical laboratory in Oakville, Ontario.

Overall project management and direction of the field program was provided by Mr. Alastair Gorman, P.Eng. Interpretation of the field data and preparation of this report was completed by Mr. Stephen Peters, P.Eng., Dr. Sydney Pang, P.Eng. 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 presents foundation recommendation for the replacement of the existing twin culverts at Wally Creek on Highway 652, located approximately 28.0 km east of Highway 11/579 (Cochrane Area) within the Township of Stimson.

Based on the terms of reference, the existing culverts, constructed in 1964, consists of twin structural Steel Plate Pipe (SPP) culvert each with a 2.0 m span and 20.0 m long. The embankment fill height above the culvert is in the order of approximately 1.7 to 1.8 m.

The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained during the course of this investigation. There is no archived foundation information available for the existing culverts. Select photographs showing the existing conditions of the culvert area are included in Appendix E for reference.

8 CULVERT FOUNDATIONS

8.1 General

The current project requirements involve replacement of the existing twin SSP pipe culverts with twin 2400 by 1800 mm concrete box culverts along the same alignment. It is understood that highway platform widening to the south side in the order of 2 to 3 m will be required during construction. No highway grade raise are currently planned. Physical dimension for the proposed culvert, obtained from URS, are presented in Table 8-1, below.

Table 8-1. Physical Data of Proposed Replacement Culverts

Culvert # C05	Borehole Numbers	Approx. Invert Elevation (m)		Length (m)	Width (m)	Height (m)
		Inlet	Outlet			
East Culvert	WC13-01 & 02 (Near culvert inlet) WC13-03, 04, 05 & 06 (Through highway embankment near culvert alignment)	296.58	296.50	22.0	2.8	2.2
West Culvert	WC13-07 & WC13-08 (Near culvert outlet)	296.58	296.50	22.0	2.8	2.2

Note: All dimensions are preliminary and subject to change

8.2 Foundation Alternatives

This section presents discussions on alternate types of replacement culverts and foundation alternatives, and provides recommendations on feasible and/or preferred foundation option. Several common culvert and foundation types are listed below and a comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix D.

Concrete, Open Footing Culvert

Concrete, open footing culverts are not considered suitable for this site from a foundation engineering perspective as the compressible silty clay subgrade will provide low geotechnical resistances and has potential for post construction settlement.

Circular Pipes (Concrete, CSP, HDPE)

From a foundation engineering standpoint, concrete, CSP and HDPE pipes are technically feasible alternatives, provided that other design issues including flow capacity, hydraulic properties and durability can be satisfied.

Concrete Box (Closed) Culvert

Given the subsurface conditions and the anticipated construction sequencing, the proposed precast twin concrete box culverts are the preferred option from a foundation engineering standpoint. Precast sections, rather than cast-in-place construction, can be installed rapidly with less potential for disturbance of the founding soils during installation.

This report focuses on providing foundation recommendations on the design and construction of box culverts and the associated walls.

8.3 Foundation Design for Box Culverts

It is understood that the inverts of the replacement culverts are approximately the same as those of the existing culverts. Foundation design aspects for the replacement culverts include subgrade conditions, geotechnical resistances for the retaining walls, settlement of founding soils, lateral earth pressures, erosion control, protection system design and groundwater control, staged excavation, and stability of widening detour embankment.

8.3.1 Concrete Box Culverts

Since the replacement culverts will be constructed on the same alignments as the existing culverts, it is anticipated that the subgrade soils within the culvert footprints will not be subjected to any significant additional loading.

In order to provide a more uniform foundation subgrade condition, a minimum 300 mm thick layer of bedding material conforming to OPSS 1010 Granular A requirements must be provided under the base of the box culverts as per OPSD 803.010. The bedding material must be placed on the approved subgrade 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.

The underside of the Granular A pad must be founded at or below Elevation 296.5 m on the undisturbed, firm silty clay. Any soft soils at the design subgrade level must be sub-excavated and replaced with engineered fill as outlined below. The recommended geotechnical resistances for this founding elevation, under the existing culvert footprints, are as follows:

- Factored Geotechnical Resistance at ULS of 100 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 65 kPa.

Resistance to lateral forces / sliding resistance between the precast concrete and the underlying Granular A should be evaluated in accordance with the CHBDC (2010) assuming an ultimate coefficient of friction of 0.4.

It is recommended that the culverts 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 adjacent to the new twin culverts. Consideration may be given to using Retained Soil Systems (RSS) walls and/or gabion walls.

Borehole information indicates that the founding condition at the likely wall locations generally consist of firm silty clay.

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 at or below Elevation 296.5 m on the undisturbed, firm silty clay deposit. An RSS wall founded at these levels may be designed using a factored geotechnical resistance at ULS of 100 kPa and a geotechnical resistance at SLS of 65 kPa. The RSS may be founded on engineered fill resting on the silty clay 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 laterally 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 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. A preliminary assessment indicates that a properly designed and constructed RSS retained embankment at this site would satisfy global stability requirements.

8.3.2.2 Gabion Walls

From a foundation standpoint, it is recommended that any gabion walls be supported on a pad of engineered fill that is itself resting on the firm silty clay at or below approximate Elevation 296.5 m. The pad is required to provide subgrade uniformity along the gabion wall alignments and should consist of a minimum 300 mm of compacted Granular A materials. For the recommended founding elevation, the geotechnical resistances recommended above for the RSS walls may be used for designing the gabion walls. Load inclination and eccentricity should also be taken into account as outlined above. The horizontal resistance against sliding between the base of the wall and the underlying engineered fill pad or undisturbed, native silty clay may be evaluated as recommended for the RSS walls above.

The gabion walls should be designed as a gravity wall which involves checking for internal stability, overturning stability and sliding resistance. Global stability of the gabion walls will be analyzed by Thurber once the detailed configurations of the walls are known. A preliminary assessment indicates that a properly designed and constructed gabion retained embankment would satisfy global stability requirements.

8.3.3 Settlements

It is understood that there is no grade raise at this site. The existing twin SPP culverts are to be replaced with twin concrete box culverts along the same alignments. The opening sizes of the two culverts are similar. Taking into consideration the proposed conceptual construction sequencing for this site, it is anticipated that rebound of the subgrade after removal of the existing culvert and the surrounding fill will be negligible. Due to the slightly heavier weight of the concrete box compared to the SPP, the firm silty clay subgrade soils would be subjected to additional load resulting in some post construction consolidation settlements. The estimated post construction settlement is in the order of 5 to 10 mm within 10 years. Should the top of pavement profile need to be maintained at the culvert location, consideration may be given to resurfacing of the pavement at some point within five years after completion of construction.

8.3.4 Subgrade Preparation

After the excavation and removal of the existing SPP and surrounding soils are completed to the design founding elevation, any remaining fill, topsoil, pear, creek bed deposits, disturbed soils and any deleterious materials within the culvert replacement footprint must be sub-excavated to undisturbed native firm silty clay at or below the desired founding elevations. The exposed surface must be inspected to confirm that the subgrade is suitable and uniformly competent. Any soft areas should be sub-excavated and replaced with well compacted granular fill consisting of compacted OPSS 1010 Granular A or Granular B Type II material.

Culvert construction must be carried out in the dry.

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 culverts at Wally Creek. The highway embankment will be widened to the north side in order to maintain one lane of traffic during culvert replacement.

Construction sequencing proposed by URS is shown on staging plans. The main features outlined in these plans are as follows:

- One lane of traffic will be maintained at all times during construction
- Cofferdams are required to be installed at the inlet and outlet areas as part of the creek flow and surface water diversions
- Creek flow will be maintained at all times
- Pumping from sumps is anticipated to be required
- Roadway protection will be required during 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 interlocking steel sheet piles will be required. Foundation recommendations for design of such a system are provided in Section 13 of this report. Foundation aspects of the detour embankment design and construction will be addressed Section 10.2.

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 Granular B Type II conforming to the requirements of OPSS 1010. Reference should be made to the backfill arrangements stipulated in OPSD 803.01 as appropriate. Excavated granular embankment fill may be considered for reuse (see section 12 below).

All fills must be placed in regular lifts and be compacted in accordance with OPSS 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 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)

The culvert pipes must be designed to withstand full hydrostatic pressure assuming a water level at least equal to the design creek water level. This is applicable when the water level behind the culvert wall is higher than the creek 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 any wing wall or unrestrained wall.

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

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	-

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. Care must be exercised when compacting the fill immediately above the crown of the box in order not to damage the box.

10 EMBANKMENT DESIGN AND CONSTRUCTION

10.1 Culvert Replacement

The existing highway embankment is 2 to 3 m in height at the culverts. It is understood that that there is no planned grade raise at this site.

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS 206. The embankment material should consist of either the excavated granular fill discussed above, or imported Granular A or Granular B Type II material. Excavated granular fill may be reused as backfill provided the following conditions are satisfied:

- There is sufficient space to stockpile the excavated fill on site and control the moisture content within acceptable limits for compaction
- No peat, organics, or clay are included in the fill
- Gradation and compaction characteristics meet the requirements prior to reuse as backfill

Results of limit equilibrium stability analysis carried out for this proposed 3H : 1V slope configuration indicates that the short term (undrained) and long term (drained) scenarios give factors of safety in the order of 1.5 (see Appendix F). Taking into consideration the relatively low embankment height, the results generally satisfy typical MTO criteria for global stability.

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 culvert subgrade and embankment footprints. Inspection and approval of the foundation surfaces by qualified geotechnical personnel is recommended.

10.2 Embankment Widening for Detour

Widening of the existing highway embankment on the south side to accommodate a temporary traffic detour lane will require placement and compaction of granular fill. Provided that the proposed Granular A material is placed as recommended, it is anticipated that the existing slope inclination of 2H : 1 for an overall 3 m high embankment (2 m above the culverts), with temporary steepening to 1.5H : 1V, 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.

As the new fill is placed on the existing embankment slope, it is anticipated that settlement due to elastic compression of the underlying native silty clay will take place. It is anticipated that the wedge of new fill would induce in the order of 5 to 10 mm of settlement. This immediate settlement is expected to be completed by the end of construction.

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, rip-rap should be provided over all surfaces with which creek water is likely to be in contact. 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 804.

It is recommended that a clay seal or a concrete cut-off wall be used to minimize the potential for 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 1205. A geo-synthetic clay liner may be used as a clay seal.

12 EMBANKMENT DESIGN AND CONSTRUCTION

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 and native silty clay 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 to 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 and compaction characteristics are confirmed prior to reuse as backfill.

12.3 Excavations

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

Any protection system should be designed by licensed Professional Engineers experienced in such designs. OPSS 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

Groundwater perched within the embankment fill will seep into the excavations during culvert replacement. Surface runoff will also tend to accumulate in these excavations. The groundwater level is expected to be largely governed by the water level in the creek. As discussed in the previous section 8.4, a combination of the use of cofferdams at the inlet, creek water diversion, protection systems such as sheet piled enclosures and pumping from filtered sumps will be required to maintain dry excavations during the course of staged construction.

13 ROADWAY PROTECTION DESIGN

Roadway protection will be required during various stages of construction. The design of roadway protection is the responsibility of the Contractor. However, one option that is considered to be suitable for use at this site is steel interlocking sheet pile enclosures which are also anticipated to provide an effective groundwater cutoff. It is anticipated that the sheet piles will need to be extended into the very stiff to firm native silty clay to develop the required toe resistance.

An interlocking sheet piled wall 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)
	=	0.36 (silty clay)
K_p	=	2.8 (silty clay)

Full hydrostatic pressure should be considered assuming a water level at least equal to the design creek water level.

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 for a cantilevered sheet piled wall.

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.

- Effective dewatering of the temporary excavation for installation of culvert
- removal of peat, organics, soft soils and alluvial deposits near creek and stream channels,
- disturbance of the soil subgrade within the culvert foundation footprints,
- confirmation that the culvert backfills and approach fills 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 Mr. Alastair Gorman, P.Eng. and Dr. P.K. Chatterji, P.Eng.

THURBER ENGINEERING LTD.

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Geotechnical Engineer



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Associate, Senior Foundations Engineer



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Principal, Designated MTO Contact



Appendix A

Record of Borehole Sheets

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

C_{pen}

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.

EXPLANATION OF ROCK LOGGING TERMS






ROCK WEATHERING CLASSIFICATION

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

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
	(MPa)	(psi)	
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.

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			

RECORD OF BOREHOLE No WC13-01

1 OF 1

METRIC

GWP# 5114-09-01 LOCATION Wally Creek Culvert N 5 435 099.2 E 329 317.4 ORIGINATED BY KMY
HWY 652 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2013.10.05 - 2013.10.05 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 (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P W W _L	WATER CONTENT (%)					
								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
298.6	TOPSOIL: (100 mm), trace sand, trace rootlets SAND , trace to some silt, trace gravel Loose to Very Loose Light Brown Moist to Wet		1	SS	4									3 94 3 (SI+CL)	
0.0															Split spoon wet
0.1															
297.0	Silty CLAY , trace to some sand, trace organics Firm to Soft Grey Moist		2	SS	1		298								0 13 45 42
1.6			3	SS	1		297								
			4	SS	7		296								
							295								
			5	SS	3		294								
							293								
			6	SS	1		292								
291.6			7.0												
END OF BOREHOLE AT 7.0 m. Piezometer installation consists of 19 mm diameter Schedule 40 PVC pipe with a 1.52 m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Nov. 1/13 0.2 298.4 Nov. 7/13 0.2 298.4															

ONTMT4S 4069.GPJ 2012TEMPLATE(MTO).GDT 12/23/13

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No WC13-02

1 OF 1

METRIC

GWP# 5114-09-01 LOCATION Wally Creek Culvert N 5 435 092.6 E 329 336.0 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.05 - 2013.10.05 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			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				W P W W L										
								20 40 60 80 100	○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	WATER CONTENT (%)									
299.0																						
0.0																						
	TOPSOIL, trace sand, trace rootlets						299															
	Silty CLAY, trace to some sand, trace gravel		1	SS	8																	
	Stiff to to Firm																					
	Grey		2	SS	4		298															
	Moist																					
			3	SS	4		297															
			4	SS	12													4	5	33	58	
							296															
			5	SS	3		295															
			6	SS	1		294															
			7	SS	1		293												0	12	40	48
292.0																						
7.0	END OF BOREHOLE AT 7.0 m. BOREHOLE BACKFILLED WITH CUTTINGS AND BENTONITE HOLEPLUG TO SURFACE.																					

ONTMT4S 4069.GPJ 2012TEMPLATE(MTO).GDT 12/23/13

+³, ×³: Numbers refer to
Sensitivity

20
15
10
5
0
5
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No WC13-03

1 OF 2

METRIC

GWP# 5114-09-01 LOCATION Wally Creek Culvert N 5 435 090.6 E 329 317.9 ORIGINATED BY SLL
 HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.05 - 2013.10.05 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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						WATER CONTENT (%) w _p w w _L				
299.9								20	40	60	80	100						
0.0	ASPHALT: (25 mm)																	
299.3	SAND, some gravel to gravelly Very Dense Brown Moist (FILL)		1	SS	50/ 0.150													
0.6	SAND, trace silt, trace gravel, occasional cobbles Very Dense to Loose Brown Moist (FILL)		2	SS	59													
			3	SS	15													
			4	SS	5													
			5	SS	4													
296.2	Silty CLAY, trace to some sand Firm to soft Grey Moist		6	SS	7													
3.7			7	SS	4													
			8	SS	2													
			9	SS	2													
			10	SS	WH													

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No WC13-03

2 OF 2

METRIC

GWP# 5114-09-01 LOCATION Wally Creek Culvert N 5 435 090.6 E 329 317.9 ORIGINATED BY SLL
 HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.05 - 2013.10.05 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL LIMIT MOISTURE LIQUID CONTENT LIMIT			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				WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
								20 40 60 80 100	20 40 60							
	Continued From Previous Page															
288.8	Silty CLAY , trace to some sand Firm to soft Grey Wet		11	SS	12		289	3.0 +								
11.1	Sandy															
288.2							288									
11.7			12	SS	PH		287									
								+								
			13	SS	WH		286									
															0 6 24 70	
			14	SS	WH		285	5.0 +								
283.6							284									
16.3	END OF BOREHOLE AT 15.8 m. BOREHOLE OPEN TO 1.7 m AND WATER LEVEL AT 1.5 m. BOREHOLE BACKFILLED WITH SAND TO 0.1 m, THEN ASPHALT TO SURFACE.							5.0 								

ONTMT4S 4069.GPJ 2012TEMPLATE(MTO).GDT 12/23/13

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

METRIC

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _P W W _L				
300.0	0.0	ASPHALT: (20mm)												
299.5	0.5	SAND, some gravel to gravelly, trace silt, with asphalt fragments Very Dense Brown Moist (FILL)	1	SS	50/									
298.6	1.4	SAND, trace silt, trace gravel Compact Brown Moist (FILL)	2	SS	24									
297.6	2.4	PEAT, with wood pieces and roots Firm Black Wet	3	SS	8									
		Silty CLAY, trace to some sand Firm to Soft Brown Moist	4	SS	8									
		With silt pockets	5	SS	7									
			6	SS	2									
			7	SS	1									
			8	SS	WH									
			9	SS	WH									
			10	SS	1									


(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No WC13-04

2 OF 3

METRIC

GWP# 5114-09-01 LOCATION Wally Creek Culvert N 5 435 085.2 E 329 344.0 ORIGINATED BY SLL
HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
DATUM Geodetic DATE 2013.10.05 - 2013.10.05 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 (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P W W _L	20 40 60	GR SA SI CL								
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE			WATER CONTENT (%)								
	Silty CLAY , trace to some sand Firm to Soft Brown Moist						290	2.0 +											
			11	SS	WH		289												
			12	SS	WH		288	3.0 +											
			13	SS	WH		287	4.0 +											
							286												
							285	6.0 +											
			14	SS	WH		284												
284.2																			
15.8	End of sampling at 15.8 m and start DCPT							3.0 +											
							283												
							282												
							281												

RECORD OF BOREHOLE No WC13-04

3 OF 3

METRIC

GWP# 5114-09-01 LOCATION Wally Creek Culvert N 5 435 085.2 E 329 344.0 ORIGINATED BY SLL
 HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.05 - 2013.10.05 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100 PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L WATER CONTENT (%) 20 40 60 UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				
	Continued From Previous Page						280 279 278		
277.7 22.3	END OF BOREHOLE AND DCPT AT 22.3 m ON PROBABLE BEDROCK. BOREHOLE OPEN TO 1.9 m AND WATER LEVEL AT 1.7 m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.2 m AND CUTTINGS TO SURFACE.								

RECORD OF BOREHOLE No WC13-05

1 OF 3

METRIC

GWP# 5114-09-01 LOCATION Wally Creek Culvert N 5 435 083.5 E 329 307.3 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.09 - 2013.10.09 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						WATER CONTENT (%)			
								20 40 60 80 100						20 40 60			
299.9																	
0.0																	
0.1																	
299.1																	
0.8																	

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No WC13-05

2 OF 3

METRIC

GWP# 5114-09-01 LOCATION Wally Creek Culvert N 5 435 083.5 E 329 307.3 ORIGINATED BY KMY
HWY 652 BOREHOLE TYPE Casing COMPILED BY AN
DATUM Geodetic DATE 2013.10.09 - 2013.10.09 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			SHEAR STRENGTH kPa				WATER CONTENT (%)								
								20 40 60 80 100				w _P w w _L								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
	Continued From Previous Page																			
282.7 17.2	Silty CLAY , trace to some sand, with rootlets Firm to Soft Grey Moist		10	SS	WH															
			11	SS	WH															
			12	SS	WH															
			13	SS	WH															
									</											

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
20
15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No WC13-05

3 OF 3

METRIC

GWP# 5114-09-01 LOCATION Wally Creek Culvert N 5 435 083.5 E 329 307.3 ORIGINATED BY KMY
HWY 652 BOREHOLE TYPE Casing COMPILED BY AN
DATUM Geodetic DATE 2013.10.09 - 2013.10.09 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL LIQUID MOISTURE CONTENT		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		WATER CONTENT (%)			
	Continued From Previous Page							20 40 60 80 100	20 40 60				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
274.9							279						
25.0	END OF BOREHOLE AND DCPT AT 25.0 m. BOREHOLE BACKFILLED WITH HOLEPLUG TO SURFACE.						278						
							277						
							276						
							275						

RECORD OF BOREHOLE No WC13-06

1 OF 3

METRIC

GWP# 5114-09-01 LOCATION Wally Creek Culvert N 5 435 079.2 E 329 330.5 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.06 - 2013.10.06 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							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
300.0							20	40	60	80	100	PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	
0.0	ASPHALT: (20 mm)														
299.2	SAND, some gravel to gravelly, trace silt Very Dense Brown Moist (FILL)		1	SS	48										
0.8	SAND, trace silt, trace gravel Compact to Loose Brown Moist (FILL)		2	SS	32										
			3	SS	15										
			4	SS	7										
			5	SS	7										
296.3	Silty CLAY, trace to some sand Firm Grey Wet		6	SS	7										
3.7			7	SS	4										
			8	SS	3										
			9	SS	2										
			10	WH	0										

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

SOIL PROFILE						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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES		SHEAR STRENGTH kPa			WATER CONTENT (%)					
			NUMBER	TYPE	"N" VALUES			○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × LAB VANE	w _p w w _L			
	Continued From Previous Page												
	Silty CLAY Very Soft Grey Wet						290	4.0 +					
			11	WH	0		289						0 14 23 63
			12	WH	0		288	4.0 +					
							287	6.0 +					
			13	WH	0		286						
							285	3.0 +					
			14	WH	0								
284.2 15.8	End of sampling and start DCPT at 15.8 m						284	4.0 +					
							283						
							282						
							281						

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No WC13-06

3 OF 3

METRIC

GWP# 5114-09-01 LOCATION Wally Creek Culvert N 5 435 079.2 E 329 330.5 ORIGINATED BY KMY
HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
DATUM Geodetic DATE 2013.10.06 - 2013.10.06 CHECKED BY SKP

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
	Continued From Previous Page							20 40 60 80 100							
							280								
							279								
							278								
							277								
							276								
275.6 24.4	END OF DCPT AND BOREHOLE AT 24.4 m. BOREHOLE OPEN TO 2.5 m AND FREE WATER AT 2.0 m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.1 m AND CUTTINGS AND BENTONITE HOLEPLUG TO SURFACE.														

RECORD OF BOREHOLE No WC13-07

1 OF 1

METRIC

GWP# 5114-09-01 LOCATION Wally Creek Culvert N 5 435 075.6 E 329 315.9 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.06 - 2013.10.06 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						
298.5														
0.0														
0.1	ROOTMAT (75 mm)		1	SS	2		298							Split spoon wet
	SAND, trace silt, some rootlets Very Loose Light Brown Wet													
297.7			2	SS	3		297							
0.8	Silty CLAY, trace to some sand Firm to Soft Grey Moist		3	SS	12									0 0 39 61
							296							
			4	SS	4		295							
								1.8						
							294							
			5	SS	4		293							
								1.5						
			6	SS	2		292							0 11 37 52
291.4								1.1						
7.1	END OF BOREHOLE AT 7.0 m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 5.8 m AND CUTTINGS TO SURFACE.													

ONTMT4S 4069.GPJ 2012TEMPLATE(MTO).GDT 12/23/13

RECORD OF BOREHOLE No WC13-08

1 OF 1

METRIC

GWP# 5114-09-01 LOCATION Wally Creek Culvert N 5 435 072.1 E 329 332.4 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.04 - 2013.10.04 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT LIMIT			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				WATER CONTENT (%)				
								20 40 60 80 100					W _P W W _L			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
298.2																
0.0	ROOTMAT		1	SS	3		298									
	Silty SAND , trace gravel, trace clay															
	Very Loose															
	Brown															
297.4	Wet															
0.8	Silty CLAY , trace to some sand, trace gravel		2	SS	9										Split spoon wet	
	Stiff to Soft															
	Grey															
	Wet															
			3	SS	35										0 0 37 63	
			4	SS	11		296									
			5	SS	16		295									
			6	SS	3		294								0 13 37 50	
			7	SS	0		293									
			8	SS	2		292									
291.5	END OF BOREHOLE AT 6.7 m. Piezometer installation consists of 19 mm diameter Schedule 40 PVC pipe with a 1.52 m slotted screen.															
6.7																
	WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Nov. 1/13 0.2 298.0 Nov. 7/13 0.2 298.0															

ONTMT4S 4069.GPJ 2012TEMPLATE(MTO).GDT 12/23/13

Appendix B

Laboratory Test Results

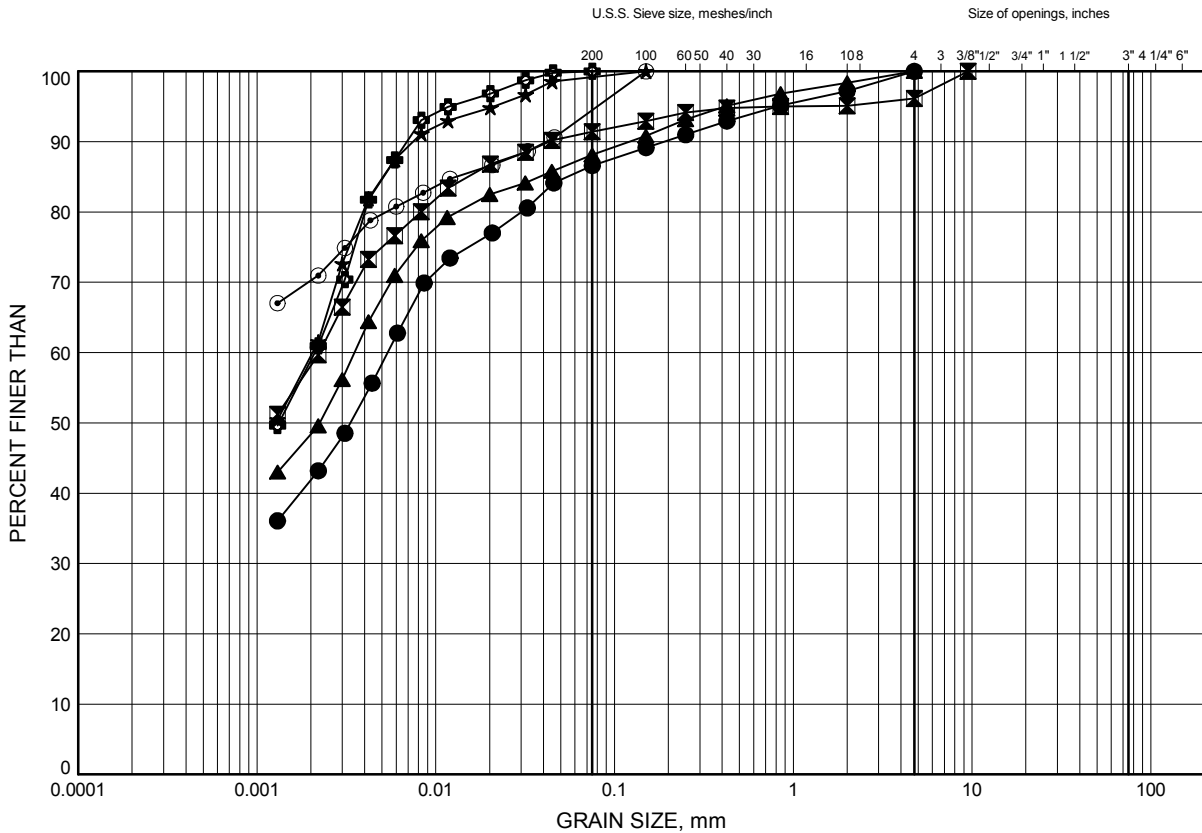
19-4406-9

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B1

SILTY CLAY, Trace to Some Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	WC13-01	4.11	294.49
⊠	WC13-02	2.59	296.41
▲	WC13-02	6.40	292.60
★	WC13-03	4.11	295.79
⊙	WC13-03	14.02	285.88
⊕	WC13-04	4.11	295.89

Date December 2013

GWP# 5114-09-01



Prep'd AN

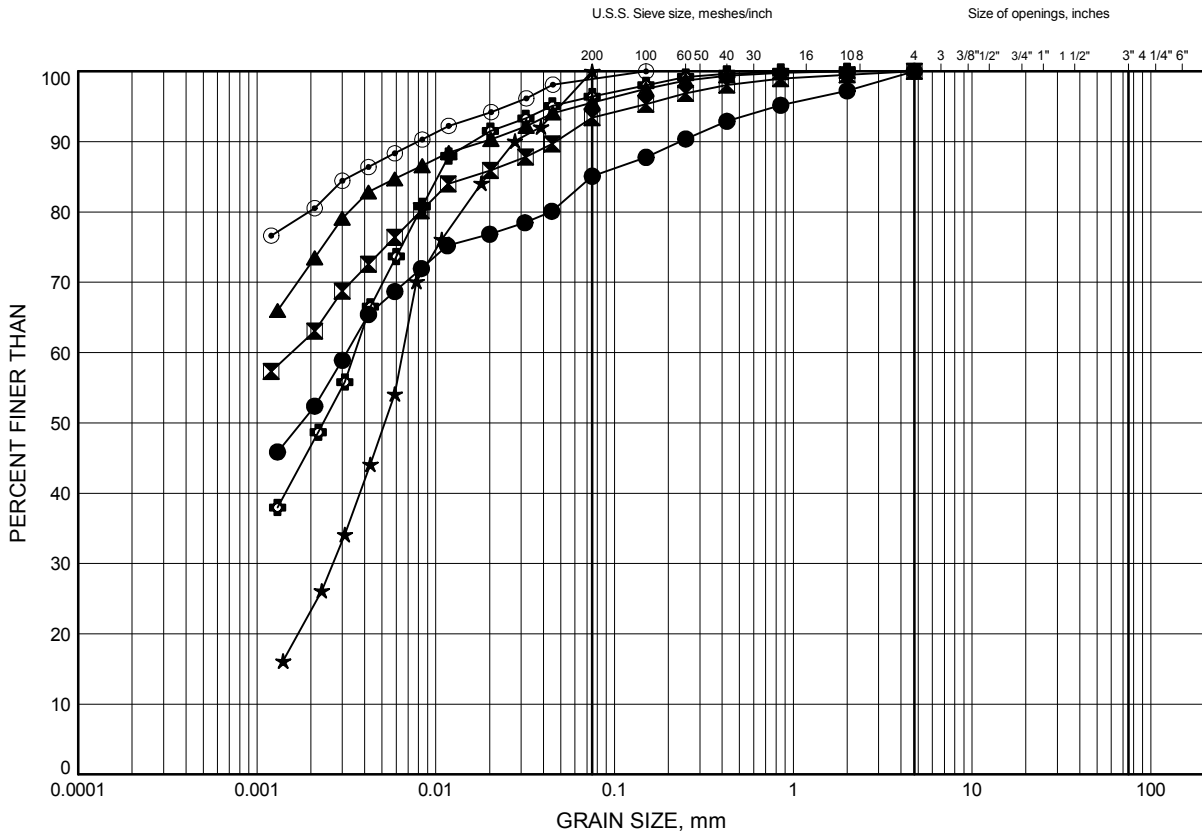
Chkd. LPG

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B2

SILTY CLAY, Trace to Some Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	WC13-04	7.92	292.08
⊠	WC13-04	12.50	287.50
▲	WC13-05	4.11	295.79
★	WC13-05	6.86	293.04
⊙	WC13-05	13.26	286.64
⊕	WC13-06	6.40	293.60

Date December 2013

GWP# 5114-09-01



Prep'd AN

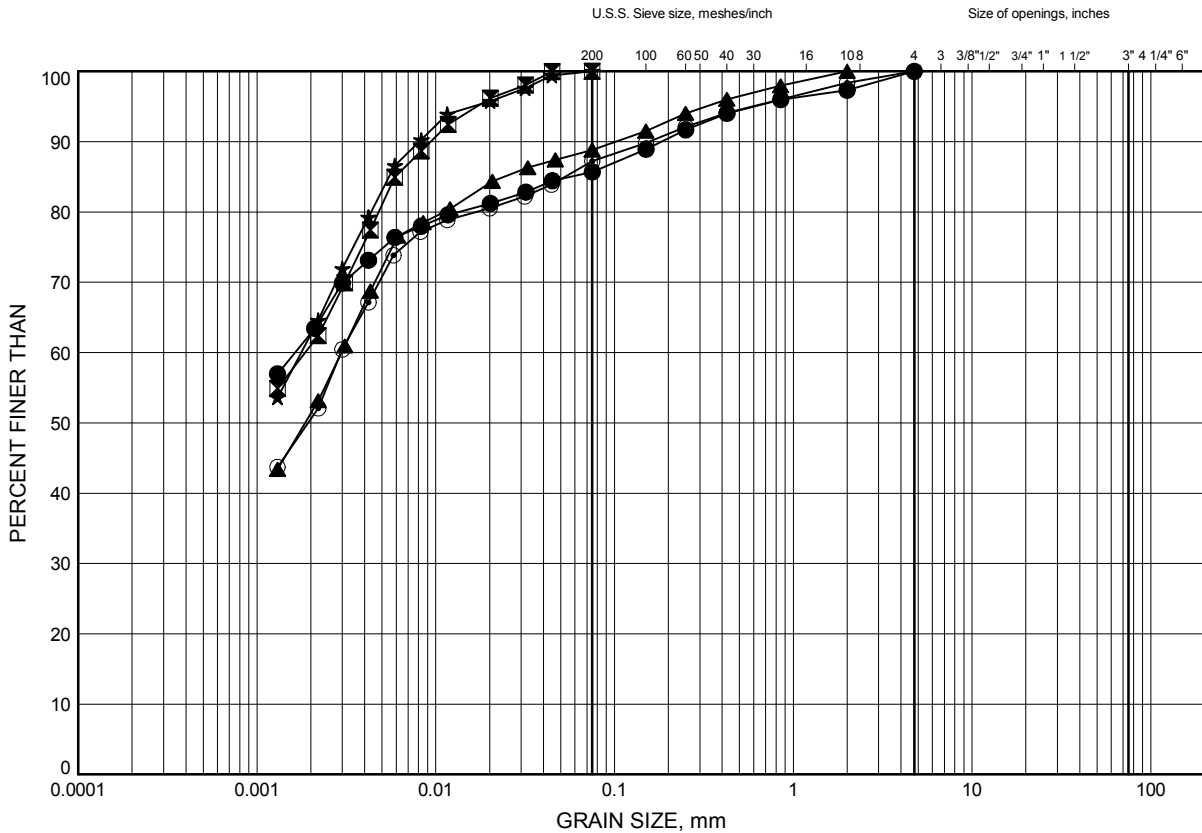
Chkd. LPG

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILTY CLAY, Trace to Some Sand



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	WC13-06	10.97	289.03
⊠	WC13-07	1.83	296.67
▲	WC13-07	6.40	292.10
★	WC13-08	1.83	296.37
⊙	WC13-08	4.11	294.09

Date December 2013

GWP# 5114-09-01



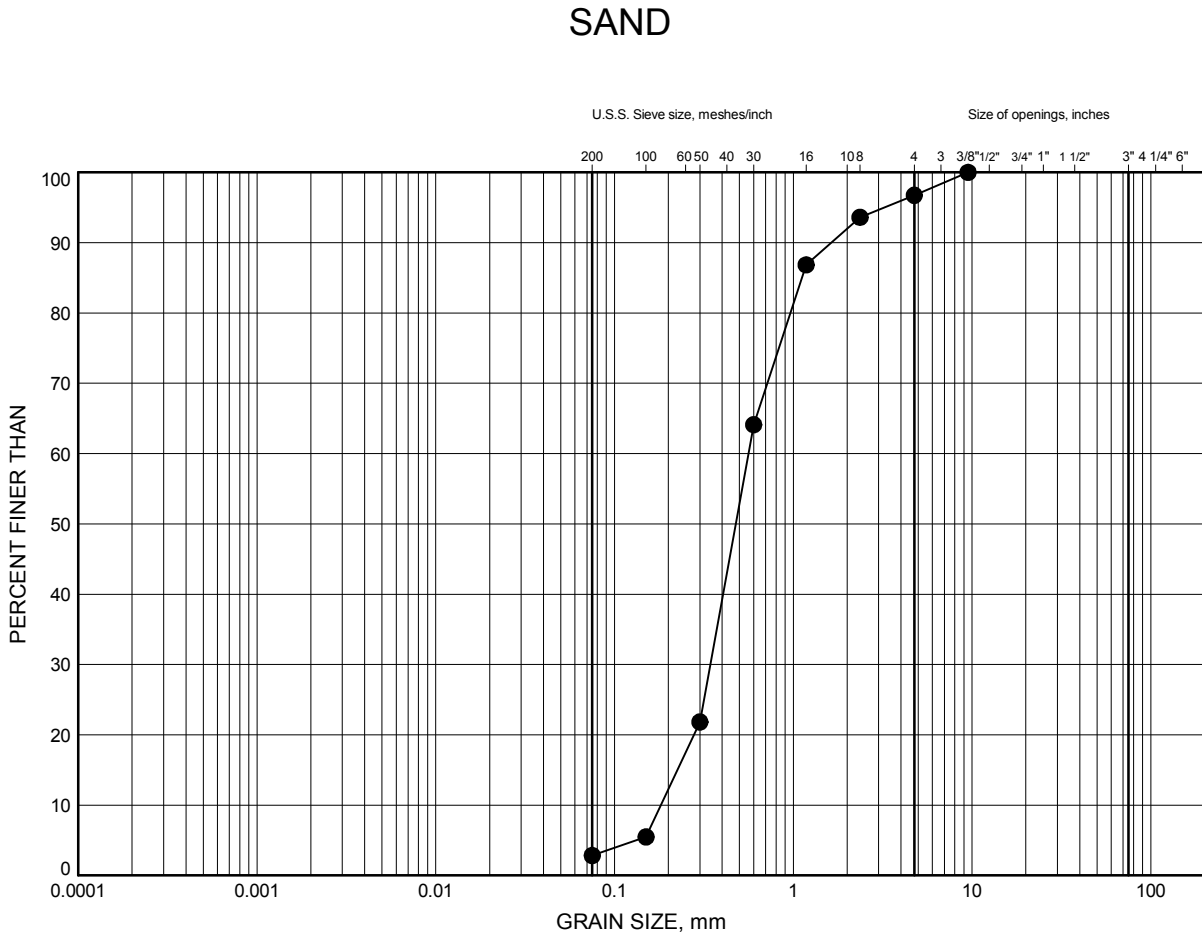
Prep'd AN

Chkd. LPG

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	WC13-01	0.13	298.47

Date December 2013

GWP# 5114-09-01



Prep'd AN

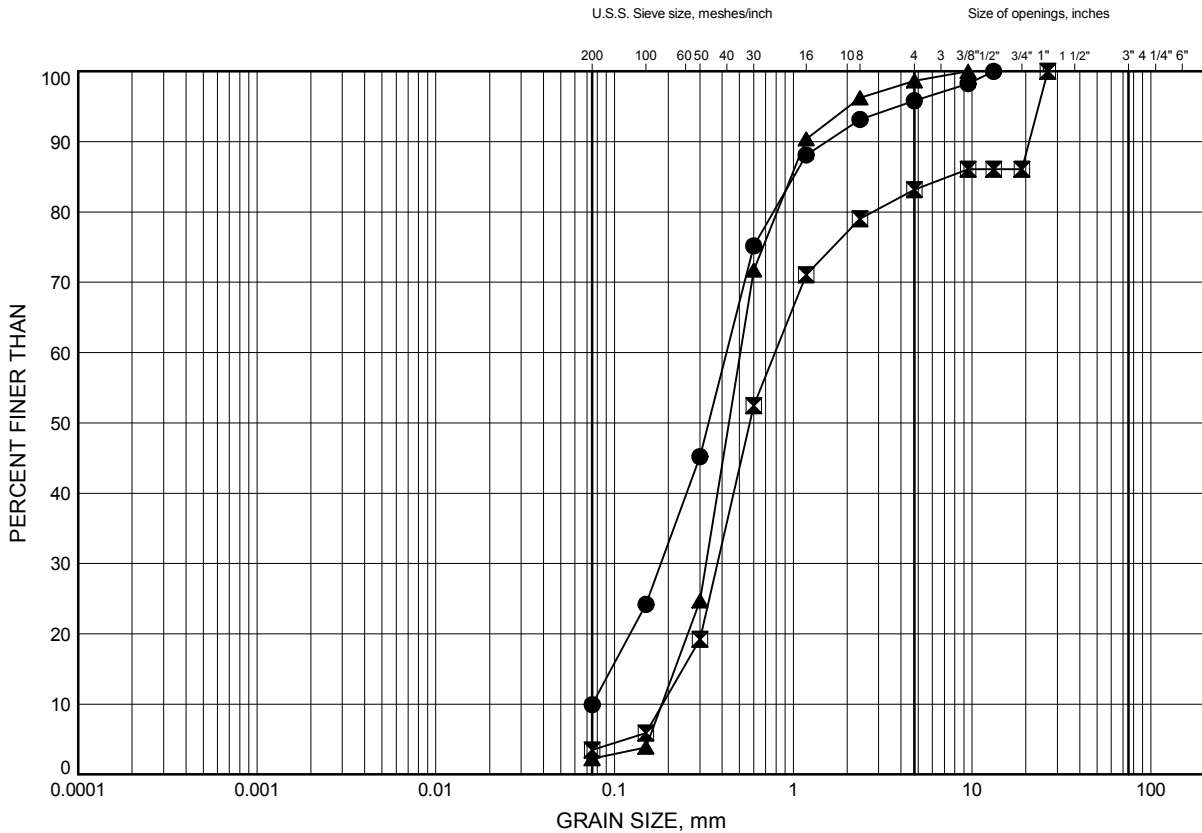
Chkd. LPG

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B5

SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	WC13-03	1.07	298.83
⊠	WC13-05	1.83	298.07
▲	WC13-06	3.35	296.65

Date December 2013

GWP# 5114-09-01



Prep'd AN

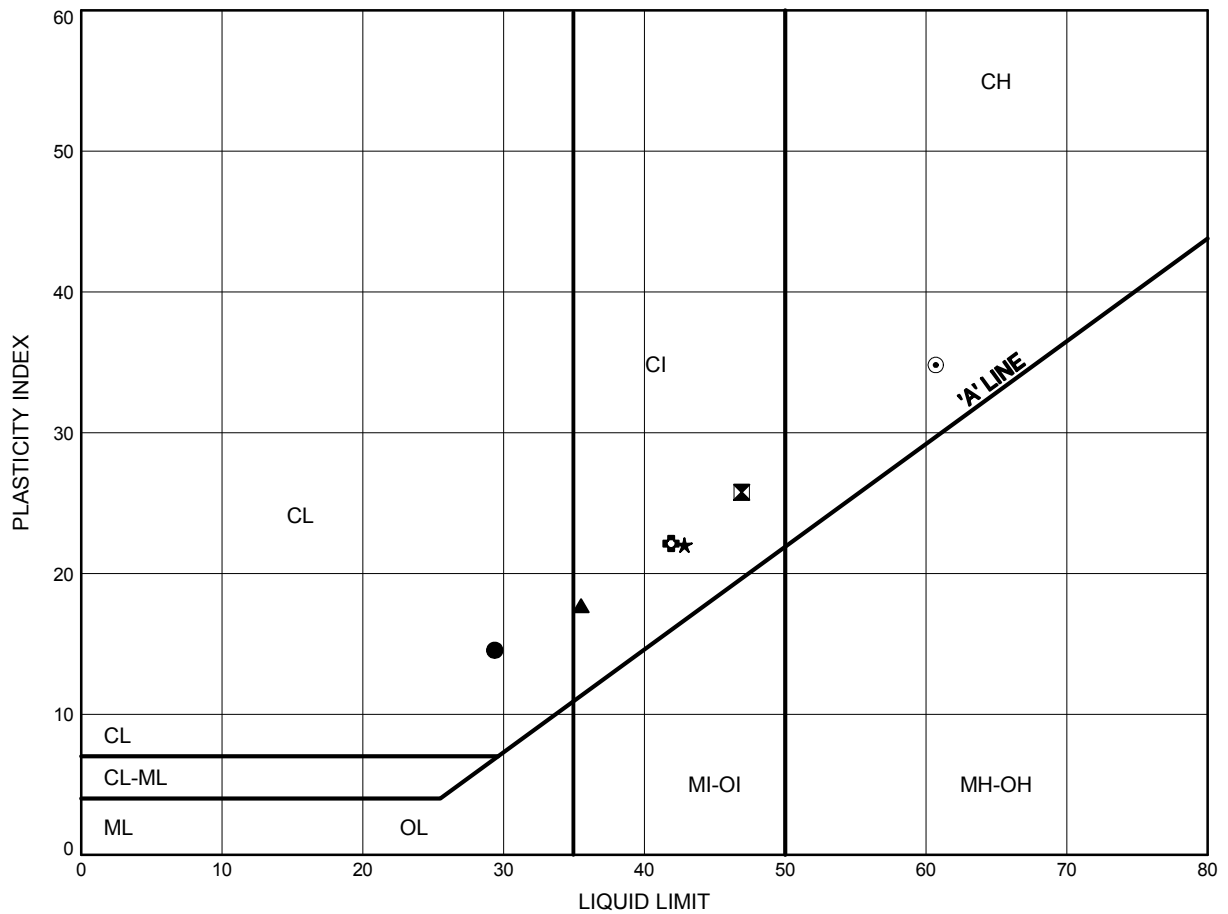
Chkd. LPG

Hwys 11, 583, 652 Culverts - Foundations

ATTERBERG LIMITS TEST RESULTS

FIGURE B6

SILTY CLAY, Trace to Some Sand



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	WC13-01	4.11	294.49
⊠	WC13-02	2.59	296.41
▲	WC13-02	6.40	292.60
★	WC13-03	4.11	295.79
⊙	WC13-03	14.02	285.88
⊕	WC13-04	4.11	295.89

Date December 2013

GWP# 5114-09-01



Prep'd AN

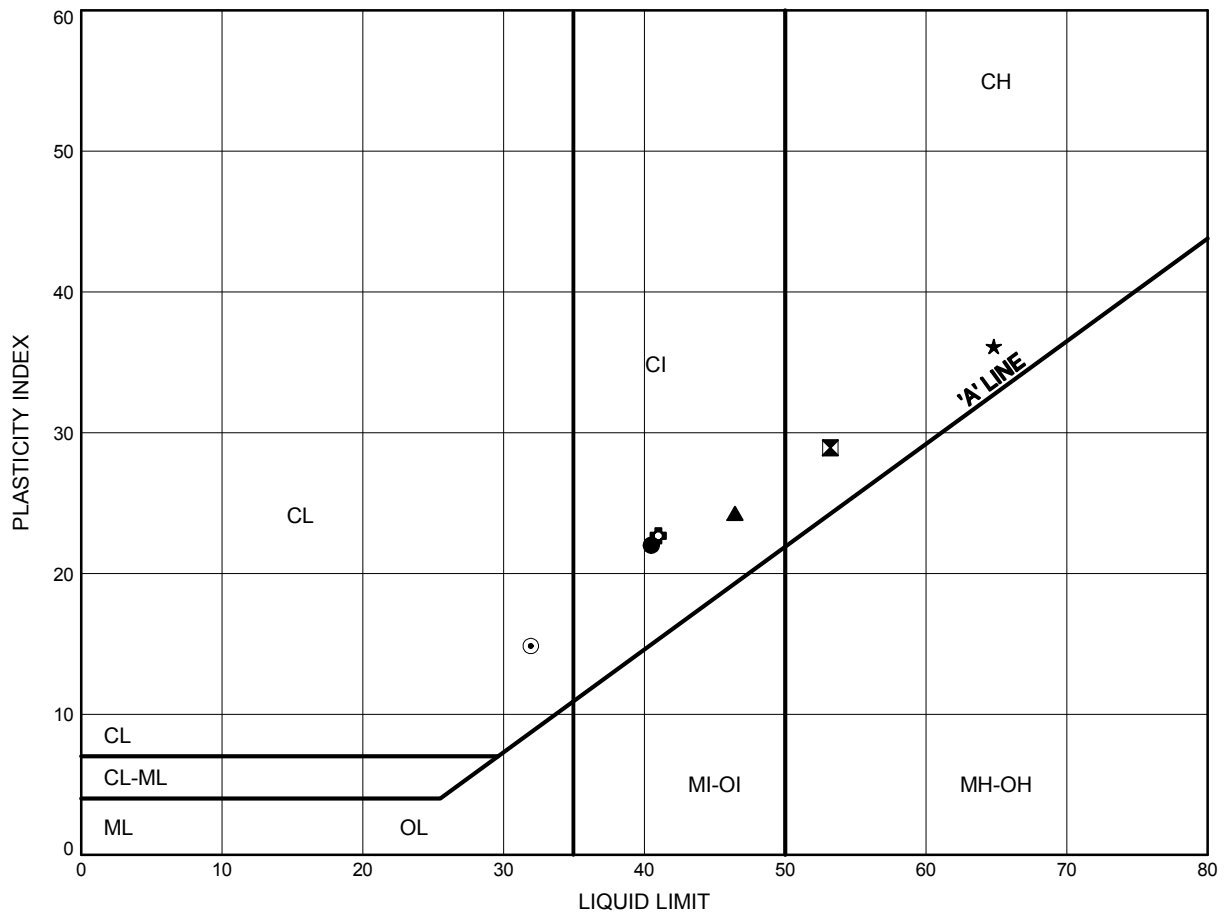
Chkd. LPG

Hwys 11, 583, 652 Culverts - Foundations

ATTERBERG LIMITS TEST RESULTS

FIGURE B7

SILTY CLAY, Trace to Some Sand



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	WC13-04	7.92	292.08
⊠	WC13-04	12.50	287.50
▲	WC13-05	4.11	295.79
★	WC13-05	13.26	286.64
⊙	WC13-06	6.40	293.60
⊕	WC13-06	10.97	289.03

Date December 2013

GWP# 5114-09-01



Prep'd AN

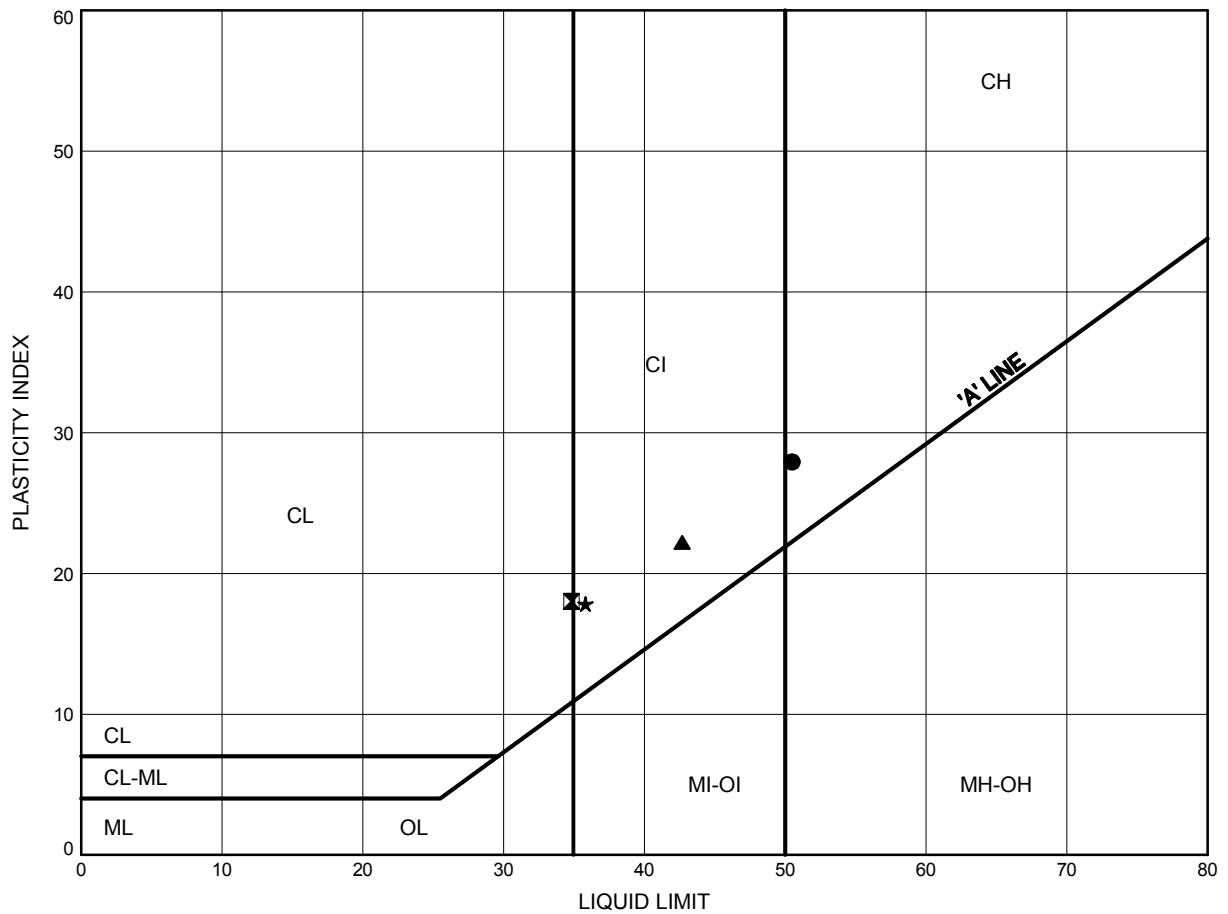
Chkd. LPG

Hwys 11, 583, 652 Culverts - Foundations

ATTERBERG LIMITS TEST RESULTS

FIGURE B8

SILTY CLAY, Trace to Some Sand



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	WC13-07	1.83	296.67
⊠	WC13-07	6.40	292.10
▲	WC13-08	1.83	296.37
★	WC13-08	4.11	294.09

Date December 2013

GWP# 5114-09-01

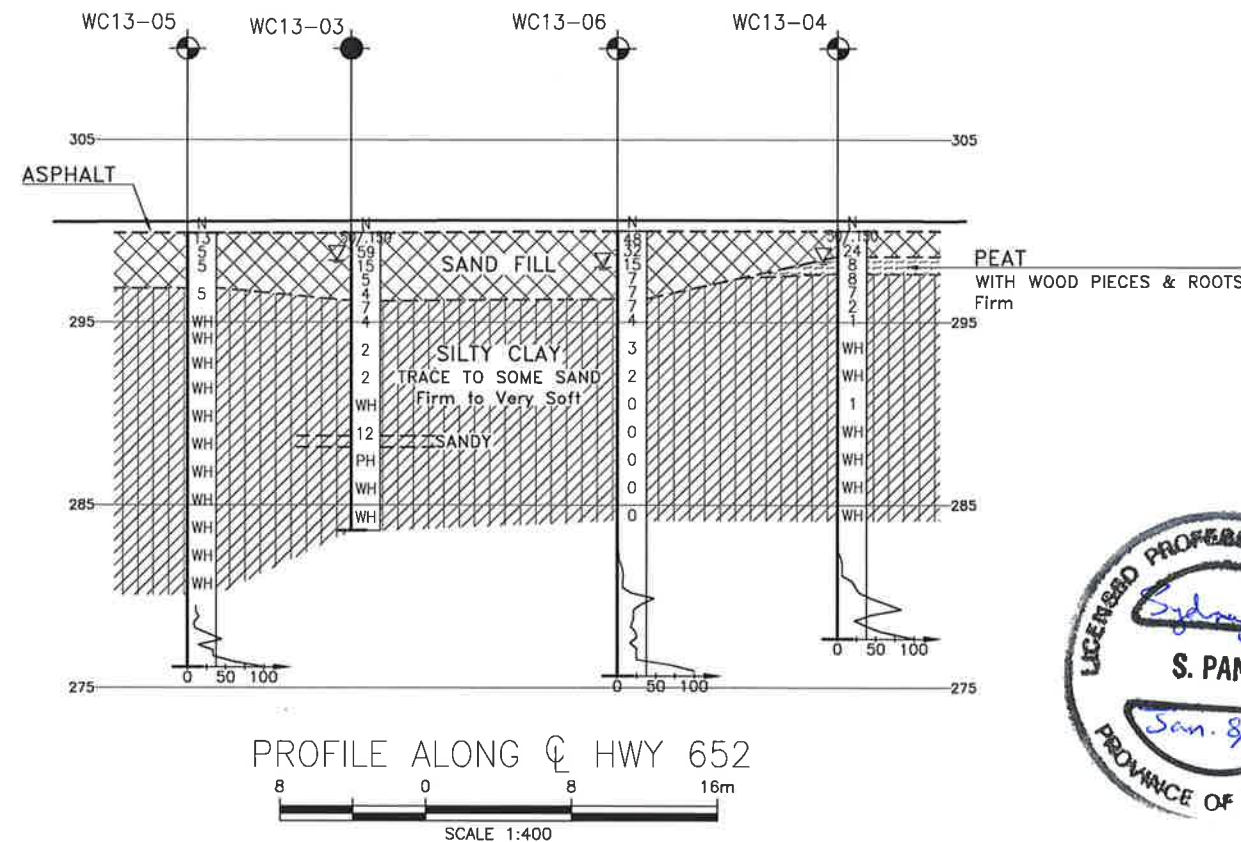
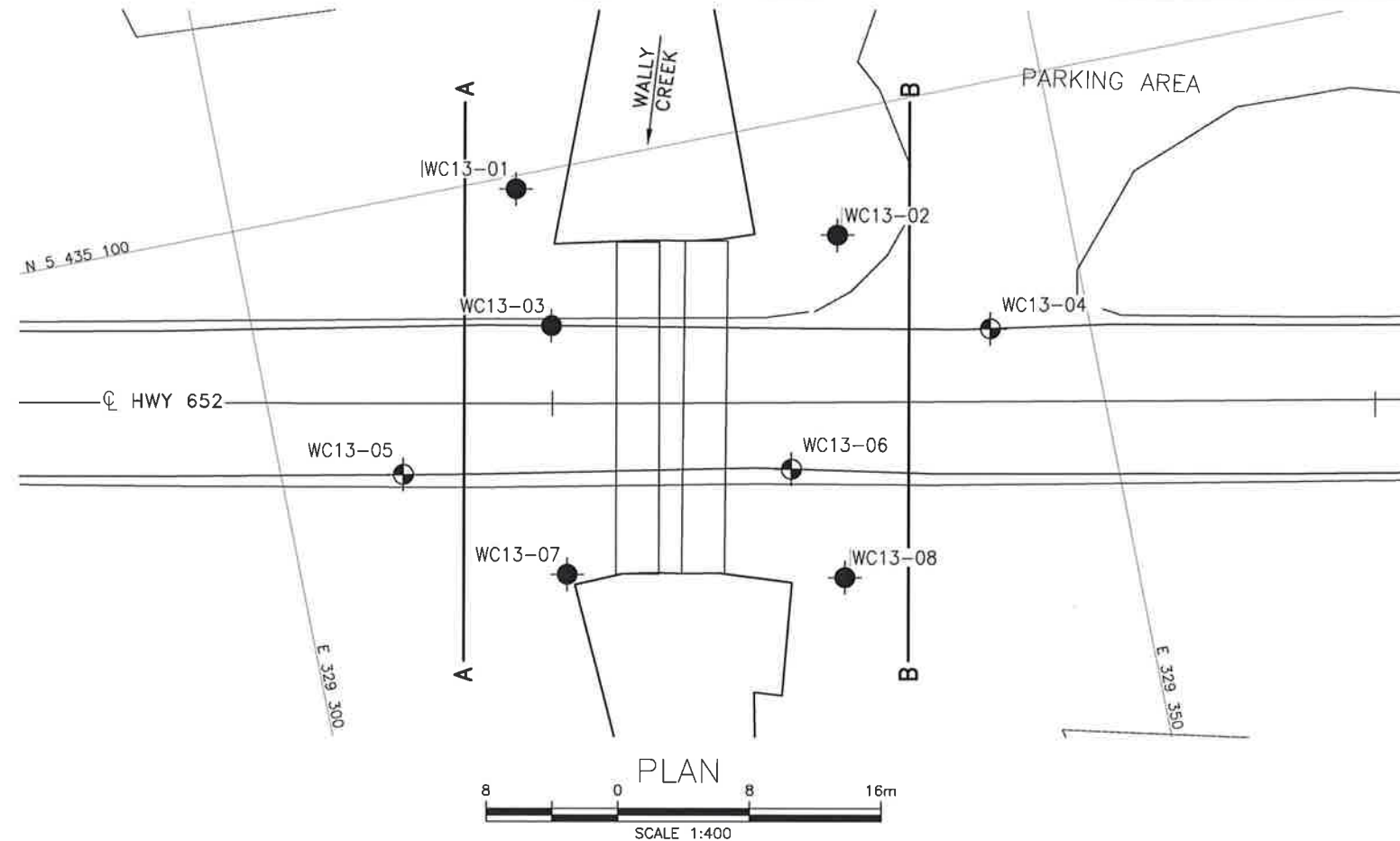


Prep'd AN

Chkd. LPG

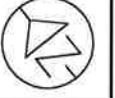
Appendix C

Borehole Locations and Soil Strata Drawings



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

CONT No
GWP No 5193-13-00

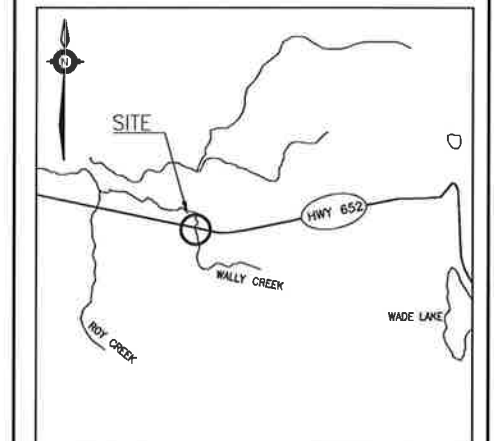


HIGHWAY 652
WALLY CREEK
CULVERT REPLACEMENT I
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

URS

THURBER ENGINEERING LTD.



LEGEND

●	Borehole
⊙	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60' Cone, 475J/blow)
WH	Weight Hammer
PH	Pressure, Hydraulic
▽	Water Level
⊥	Head Artesian Water
⊥	Piezometer
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
WC13-01	298.6	5 435 099.2	329 317.4
WC13-02	299.0	5 435 092.6	329 336.0
WC13-03	299.9	5 435 090.6	329 317.9
WC13-04	300.0	5 435 085.2	329 344.0
WC13-05	299.9	5 435 083.5	329 307.3
WC13-06	300.0	5 435 079.2	329 330.5
WC13-07	298.5	5 435 075.6	329 315.9
WC13-08	298.2	5 435 072.1	329 332.4

-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.

GEOCRES No. 42H-57

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	SKP	CHK	SKP
DRAWN	AN/MFA	CHK	AEG
SITE	39E-227C	STRUCT	DWG 2

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

CONT No
GWP No 5193-13-00

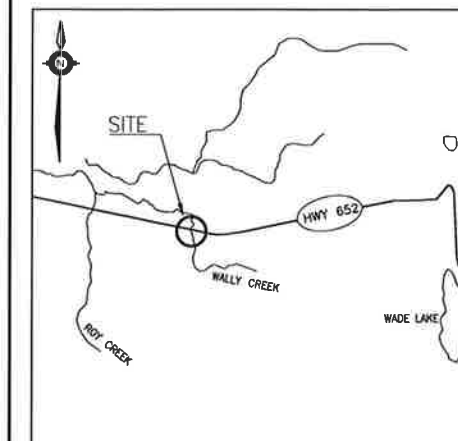
HIGHWAY 652
WALLY CREEK
CULVERT REPLACEMENT II
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

URS



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)
WH	Weight Hammer
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
A/R	Auger Refusal

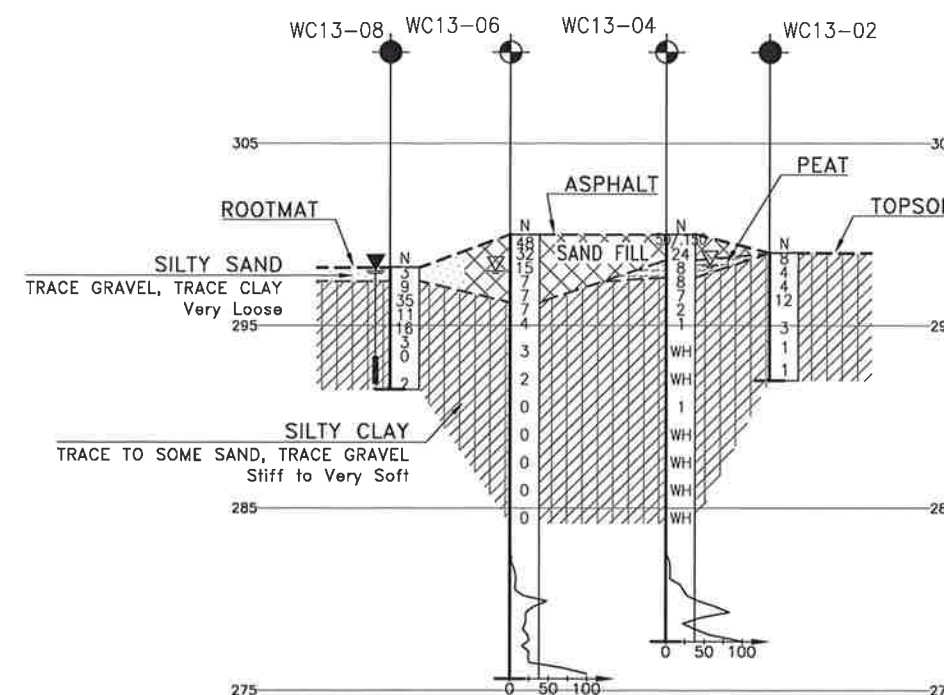
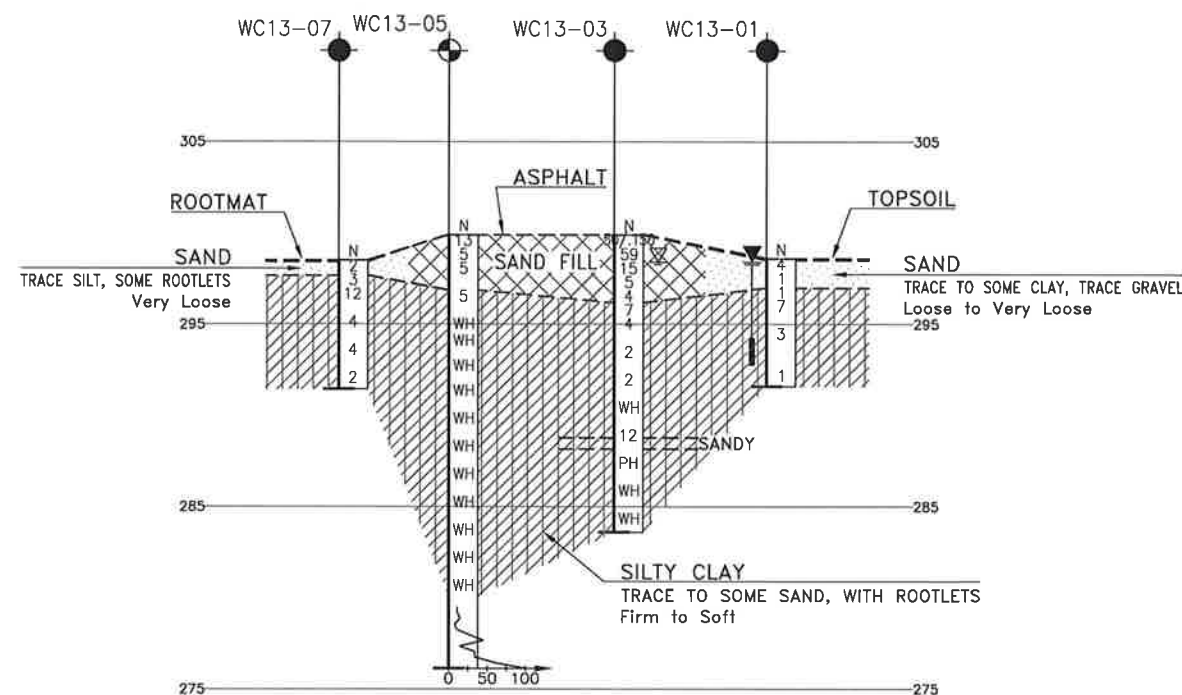
NO	ELEVATION	NORTHING	EASTING
WC13-01	298.6	5 435 099.2	329 317.4
WC13-02	299.0	5 435 092.6	329 336.0
WC13-03	299.9	5 435 090.6	329 317.9
WC13-04	300.0	5 435 085.2	329 344.0
WC13-05	299.9	5 435 083.5	329 307.3
WC13-06	300.0	5 435 079.2	329 330.5
WC13-07	298.5	5 435 075.6	329 315.9
WC13-08	298.2	5 435 072.1	329 332.4

-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.

GEOCRES No. 42H-57

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	SKP	CHK	SKP
DRAWN	AN/MFA	CHK	AEG
SITE	39E-227C	STRUCT	DWG 3



Appendix D

Foundation Alternatives Comparison

COMPARISON OF ALTERNATIVE CULVERT TYPES

Location	Concrete Open Footing Culvert	Concrete Rigid Box Culvert	Concrete Circular Pipe Culvert
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. Compressible founding subgrade will provide low geotechnical resistances. ii. Potential for post construction settlement. <p style="text-align: center;">NOT RECOMMENDED</p>	<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 style="text-align: center;">RECOMMENDED</p>	<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. <p style="text-align: center;">GENERALLY FEASIBLE</p>

Appendix E

Selected Photographs of Culvert Extension Locations

Wally Creek Culvert Replacement
Highway 652



Photo 1: Wally Creek Culvert Inlet



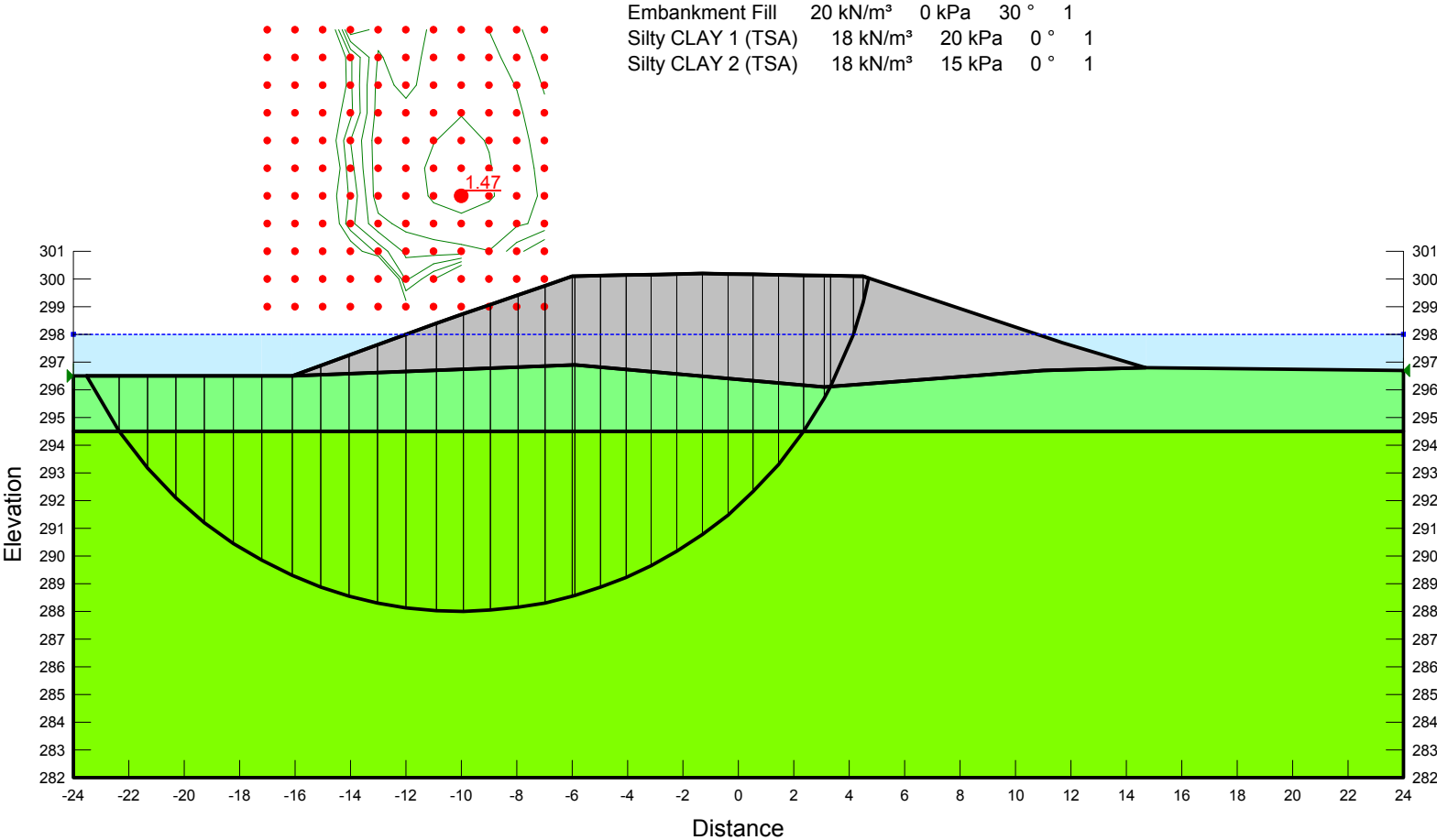
Photo 2: Wally Creek Culvert Outlet

Appendix F

Selected Stability Analysis Results

Title: Wally Creek Culvert
Comments: Highway 652, Township of Stimson, Cochrane, Ontario
Name: Analysis 1

Method: GLE, Half-Sine
Minimum Slip Surface Depth: 1 m
Seismic: 0
Center: (-10, 303) m

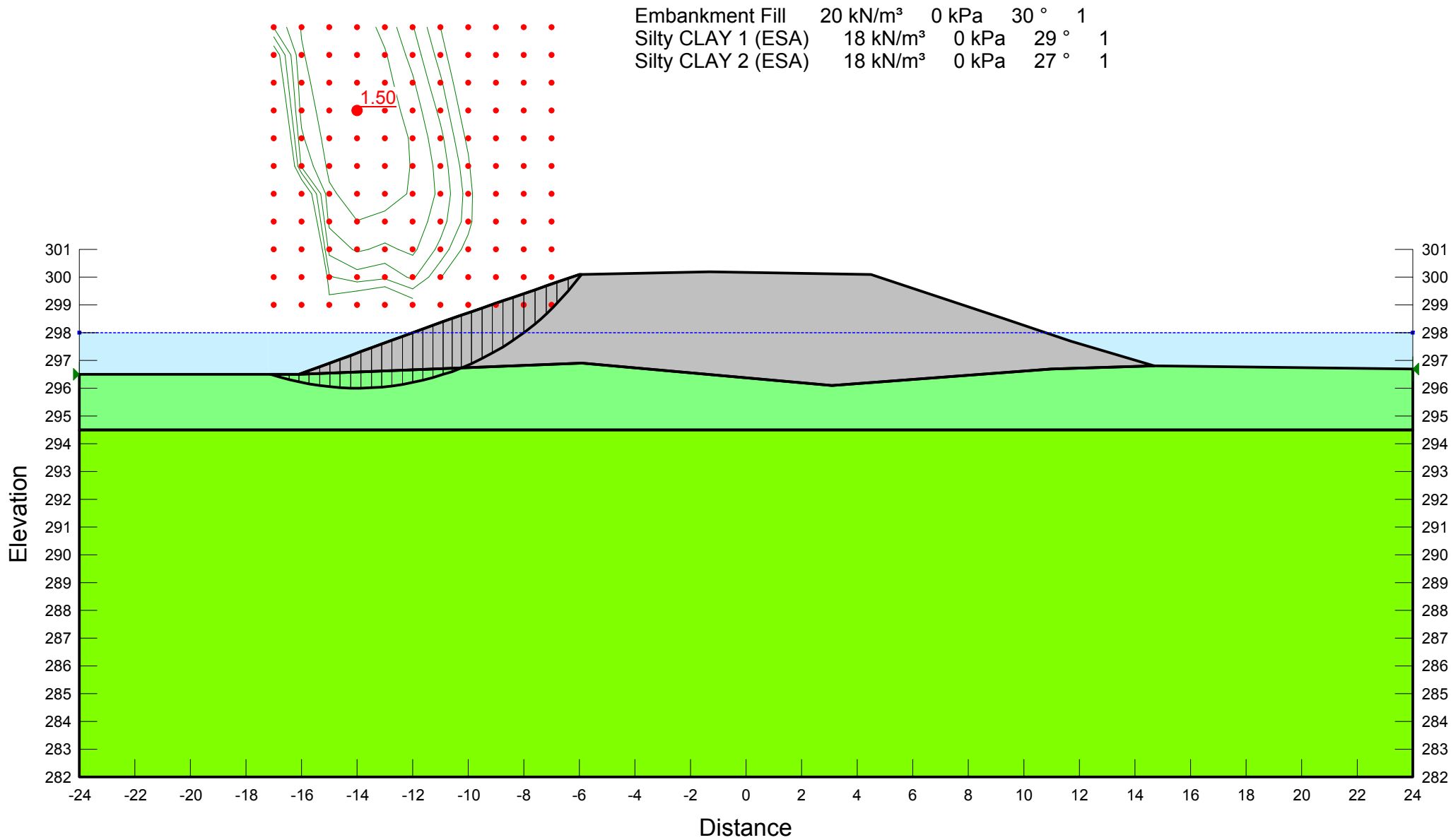


Reviewed By: _____
Last Edited By: Luke Gilarski
Last Solved Date: 2015-01-08, 10:47:14 AM
Directory: H:\19\4406\9 Highways 11, 583, 652 Culverts 5012-E-0033-Foundations\Analysis\Wally Creek\WalleyCreek_003.gsz

Figure 1

Title: Wally Creek Culvert
Comments: Highway 652, Township of Stimson, Cochrane, Ontario
Name: Analysis 2

Method: GLE, Half-Sine
Minimum Slip Surface Depth: 1 m
Seismic: 0
Center: (-14, 306) m



Reviewed By: _____

Last Edited By: Luke Gilarski

Last Solved Date: 2015-01-08, 10:48:20 AM

Directory: H:\19\4406\9 Highways 11, 583, 652 Culverts 5012-E-0033-Foundations\Analysis\Wally Creek\WalleyCreek_003.gsz

Figure 2