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FINAL
FOUNDATION INVESTIGATION AND DESIGN REPORT

Highway 535 Rehabilitation
Culvert Replacement – Site No. 46-462/C
Venus Creek Culvert
TWP. of Hagar
GWP 5573-04-00

Highway 535
From 20.2 km north of Highway 64 to Highway 17;
Including Highway 17/Highway 535 (Hagar) Intersection;
and OVR to 0.1 km north of Roy Lumber Co.
District of Sudbury

MEL Ref. No.: 11/04/11046-F3 October, 2011

Submitted to:

AECOM Canada Ltd.
189 Wyld Street
North Bay, Ontario
P1B 1Z2

Geocres No.41I-274

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1.0 INTRODUCTION

LVM | MERLEX has been retained by AECOM Canada Ltd., on behalf of the Ministry of Transportation of Ontario (MTO), to carry out a foundation investigation for the proposed replacement of a culvert and the associated design of a roadway protection system. This culvert replacement (GWP 5573-04-00) is located on Highway 535, some 7.8 km north of Hwy 17, in the Township of Hagar.

The foundation investigation location was specified by the MTO in the RFP/TPM documentation Agreement No. 5010-E-0015. The terms of reference for the scope of work are outlined in MEL's proposal P-10-169, dated December, 2010. The purpose of this investigation was to determine the subsurface conditions in the areas of the culvert in order to provide design recommendations. LVM | MERLEX investigated the foundation areas by the drilling of boreholes, carrying out in-situ tests, and performing laboratory testing on select samples.

2.0 SITE DESCRIPTION

The foundation investigation for this culvert is located at Station 17+607, Township of Hagar (Site No. 46-462/C). The topography at the site is generally of low relief. The existing highway embankment currently supports two undivided lanes of highway, running in a north south direction. The existing highway, at the culvert location, is constructed on a fill embankment some 3 m in height, with centerline elevation at 243.0 m at the culvert. The culvert at this location is a 3.1x2.3 m SPCSPA culvert, some 12 m in length. The elevation of the stream bottom is at 240.0 m (see Photo Essay, Appendix D).

Infrastructure at the culvert location consists of overhead power and communication wires on the west (left) side of the highway.

2.1 Site Physiography and Surficial Geology

This project is located in the Geomorphic Sub-province known as the North Shore - Sudbury Ridges and Pockets. The topography on this section of Highway 535 is generally rolling. There are a few exposed bedrock ridges. At many locations, significant layers of earth overlay the bedrock. Organic terrain was also observed. Within the project area overburden consists primarily of silty clay, overlying silts and sands.

Bedrock in the area, as indicated on OGS Map 2506, is of the Late to Middle Precambrian Era. At the location of this culvert foundation investigation, the bedrock comprises of Metasediments including conglomerate, sandstone, siltstone, chert, and iron formations.

3.0 INVESTIGATION PROCEDURES

The fieldwork for this investigation was carried out between May 18th and June 28th, 2011, during which five (5) sampled boreholes were advanced. For the purposes of foundation design for the culvert replacement, one borehole was advanced through the embankment at the culvert location, and one borehole was advanced at the inlet and outlet of the culvert. Two boreholes were advanced through the embankment, one up and one down chainage from the culvert, for the purposes of design of a roadway protection system.

The field investigation was carried out using a Bombardier mounted CME drilling rig equipped with hollow stem augers, standard augers, and routine geotechnical sampling equipment. Soil samples were obtained at the borehole locations at regular intervals of depth using the standard 50 mm O.D. split spoon sampler advanced in accordance with the Standard Penetration Test

(SPT) procedures (ASTM D-1586). The SPT method involves advancing a 50 mm O.D. split spoon sampler with the force of a 63.5 kg hammer freely dropping 760 mm mounted in a trip (automatic) hammer. The number of blows per 300 mm penetration was recorded as the "N" value. At the boreholes, a Dynamic Cone Penetration Test (DCPT) was carried out to give a continuous plot of the soil resistance with depth. When cohesive deposits were encountered, the in-situ strength was measured using an "N" size field vane, vane collar, and calibrated torque meter. All samples taken during this investigation were stored in labeled airtight containers for transport to our North Bay laboratory for visual examination and select laboratory testing.

Groundwater conditions in the open boreholes were observed during the advancement of, and immediately following, completion of the individual boreholes. All open boreholes were backfilled upon completion with compacted auger cuttings in the general order they were removed and, where necessary, bentonite pellet backfill was added to the boreholes to bring them up to grade. At the boreholes through the embankment, the upper portion of the hole, where necessary, was backfilled with an asphalt cold patch to seal the existing asphalt surface. The field work for this investigation was under the full time direction of a senior member of our engineering staff, who was responsible for locating the boreholes, clearing the borehole locations of underground services, in-situ sampling and testing operations, logging of the boreholes, labeling and preparation of samples for transport to our North Bay laboratory, plus overall drill supervision. All samples received a visual confirmatory inspection in our laboratory. Laboratory testing of select samples included routine testing for natural moisture content determination and particle size analysis as well as Atterberg Limits testing. The results of the laboratory testing are presented on the individual Record of Borehole Sheets (Appendix B), with a summary of results presented on the laboratory sheets in Appendix C (Figures Nos. L-1 to L-5).

The location of the individual boreholes were determined in the field using highway chainage (established by others) and offset relative to highway centerline. The MTO co-ordinates, northing and easting, were then established for the boring locations. Elevations contained in this report are referenced to a geodetic datum.

4.0 SUBSURFACE CONDITIONS

Details of the subsurface conditions revealed by the investigation program are presented on the enclosed Record of Borehole Logs (Appendix B) and on Figure No. 2 (Appendix C). Please note that stratigraphic delineation presented on the borehole logs and soil strata plot are the results of non-continuous sampling, response to drilling progress, the results of SPT and Dynamic Cone Penetration Test (DCPT) plus field observations. Typically such boundaries represent transitions from one zone to another and are not an exact demarcation of specific geological unit. Additional consideration should be given to the fact that subsurface conditions may vary markedly between adjacent boreholes and beyond any specific boring location, and are shown on the drawings for illustration purposes only.

4.1 Venus Creek Culvert, Station 17+607, TWP of Hagar – Site No. 46-462/C

A plan and profile illustrating the borehole locations and stratigraphic sequences is shown on Figure No. 2, Appendix C. During the course of the exploration program, five (5) sampled boreholes were put down at this site, with Borehole Nos. 1, 2, and 3, advanced through the existing embankment, and Borehole Nos. 4 and 5 advanced at either end of the culvert. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 to 5 were recorded at 243.0, 243.0, 242.9, 241.9, and 241.8 m, respectively.

4.1.1 Surficial Layers

At surface at Borehole Nos. 1 to 3, a surficial pavement structure consisting of 75 mm of asphalt and 150 to 200 mm of crushed gravel was encountered. At surface at Borehole Nos. 4 and 5, a surficial layer of silty to sandy organics some 100 to 200 mm thick was penetrated.

4.1.2 Embankment Fill

Underlying the surficial pavement structure at Borehole Nos. 1 to 3, a deposit of granular fill consisting of brown gravel and sand trace silt was penetrated. Occasional cobbles and boulder size rock was encountered in this deposit. The natural moisture content measured on samples of this deposit was in the order of 2 to 18%. Gradation analyses were carried out on two (2) samples of this deposit, the results of which indicated 42 to 56% gravel size particles, 40 to 53% sand size particles, and 4 to 5% silt and clay size particles (Figure No. L-1, Appendix C). Based on SPT ‘N’ values of 6 to 22 blows per 300 mm penetration, the compactness of this deposit was described as loose to compact. This deposit was encountered to depths of 3.7, 2.0, and 2.1 m below ground surface at Borehole Nos. 1 to 3, respectively (elevations 239.3, 241.0, and 240.8 m, respectively).

4.1.3 Fill

Underlying a layer of surficial organics some 50 mm thick at Borehole No. 5, a deposit of fill consisting of brown silt trace sand trace gravel was penetrated. The natural moisture content measured on samples of this deposit was in the order of 13%. This deposit was encountered to a depth of 0.8 m below ground surface (elevation 241.0 m).

4.1.4 Clayey Organics

Underlying the embankment fill at Borehole No. 2 and underlying the fill at Borehole No. 5, a deposit of black clayey organics trace wood and fine fibers was penetrated. The natural moisture content measured on samples of this deposit was in the order of 40 to 100%. An Atterberg Limit test was carried out on a sample of this deposit, the result of which indicated a liquid limit in the order of 81% and a plastic limit in the order of 49%. Based on the results of Atterberg Limits testing, this deposit was classified under USCS as clayey organics (OH) (Figure No. L-4, Appendix C). This deposit was encountered to depths of 3.4 and 2.0 m below ground surface at Borehole Nos. 2 and 5 respectively (elevations 239.6 and 239.8 m, respectively).

4.1.5 Silty Clay

Underlying the embankment fill at Borehole Nos. 1 and 3, underlying the silty organics at Borehole Nos. 2 and 5, and underlying the surficial organics at Borehole No. 4, a deposit of grey silty clay trace sand was penetrated. The natural moisture content measured on samples of this deposit was in the order of 37 to 55%. A hydrometer analysis were carried out on two sample of this deposit, the results of which indicated 0% gravel size particles, 0 to 3% sand size particles, 50 to 53% silt size particles, and 47% clay size particles (Figure No. L-2, Appendix C). Atterberg Limits testing was carried on five (5) samples of this deposit, the results of which indicated a Liquid Limit in the order of 33 to 50% and a Plastic Limit in the order of 18 to 22%. Based on the results of Atterberg Limits testing, this deposit was classified under USCS as silty clay of medium to low plasticity (CI to CL) (see Figure No. L-4, Appendix C). Based on in-situ shear strengths which ranged from 18 to 60, the consistency of this deposit was described as soft to stiff (see Figure No. L-5, Appendix C). This deposit was encountered to a depth of 3.8 m below grade at Borehole No. 5 (elevation 238.0 m). Auger refusal was encountered in this deposit at depths of 6.1, 6.6, 4.1, and 2.8 m below grade at Borehole Nos. 1 to 4 respectively (elevations 236.9, 236.4, 238.8, and 239.2 m, respectively). DCPT refusal was encountered in this deposit at depths of 6.4 and 2.7 m below grade at Borehole Nos. 1 and 4 respectively (elevations 236.6 and 239.1 m, respectively).

4.1.6 Sand

Underlying the silty clay at Borehole No. 5, a deposit of grey sand some silt some gravel was penetrated. The natural moisture content measured on samples of this deposit was in the order of 15%. A gradation analysis was carried out on one (1) sample of this deposit the results of which indicated 13% gravel size particles, 76% sand size particles, and 11% silt and clay size particles (see Figure No. L-3, Appendix C). Based on SPT 'N' values of 22 to 23 blows per 300 mm penetration, the compactness of this deposit was described as compact. Auger and DCPT refusal was encountered in this deposit at a depth of 5.2 m below grade (elevation 236.6 m).

4.2 Groundwater Conditions

Surface water was encountered in the culvert at an elevation of 241.7 m, at the time of this investigation. Measurements of the groundwater table and cave-in levels were undertaken, where possible, in the open boreholes during the advance of the individual borings and upon completion. These levels are recorded on the individual Record of Borehole Log Sheets (Appendix B). Groundwater was encountered in Borehole Nos. 2, 4, and 5 with the water level reading in the open boreholes recorded at elevations 241.9, 241.8 and 241.7 m, respectively. Borehole Nos. 1 and 3 were advanced through the embankment. Both Borehole Nos. 1 and 3 were dry upon completion and were backfilled immediately upon completion of sampling. The groundwater levels will fluctuate seasonally.

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M. A. Merleau, P. Eng.
Principal Engineer
MTO Designate

J. R. Berghamer, P. Eng.
Regional Manager

5.0 DESIGN COMMENTS AND RECOMMENDATIONS

5.1 General

A foundation investigation was carried out for a proposed culvert replacement and for the design of a roadway protection system, as identified in the RFP. This 3.1x2.3 m diameter SPCSPA culvert is located within GWP 5573-04-00 and is identified as Site No. 46-462/C, at Station 17+607 in the Township of Hagar.

The existing 3.1x2.3 SPCSPA culvert is some 12 m long. The existing highway embankment at the culvert location currently supports two undivided lanes of highway, running in a north south direction. Flow through the culvert is from east to west. Based on data from this foundation investigation, the embankment supporting the existing pavement structure at this site has been constructed using granular materials (pavement structure) over granular and earth fills consisting generally of sands with varying silt content. The native material underlying the fill generally consisted of soft to stiff silty clays underlain by silts and sands with refusal at depths of 2.7 to 6.6 m below existing grade (elevations 239.2 to 236.4 m).

It is understood that, to replace the existing 3.1x2.3 m SPCSPA culvert, either three (3) 2.0 m diameter CSP culverts or a single 3.3x1.8 m concrete box culvert, both options 18 m in length, are being considered. It is further understood that the concrete box culvert is the favoured replacement. The box culvert will be constructed at a similar alignment and the skew to the existing culvert.

5.2 Foundation Considerations

The founding native silty clays are considered acceptable for culvert support and for a conventional highway embankment of this height, and bearing resistance and/or embankment stability should not be an issue provided the natural bearing surface is undisturbed and groundwater is controlled during construction, as discussed in Section 5.6.

Based on the characteristics of the native clay subgrade present below the culvert, the response of the existing embankment, and a founding elevation similar to that of the existing culvert, a factored bearing resistance at ULS of 80 kPa can be used for the undisturbed native silty clay subgrade. It is understood that there will not be a significant change in grade at the culvert locations. As such, a geotechnical resistance at SLS of 50 kPa can be used for new loads (if any), in consideration of 25 mm of combined immediate and long term (consolidation) settlement.

The existing embankment has preloaded the soils at the culvert locations and since there will be no change in the height of the embankment, and therefore no increase in embankment load, no appreciable settlement of the embankment is anticipated.

5.3 Culvert Design, Bedding, and Embedment

The embankment consists of granular soils (pavement structure) overlying granular and earth fill. The results of this investigation indicate that, below the culvert invert, the native soils at Borehole Nos. 1 to 5 consist of a soft to stiff (generally firm) silty clay. A layer of organics was noted at the ground surface beyond the existing embankment. A review of the condition of the surface treatment, at the culvert locations, did not reveal any major cracking or distresses and in general the embankment appears to have performed well.

It is understood that the preferred type of replacement culvert will be a concrete box culvert. Bedding for a rigid concrete box culvert should consist of Granular A with a thickness of 300 mm. The bedding under the middle third of the box unit base should be loosely placed and uncompacted. The upper 75 mm portion of the Granular A bedding should be uncompacted throughout and incorporated as the top levelling course in conformance with OPSS 422. During backfilling, the embankment fill should be placed in a balanced manner on the outer sides of both box units. Cover material for concrete box culverts can consist of Granular A and placed to the dimensions as shown on MTOD-803.021.

If flexible pipes (i.e. CSP) are used for replacement, embedment material could consist of Granular B Type I provided the maximum size of stone inclusions is limited to 25 mm or less in size and the back fill is placed in accordance with OPSD 802.010 for a Type 3 soil. The material in the haunch area must be compacted to 100% Standard Proctor Dry Density prior to placing the remainder of the embedment material.

The geotechnical report, also completed by LVM | MERLEX, Reference No. 11/04/11046-P1, indicated the culvert was backfilled with a granular material and that no frost tapers are required. As such the existing embankment granulars can be used for backfilling.

The joints between precast box units should be covered with a strip of Non-Woven Class II Geotextile 600 mm in width, centered over the joints, covering the top of the culvert and extending halfway down the sides of the culvert, to prevent the infiltration of fines. Since the culvert site has previously supported a culvert and there will not be a grade raise, at the culvert location, the underlying clays have been preloaded and since there will be no increase in load installing the culvert on a camber will not be necessary

Apron (cut-off) walls, 1.2 m deep, must be added to the ends of the rigid box culverts in accordance with the MTO Concrete Culvert Design Manual. It is understood that wing walls will also be added at the concrete box culvert ends, as such an apron of rock protection should not be required. Clay seals are not considered necessary.

5.4 Culvert Installation and Construction Staging Considerations

The existing culvert is established in a granular fill embankment some 3.0 m in height. The embankment material is considered a Type 3 soil as defined in the Occupational Health and Safety Act and Regulations for Construction Projects. Temporary open excavations will be stable above the groundwater table at an angle of 1H:1V, however, below the groundwater table, the side slopes may have to be cut back to an angle of 2H:1V, possibly shallower, dependent upon the Contractors' chosen method of controlling the groundwater.

The base of the stream is at elevation 240.0 m, with the top of the embankment at elevation 243.0 m at centerline. As such, the embankment at this location is some 3.0 m in height above the stream bottom at the centerline. Therefore, a 3.6 m deep excavation will be required (i.e. to elevation 239.4 m), with the invert of the box culvert placed a distance equal to 10% of the box height below the stream bed, and allowing for a minimum of 200 mm of bedding below the culvert. The present platform width at this location is some 10.5 m as can be seen on the cross section shown on Figure No. 2. The platform width at this location, as is, will be insufficient to carry out an open excavation using staged construction without sliver widening and/or temporarily lowering the vertical alignment locally. It is understood that roadway protection is anticipated at this culvert location.

5.4.1 Roadway Protection

Installation of a roadway protection system for use in the culvert replacement operation will require penetration through some 3 m of embankment fill and the underlying firm clays. One possible method of constructing a temporary vertical wall for roadway protection along the centreline of the highway alignment, would be to drive steel sheet piles through the embankment fill into the underlying clays. If a cobble/small boulder size rock is encountered during driving of a sheet section, the individual section could be left high and the cobble/small boulder removed during excavation to allow continued driving. The sheet pile design should be carried out by a structural engineer with experience designing sheet pile walls. Conceptual shoring locations are illustrated on Figure No. SK-1, Appendix E.

Considering the cohesionless nature of the embankment fills (granular pavement structure over granular fills) a rectangular pressure distribution over the height of the cut would be appropriate. The width of the apparent rectangular pressure distribution, over the height of excavation, can be considered equal to $0.65*K_a*\gamma*H$, where $K_a=0.30$, and $\gamma=20.0\ kN/m^3$.

Considering the limited depth of excavation, and provided a sheet pile of sufficiently robust section is used, a whaler and raker may be used to span the width of the box culverts, however, a tieback system may also be chosen by the contractor. If tiebacks are used, the resistance (R) for grouted anchors, located outside the active failure wedge, in cohesionless soils can be estimated from the following equation as supplied in the Canadian Foundation Manual (4th Edition):

$\mathbf{R = \sigma_z' A_s L_s \alpha_g}$ Where: $\mathbf{\sigma_z'}$ = effective vertical stress at the midpoint of the load carrying length

$\mathbf{A_s}$ = effective unit surface area of the anchor

$\mathbf{L_s}$ = effective embedment length of the anchor

α_g = anchorage coefficient use 1.0 for granular backfill

Unless the pull-out resistance (capacity) of the anchor is proven with a load test program, the allowable anchor load (as suggested by the Canadian Foundation Engineering Manual, 4th

Edition), is commonly obtained by dividing the computed capacity of the anchor by a factor of safety of 3. Alternatively, proprietary anchor systems can be used.

The temporary roadway protection system should be designed and constructed to comply with OPSS 539. In consideration of the location of the roadway protection and traffic volume, a performance level 2 is considered appropriate. However, a detailed monitoring system must be implemented by the contractor in order to guarantee the serviceability of the half of the structure which is carrying traffic, specifically during critical stages of construction. The monitoring system shall include scaled survey targets attached to the roadway protection shoring, surveyed by a registered land surveyor or professional engineer as identified in OPSS 539, to ensure that the horizontal displacement and angular distortion do not exceed the limits as outlined in 539.04.02.01.

5.5 Lateral Earth Pressures

Lateral earth pressures should be computed in accordance with the Canadian Highway Bridge Design Code (CHBDC). The design parameters for the bedding and backfill materials are as follows:

	Granular A	**Granular B Type I**	**SSM/ Existing Embankment Material**
Angle of Internal Friction (degrees)	35	30	30
Unit weight (KN/m^3)	22	20	18
Active earth pressure (Ka)	0.27	0.33	0.33
At-rest earth pressure (Ko)	0.43	0.50	0.50

For rigid structures, such as precast concrete box, deflection cannot occur, as such the “at-rest” condition (Ko) applies. For flexible structures, such as CSP culverts, deflection can occur, as such the “active” condition (Ka) applies.

5.6 Excavation, Dewatering, and Embankment Reconstruction

All excavations greater than 1.2 m in depth must be sloped or shored in accordance with the Occupational Health and Safety Act Regulations for Construction Projects. Temporary open excavations will be stable above the groundwater table at an angle of 1H:1V, as the embankment soils are considered a Type 3 soil as defined in the Occupational Health and Safety Act and Regulations for Construction Projects. Final embankment slopes should be established at the standard angle of 2H:1V.

Bedrock was not encountered within the anticipated depth of excavation, therefore bedrock excavation and/or blasting operations are not anticipated.

Excavations must be maintained in an unwatered condition during excavation and foundation construction and every reasonable effort must be made to prevent disturbing the founding subgrade. The groundwater level was recorded at elevations 241.7 to 241.9 m, at the time of this investigation. Groundwater control, in accordance with OPSS 517 and 518, will be required to maintain a stable subgrade during culvert installation.

During construction, local temporary sandbagging, combined with installation of filtered sumps and pumping from the base of the excavation will, at a minimum, be required to maintain the excavation in an unwatered condition during subgrade preparation. Temporary sheet pile type cofferdams or possibly a sand bag dam can also be considered for controlling stream flow depending upon anticipated flow at time of construction. By-pass pumping through a separate diversion pipe through the embankment should be considered for diverting stream flow. Ultimately, the method of dewatering and stream diversion will be the choice of the contractor; however the importance of maintaining the subgrade in an unwatered stable condition during excavation and foundation construction cannot be stressed enough.

5.7 Construction Concerns

Considering the platform widths and the relatively shallow depths of expected excavation, no major construction concerns are anticipated if carried out in general conformance to that discussed above.

6.0 CLOSURE

Information provided in this report is valid only at the locations described above. Any assumptions of continuity of soil stratigraphy between boreholes, as shown on the enclosed cross-sections, is intended as an aid for design purposes only and does not constitute a statement of existing conditions for contractual or construction purposes. Field investigation was carried out using a CME drill rig mounted on a Bombardier carrier owned by Chrisdamat Management Ltd. The report was prepared by Mr. J. R. Berghamer, P. Eng and reviewed by the firm's principal and MTO designate Mr. M. A. Merleau, P. Eng.

Details of the investigation, the material analysis and recommendation in this report are considered to be complete. However, should any questions arise, please do not hesitate to contact the undersigned.

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M. A. Merleau, P. Eng.
Principal Engineer
MTO Designate

J. R. Berghamer, P. Eng.
Regional Manager

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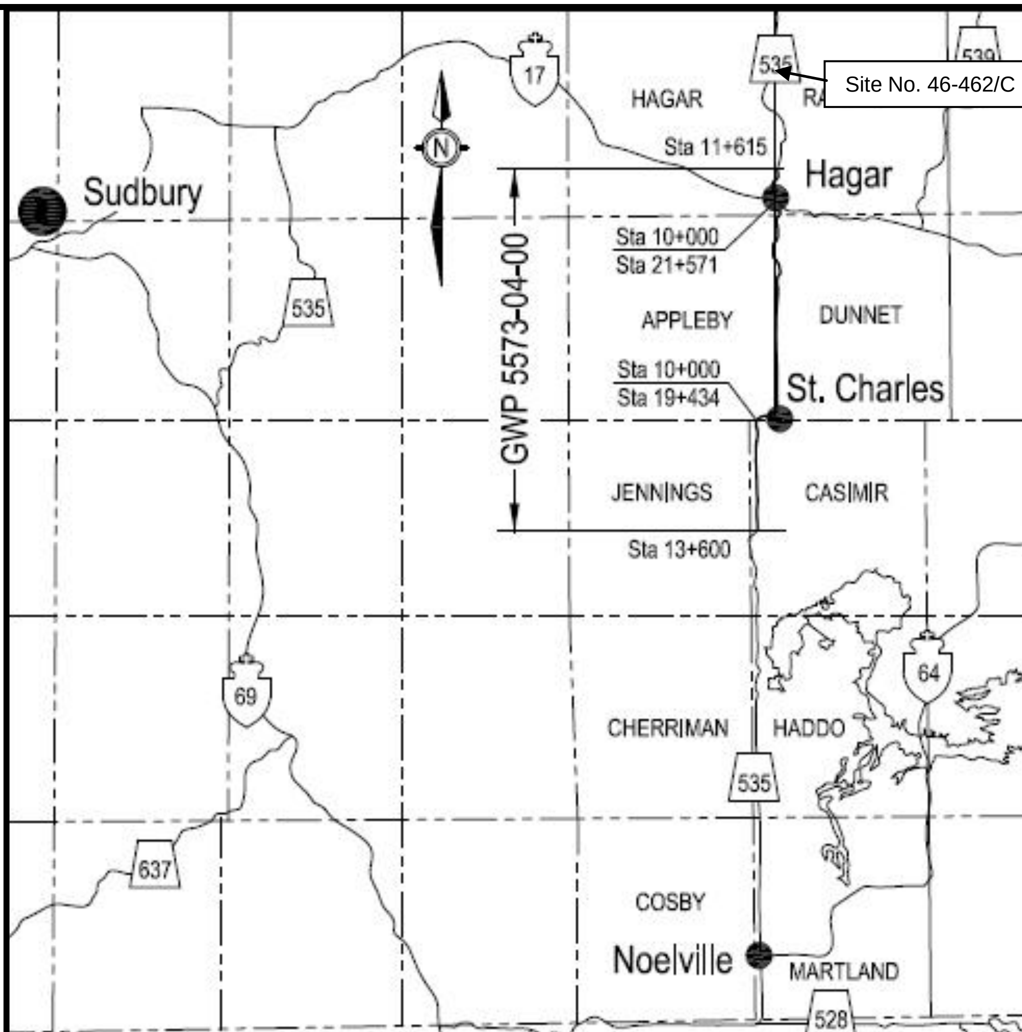
Appendix A Key Plan

Figure No. 1: Key Plan

KEY PLAN

Figure No. 1

NOT TO SCALE



FINAL
FOUNDATON INVESTIGATION
AND DESIGN REPORT
GWP 5573-04-00
Highway 535
From 20.2 km North of
Highway 64, Northerly 18.3 km
To Highway 17 at Hagar
and
From the OVR Crossing at
Hagar, Northerly 1.4 km

Ref. No.: 11/04/11046-F3 October, 2011

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Appendix B Abbreviations
Record of Borehole Sheets

Enclosure No. 1: List of Abbreviations and Symbols
Enclosure Nos. 2 to 6: Record of Borehole Sheets

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LIST OF ABBREVIATIONS AND DESCRIPTION OF TERMS

The abbreviations and terms, used to describe retrieved samples and commonly employed on the borehole logs, on the figures and in the report are as follows:

1. ABBREVIATIONS

AS Auger Sample
CS Chunk Sample
DS Denison type sample
FS Foil Sample
NP Non Plastic
PH Sampler advanced by hydraulic pressure
PM Sampler advanced by manual pressure
RC Rock core with size & percentage of recovery
SS Split Spoon
ST Slotted Tube
TO Thin-walled, open
TP Thin-walled, piston
WS Wash Sample

2. PENETRATION RESISTANCE/"N"

Dynamic Cone Penetration Test (DCPT):

A continuous profile showing the number of blows for each 300 mm of penetration of a 50 mm diameter 60° cone attached to AW rod driven by a 63 kg hammer falling 760 mm.

Plotted as —•—•—•—•

Standard Penetration Test (SPT) or "N" Values

The number of blows of a 63 kg hammer falling 760 mm required to advance a 50 mm O.D. drive open sampler 300 mm.

3. SOIL DESCRIPTION

a) *Cohesionless Soils:*

"N" (blows/0.3 m)	*Relative Density*
0 to 4	very loose
4 to 10	loose
10 to 30	compact
30 to 50	dense
over 50	very dense

3. SOIL DESCRIPTION (Cont'd)

b) *Cohesive Soils:*

Undrained Shear Strength (kPa)	*Consistency*
Less than 12	very soft
12 to 25	soft
25 to 50	firm
50 to 100	stiff
100 to 200	very stiff
over 200	hard

c) *Method of Determination of Undrained Shear Strength of Cohesive Soils:*

+ 3.2 - Field Vane test in borehole. The number denotes the sensitivity to remoulding.

D - Laboratory Vane Test

¨ - Compression test in laboratory

For a saturated cohesive soil the undrained shear strength is taken as one-half of the undrained compressive strength.

4. TERMINOLOGY

Terminology used for describing soil strata is based on the proportion of individual particle sizes present in the samples (please note that, with the exception of those samples subject to a grain-size analysis, all samples were classified visually and the accuracy of visual examination is not sufficient to determine exact grain sizing):

Trace, or occasional	Less than 10%
Some	10 to 20%
With	20 to 30%
Adjective (i.e. silty or sandy)	30 to 40%
And (i.e. sand and gravel)	40 to 60%

5. LABORATORY TESTS

P Standard Proctor Test
A Atterberg Limit Test
GS Grain Size Analysis
H Hydrometer Analysis
C Consolidation

List of Abbreviations and Description of Terms

SAMPLE DESCRIPTION NOTES:

1. **FILL:** The term fill is used to designate all man-made deposits of natural soil and/or waste materials. The reader is cautioned that fill materials can be very heterogeneous in nature and variable in depth, density and degree of compaction. Fill materials can be expected to contain organics, waste materials, construction materials, shot rock, rip-rap, and/or larger obstructions such as boulders, concrete foundations, slabs, abandoned tanks, etc.; none of which may have been encountered in the borehole. The description of the material penetrated in the borehole therefore may not be applicable as a general description of the fill material on the site as boreholes cannot accurately define the nature of fill material. During the boring and sampling process, retrieved samples may have certain characteristics that identify them as 'fill'. Fill materials (or possible fill materials) will be designated on the Borehole Logs. If fill material is identified on the site, it is highly recommended that testpits be put down to delineate the nature of the fill material. However, even through the use of testpits defining the true nature and composition of the fill material cannot be guaranteed. Fill deposits often contain pockets or seams of organics, organically contaminated soils or other deleterious material that can cause settlement or result in the production of methane gas. It should be noted that the origins and history of fill material is frequently very vague or non-existent. Often fill material may be contaminated beyond environmental guidelines and the material will have to be disposed of at a designated site (i.e. registered landfill). Unless requested or stated otherwise in this report, fill material on this site has not been tested for contaminants however, environmental testing of the fill material can be carried out at your request. Detection of underground storage tanks cannot be determined with conventional geotechnical procedures.

2. **TILL:** The term till indicates a material that is an unstratified, glacial deposit, heterogeneous in nature and, as such, may consist of mixtures and pockets of clay, silt, sand, gravel, cobbles and/or boulders. These heterogeneous deposits originate from a geological process associated with glaciation. It must be noted that due to the highly heterogeneous nature of till deposits, the description of the deposit on the borehole log may only be applicable to a very limited area and therefore, caution must be exercised when dealing with a till deposit. When excavating in till, contractors may encounter cobbles/boulders or possibly bedrock even if they are not indicated on the borehole logs. It must be appreciated that conventional geotechnical sampling equipment does not identify the nature or size of any obstruction.

3. **BEDROCK:** Auger refusal may be due to the presence of bedrock, but possibly could also be due to the presence of very dense underlying deposits, boulders or other large obstructions. Auger refusal is defined as the point at which an auger can no longer be practically advanced. It must be appreciated that conventional geotechnical sampling equipment does not differentiate between nature and size of obstructions that prevent further penetration of the boring below grade. Bedrock indicated on the borehole logs will be labeled 'possibly' or 'probable' etc. based on the response of the boring and sampling equipment, surrounding topography, etc. Bedrock can be proven at individual borehole locations, at your request, by diamond core drilling operations or, possibly, by testpits. It must also be appreciated that bedrock surfaces can be, and most times are, very erratic in nature (i.e. sheer drops, isolated rock knobs, etc.) and caution must be used when interpreting subsurface conditions between boreholes. A bedrock profile can be more accurately estimated, at the clients' request, through a series of closely positioned unsampled auger probes combined with core drilling.

4. **GROUNDWATER:** Although the groundwater table may have been encountered during this investigation and the elevation noted in the report and/or on the record of boreholes, it must be appreciated that the elevation of the groundwater table will fluctuate based upon seasonal conditions, localized changes, erratic changes in the underlying soil profile between boreholes, underlying soil layers with highly variable permeabilities, etc. These conditions may affect the design and type and nature of dewatering procedures. Cave-in levels recorded in borings give a general indication of the groundwater level in cohesionless soils however, it must be noted that cave-in levels may also be due to the relative density of the deposit, drilling operations etc.

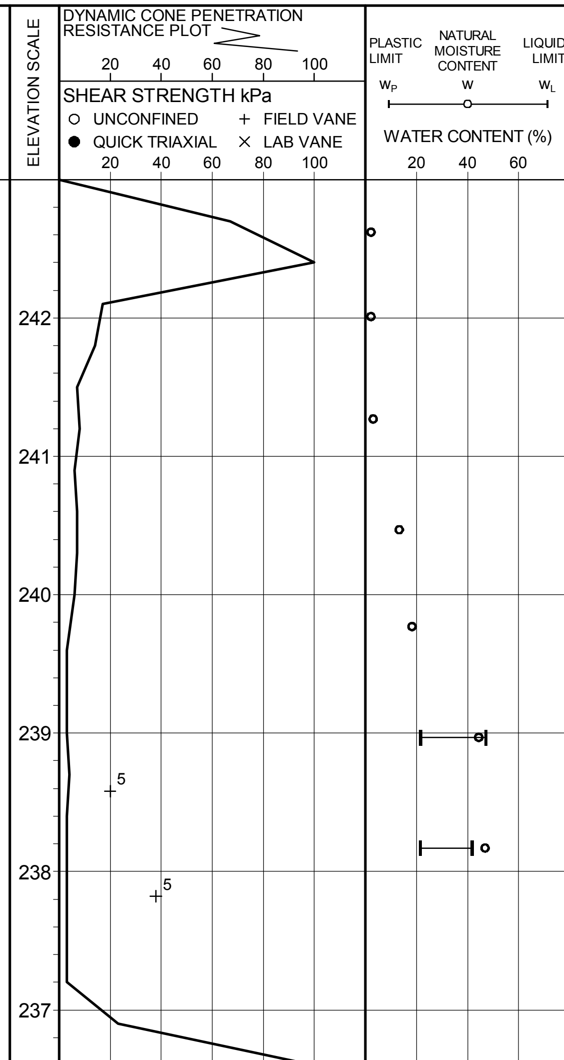
ENCLOSURE NO.:2 (Pg. 1 of 1)

METRIC

RECORD OF BOREHOLE NO. 1

REFERENCE: 11/04/11046-F3	DATUM: Geodetic	LOCATION: Station 17+609, 1.8 m Rt - Hagar Township	ORIGINATED BY: JL
PROJECT: GWP 5573-04-00, Highway 535 - Site No. 46-462/C		BOREHOLE TYPE: Track Mounted CME 45B - Hollow Stem Augers	COMPILED BY: AT
CLIENT: AECOM Inc.		DATE (Started): May 18, 2011 / DATE (Completed): May 18, 2011 / TIME: 11:30:00 AM	CHECKED BY: JRB

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
243.0	Ground Surface				
0.0	25 mm asphalt 200 mm crushed gravel FILL - brown gravel and sand trace silt	1	AS	N/A	
	(loose/compact)	2	SS	22	56 40 (4)
	gravel	3	SS	9	
		4	SS	17	
		5	SS	18	
239.3 / 3.7	SILTY CLAY - grey silty clay (medium plasticity)	6	SS	WH	
	(soft/firm)	7	SS	PM	
236.9 / 6.1	Auger Refusal Continuation of DCPT				
236.6 / 6.4	DCPT Refusal End of Borehole				



COMMENTS

The stratification lines represent approximate boundaries. The transition may be gradual.

+3, ×3: Numbers on right refer to Sensitivity. Numbers on left refer to values greater than 120 kPa

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

Date (yy/mm/dd)/Time	Water Depth (m)	Cave In (m)
1) 5/18/11 11:30:00 AM	DRY	0.7
2)	-	-
3)	-	-

MEL-GEO 11046 - BH LOGS - VENUS CREEK.GPJ MEL-GEO.GDT 10/11/11

ENCLOSURE NO.:3 (Pg. 1 of 1)

METRIC

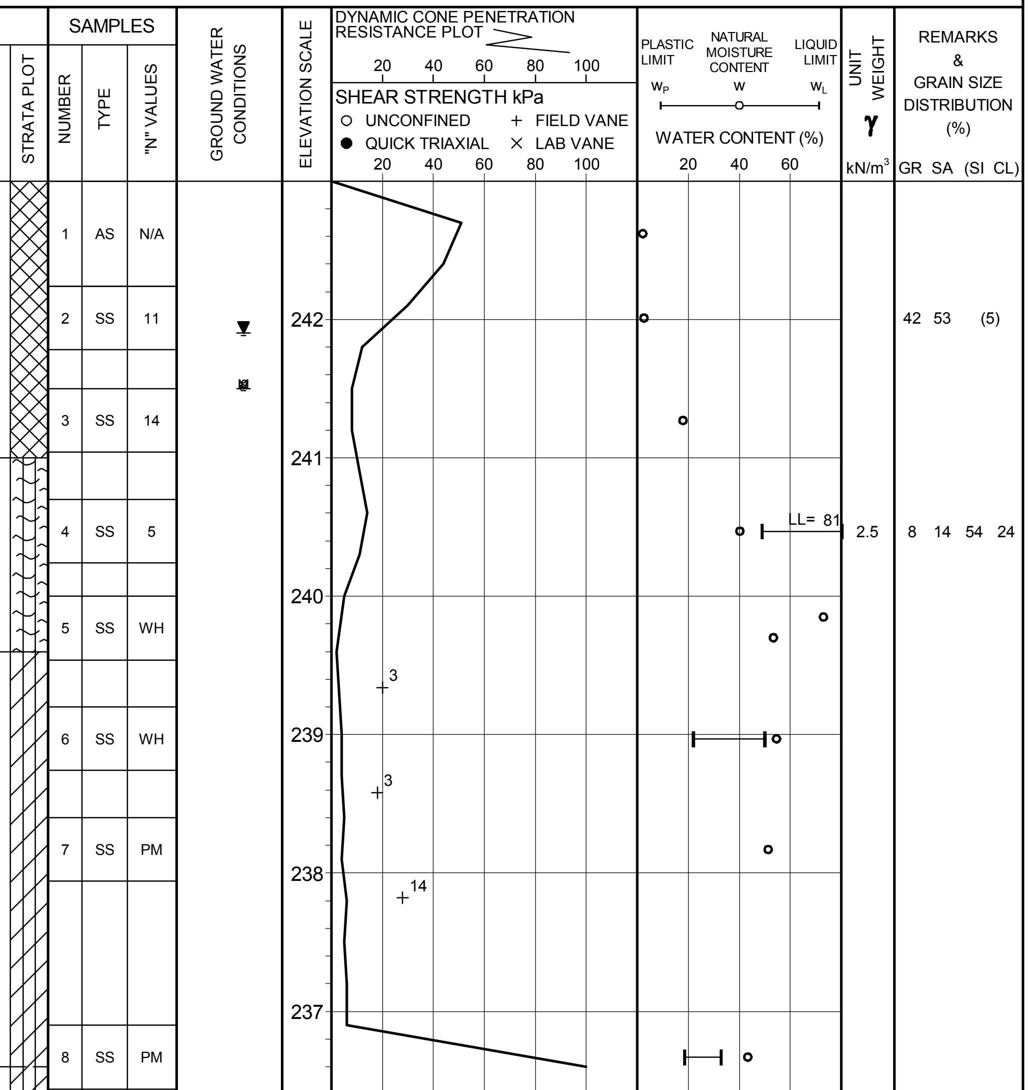
RECORD OF BOREHOLE NO. 2

REFERENCE 11/04/11046-F3 DATUM Geodetic LOCATION Station 17+618, 2 m Rt - Hagar Township ORIGINATED BY JL

PROJECT GWP 5573-04-00, Highway 535 - Site No. 46-462/C BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT

CLIENT AECOM Inc. DATE (Started) May 18, 2011 DATE (Completed) May 18, 2011 TIME 2:00:00 PM CHECKED BY JRB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	GR	SA	(SI	CL)
243.0	Ground Surface								
0.0	25 mm asphalt 200 mm crushed gravel FILL - sand and gravel trace silt occasional cobbles and boulders (compact)	1	AS	N/A					
		2	SS	11		42	53	(5)	
		3	SS	14					
241.0 2.0	CLAYEY ORGANICS - black clayey organics some sand trace gravel trace wood	4	SS	5	2.5	8	14	54	24
		5	SS	WH					
239.6 3.4	SILTY CLAY - grey silty clay (medium to low plasticity) (soft/firm)	6	SS	WH					
		7	SS	PM					
		8	SS	PM					
236.6 6.4	DCPT Refusal								
236.4 6.6	Auger Refusal End of Borehole								



COMMENTS

+3, ×3 : Numbers on right refer to Sensitivity. Numbers on left refer to values greater than 120 kPa

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

Date (yy/mm/dd)/Time	Water Depth (m)	Cave In (m)
1) 5/18/11 2:00:00 PM	1.1	1.5
2)	-	-
3)	-	-

The stratification lines represent approximate boundaries. The transition may be gradual.

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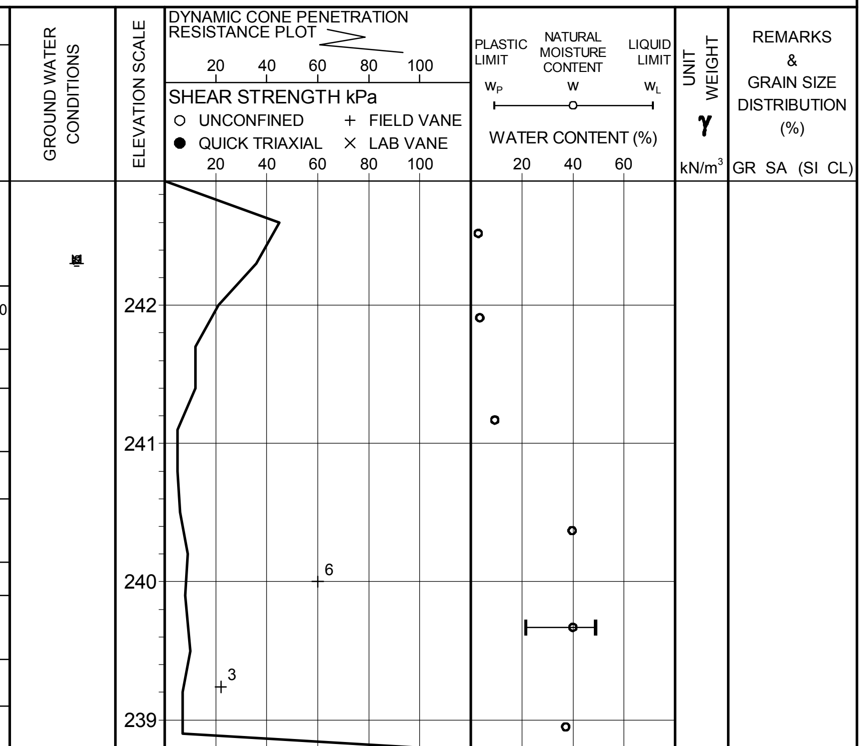
ENCLOSURE NO.:4 (Pg. 1 of 1)

METRIC

RECORD OF BOREHOLE NO. 3

REFERENCE: 11/04/11046-F3	DATUM: Geodetic	LOCATION: Station 17+600, 2 m Rt - Hagar Township	ORIGINATED BY: JL
PROJECT: GWP 5573-04-00, Highway 535 - Site No. 46-462/C		BOREHOLE TYPE: Track Mounted CME 45B - Hollow Stem Augers	COMPILED BY: AT
CLIENT: AECOM Inc.		DATE (Started): May 18, 2011 DATE (Completed): May 18, 2011 TIME: 3:45:00 PM	CHECKED BY: JRB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES
242.9	Ground Surface			
0.0	25 mm asphalt 200 mm crushed gravel FILL - gravel and sand trace silt occasional cobbles (loose/compact)	1	AS	N/A
		2	SS	50/100 mm
		3	SS	6
240.8 2.1	SILTY CLAY - grey silty clay (medium plasticity) (stiff/firm)	4	SS	WH
		5	SS	WH
		6	SS	WH
238.8 4.1	Auger Refusal DCPT Refusal End of Borehole			



COMMENTS

The stratification lines represent approximate boundaries. The transition may be gradual.

+3, ×3 : Numbers on right refer to Sensitivity. Numbers on left refer to values greater than 120 kPa

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

Date (yy/mm/dd)/Time	Water Depth (m)	Cave In (m)
1) 5/18/11 3:45:00 PM	DRY	0.6
2)	-	-
3)	-	-

MEL-GEO 11046 - BH LOGS - VENUS CREEK.GPJ MEL-GEO.GDT 10/11/11

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ENCLOSURE NO.:5 (Pg. 1 of 1)

METRIC

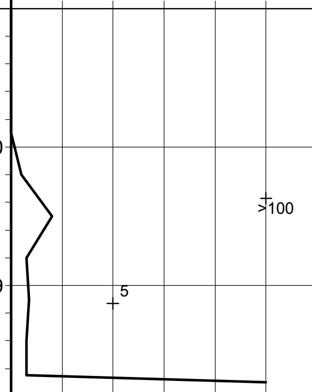
RECORD OF BOREHOLE NO. 4

REFERENCE 11/04/11046-F3 DATUM Geodetic LOCATION Station 17+601, 14 m Rt - Hagar Township ORIGINATED BY JL

PROJECT GWP 5573-04-00, Highway 535 - Site No. 46-462/C BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY RG

CLIENT AECOM Inc. DATE (Started) June 28, 2011 DATE (Completed) June 28, 2011 TIME 12:50:00 PM CHECKED BY JRB

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	SHEAR STRENGTH kPa	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
241.0	Ground Surface							
0.0	Free water at surface 100 mm Grass and Organics SILTY CLAY - brown to grey silty clay (very stiff)	1	AS	N/A	Water level (0.1 m)			
	(medium plasticity)	2	SS	3		Field vane >100		
	(firm)	3	SS	WH		Field vane 5	WP–W–WL	0 0 53 47
		4	SS	PM	Cave-in (2.6 m)			
238.3 238.2 2.7 2.8	DCPT Refusal Auger Refusal End of Borehole							



COMMENTS

+3, ×3 : Numbers on right refer to Sensitivity. Numbers on left refer to values greater than 120 kPa

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

Date (yy/mm/dd)/Time	Water Depth (m)	Cave In (m)
1) 6/28/11 12:50:00 PM	0.1	2.6
2)	-	-
3)	-	-

The stratification lines represent approximate boundaries. The transition may be gradual.

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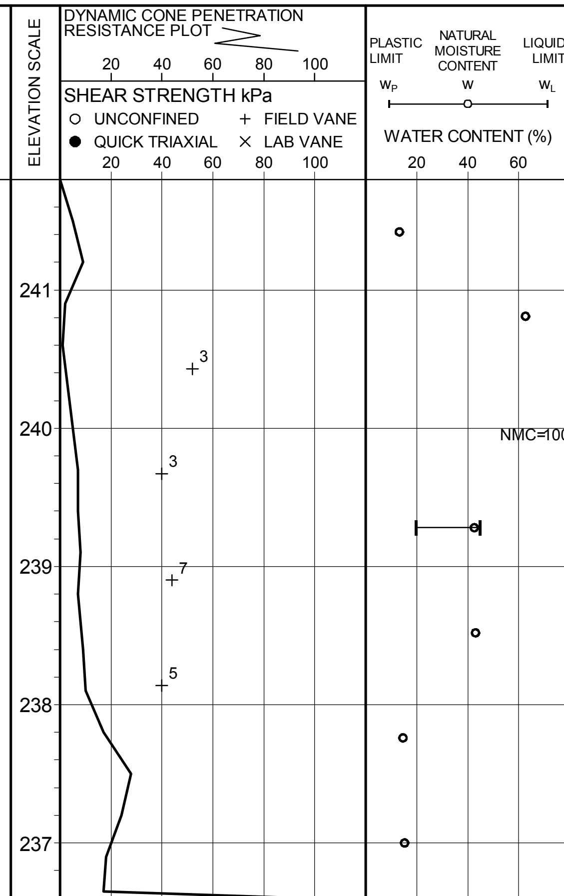
ENCLOSURE NO.:6 (Pg. 1 of 1)

METRIC

RECORD OF BOREHOLE NO. 5

REFERENCE 11/04/11046-F3	DATUM Geodetic	LOCATION Station 17+606, 15 m Lt - Hagar Township	ORIGINATED BY JL
PROJECT GWP 5573-04-00, Highway 535 - Site No. 46-462/C		BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers	COMPILED BY RG
CLIENT AECOM Inc.		DATE (Started) June 28, 2011 / DATE (Completed) June 28, 2011 / TIME 11:20:00 AM	CHECKED BY JRB

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	SHEAR STRENGTH kPa (Field Vane)	WATER CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
241.8	Ground Surface						
0.0	50 mm Grass and organics						
	FILL - brown silt trace sand trace gravel	1	AS	N/A			
241.0 / 0.8	CLAYEY ORGANICS - black clayey organics and fine fibrous peat (firm)	2	SS	WH			
					+ (sensitivity 3)		
		3	SS	WH		NMC=100	
239.8 / 2.0	SILTY CLAY - grey silty clay trace sand (firm) (medium plasticity)				+ (sensitivity 3)		
		4	SS	PM			0 3 50 47
					+ (sensitivity 7)		
		5	SS	PM			
					+ (sensitivity 5)		
238.0 / 3.8	SAND - grey sand some gravel some silt (compact)	6	SS	22			13 76 (11)
		7	SS	23			
236.6 / 5.2	DCPT Refusal Auger Refusal End of Borehole						



COMMENTS

The stratification lines represent approximate boundaries. The transition may be gradual.

+3, ×3 : Numbers on right refer to Sensitivity. Numbers on left refer to values greater than 120 kPa

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

Date (yy/mm/dd)/Time	Water Depth (m)	Cave In (m)
1) 6/28/11 11:20:00 AM	0.1	3.8
2)	-	-
3)	-	-

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Appendix C Borehole Location Plan Labwork

Figure No. 2: Borehole Location and Soil Strata
Figure No. L-1 to L-3: Grain Size Analysis Graph
Figure No. L-4: Plasticity Chart
Figure No. L-5: In-Situ Shear Strengths Chart

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METRIC

Dimensions are in meters and/or millimeters unless otherwise shown. Stations are in kilometers + meters.

Geo Cres No 41I–274
WP No 5573–04–00

HWY NO. 535 – Township of Hagar

Venus Creek Culvert Replacement – Sta. 17+607

BOREHOLE LOCATIONS & SOIL STRATA

Figure 2

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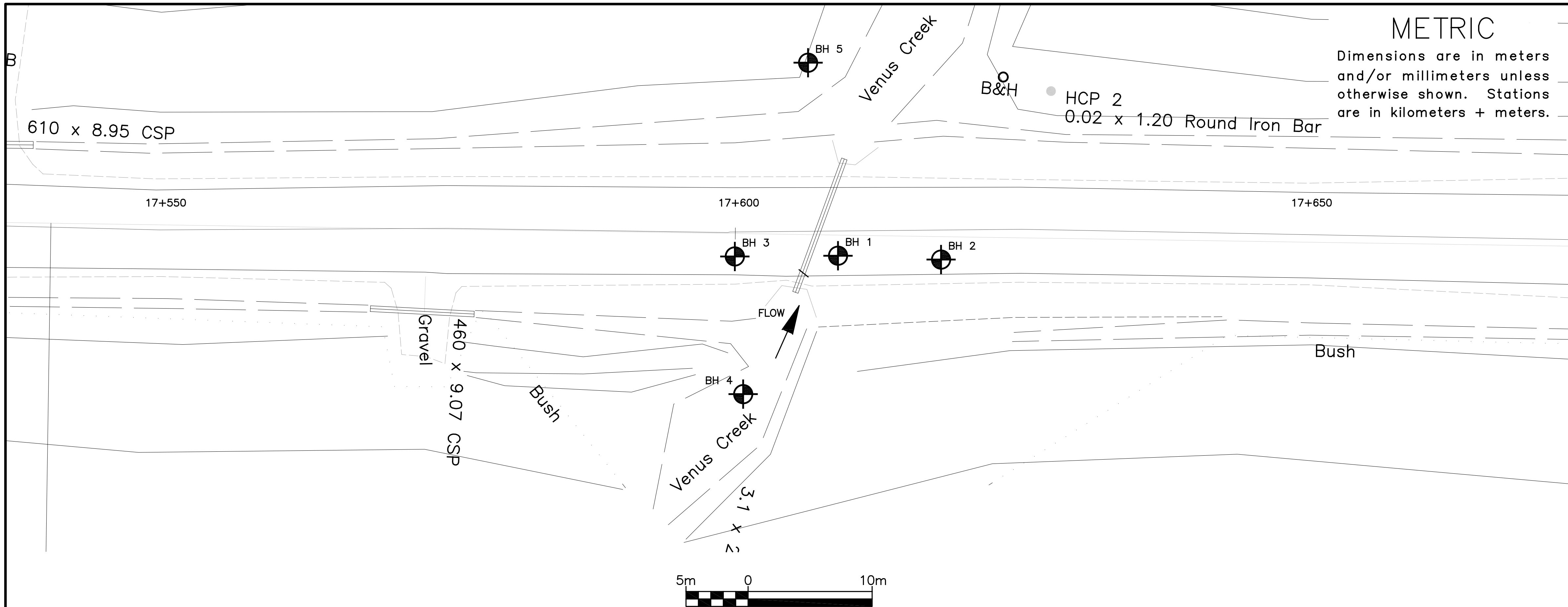
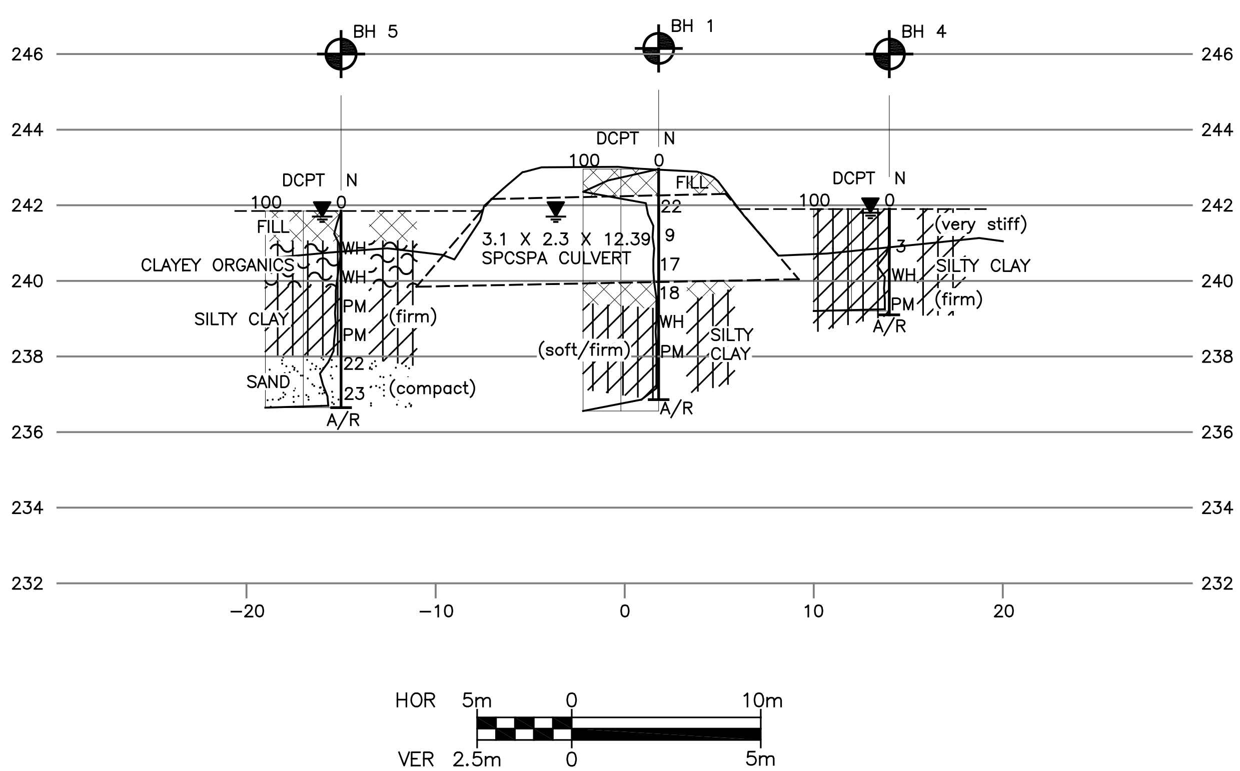
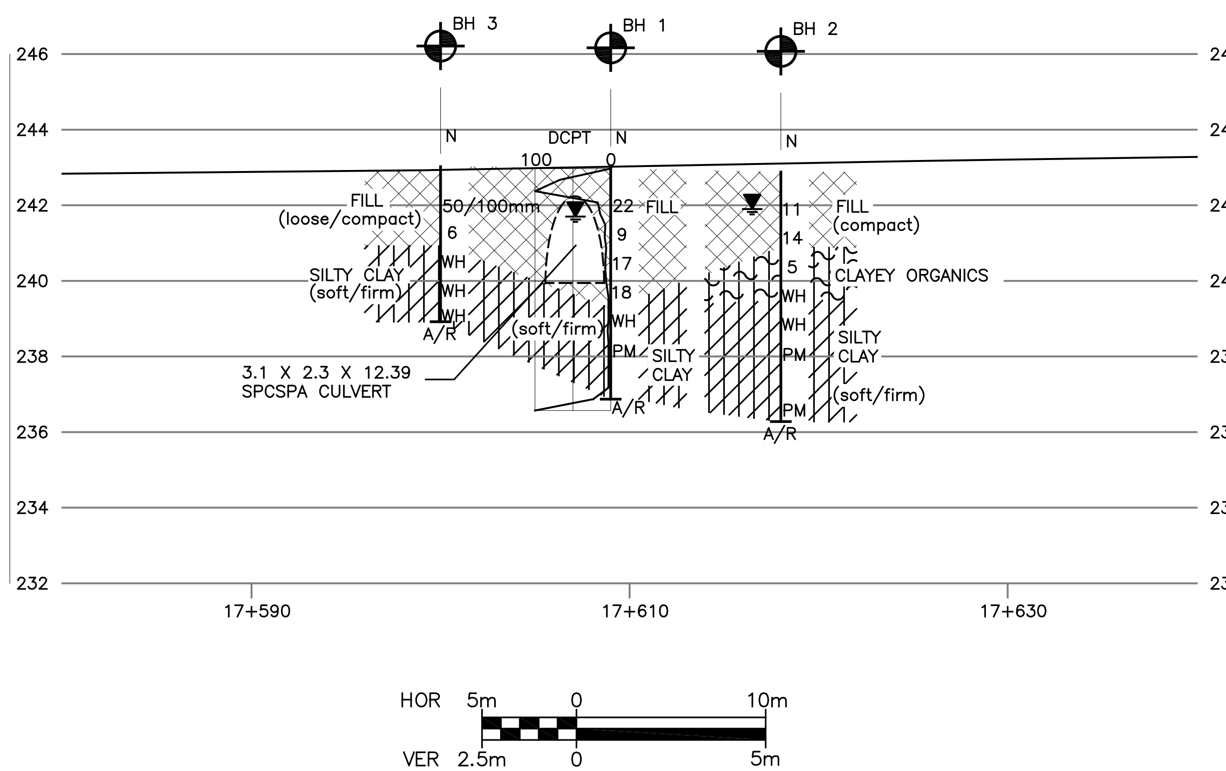


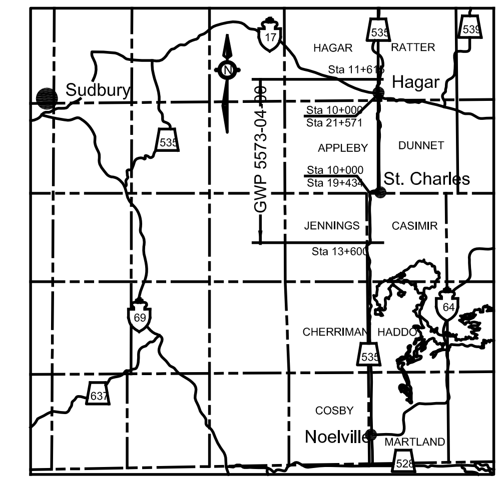
PLAN



CROSS SECTION



PROFILE



KEY PLAN – NOT TO SCALE

LEGEND

- Borehole
- Dynamic Cone Penetration Test
- "N" Blows/0.3 m (Std Pen Test, 475 J/blow)
- DCPT Blows/0.3 m (60° Cone, 475 J/blow)
- Water Level at Time of Investigation
- A/R Auger Refusal at Elevation
- E/S End of Sampling

Borehole No.	Elev.	O/S	STATION
Borehole No. 1	243.0	1.8m Rt	17+609
Borehole No. 2	243.0	2m Rt	17+618
Borehole No. 3	242.9	2m Rt	17+600
Borehole No. 4	241.0	14m Rt	17+601
Borehole No. 5	241.8	15m Lt	17+606

NOTE 1:
The boundaries between soil strata have been established at the borehole locations only. The boundaries illustrated and stratigraphy between boreholes on this drawing are assumed based on borehole data and may vary. They are intended for design only.

REVISIONS	DATE	BY	DESCRIPTION

HWY No. 535 – Hagar Twp – Venus Creek		REF 11046
SUBM'D		SITE 46–462/C
DRAWN RG	CHK MAM	DATE July 2011	FIG 1

Reference No.: 11/04/11046-F3
Date: October 2011

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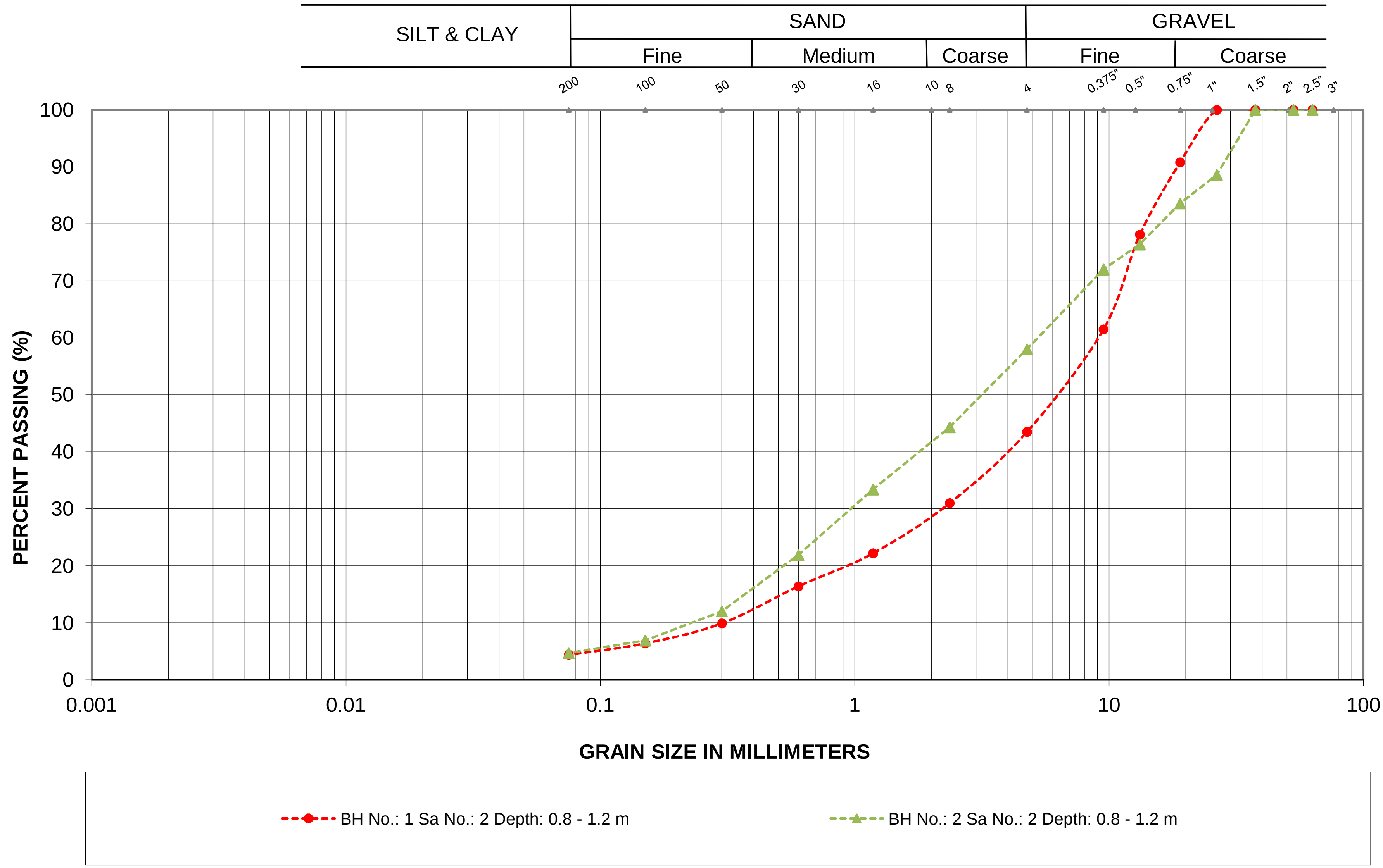
GRAIN SIZE ANALYSIS



G.W.P.: 5573-04-00
LOCATION: Hwy 535
SITE: 46-462/C

EMBANKMENT FILL

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FIGURE L-1

Reference No.: 11/04/11046-F3
Date: October 2011

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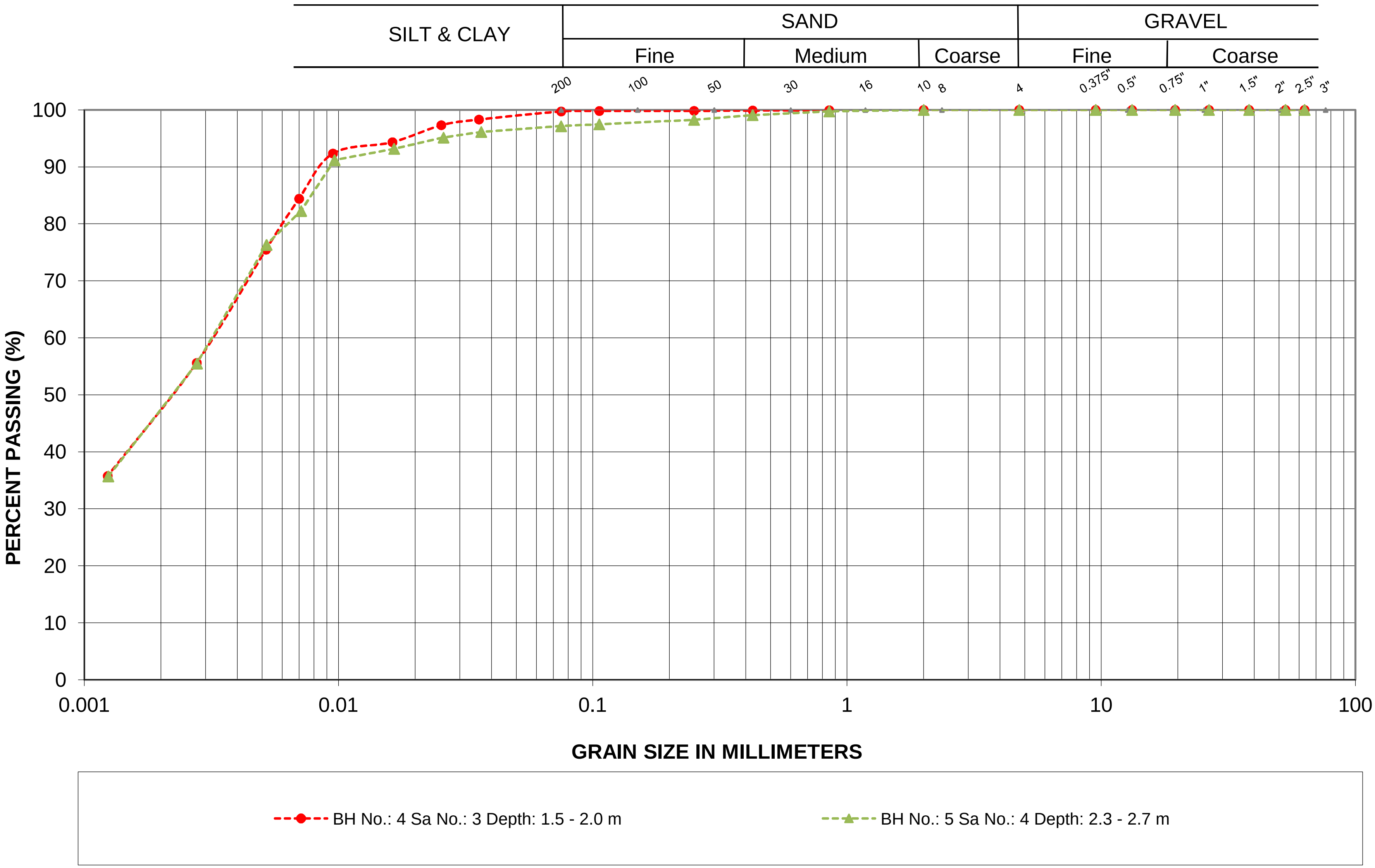
GRAIN SIZE ANALYSIS



G.W.P.: 5573-04-00
LOCATION: Hwy 535
SITE: 46-462/C

SILTY CLAY

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FIGURE L-2

Reference No.: 11/04/11046-F3
Date: October 2011

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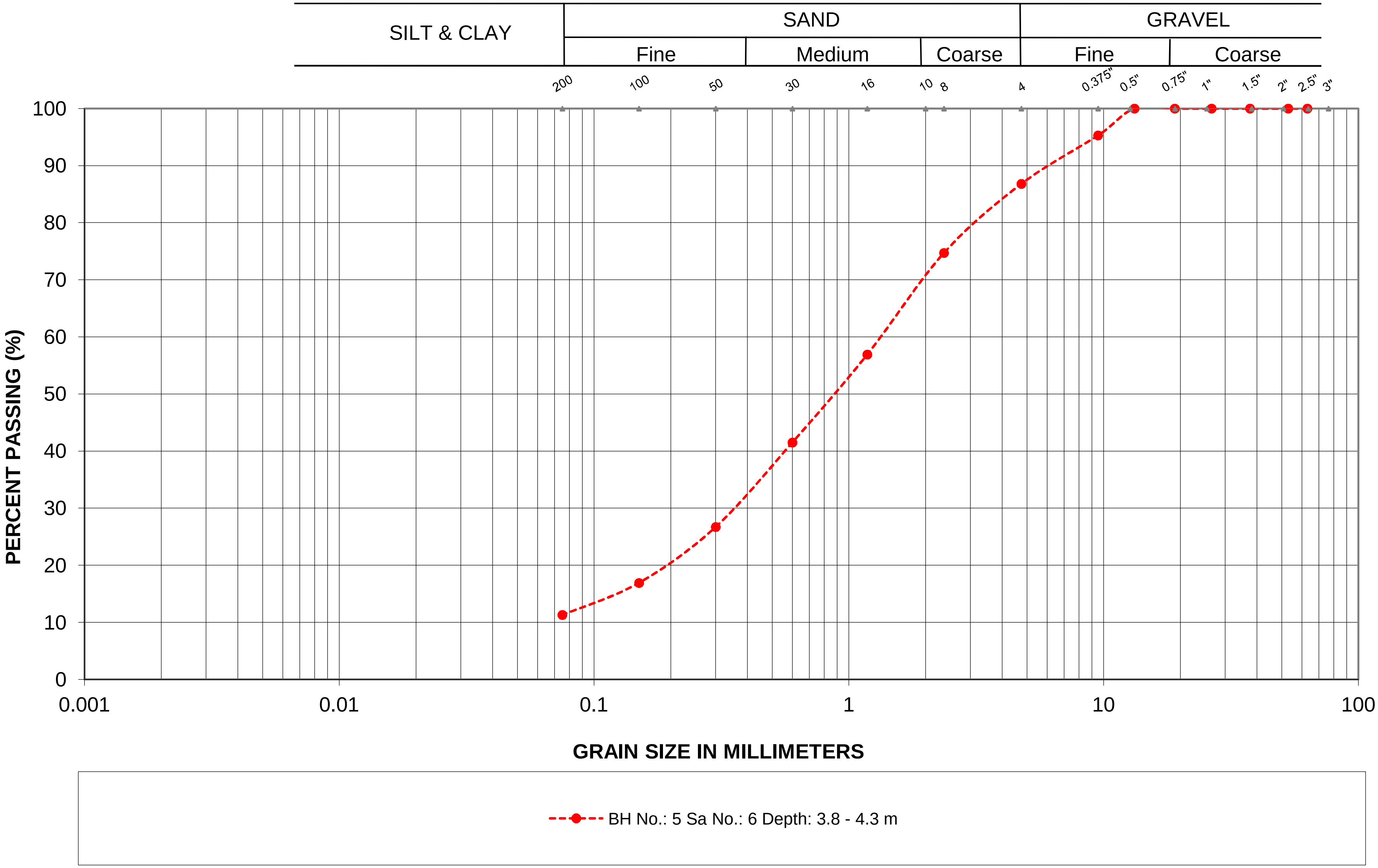
GRAIN SIZE ANALYSIS



G.W.P.: 5573-04-00
LOCATION: Hwy 535
SITE: 46-462/C

SAND

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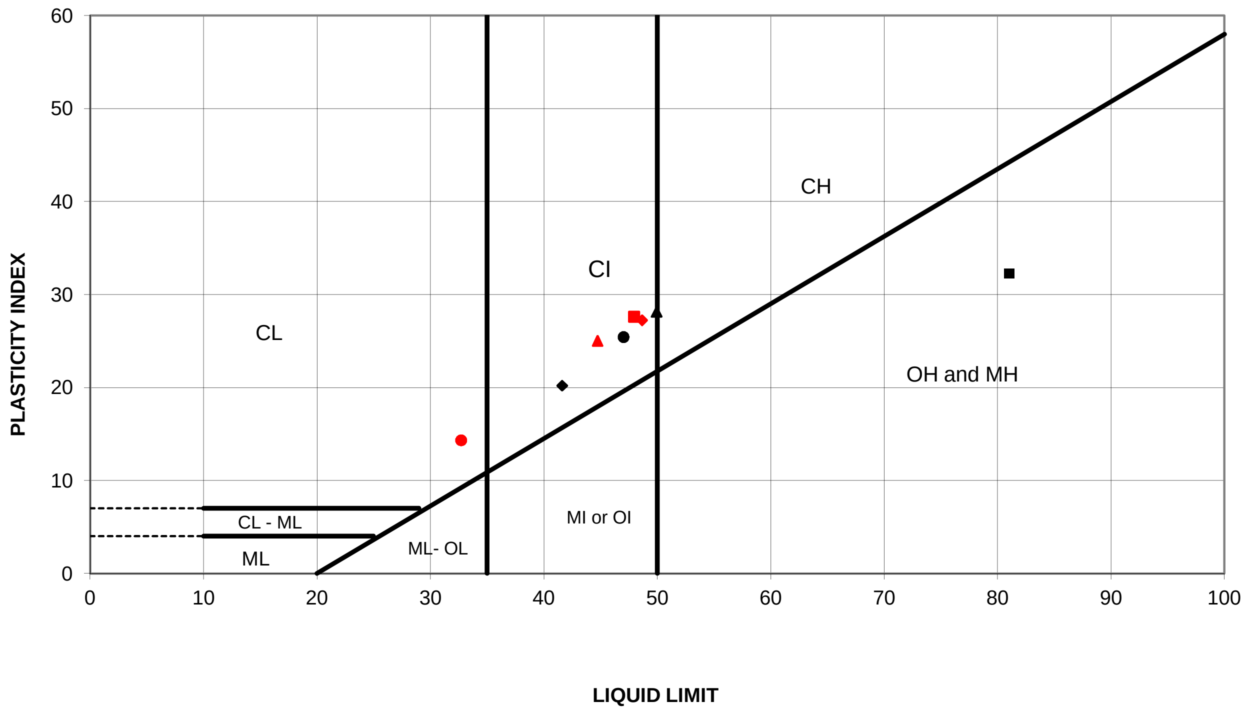
FIGURE L-3

ATTERBERG LIMITS TEST RESULTS	FIGURE L-4

ATTERBERG INDICES



SYMBOL	BH	Sa. No.	Depth(m)	Elev.(m)	Liquid Limit	Plastic Limit	Plasticity Index	NMC %
●	1	6	3.8	239.2	47.0	21.6	25.4	44.4
◆	1	7	4.6	238.4	41.6	21.4	20.2	46.8
■	2	4	2.3	240.7	81.0	48.7	32.3	40.2
▲	2	6	3.8	239.2	49.9	21.8	28.2	54.5
● (red)	2	8	6.1	236.9	32.7	18.4	14.3	43.4
◆ (red)	3	5	3.0	239.9	48.7	21.4	27.2	39.9
■ (red)	4	3	1.5	240.4	47.9	20.3	27.6	37.4
▲ (red)	5	4	2.3	239.5	44.7	19.7	25.0	42.5

Date: Oct-11
Project: Hwy 535 - Site 46-462/C
G.W.P: 5573-04-00

Prep'd: AT
Chkd: RG
Ref. No.: 11/04/11046-F3

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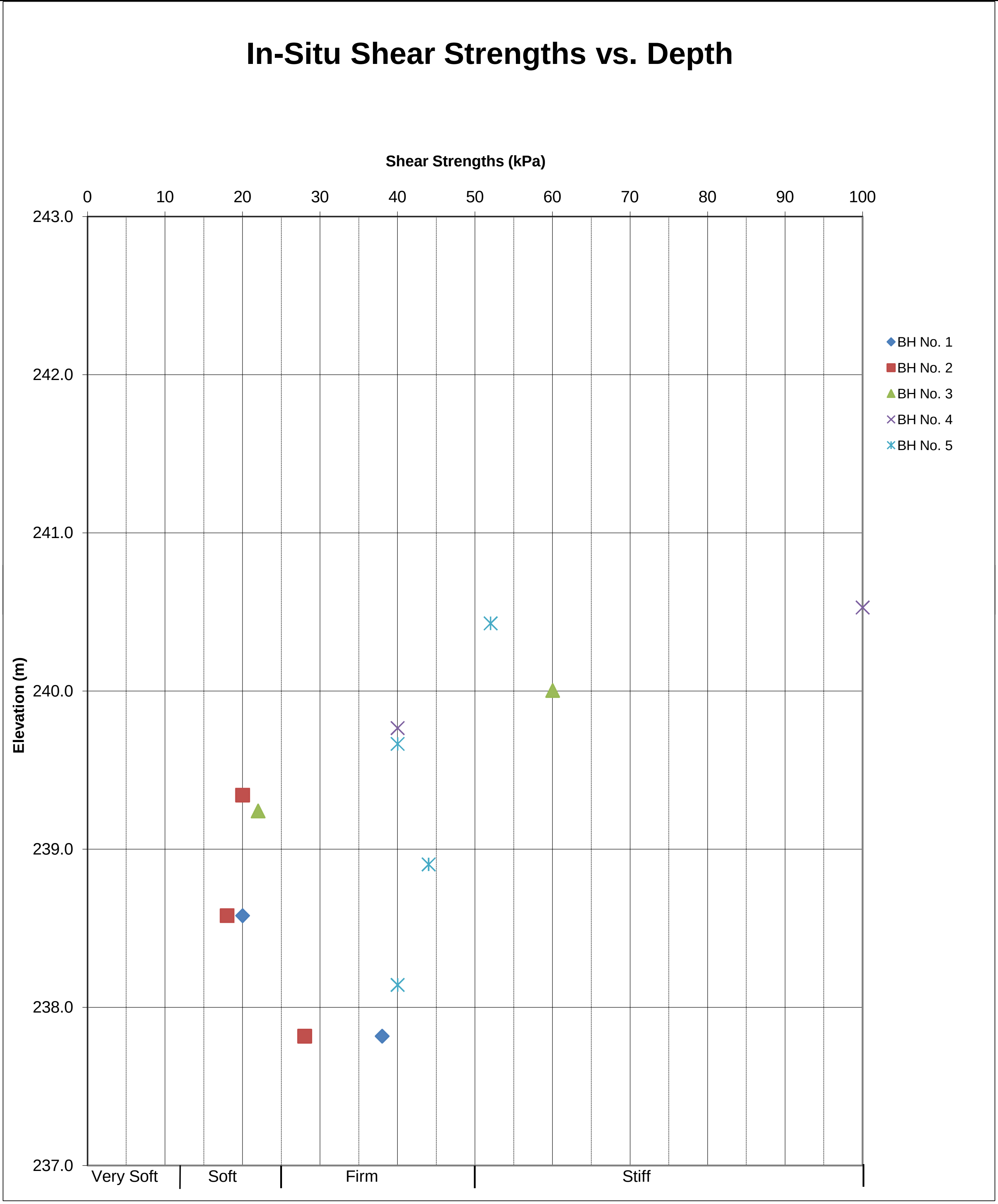
IN-SITU SHEAR STRENGTHS	Figure No. L-5



Project: 11/04/11046-F3
GWP: 5573-04-00

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Date: October 2011
Checked:MAM

Appendix D Photo Essay

Enclosure No. 7: Photo Essay

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Top: Embankment at culvert outlet, looking north Bottom: Embankment at culvert inlet, looking north	Photo: 1 - 2

Reference Number: 11/04/11046-F3	Provided By: LVM | MERLEX
Project: Hwy 535 – Venus Creek Culvert – Site No. 46-462/C	Date: May 2011

Top: Stream at culvert outlet, looking east Bottom: Stream at culvert inlet, looking west	Photo: 3 - 4

Reference Number: 11/04/11046-F3 Project: Hwy 535 – Venus Creek Culvert – Site No. 46-462/C	Provided By: LVM | MERLEX Date: May 2011

Appendix E Shoring Sketch

Figure No. SK-1: Conceptual Shoring Sketch

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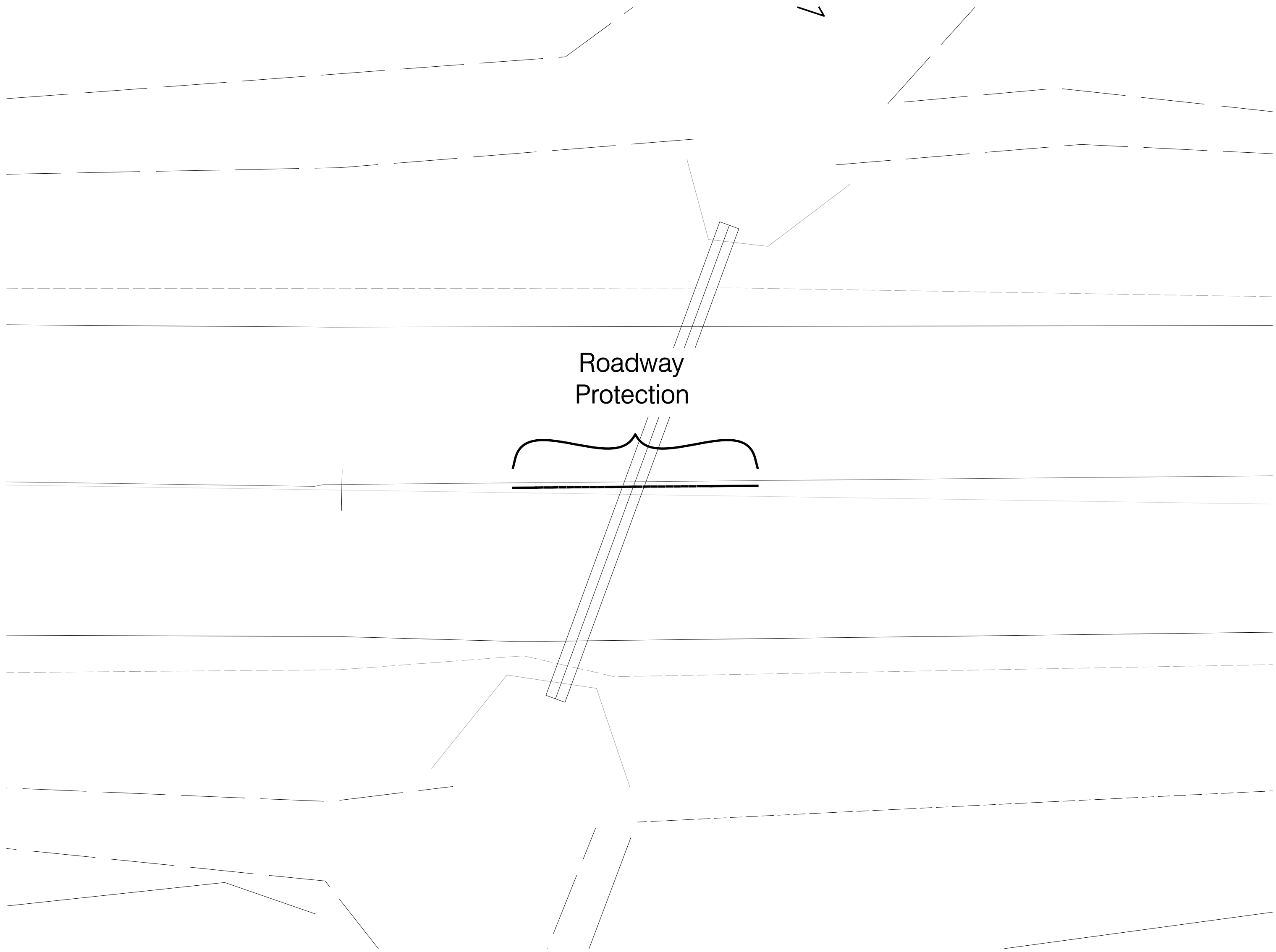
REF: 11046-F3



HWY 535 - Township of Hagar - Site 46-462/6 Conceptual Shoring Locations - Venus Creek Culverts	FIGURE SK-1