Submitted To Triton Engineering Services Limited
18 Robb Blvd Unit 8, Orangeville, Ontario L9W 3L2
On Behalf of the Ontario Ministry of Transportation

Highway 144 Grading and Resurfacing
Culvert Replacement
Station 22+343 - TWP of Dowling
GWP 5081-06-00

Highway 144
GWP 5081-06-00
From 1.5 km South of Sudbury Municipal Road 8, Northerly 18.1 km to Cartier West Entrance (Center Street)

FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

Date: October 7, 2013
Ref. Nº: 11/11/11209-F2

Geocres No. 41I-298

LVM | MERLEX

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Final Foundation Investigation and Design Report

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Property and Confidentiality

Test results mentioned herein are only valid for the sample(s) stated in this report.

LVM inc.'s subcontractors who may have accomplished work either on site or in laboratory are duly qualified as stated in our Quality Manual's procurement procedure. Should you require any further information, please contact your Project Manager."

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1 INTRODUCTION

LVM | MERLEX has been retained by Triton Engineering Services Limited, on behalf of the Ministry of Transportation of Ontario (MTO), to carry out a foundation investigation for the proposed replacement of an existing culvert and design of a protection system. This culvert replacement is located on Highway 144, some 500 m South of Regional Road 8, in the Township of Dowling.

The foundation investigation location was specified by the MTO in the RFP/TPM documentation Agreement No. 5010-E-0051. The terms of reference for the scope of work are outlined in LVM | MERLEX's Proposal P-11-023, dated June, 2011. The purpose of this investigation was to determine the subsurface conditions in the area of the culvert in order to provide geotechnical design recommendations. LVM | MERLEX investigated the foundation area by the drilling of boreholes, carrying out in-situ tests, and performing laboratory testing on select samples.

2 SITE DESCRIPTION

The foundation investigation for this CSP culvert is located at Station 22+343, Township of Dowling. The topography at the site is a low wet land area with flooded organic terrain to the west (left) and east (right) of the embankment. The existing highway embankment currently supports three undivided lanes of highway, two in the northbound direction and one in the southbound direction. The existing highway, at the culvert locations, is constructed on a fill embankment some 3.7 m in height, with centerline elevation of 372.3 m at the culvert location. The culvert at this location is a 910 mm diameter CSP culvert, some 27.6 m in length. Flow through the culvert is from left (west) to right (east) (see Photo Essay, Appendix 4).

Infrastructure at the culvert location consists of overhead power and communication wires on both the west (left) and east (right) sides of the highway.

2.1 SITE PHYSIOGRAPHY AND SURFICIAL GEOLOGY

This project is located in the Geomorphic Sub-province known as the Eastern Sandy Uplands. The topography on this section of Highway 144 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 sands.

Bedrock in the area, as indicated on OGS Map 2506, is of the Early Precambrian Era. At the location of this culvert foundation investigation, the bedrock comprises of Felsic Igneous and Metamorphic Rocks including: granitic, metasedimentary and minor metavolcanic migmatite.

3 INVESTIGATION PROCEDURES

The field work for this investigation was carried out during the period of March 19th to April 11th, 2012, during which time five (5) sampled boreholes, and DCPTs, were advanced. For the purposes of foundation design for the culvert replacement, one borehole was advanced through the embankment slightly up chainage from the culvert, and one borehole was advanced at each the inlet and outlet ends of the culverts. Two boreholes were advanced through the embankment, one up and down chainage from the culverts, to provide subsurface data to support the design of a protection system.

The field investigation was carried out using a Bombardier and a truck 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 borehole(s) 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 Limit testing and specific gravity. The results of the laboratory testing are presented on the individual Record of Borehole Sheets (Appendix 2), with a summary of results presented on the laboratory sheets in Appendix C (Figures Nos. L-1 to L-6).

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 SUBSURFACE CONDITIONS

Details of the subsurface conditions revealed by the investigation program are presented on the enclosed Record of Borehole Logs (Appendix 2) and on Figure No. 2 (Appendix 3). 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 a 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 CULVERT STATION 22+343, TWP OF DOWLING

A plan and profile illustrating the borehole locations and stratigraphic sequences is shown on Figure No. 2, Appendix 3. During the course of the exploration program, five (5) sampled boreholes were put down at this site, with Borehole Nos. 1 and 2 advanced at the culvert ends. Boreholes No. 3 to 5 were advanced through the existing embankment. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 to 5 were recorded at 369.6, 368.8, 371.9, 372.6, and 372.2 m, respectively.

4.1.1 Pavement Structure

At surface at Borehole Nos. 3 to 5, a layer of asphalt some 150 mm thick was penetrated. The asphalt was underlain by a base layer of crushed gravel some 175 to 200 mm thick.

4.1.2 Embankment Fill

Underlying the surficial pavement structure at Borehole Nos. 3 to 5, a deposit of fill described as brown to grey sand trace to with gravel, trace to with silt was penetrated. The natural moisture content measured on samples of this deposit was in the order of 3 to 20%. Gradation analyses were carried out on five (5) samples of this deposit, the results of which indicated 1 to 27% gravel size particles, 43 to 92% sand size particles, and 3 to 30% silt and clay size particles (Figure No. L-1, Appendix 3). Based on SPT ‘N’ values of 2 to 48 blows per 300 mm penetration, the compactness of this deposit was described as very loose to dense. This deposit was encountered to depths of 3.4 m below grade at Borehole Nos. 3 to 5 (elevations 368.5, 369.2, and 368.8 m, respectively).

4.1.3 Fill

At surface at Borehole No. 1, a deposit of fill consisting of brown sand and gravel to gravelly sand, trace silt was penetrated. Trace organics were encountered in this deposit. Occasional cobbles and boulders were encountered in this deposit. The natural moisture content measured on samples of this deposit was in the order of 13 to 19%. Gradation analyses were carried out on two (2) samples of this deposit, the results of which indicated 29 to 43% gravel size particles, 49 to 54% sand size particles, and 8 to 17% silt and clay size particles (Figure No. L-2, Appendix 3). Based on SPT 'N' values of 8 to 16 blows per 300 mm penetration, the compactness of this deposit was described as loose to compact. This deposit was encountered to a depth of 1.9 m below grade (elevation 367.7 m).

4.1.4 Organics

At surface at Borehole No. 2, and underlying the fill at Borehole No. 1, a deposit of black silty organics was penetrated. The natural moisture content measured on samples of this deposit was in the order of 77 to 227%. This deposit was encountered to depths of 2.6 and 1.4 m below existing grade at Borehole Nos. 1 and 2, respectively (elevations 367.0 and 367.4 m, respectively).

4.1.5 Sand and Gravel

Underlying the silty organics at Borehole No. 2, and underlying the embankment fill at Borehole Nos. 3, 4, and 5, a deposit of grey sand and gravel, to gravelly sand, trace silt was penetrated. Occasional cobbles and boulders were encountered in this deposit. Trace organics were encountered in this deposit at Borehole No. 3. The natural moisture content measured on samples of this deposit was in the order of 11 to 20%. Gradation analyses were carried out on two (2) samples of this deposit, the results of which indicated 37 to 47% gravel size particles, 44 to 54% sand size particles, and 9% silt and clay size particles (Figure No. L-3, Appendix 3). Based on SPT 'N' values of 17 to 37 blows per 300 mm penetration, the compactness of this deposit was described as compact to dense. This deposit was encountered to depths of 2.7, 4.6, 5.8, and 4.3 m below grade at Borehole Nos. 2 to 5, respectively (elevations 366.1, 367.3, 366.8, and 367.9 m, respectively).

4.1.6 Sand

Underlying the silty organics at Borehole No. 1, and underlying the sand and gravel at Borehole Nos. 3 and 5, a deposit of sand, some to with gravel, some to with silt was penetrated. Occasional cobbles and boulders were encountered in this deposit at Borehole No. 1. The natural moisture content measured on samples of this deposit was in the order of 9 to 18%. Gradation analyses were carried out on three (3) samples of this deposit, the results of which indicated 16 to 21% gravel size particles, 53 to 68% sand size particles, and 16 to 30% silt and clay size particles (Figure No. L-4, Appendix 3). Based on SPT 'N' values of 15 to 40 blows per 300 mm penetration, the compactness of this deposit was described as compact to dense. This deposit was encountered to a depth of 6.1 m below grade at Borehole No. 5 (elevation 366.1

m). Auger refusal was encountered in this deposit at depths of 4.4 and 7.1 m below grade at Borehole Nos. 1 and 3, respectively (elevations 365.2 and 364.8 m, respectively).

4.1.7 Silt

Underlying the sand and gravel at Borehole Nos. 2 and 4, and underlying the sand at Borehole No. 5, a deposit of grey silt, some to with sand, trace gravel, trace clay was penetrated. The natural moisture content measured on samples of this deposit was in the order of 14 to 30%. Gradation analyses were carried out on two (2) samples of this deposit, the results of which indicated 0 to 5% gravel size particles, 15 to 25% sand size particles, 63 to 78% silt size particles, and 7% clay size particles (Figure No. L-5, Appendix 3). Based on SPT 'N' values of 15 to 43 blows per 300 mm penetration, the compactness of this deposit was described as compact to dense. Auger refusal was encountered in this deposit at depths of 3.0, 8.2, and 7.1 m below grade at Borehole Nos. 2, 4, and 5, respectively (elevations 365.8, 364.4, and 365.1 m, respectively).

4.1.8 DCPT

Dynamic Cone Penetration Tests were advanced at all five borehole locations. The DCPT plots are graphically illustrated on the individual borehole logs. DCPT refusal was encountered at depths of 1.4, 1.5, 6.6, 8.0, and 7.1 m below grade at Borehole Nos. 1 to 5, respectively (elevations 368.2, 367.3, 365.3, 364.6, and 365.1 m, respectively).

4.2 GROUNDWATER DATA

The water level in the culvert was measured at an elevation of 369.4 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 presented on the individual Record of Borehole Log Sheets (Appendix 2). The water levels in the boreholes were measured at elevations 368.7, 368.8, 368.9, 368.3, and 369.0 m upon completion at Borehole Nos. 1 to 5, respectively.

The groundwater and river water levels will fluctuate seasonally/yearly.

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

A foundation investigation was carried out for the proposed replacement of an existing culvert and for a protection system, as identified in the RFP.

The existing culvert is a 910 mm diameter CSP culvert some 27.6 m long. This 910 mm diameter CSP culvert is located at Station 22+343 in the Township of Dowling. The existing highway embankment at the culvert location currently supports three undivided lanes of highway, two running in the north direction and one running in the south direction. Flow through the culvert is from west to east. Based on data from this foundation investigation, the embankment supporting the existing pavement structure at this site has been constructed using earth fill. The native material underlying the fill generally consisted of compact to dense sands and gravels with auger refusal varying between elevations 364.4 and 365.8 m, at the borehole locations.

It is understood that it proposed to replace the existing 910 mm CSP culvert with a 900 mm flexible culvert (CSP, or High Density Polyethylene (HDPE)). However, the new culvert will likely be constructed at a similar alignment and skew to the existing culvert. The final vertical alignment of the highway will essentially remain the same.

5.2 FOUNDATION CONSIDERATIONS

The founding native compact to dense sands and gravels present below the existing embankment are considered adequate for support of a culvert and for a conventional highway embankment of this height. Bearing resistance should not be a major issue provided the natural bearing surface is not disturbed during construction and groundwater is controlled during construction, as discussed in Section 5.6.

Considering a 900 mm diameter flexible culvert, and based on the characteristics of the native sand and gravel 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 650 kPa can be used for a closed culvert (i.e. precast concrete box culvert or CSP/concrete pipe culvert). In consideration of the width/diameter of the culvert and the depth of overburden, a geotechnical reaction at SLS of 200 kPa can be used for design, in consideration of less than 25 mm settlement and preloading associated with the existing embankment.

If an open culvert (i.e. concrete frame open culvert, with 1 m wide wall footings, or a pipe arch culvert on 1 m wide footings) is considered, then a factored Bearing resistance at ULS of 100 kPa, and a geotechnical reaction at SLS of 100 kPa would apply for design, taking into consideration the limited depth of overburden and smaller footing width. Considering the relatively small culvert size, an open box or arch culvert is likely not practical for this site, in consideration of the footing depth required for frost cover and scour protection.

5.2.1 Slope Stability

The maximum height of fill above surrounding grade for the embankment at this location is some 3.7 m at the culvert location. A stability analysis, using the GEO-SLOPE computer program, Slope/W (GeoStudio 2007, version 7.17, Geo-Slope International Ltd.), was carried out at this location with standard embankment slopes of 2H:1V in earth fills. The embankment material was modeled as earth fill, using a unit weight of 20 kN/m^3 and a friction angle of 30°. The native sand and gravel deposit was modeled using representative values of unit weight of 20 kN/m^3 and a friction angle of 30°. The native sand was modeled using representative values of unit weight of 19 kN/m^3 and a friction angle of 30°. The native silt was modeled using representative values of unit weight of 17.5 kN/m^3 and a friction angle of 28°. The unit weights and friction angles for the slope calculations are based on general representative values for soil types, obtained through laboratory testing. The results of the analysis indicated a factor of safety in the order of 1.44 against failure through the native sand and gravel subgrade (see Figure No. S-1, Appendix 5). The embankment slopes should be established at the standard 2H:1V angle in earth fill. The stability of the finished embankment slope will not be an issue provided they are properly constructed.

5.3 CULVERT DESIGN, BEDDING, AND EMBEDMENT

The embankment was constructed with earth fills. The results of this investigation indicate that, below the culvert invert, the native soils consist generally of compact to dense sands and gravels. A review of the condition of the pavement surface, at the culvert location, revealed minor asphalt cracking, however, in general, the embankment appears to have performed well (see Photo Essay, Appendix 4).

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. As such, installing the culvert on a camber will not be required at this site.

Due to the height and composition of the embankment at the culvert location frost tapers shall not be required, as per the geotechnical report also by LVM | MERLEX, Ref No. 11/11/11209-P1.

5.3.1 Flexible Steel Culvert

It is understood that a flexible culvert (i.e. CSP/SPCSP/HDPE) will be used for culvert replacement at this site. If a flexible pipe is 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 material 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. During backfilling the embankment fill should be placed in a balanced manner on the outer sides of the culvert unit. The elevation difference of the backfill on either side of the culvert during backfilling must be limited to a maximum 200 mm.

Considering the nature of the embankment fill and shallow culvert slope, inlet clay seals along the culvert or outlet cut-off walls are not required. However, the inlet and outlet stream bed shall be protected with a rip-rap (R-10 size as per OPSS 1004) apron. The apron shall be 3 m in width, 300 mm thick and placed as per OPSD 810.010.

5.3.2 Rigid Concrete Culvert

A concrete pipe could also be considered for culvert replacement at this site. However, due to the culvert size, a concrete box culvert is not warranted at this site. A Class B Bedding for the concrete pipe shall consist of Granular A with a thickness of 200 mm. Alternatively, specifically if construction is carried out under wet conditions, a 19 mm clear stone bedding could be used, which would aid in dewatering operations. During backfilling, the embedment fill should be placed in a balanced manner on each side of the pipe. The elevation difference of the backfill on either side of the pipe during backfilling must be limited to a maximum 200 mm. Cover material for concrete pipe can consist of Granular A and placed to the dimensions as shown on OPSD 802.031.

The inlet and outlet stream bed shall be protected with a rip-rap (R-10 size as per OPSS 1004) apron. The apron shall be 3 m in width, 300 mm thick and extend across the stream bed and placed as per OPSD 810.010.

Clay seals are generally used where significant head differences exist between the inlet and outlet of a culvert to prevent flow through the embankment. Clay seals are not considered necessary considering the anticipated water levels and flow at this culvert location.

5.4 CULVERT INSTALLATION AND CONSTRUCTION STAGING CONSIDERATIONS

The existing culverts are established in an earth fill embankment some 3.7 m in height. The invert elevation of the existing culvert is at 368.6 m, with the top of the embankment at elevation 372.3 m at centerline. As such, the embankment at this location is some 3.7 m in height above the culvert invert at the centerline. Therefore, a minimum 3.9 m deep excavation (i.e. to elevation 368.4 m) will be required in consideration of a 200 mm thick layer of bedding/embedment material. The present platform width at this location is some 14.5 m as can be seen on the cross section on Figure No. 2. The preferred method of culvert replacement is open cut excavation with staging operations.

5.4.1 Staged Construction

As noted above, the required depth of excavation will be some 4.0 m. The present platform width at this location is some 14.5 m as can be seen on the cross section on Figure No. 2. As such, staged construction using open cut staged sequencing and a 24/7 operation for traffic control while limiting traffic flow to one lane can be carried out at this location. A minor lowering of the grade will be required (see Figure No. SK-3, Appendix E).

A possible staging plan for a continuous open cut excavation under traffic control, as shown on Figure No. SK-3, Appendix E, is as follows:

- Locally lower the grade at the culvert location some 400 mm.
- Limit traffic to a single lane on the left under 24/7 traffic control.
- Open cut excavate, to the right, and install approximately 14 m of new culvert.
- Reconstruct the embankment on the right, with a minimum platform width of 4 m for traffic.
- Divert the single lane of traffic to the right and continue open excavation to install the remainder of the culvert on the left.

As the width of the platform increases on the right, the traffic can revert to two lanes when sufficient width permits

5.4.2 Protection System

As noted, staged operations with open cut excavations are the preferred method of culvert replacement. However, if an open excavation cannot be carried out, then a temporary protection system can be used to carry out the culvert replacement. The installation of a protection system for use in the culvert replacement operation will require penetration through some 3.4 m of embankment fill. The embankment fill is underlain by compact to dense sands and gravels. Cobbles and small boulders were encountered during drilling, however, the concentration was limited and did not prevent auger advance. As such, it is anticipated that a conventional shoring system consisting of driven sheet piles can be considered for a protection system at this culvert, provided a sheet pile of sufficiently robust section is used.

See Table A, Appendix E, for advantages and disadvantages for the different type of protection system considered for this site. Conceptual shoring locations and sections are illustrated on Figure Nos. SK-4 and SK-5, Appendix E.

Considering the anticipated depth of excavation and provided a sheet pile of sufficiently robust cross section is used, a whaler and raker system may be used to span the width of the culvert, 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):

$R = \sigma z' \, As \, Ls \, \alpha g$ Where:

$\sigma z'$ = effective vertical stress at the midpoint of the load carrying length

As = effective unit surface area of the anchor

Ls = effective embedment length of the anchor

αg = 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.

Considering the cohesionless nature of the embankment fills (granular pavement structure over granular fills) a rectangular apparent pressure distribution over the height of the cut would be appropriate for design of the temporary shoring. The width of the apparent rectangular pressure distribution, over the height of excavation, can be considered equal to 0.65*Ka*γ*H, where:

Ka = active earth pressure,

γ = unit weight, and

H = height of wall above the base of excavation.

The protection system can be designed using the design parameters provided in section 5.5 Lateral Earth Pressures.

The temporary protection system should be designed and constructed to comply with OPSS 539. In consideration of the location of the protection system and traffic volume, a Performance Level 2 is considered appropriate.

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/embedment and backfill materials are as follows:

PARAMETER	GRANULAR A	GRANULAR B TYPE I	SSM/ EXISITING FILL	NATIVE SAND AND GRAVEL	NATIVE SILT
Unit Weight (kN/m^3)	23.0	21.0	20	20.0	17.5
Angle of Internal Friction	34°	31°	30°	30°	28
Coefficient of Active Earth Pressure (Ka)	0.28	0.32	0.33	0.32	0.36
Coefficient of Passive Earth Pressure (Kp)	3.54	3.12	3.00	3.12	2.77
Coefficient of Earth Pressure at Rest (Ko)	0.44	0.48	0.50	0.48	0.53

For rigid structures, such as a precast concrete box culvert, 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, at a minimum, be sloped or shored in accordance with the Occupational Health and Safety Act Regulations for Construction Projects.

The embankment material, above the water table, is considered a Type 3 soil as defined in the Occupational Health and Safety Act and Regulations for Construction Projects. Temporary open excavations above the groundwater table, could be cut back at an angle of 1H:1V, provided they are monitored full time. If temporary open excavations are to be left unattended they should be flattened to a slope of 1.5H:1V. Below the groundwater table, the side slopes will have to be cut back to an angle of 2H:1V, possibly shallower, dependent upon the Contractors' chosen method of controlling the groundwater.

The embankment should be reconstructed using earth fill. Final (permanent) embankment side slopes in earth fills should be established at the standard angle of 2H:1V, or flatter.

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 a dewatered condition during excavation and foundation construction and every reasonable effort must be made to prevent disturbing (piping/boiling) at the founding subgrade. The groundwater level was recorded at elevations 368.3 to 369.0 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.

The water level in the creek was recorded at elevation 369.4 m at the time of this investigation, and excavations to elevation 368.3 m would be required to install the culvert and bedding. As such, a 1.1 m head of water must be controlled during excavation and 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 dewatered 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 excavation, dewatering, and stream flow diversion will be the choice of the contractor; however the importance of maintaining the subgrade in a dewatered stable condition during excavation and foundation construction cannot be stressed enough.

5.7 CONSTRUCTION CONCERNS

Considering the nature of the granular fill embankment and the generally shallow groundwater table, no major construction concerns are anticipated if construction is carried out in general conformance with the above discussion. It is again noted that cobbles and boulder size rock was encountered in the fill at Borehole No. 1 and underlying the embankment fill at Borehole Nos. 3, 4, and 5. The contractor should be prepared to excavate soils containing cobble and boulder size rock.

6 STATEMENT OF LIMITATIONS

The design recommendations given in this geotechnical report are applicable only to the project described in the text and only if constructed substantially in accordance with details of alignment and elevations stated in the report. Since all details of the design may not be known, in our analysis certain assumptions had to be made. The actual conditions may however, vary from those assumed, in which case changes and modifications may be required to our geotechnical recommendations. We recommend, therefore, that we be retained and provided the opportunity during the design stage to review the design drawings, site survey information, proposed elevations, etc. to verify that they are consistent with our recommendations or the assumptions made in our analysis. It is further recommended that we be retained to review the final design drawings and specifications relative to the geotechnical recommendations.

If, during construction, conditions in the field vary from those assumed at the design stage, an engineer from this office must be notified immediately.

Proper subgrade preparation, groundwater control, compaction, etc. are all critical aspects of the bearing capacity of native soils. It must be noted that different aspects of the geotechnical design are based on the assumption that LVM | MERLEX will be retained during site preparation and construction of the proposed works to ensure that both the geotechnical site characteristics and the construction operations/techniques are consistent with our recommendations. Should LVM | MERLEX not be involved during the full construction phase, our liability is strictly limited to the factual information contained herein only.

The comments in this report are intended solely for the guidance of the design engineer and address the geotechnical conditions only. The number of boreholes required to determine the localized conditions between boreholes directly affecting construction costs, equipment, scheduling, etc. would in fact be greater than what has been carried out for design purposes. Therefore, contractors bidding on this project or undertaking this work should make their own interpretations of the factual borehole results and carry out further work as they deem necessary to assess the scope of the project.

Section 5 of this reported is intended for the use of the client and the design team only and is not intended to be included in the tender documents. Inclusion of the factual information (Sections 1 to 5 inclusive) in the tender documents is furnished merely for the general information of bidders and is not in any way warranted or guaranteed by or on behalf of the owner or the owner's consultants and its subconsultants or the consultants' or subconsultants' employees, and neither the owner nor its consultants or its employees shall be liable for any representations negligent or otherwise contained in the documents.

Appendix 1 Key Plan

Drawing No. 1 Key Plan

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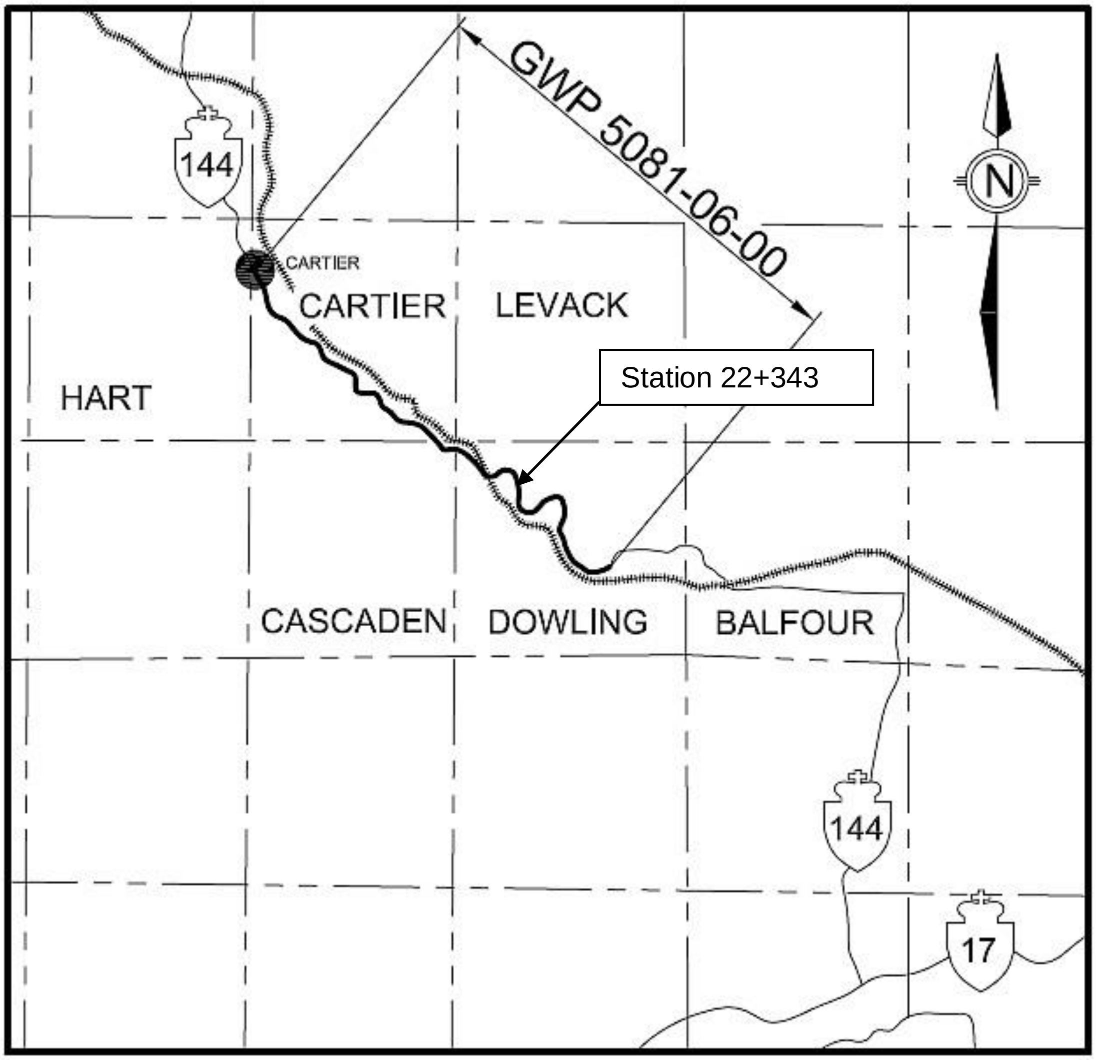
KEY PLAN **Drawing No. 1**

NOT TO SCALE



FINAL
FOUNDATION INVESTIGATION
AND DESIGN REPORT
GWP 5081-06-00

Highway 144 – Station 22+343, TWP of Dowling

From 1.5 km South of Sudbury Municipal Road 8, Northerly 18.1 km To Cartier West Entrance (Center Street)

MEL Ref. No.: 11/11/11209-F2 October 2013

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Appendix 2 Subsurface Data

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

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LIST OF ABBREVIATIONS & 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
NFP No Further Progress
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

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

3. SOIL DESCRIPTION (Cont'd)

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%

Terminology for cobbles and/or boulders frequency is an estimate based on drill response and field observations:

Occasional	Obstructions encountered in borehole, however advance is not severely impeded
Numerous	Obstructions appear essentially continuous over drilled length

5. LABORATORY TESTS

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

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

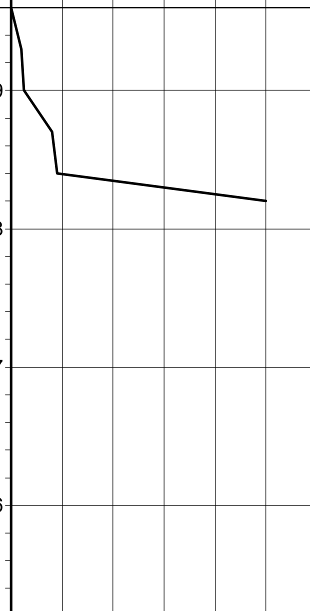
RECORD OF BOREHOLE NO. 1

L|V|M

REFERENCE 11/11/11209-F2	DATUM Geodetic	LOCATION N 5163656.3 E 273381.1 - Dowling Township Station 22+340.5	ORIGINATED BY JL
PROJECT GWP 5081-06-00, Highway 144		BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers	COMPILED BY MCM
CLIENT Triton Engineering Services Limited		DATE (Started) 2012 March 19 / DATE (Completed) 2012 March 19 / TIME (Completed) 2:40:00 PM	CHECKED BY JRB

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	NATURAL MOISTURE CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
369.6	Ground Surface						
0.0	FILL - brown sand and gravel to gravelly sand trace to some silt trace organics ocassional cobbles/boulders (loose/compact)	1	AS		▽	o	
		2	SS	16	▽	o	43 49 (8)
368.2 1.4	DCPT Refusal	3	SS	8		o	29 54 (17)
367.7 1.9	ORGANICS - dark brown silty organics	4	SS	34		o	
367.0 2.6	SAND - grey sand with gravel with silt occasional cobbles/boulders (compact/dense)	5	SS	45	Cave in	o	21 54 (25)
		6	SS	23		o	
365.2 4.4	Auger Refusal End of Borehole						

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; ELEVATION SCALE 369, 368, 367, 366; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³



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 (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1) 12/3/14 2:30:00 PM	0.4	3.3
2) 12/3/22 2:50:00 PM	0.9	-
3)	-	-

MEL-GEO 11209 - AREA 2 - BOREHOL LOGS.GPJ MEL-GEO.GDT 13/10/4

L|V|M
120 Progress Court, North Bay, On P1A 0C2 Phone: (705)476-2550 Fax: (705)476-8882 Email: northbay@lvm.ca

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

METRIC

RECORD OF BOREHOLE NO. 2

L|V|M

REFERENCE 11/11/11209-F2 DATUM Geodetic LOCATION N 5163664.4 E 273406.1 - Dowling Township Station 22+344 ORIGINATED BY JL

PROJECT GWP 5081-06-00, Highway 144 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT

CLIENT Triton Engineering Services Limited DATE (Started) 2012 April 10 DATE (Completed) 2012 April 10 TIME (Completed) 10:45:00 AM CHECKED BY JRB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	Shear strength / DCPT	Water content (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
368.8	Ground Surface							
0.0	Organics - black silty organics	1	AS			Field vane 8	131	
		2	SS	WH	Cave in		227	
367.4 / 367.3 / 1.5	SAND and GRAVEL - sand and gravel occasional cobbles/boulders DCPT Refusal	3	SS	25/0 mm				
		4	SS	25/0 mm				
366.1 / 2.7	SILT - grey silt with sand trace gravel trace clay	5	AS					5 25 63 7
365.8 / 3.0	Auger Refusal End of Borehole							

ELEVATION SCALE: 368, 367, 366

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 W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m^3

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 (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1) 12/4/10 10:45:00 AM	0	1.2
2)	-	-
3)	-	-

MEL-GEO 11209 - AREA 2 - BOREHOL LOGS.GPJ MEL-GEO.GDT 13/10/4

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

METRIC

RECORD OF BOREHOLE NO. 3

LVM

REFERENCE 11/11/11209-F2 DATUM Geodetic

LOCATION N 5163651.1 E 273401.9 - Dowling Township Station 22+333

ORIGINATED BY JL

PROJECT GWP 5081-06-00, Highway 144

BOREHOLE TYPE Truck Mounted CME 45B - Hollow Stem Augers

COMPILED BY AT

CLIENT Triton Engineering Services Limited

DATE (Started) 2012 April 9

DATE (Completed) 2012 April 9

TIME (Completed) 3:35:00 PM

CHECKED BY JRB

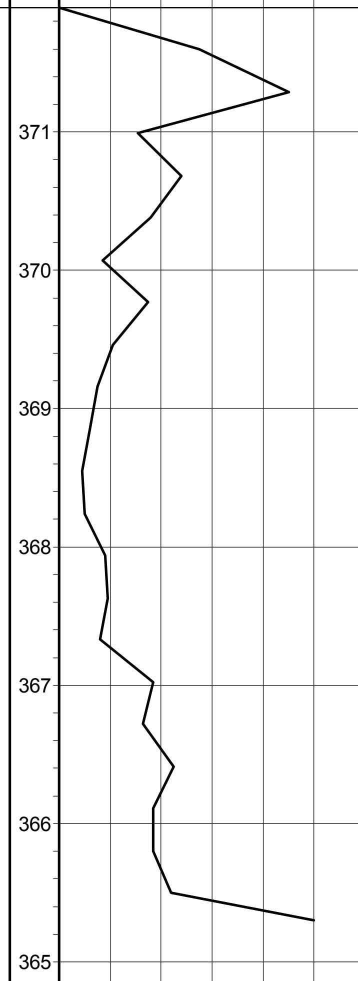
ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	NATURAL MOISTURE CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
371.9	Ground Surface						
0.0	150 mm Asphalt 200 mm Crushed Gravel FILL - brown to grey sand with gravel trace to with silt (dense/very loose)	1	AS			o	
		2	SS	38		o	26 67 (7)
		3	SS	12		o	27 43 28 2
		4	SS	12		o	
		5	SS	2	▽ (water level); cave-in symbol	o	
368.5 3.4	SAND and GRAVEL - grey sand and gravel trace silt trace organics (compact)	6	SS	26		o	47 44 (9)
367.3 4.6	SAND - grey sand some gravel with silt (compact)	7	SS	25		o	17 53 28 2
		8	SS	20		o	
365.3 6.6	DCPT Refusal						
364.8 7.1	Auger Refusal End of Borehole						

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 w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³



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 (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1) 12/4/9 3:30:00 PM	3	3.4
2)	-	-
3)	-	-

MEL-GEO 11209 - AREA 2 - BOREHOL LOGS.GPJ MEL-GEO.GDT 13/10/4

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

RECORD OF BOREHOLE NO. 4

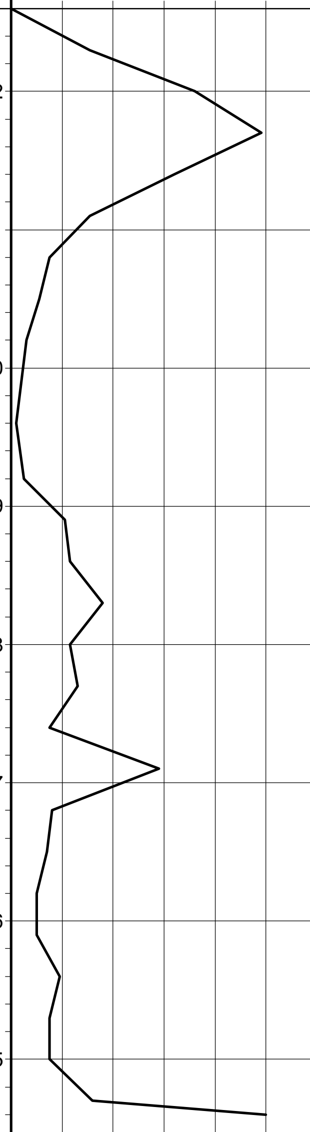
METRIC

LVM

REFERENCE	11/11/11209-F2
DATUM	Geodetic
LOCATION	N 5163670.2 E 273396.1 - Dowling Township Station 22.353
ORIGINATED BY	JL
PROJECT	GWP 5081-06-00, Highway 144
BOREHOLE TYPE	Truck Mounted CME 45B - Hollow Stem Augers
COMPILED BY	AT
CLIENT	Triton Engineering Services Limited
DATE (Started)	2012 April 10
DATE (Completed)	2012 April 10
TIME (Completed)	3:45:00 PM
CHECKED BY	JRB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
372.6	Ground Surface					
0.0	150 mm Asphalt 200 mm Crushed Gravel FILL - brown sand trace silt trace gravel to sand and silt trace silt (very loose/dense)	1	AS		○	
		2	SS	48	○	
		3	SS	19	○	1 51 45 3
		4	SS	6	○	
		5	SS	2	○	3 92 (5)
369.2 3.4	SAND AND GRAVEL - grey sand and gravel to gravelly sand trace gravel occasional cobbles/boulders (compact/dense)	6	SS	17	○	
		7	SS	37	○	37 54 (9)
366.8 5.8	SILT - grey silt some sand trace clay (compact/dense)	8	SS	24	○	0 15 78 7
		9	SS	43	○	
364.6 8.0	DCPT Refusal					
364.4 8.2	Auger Refusal End of Borehole					

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRATA PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (372, 371, 370, 369, 368, 367, 366, 365); 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 w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) (20 40 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL).



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 (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1)	12/4/10 3:40:00 PM	4.3	4.7
2)		-	-
3)		-	-

MEL-GEO 11209 - AREA 2 - BOREHOL LOGS.GPJ MEL-GEO.GDT 13/10/4

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

METRIC

RECORD OF BOREHOLE NO. 5

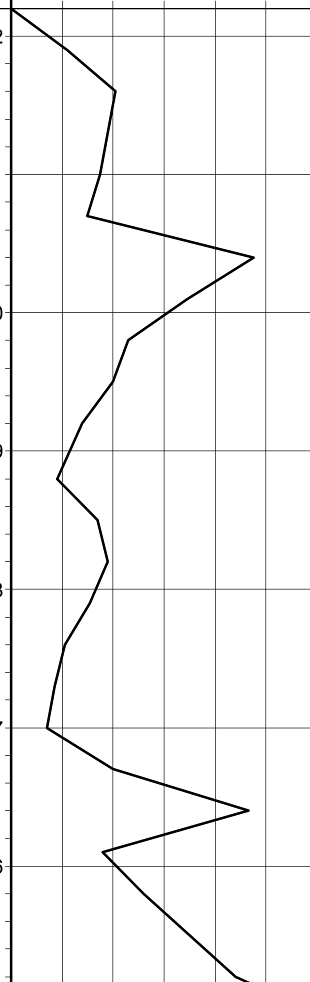
LVM

REFERENCE 11/11/11209-F2	DATUM Geodetic	LOCATION N 5163656.3 E273389.8 - Dowling Township Station 22+341.5	ORIGINATED BY JL
PROJECT GWP 5081-06-00, Highway 144		BOREHOLE TYPE Truck Mounted CME 45B - Hollow Stem Augers	COMPILED BY AT
CLIENT Triton Engineering Services Limited		DATE (Started) 2012 April 11 / DATE (Completed) 2012 April 11 / TIME (Completed) 11:42:00 AM	CHECKED BY JRB

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
372.2	Ground Surface					
0.0	150 mm Asphalt 175 mm Crushed Gravel FILL - brown sand some to with gravel some silt (very loose/compact)	1	AS		○	
		2	SS	18	○	23 62 (15)
		3	SS	24	○	
		4	SS	3	○	
		5	SS	8	○	
368.8 3.4	SAND and GRAVEL - grey sand and gravel trace silt occasional cobbles/boulders	6	SS	50/125 mm	○	
367.9 4.3	SAND - grey sand some silt some gravel (compact)	7	SS	15	○	16 68 (16)
366.1 6.1	SILT - grey silt some sand trace gravel (compact)	8	SS	15	○	
365.1 7.1	Auger Refusal DCPT Refusal End of Borehole					

Groundwater level recorded at approx. elevation 369.0 (3.2 m depth).

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); ELEVATION SCALE 372 to 366



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 (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1) 12/4/11 11:36:00 AM	3.2	3.2
2)	-	-
3)	-	-

MEL-GEO 11209 - AREA 2 - BOREHOL LOGS.GPJ MEL-GEO.GDT 13/10/4

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120 Progress Court, North Bay, On P1A 0C2 Phone: (705)476-2550 Fax: (705)476-8882 Email: northbay@lvm.ca

Appendix 3 Lab Data

Drawing No. 2: Borehole Location and Soil Strata
Figure Nos. L-1 to L-5: Grain Size Distribution Curves
Figure No. L-6: Lab Test Summary Sheet

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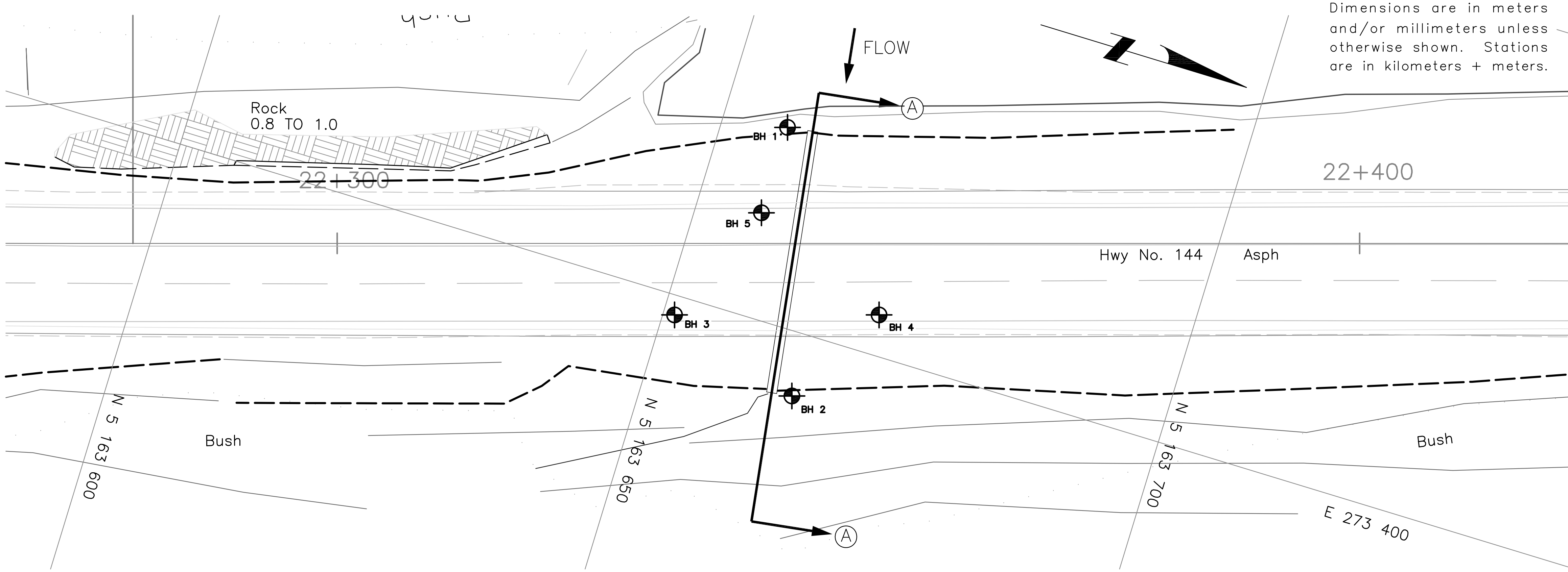
METRIC
Dimensions are in meters and/or millimeters unless otherwise shown. Stations are in kilometers + meters.

CONT No
GWP No 5081-06-00

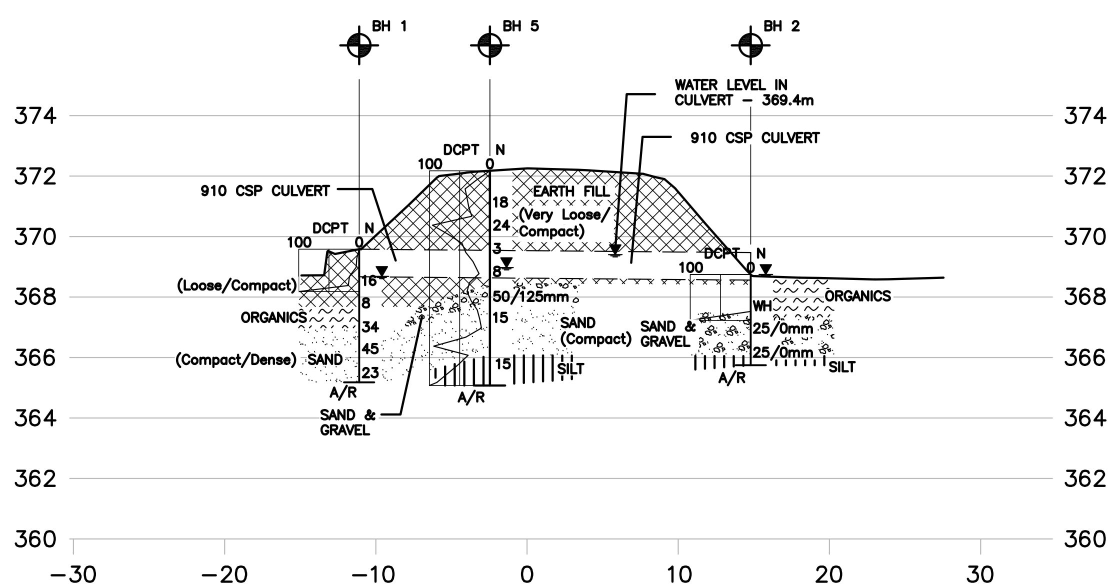
HWY NO. 144 – Township of Dowling
Culvert at Station 22+343
BOREHOLE LOCATIONS & SOIL STRATA

Drawing 2

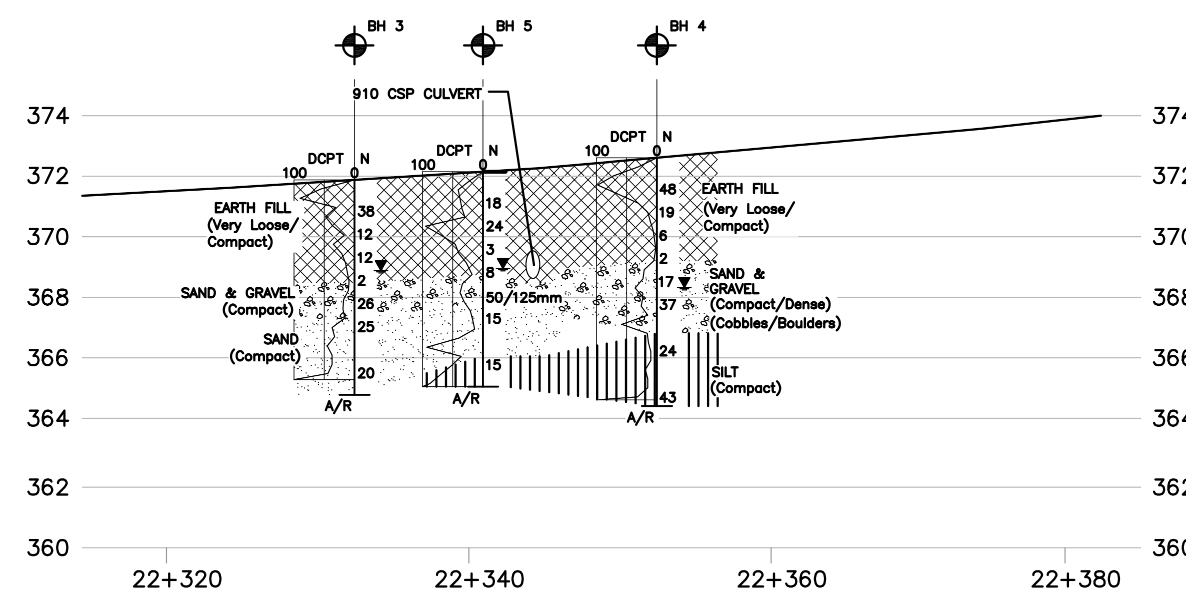
LVM | MERLEX



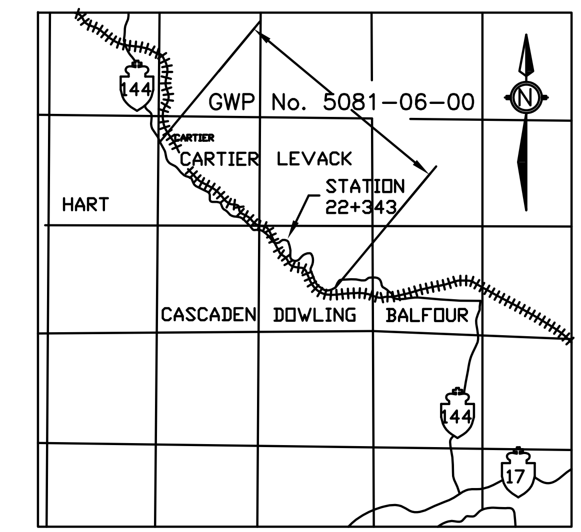
PLAN
SCALE
5m 5m



SECTION AT CULVERT (A) – (A)
SCALE
5m 5m HOR
2.5m 2.5m VER



℄ PROFILE
SCALE
5m 5m HOR
2.5m 2.5m VER



KEY PLAN – NOT TO SCALE

LEGEND

- Borehole
- Dynamic Cone Penetration Test (DCPT)
- Borehole and DCPT
- 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	Co-ordinates Northerly	Co-ordinates Easterly
Borehole No. 1	369.6	11.4m Lt	5163656.3	273381.1
Borehole No. 2	368.8	14.9m Rt	5163664.4	273406.1
Borehole No. 3	371.9	7.0m Rt	5163651.1	273401.9
Borehole No. 4	372.6	7.0m Rt	5163670.2	273396.1
Borehole No. 5	372.2	3.0m Lt	5163656.3	273389.8

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.

This drawing is for subsurface information only. Surface details and features are for conceptual illustration. The proposed structure location is shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

REVISIONS

DATE	BY	DESCRIPTION
Dec 2012	MCM	DRAFT
Oct 2013	RG	FINAL

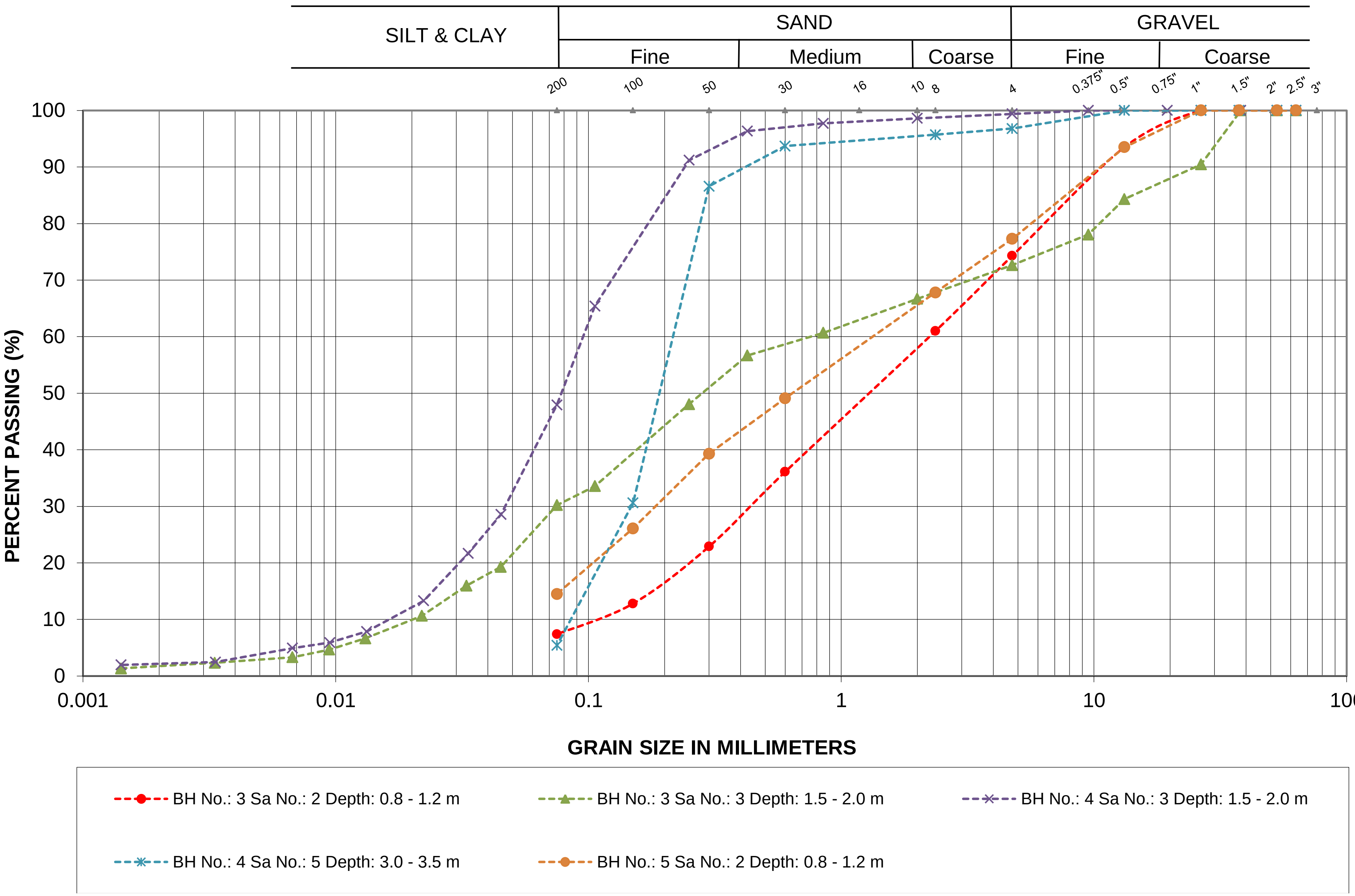
HWY No. 144 – Dowling Twp – Culvert at Station 22+343

SUBM'D	REF 11209-F2	GEOCRES 41I-298	SITE
DRAWN MCM	CHK MAM	DATE Aug 2012	FIG 2

Reference No.: 11/11/11209-F2
Date: October 2013

LVM | MERLEX

GRAIN SIZE ANALYSIS



G.W.P.: 5081-06-00
LOCATION: Hwy 144

EMBANKMENT FILL
Sand with Gravel trace to with SILT

Reference No.: 11/11/11209-F2
Date: October 2013

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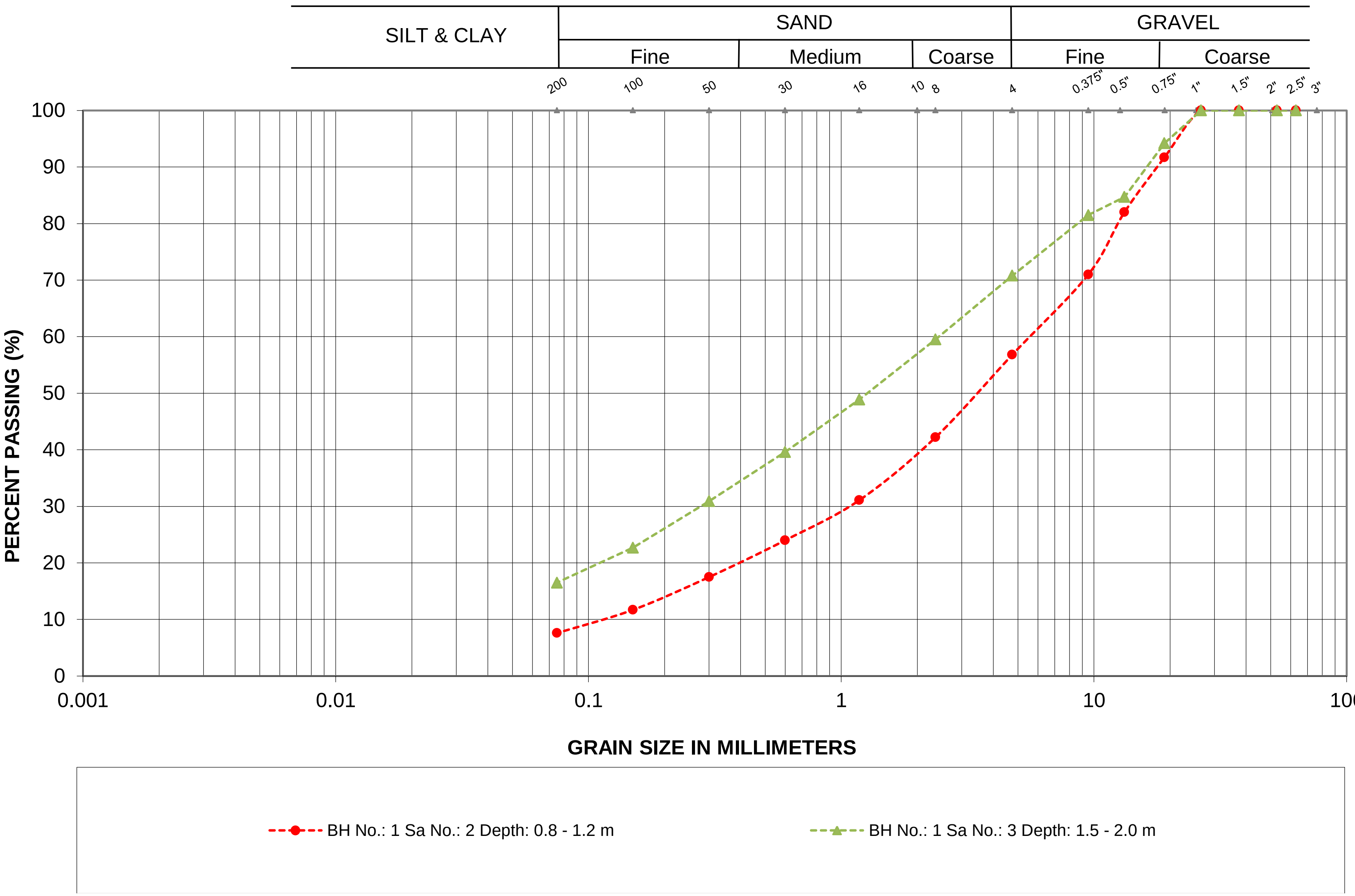
GRAIN SIZE ANALYSIS



G.W.P.: 5081-06-00
LOCATION: Hwy 144

FILL
Sand and Gravel - Gravelly Sand

Reference No.: 11/11/11209-F2
Date: October 2013

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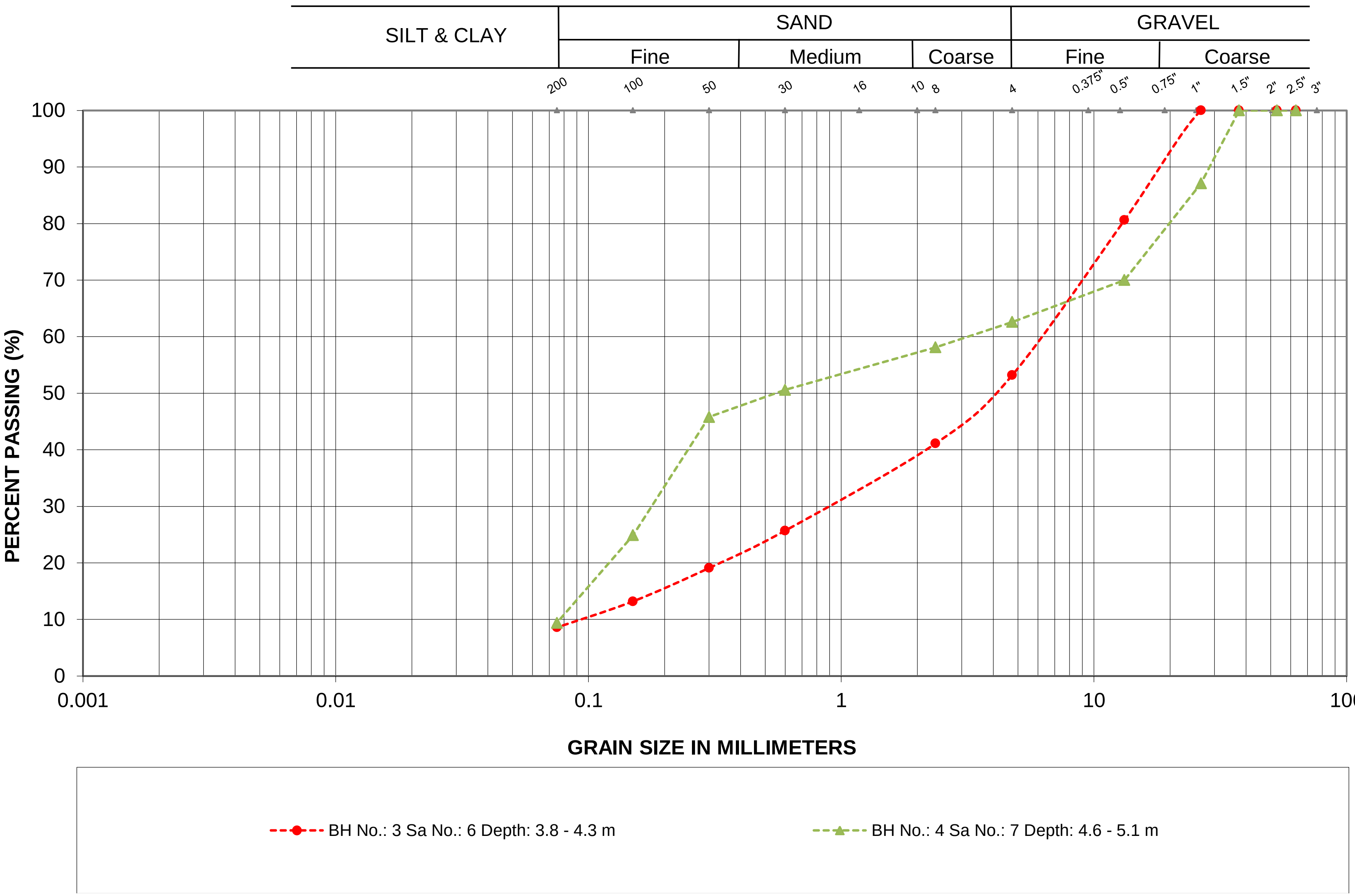
GRAIN SIZE ANALYSIS



G.W.P.: 5081-06-00
LOCATION: Hwy 144

SAND AND GRAVEL

Reference No.: 11/11/11209-F2
Date: October 2013

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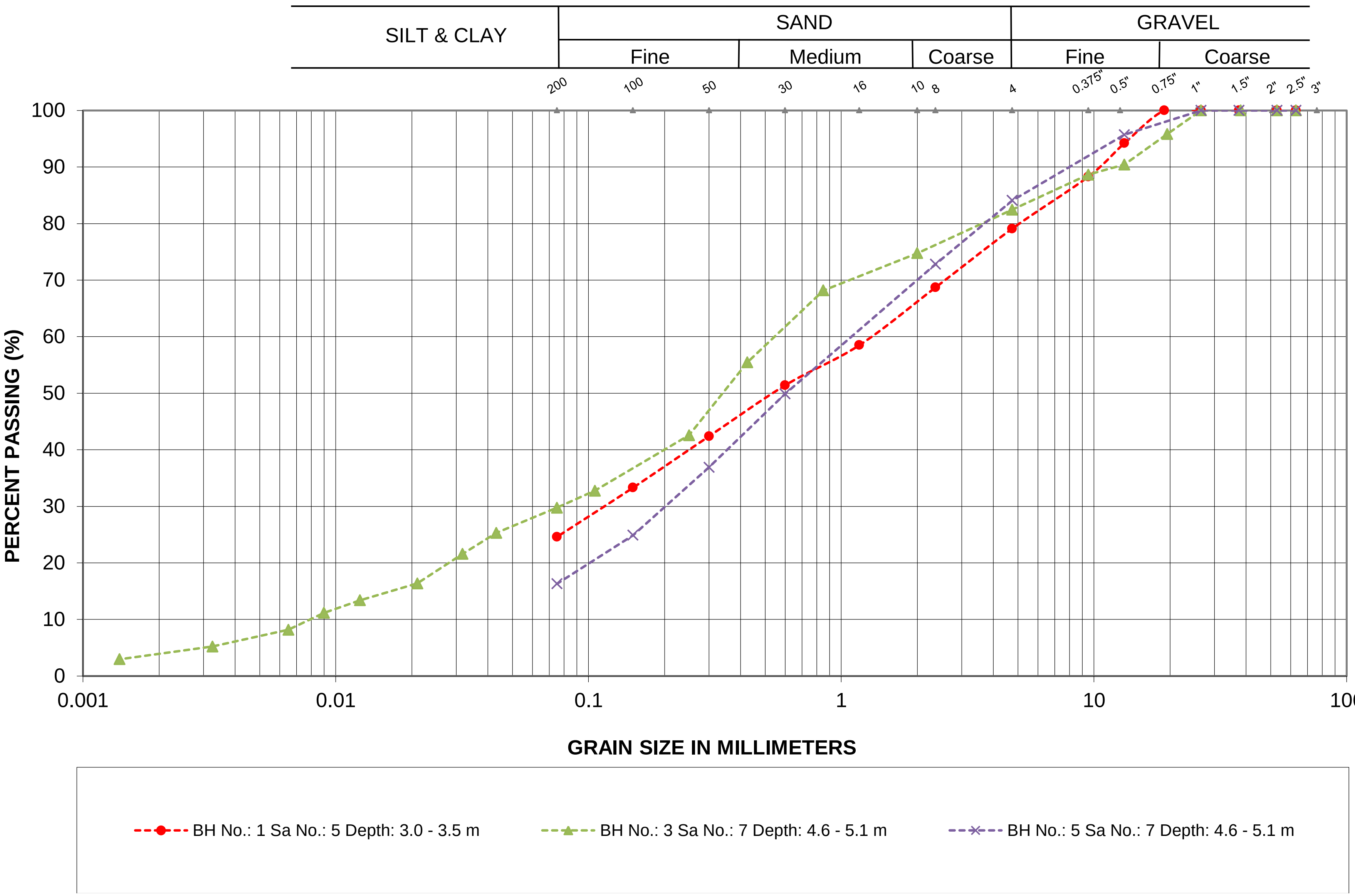
GRAIN SIZE ANALYSIS



G.W.P.: 5081-06-00
LOCATION: Hwy 144

SAND

Reference No.: 11/11/11209-F2
Date: October 2013

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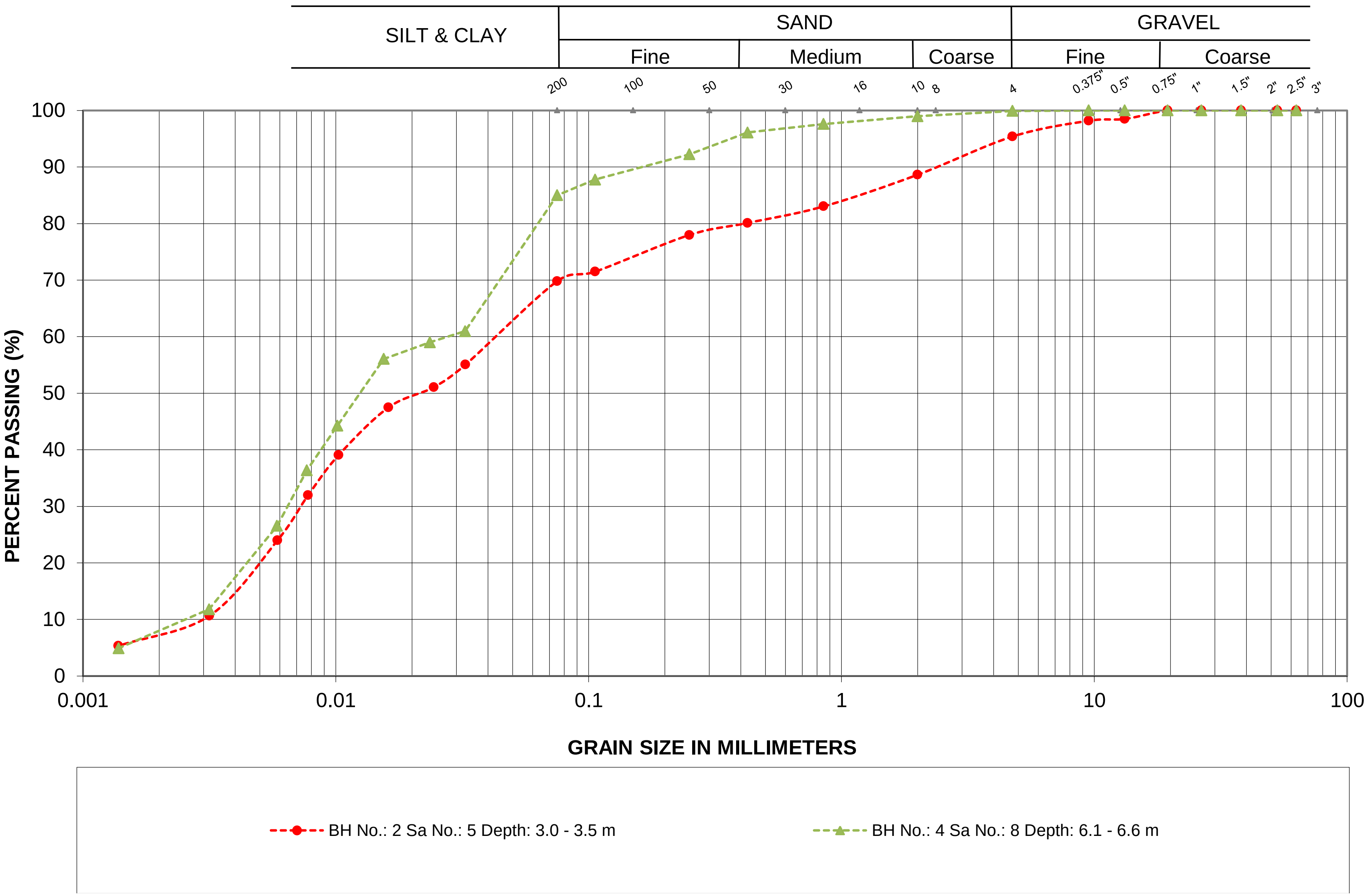
GRAIN SIZE ANALYSIS



G.W.P.: 5081-06-00
LOCATION: Hwy 144

SILT

Reference No.: 11/11/11209-F2
Date: October 2013

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Laboratory Tests - Summary Sheet

Borehole No.	Sample No.	Depth	Grain Size Analysis				NMC	Atterberg Limits			SPT 'N'	USCS	Unit Weight (kN/m3)	Remarks
			Gravel Size (%)	Sand Size (%)	Silt Size (%)	Clay Size (%)		LL (%)	PL (%)	IP (%)				
1	1	0.0					15.9				N/A			
	2	0.8	43	49	8		12.6				16			
	3	1.5	29	54	17		20.0				8			
	4a	2.3					77.5				34			
	4b	2.5					10.8				34			
	5	3.0	21	54	25		12.7				45			
	6	3.8					9.1				23			
2	1	0.0					131.0				N/A			
	2	0.8					227.0				WH			
	3	1.5									25/0 mm			
	4	2.3									25/0 mm			
	5	3.0	5	25	63	7	20.7							
3	1	0.0					3.0				N/A			
	2	0.8	26	67	7		2.8				38			
	3	1.5	27	43	28	2	11.4				12			
	4	2.3					5.1				12			
	5	3.1					14.7				2			
	6	3.8	47	44	9		19.5				26			
	7	4.6	17	53	28	2	18.0				25			
	8	6.1					10.3				20			
4	1	0.0					2.7				N/A			
	2	0.8					3.2				48			
	3	1.5	1	51	45	3	12.8				19			
	4	2.29					6.2				6			
	5	3.05	3	92	5		12.3				2			
	6	3.8					10.9				17			
	7	4.6					12.7				37			

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Laboratory Tests - Summary Sheet

Borehole No.	Sample No.	Depth	Grain Size Analysis: Gravel Size (%)	Grain Size Analysis: Sand Size (%)	Grain Size Analysis: Silt Size (%)	Grain Size Analysis: Clay Size (%)	NMC	Atterberg Limits: LL (%)	Atterberg Limits: PL (%)	Atterberg Limits: IP (%)	SPT 'N'	USCS	Unit Weight (kN/m3)	Remarks
4	8	6.1	0	15	78	7	29.8				24			
	9	7.6					16.4				43			
5	1	0.0					4.5				N/A			
	2	0.8	23	62	15		6.2				18			
	3	1.5					5.8				24			
	4	2.3					5.1				3			
	5	3.1					5.2				8			
	6	3.8					11.5				50/125 mm			
	7	4.6	16	68	16		11.6				15			
	8	6.1					14.4				15			

Appendix 4 Photo Essay

Enclosure No. 7: Photo Essay

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Existing Embankment, Left (West) Side - Looking North	Photo: 1

Culvert Inlet – Looking North	Photo: 2

Project: Hwy 144 – Station 22+343, Twp of Dowling	Photos Provided By: LVM Date: March 2012

Existing Embankment, Right (East) Side - Looking South	Photo: 3

Culvert Outlet – Looking South	Photo: 4

Project: Hwy 144 – Station 22+343, Twp of Dowling	Photos Provided By: LVM Date: March 2012

View Through Culvert – Looking East	Photo: 5
	
Project: Hwy 144 – Station 22+343, Twp of Dowling	Photos Provided By: LVM Date: March 2012

Appendix 5 Design Data

Figure No. S-1:	Slope Stability
Table A:	Comparison on Shoring Alternatives
Sketch SK-3	Conceptual Staging Operations
Sketch SK-4	Conceptual Shoring Locations
Sketch SK-5	Conceptual Shored Excavation

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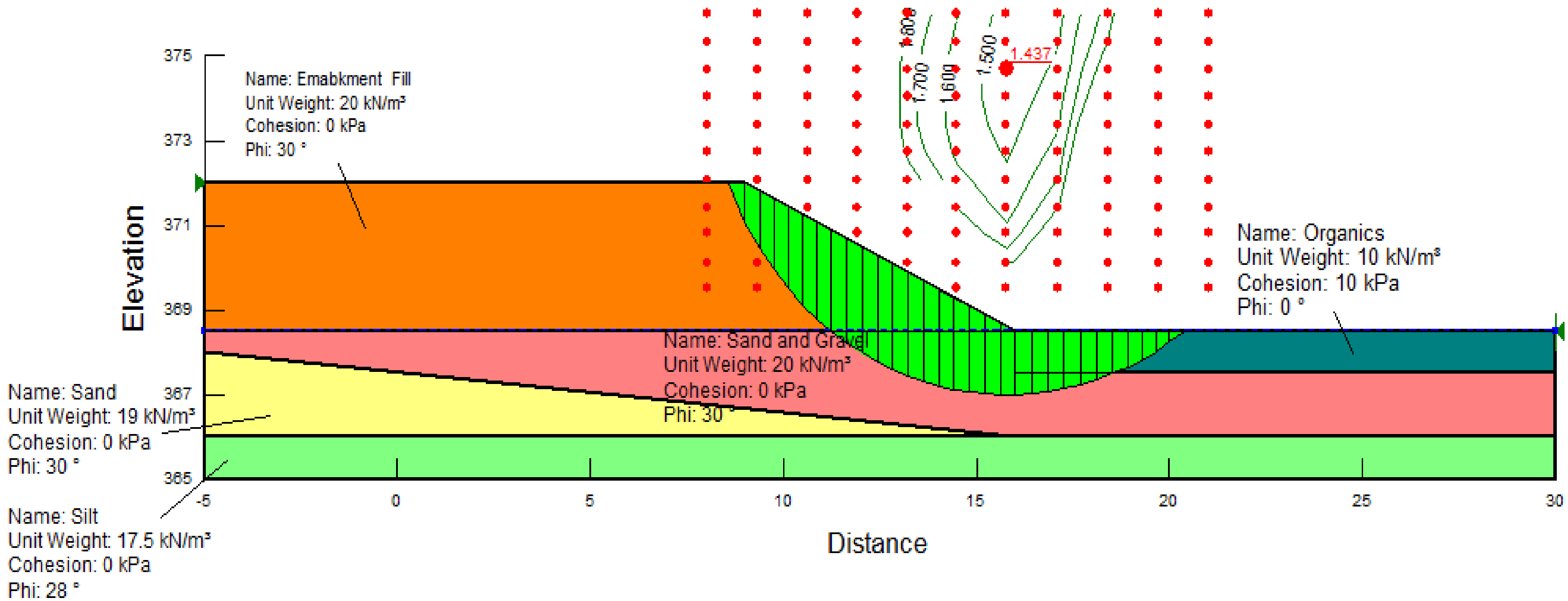
Stability Analysis
Embankment Stability
Long Term Stability
Failure of Native Material
2H:1V Slopes



Stability Analysis
Station 22+343
TWP of Dowling

Table A – Comparison of Shoring Alternatives

Method	Depth Range (m)	Advantages	Disadvantages	Remarks	Estimated Costs
Wood Sheeting	1.5 – 5	-Low cost, -Easily installed in good ground conditions	-Limited by soil conditions, -Limited depth of installation, -Low strength, -discontinuous	Considered for protection system at this site	$ 650/m^2
Steel Sheet Piles	5 – 21	-High strength, continuous, -Readily available	-Limited by soil conditions (i.e. obstructions)	Recommended for protection system at this site	$ 650/m^2
Pre-cast concrete panels	3 – 10	-Durable -Assists in minimizing seepage	-Limited depths -Can be damaged during installation -Limited by soil conditions (i.e. obstructions)	Not considered due to ground conditions and higher cost	
Soldier piles	5 – 25	-Easy installation -Readily available -Adaptable to various ground conditions	-Pre-drilling may be required -Possible ground loss	Not considered due to soil conditions and higher cost	$ 725/m^2 Predrilling $ 1,500/m^2
Tangent/ Secant/ Staggered Drilled Piles	10 – 18	-Readily available -Adaptable to various ground conditions	-Possible ground loss and/or seepage -Poor alignment tolerance	Considered for excavations requiring a protection system at this site	
Concrete Diaphragm	10 – 30	-High Strength -Durable -Can be permanent	-High cost -Requires specialized equipment/control	Not Considered due to ground conditions and higher costs	
Micropiles with reinforced shotcrete face		-Can be installed in various ground conditions -High strength -Good tolerance	-High Cost -Requires specialized equipment	Not considered due to soil conditions and higher cost	$ 1,200 – 1,500/m^2

REF.: 11/11/11209-F2

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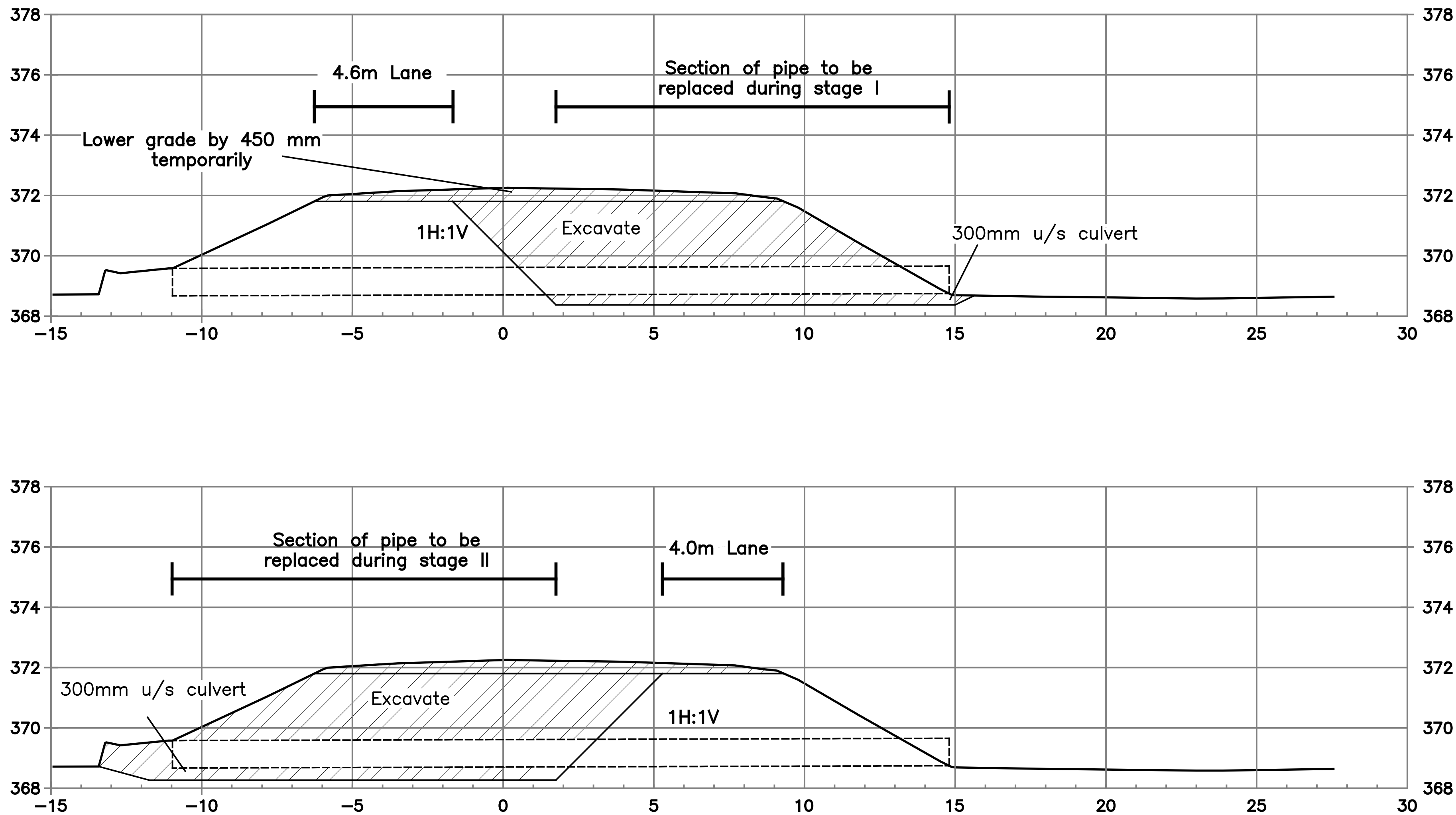
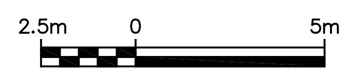


METRIC

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



HWY 144 - Township of Dowling Culvert at Station 22+343 Possible Staging - Typical Sections	FIGURE SK-3

REF.: 11209-F2

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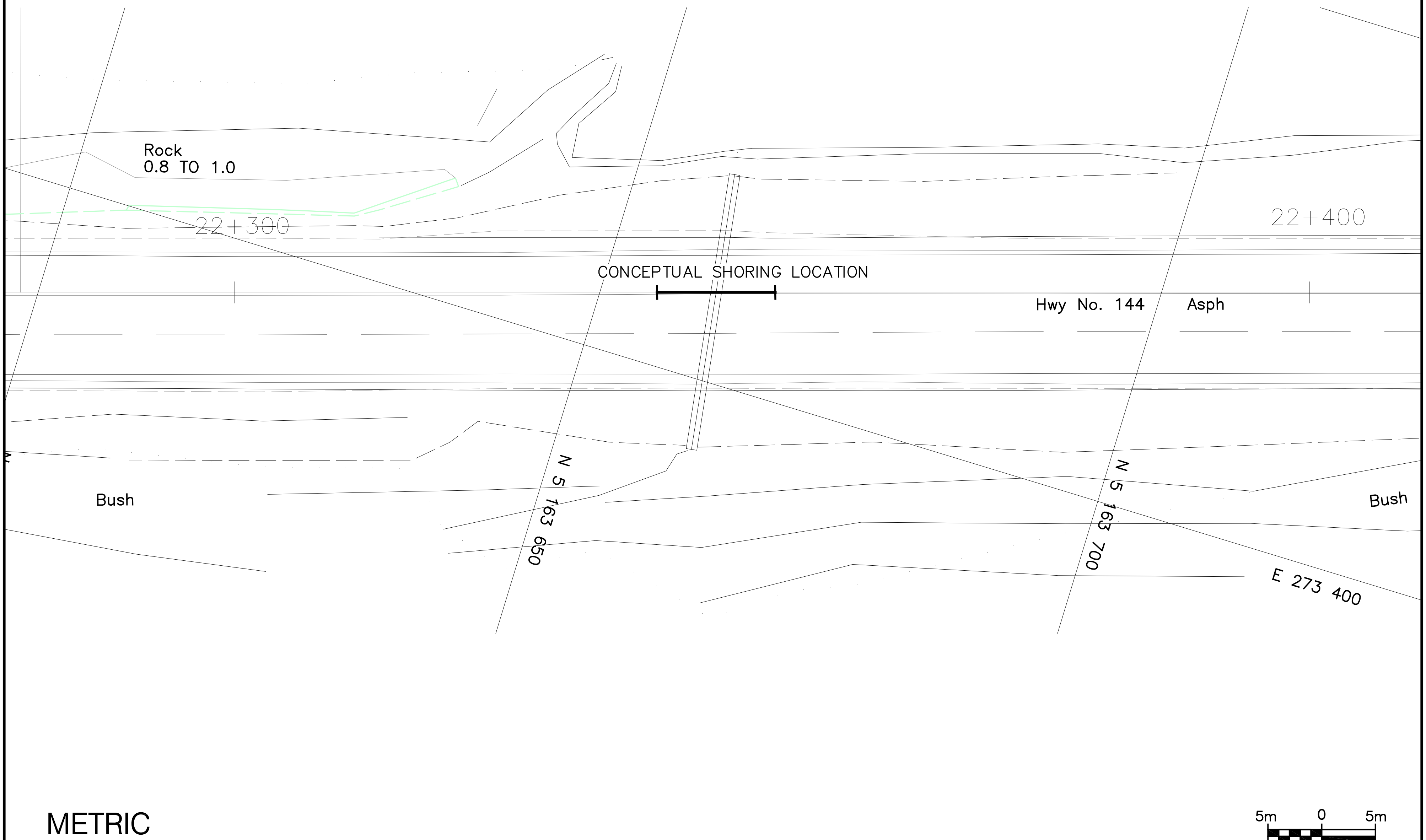

METRIC

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

HWY 144 - Township of Dowling - Culvert at 22+343 Conceptual Shoring Location	FIGURE SK-4

REF: 11/11/11209-F2

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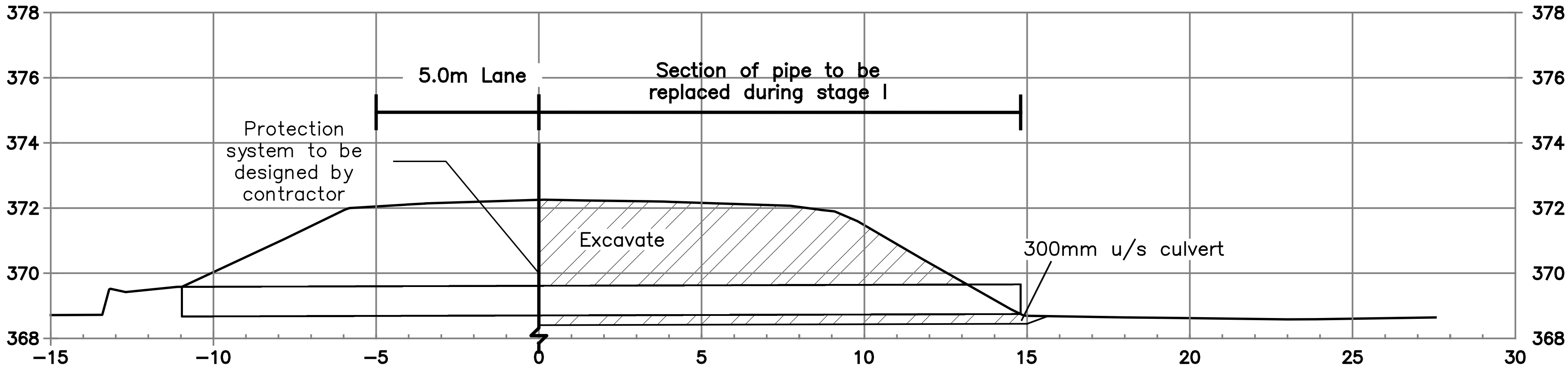

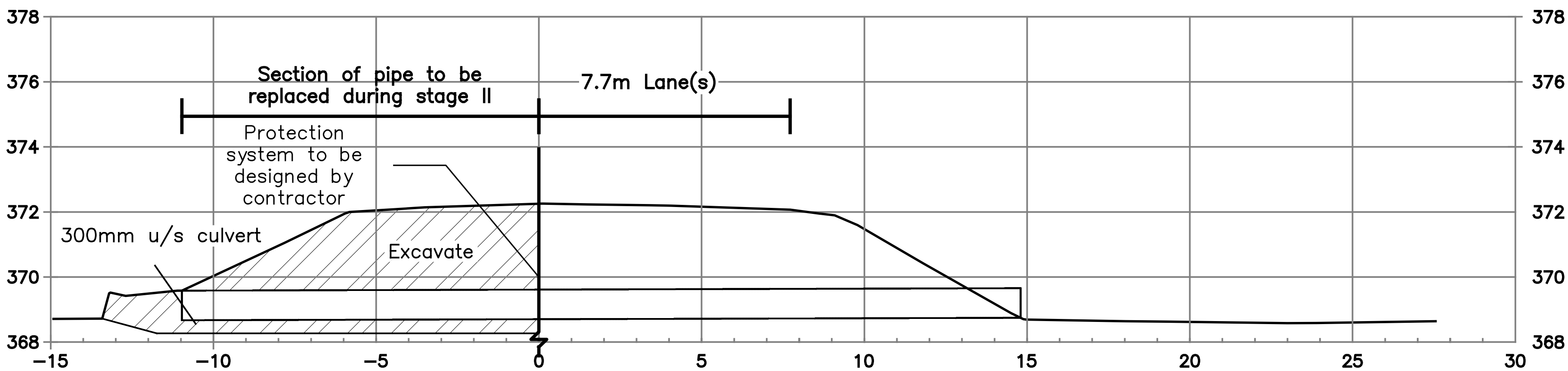

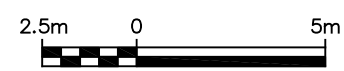

METRIC

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

HWY 144- Township of Dowling- Culvert at Station 22+343 Conceptual Roadway Protection	FIGURE SK-5