

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

**Culvert Replacement – Site No. 46-374
Station 14+722 – Twp. of Dowling
GWP 5081-06-00**

**Highway 144 From 1.5 km South of Sudbury Municipal Road 8, Northerly 18.1
km to Cartier West Entrance (Centre Street)**

FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

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LVM | MERLEX

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FINAL Foundation Investigation and Design Report

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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 existing twin culverts and design of a protection system. This culvert replacement is located on Highway 144, at Station 14+722, (some 350 m South of New Cobden Road), 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 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 these twin Structural Plate Corrugated Steel Pipe Arch (SPCSPA) culverts is located at Station 14+722, Township of Dowling (Site No. 46-374). The topography at the site is a low wet land area with flooded organic terrain to the left (south) and right (north) 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 3.6 m in height above the native subgrade, with centerline elevation of 272.0 m at the location of the twin culverts. The culverts at this location are twin 1.07x2.0 m SPCSPA culverts, 25.9 m in length. These dimensions could not be verified in the field since both culvert ends were essentially buried at the time of the investigation. Flow through the culvert would be from left (south) to right (north), based on culvert inverts, however the hydrology study has indicated that the flow is from right (north) to left (south). The left (south) end of the culverts was blocked with backfill, at the time of this investigation, as such there was no flow through the culverts (see Photo Essay, Appendix 4).

Infrastructure at the location of the twin culverts consists of overhead power and communication wires on the right (north) side 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 of the location of this culvert foundation investigation, as indicated on OGS Map 2506, comprises of Middle Precambrian Era sandstone, shale, argillite, iron formation, tuff, basalt, and limestone.

3 INVESTIGATION PROCEDURES

The field work for this investigation was carried out during the period of March 8th to 21st, during which 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 culverts, and one borehole was advanced at the inlet end and one at the outlet end 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 both a Bombardier track mounted CME and a truck mounted CME drilling rigs 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 specific gravity testing. 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-4).

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 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 14+722, 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 opposite 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 269.7, 269.9, 272.1, 271.6, and 272.2 m, respectively.

4.1.1 Surficial Layers

At existing grade at Borehole Nos. 1 and 2, a layer of snow 300 to 500 mm in thickness was encountered at the time of this investigation. At Borehole Nos. 3, 4, and 5, a pavement structure consisting of a layer of asphalt some 50 mm thick was penetrated, underlain by a layer of crushed gravel some 125 to 150 mm thick.

4.1.2 Embankment Fill

Underlying the pavement structure at Borehole Nos. 3, 4, and 5, and below the snow cover at Borehole No. 2, a deposit of granular fill consisting of brown sand some to with gravel trace to some silt was penetrated. The natural moisture content measured on samples from this deposit was in the order of 2 to 22%. Gradation analyses were carried out on seven (7) samples of this deposit, the results of which indicated 13 to 41% gravel size particles, 54 to 76% 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 45 blows per 300 mm penetration, the compactness of this deposit was described as very loose to dense, generally compact. This deposit was encountered to depths of 1.7, 3.8, 2.9, and 3.2 m below grade at Borehole Nos. 2, 3, 4, and 5, respectively (elevations 268.2, 268.3, 268.7, and 269.0 m, respectively).

4.1.3 Silty Sand

Underlying the fill at Borehole No. 2, a deposit of grey silty sand was penetrated. The natural moisture content measured on a sample of this deposit was in the order of 17%. Based on SPT 'N' values of 4 blows per 300 mm penetration, the compactness of this deposit was described as loose. This deposit was encountered to a depth of 2.1 m below grade (elevation 267.8 m).

4.1.4 Peat

At existing grade at Borehole No. 1, and underlying the embankment fill at Boreholes Nos. 4 and 5, a deposit of dark brown silty peat trace fine fibres and inclusions was penetrated. A thin layer of the brown silty organics, some 150 mm thick, was encountered at the lower interface of the fill at Borehole No. 3. The natural moisture content measured on samples of this deposit was in the order of 54 to 87%. This deposit was encountered to depths of 2.0, 3.5, and 4.1 m below grade at Borehole Nos. 1, 4 and 5, respectively (elevations 267.7, 268.1, and 268.1 m, respectively).

4.1.5 Sand and Gravel

Underlying the silty organics at Borehole Nos. 1, 3, 4, and 5, and underlying the silty sand at Borehole No. 2, a deposit of grey sand and gravel trace silt to sand some to with gravel trace to some silt was penetrated. The natural moisture content measured on samples of this deposit was in the order of 8 to 24%. Gradation analyses were carried out on four (4) samples of this deposit, the results of which indicated 15 to 51% gravel size particles, 42 to 81% sand size particles, and 4 to 17% silt and clay size particles (Figure No. L-2, Appendix 3). Based on SPT 'N' values of 20 to 74 blows per 300 mm penetration, the compactness of this deposit was described as compact to very dense, generally dense. This deposit was encountered to depths of 3.5, 3.7, 5.8, 5.2, and 6.1 m below grade at Borehole Nos. 1 to 5, respectively (elevations 266.2, 266.2, 266.3, 266.4, and 266.1 m, respectively).

4.1.6 Sand

Underlying the sand and gravel deposit at each borehole location, a deposit of grey sand trace to some silt trace gravel was penetrated. The natural moisture content measured on samples of this deposit was in the order of 18 to 28%. Gradation analyses were carried out on five (5) samples of this deposit, the results of which indicated 0 to 2% gravel size particles, 79 to 98% sand size particles, and 2 to 19% silt and clay size particles (Figure No. L-3, Appendix 3). Based on SPT 'N' values of 7 to 27 blows per 300 mm penetration, the compactness of this deposit was described as loose to compact. This deposit was encountered to depths of 10.1, 8.5, and 8.8 m below grade at Borehole Nos. 3, 4, and 5, respectively (elevations 262.0, 263.1,

and 263.4 m, respectively). Sampling was terminated in this deposit at depths of 9.6 m below grade at Borehole Nos. 1 and 2. (elevations 260.1 and 260.3 m, respectively).

4.1.7 Silty Sand

Underlying the sand deposit at Borehole Nos. 3, 4, and 5, a deposit of grey silty sand was penetrated. The natural moisture content measured on samples of this deposit was in the order of 21 to 25%. A gradation analysis was carried out on one (1) sample of this deposit, the results of which indicated 0% gravel size particles, 59% sand size particles, 39% silt size particles, and 2% clay size particles (Figure No. L-4, Appendix 3). Based on SPT 'N' values of 9 to 16 blows per 300 mm penetration, the compactness of this deposit was described as loose to compact. Sampling was terminated in this deposit at depths of 11.1 m below grade at Borehole Nos. 3 to 5 (elevations 261.0, 260.5, and 261.1 m, respectively).

4.1.8 DCPT

DCPTs were advanced from surface at each borehole. DCPT refusal was encountered at depths of 17.4, 17.1, 18.9, 20.8, and 19.2 m below grade at Borehole Nos. 1 to 5, respectively (elevations 252.3, 252.8, 253.2, 250.8, and 253.0 m, respectively).

4.2 GROUNDWATER DATA

The water level at the culvert inlet was measured at an elevation of 269.9 m, at the time of this investigation. The left (south) ditch had been backfilled with sand fill which plugged the culvert to within some 150 mm of the obvert (see Photos 4 and 5, Appendix 4). There was no flow through the culvert 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). The water levels in the boreholes were measured at elevations of 269.3 to 270.3 m upon completion.

The groundwater and river water levels will fluctuate seasonally.

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

A foundation investigation was carried for the proposed replacement of existing twin culverts and for a protection system, as identified in the RFP. These culverts have been identified as twin 1.07x2.0 m SPCSPA culverts in the RFP and are identified as Site No. 46-374, at Station 14+722 in the Township of Dowling. In general, pipe arch culverts have a greater span than rise, as such, it is likely that these culverts are actually 2.0x1.07 m SPCSPA culverts.

The existing highway, at the culvert locations, is constructed on a fill embankment some 3.6 m in height above the native subgrade, with centerline elevation of 272.0 m at the location of the twin culverts. The culvert inverts are some 3.1 m below top of exiting platform (elevation 268.9 m), based on survey plans. The existing highway embankment currently supports three undivided lanes of highway, two running in the north direction and one running in the south direction. Flow through the culvert would be from left (south) to right (north), based on culvert inverts, however the hydrology study has indicated that the flow is from right (north) to left (south). The south (left) end of both culverts was buried at the time of this investigation, and it appears that the culverts are in fair to poor condition (see Photo Essay, Appendix 4). Based on data from this foundation investigation, the embankment supporting the existing pavement structure at this site has been constructed using granular fill. The native material underlying the fill generally consisted of compact to dense sands with gravel underlain by compact sands underlain by silty sands with refusal varying between elevations 250.8 and 253.0 m, at the borehole locations.

The type of culvert(s) that will replace the existing twin culverts is currently unknown. However, it is currently understood that a precast concrete rigid frame box (RFB) culvert some 3000 by 1500 mm, with invert at an approximate elevation of 268.7 m is being considered for this site. The new culvert will likely be constructed at a similar alignment and skew as the existing culverts. It is further understood that the culvert ends will be extended by some 1 m at both ends.

5.2 FOUNDATION CONSIDERATIONS

Based on the results of this investigation, the native soils underlying the embankment consist of compact to dense sands. The founding sands present below the existing embankment are considered adequate for support of a culvert and for a conventional highway embankment of this height. Geotechnical resistance should not be an issue provided the natural bearing surface is not excessively disturbed during construction, and groundwater is controlled during construction, as discussed in Section 5.6.

In consideration of a concrete box culvert 3000 by 1500 mm, and based on the characteristics of the native sand subgrade present below the proposed culvert, the response of the existing embankment, and a founding elevation similar to that of the existing culverts, a factored Geotechnical Resistance at ULS of 450 kPa can be used for a closed culvert (i.e. precast

concrete rigid frame box culvert with invert at approximately 268.7 m). In consideration of the width of the culvert and the depth of overburden, a geotechnical reaction at SLS of 175 kPa can be used for design, in consideration of 25 mm settlement.

If an open rigid frame culvert (i.e. concrete frame open culvert, with 1 m wide strip footings) is considered, then a factored Geotechnical Resistance at ULS of 150 kPa, and a geotechnical reaction at SLS of 100 kPa would apply for design, taking into consideration the limited depth of overburden, on the interior, and smaller footing width.

A layer of dark brown silty peat was encountered at Borehole No. 1, from surface to elevation 267.7 m. A layer of peat some 0.6 to 0.9 m thick was also encountered underlying the embankment fill, to elevation 268.1 m, at Borehole Nos. 4 and 5. This indicates that some compressible peat/organics are present below the existing embankment and could possibly be present below the culverts (invert 268.9 m). If this stratum is present below the alignment of the new culvert, it must be removed and replaced with engineered fill. Engineered fill can consist of Granular A material, placed in 300 mm lifts and compacted to 100 % Standard Proctor Dry Density. This layer of engineered fill, below the culvert foundation, must extend beyond the sides of the culvert a distance equal to the thickness of the engineered fill layer.

5.2.1 Slope Stability

The maximum height of the embankment above surrounding grade at this location is some 3.1 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 granular fills. The embankment material was modeled as granular fill, using a unit weight of 21 kN/m³ and a friction angle of 31°. The native sand and gravel deposit was modeled using representative values of unit weight of 19 kN/m³ and a friction angle of 31°. The native sand was modeled using representative values of unit weight of 19 kN/m³ and a friction angle of 30°. 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 1.60 against failure through the native sand and gravel subgrade (see Figure No. S-1, Appendix 5). The finished embankment slopes should be established at the standard 2H:1V angle (or lower) in granular 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 consists of granular fills. The results of this investigation indicate that, below the culvert invert, the native soils consist of compact to dense sands. A review of the condition of the pavement surface, at the culvert locations, revealed only minor asphalt cracking. 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.

5.3.1 Rigid Concrete Culvert

A precast concrete rigid frame box culvert is being considered for culvert replacement at this site. Bedding for a rigid frame box culvert shall 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 the length/width of the box and incorporated as the top levelling course in conformance with OPSS 422. A modulus of subgrade reaction of 200 kPa/mm can be used for design for a Granular A bedding. Alternatively, specifically if construction is carried out under wet conditions, a 19 mm clear stone bedding and levelling coarse should be used, which would aid in dewatering applications.

Prior to the placement of the bedding, a Class II geotextile with a FOS of 105 to 210 um should be placed over the prepared subgrade. During backfilling the embankment fill should be placed in a balanced manner on the outer sides of the box unit. The elevation difference of the backfill on either side of the box unit must be limited to a maximum of 300 mm. Backfilling and construction of pre-cast concrete box culverts shall be in accordance with OPSS 422. Cover material for concrete box culverts can consist of Granular A, placed to the dimensions as shown on MTOD-803.021.

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 joint, covering the top of the culvert and extending halfway down the sides of the culvert to prevent the infiltration of fines.

Apron (cut-off) walls, 1.2 m deep, must be added to the ends of the rigid frame box culvert in accordance with the MTO Concrete Culvert Design Manual. An apron of rock protection would be required at the culvert ends, for a distance of 5 m either side of the culvert, unless wing walls are added at the culvert ends. 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 3.1 m in height. The invert elevation of the existing culverts is at 268.9 m, with the top of the embankment at elevation 272.0 m at centerline. As such, the embankment at this location is some 3.1 m in height above the culvert invert at the centerline. Therefore, a minimum 3.6 m deep excavation (i.e. to elevation 268.4 m) will be required, to allow for placement of 300 mm of bedding and leveling course, and to place the invert of the box culvert a distance equal to 10% of the box height, below the stream bed level.

5.4.1 Staged Construction

As noted above, the invert elevation of the existing culvert is at 268.9 m, at centerline, with the top of the embankment at elevation 272.0 m at centerline. As such, the embankment at this location is some 3.1 m in height above the culvert inverts and the required depth of excavation will be some 3.6 m, allowing for bedding and invert depression. The present platform width, at this location, is some 19 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 and is recommended for culvert replacement at this location (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:

- Limit traffic to a single lane on the left under 24/7 traffic control.
- Open cut excavate, to the right, and install approximately 15 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 vertical alignment can be raised, and the traffic can revert to two lanes when sufficient width permits

5.4.2 Protection System

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 3.8 m of embankment fill. The embankment fill is underlain by compact to dense sands and gravels. 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.

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):

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

carrying length

A_s = effective unit surface area of the anchor

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.

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 $0.65 \cdot K_a \cdot \gamma \cdot H$, where:

K_a = active earth pressure,

γ = unit weight, and

H = height of wall above the base of excavation.

The protection system can be designed using the lateral earth pressure 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 OR EXISTING FILL	NATIVE SAND AND GRAVEL	NATIVE SANDS
Unit Weight (kN/m^3)	22.8	21.0	19.0	19.0
Angle of Internal Friction	34°	31°	31°	30°
Coefficient of Active Earth Pressure (K_a)	0.28	0.32	0.32	0.33
Coefficient of Passive Earth Pressure (K_p)	3.54	3.12	3.12	3.00
Coefficient of Earth Pressure at Rest (K_o)	0.44	0.48	0.48	0.50

For rigid structures, such as a precast concrete box culvert, deflection cannot occur, as such the “at-rest” condition (K_0) applies. For flexible structures, such as CSP culverts and sheet pile walls deflection can occur, as such the “active” condition (K_a) 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 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. 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.

It should be noted that organics were encountered underlying the embankment fill at BH Nos. 4 and 5. If organics are encountered below the culverts, during the excavation for the culvert replacement, the organics must be removed from within the area of influence of the culverts to the native mineral soil (i.e. native sands and gravels) (see Section 5.1).

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 water level was recorded at between elevations 269.3 to 270.3 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 to the north of the embankment was recorded at elevation 269.9 m at the time of this investigation and excavations to elevation 268.4 m would be required to install the culvert and bedding. As such, a head of water of some 1.5 m must be controlled during excavation and culvert installation. The south end of both culverts was plugged at the time of investigation and water appeared ponded to the north of the outlet ends. Local drainage improvements may lower the water level of the stream at this location and aid in dewatering operations.

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, or possibly one of the existing twin pipes, should be considered for diverting stream flow, if required.

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.

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.

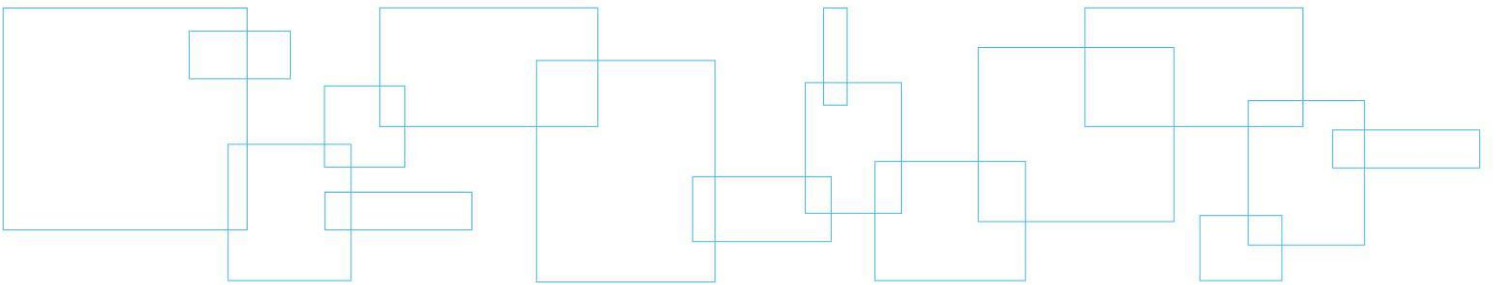
The comments in this report are intended solely for the guidance of the design engineer and address the geotechnical conditions only. The number of boreholes required to determine the localized conditions between boreholes directly affecting construction costs, equipment, scheduling, etc. would in fact 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

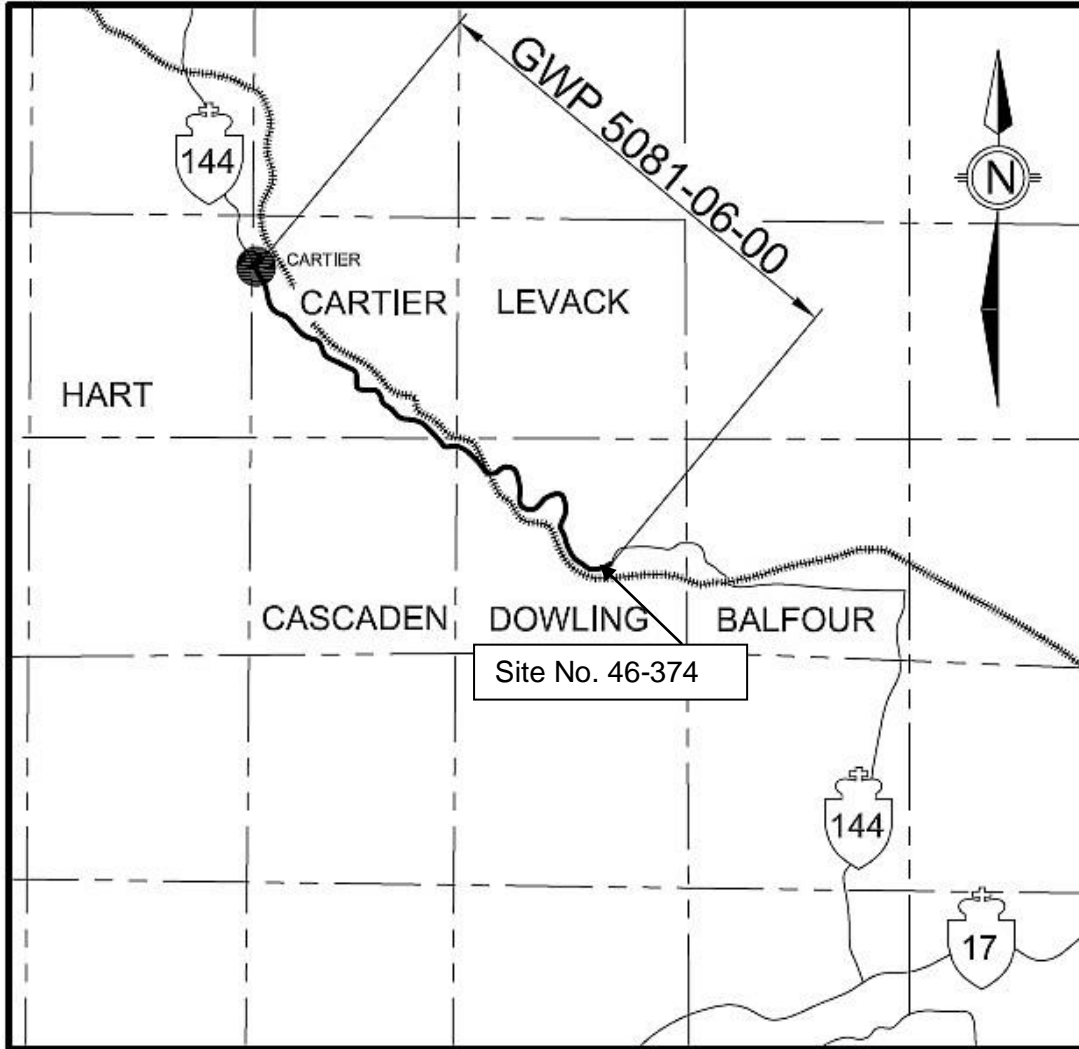
Key Plan



KEY PLAN

Drawing No. 1

NOT TO SCALE



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

Highway 144 – Site No. 46-374

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

MEL Ref. No.: 11/11/11209-F1

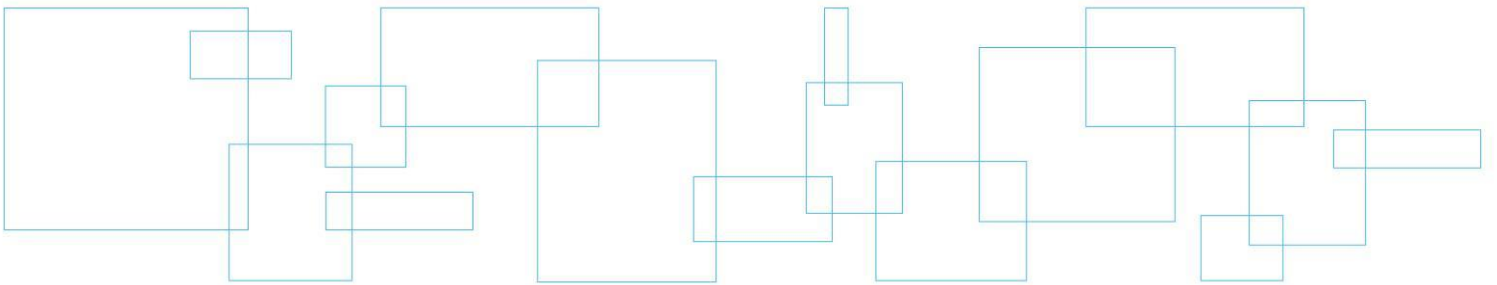
October 2013

LVM | MERLEX

Appendix 2 Subsurface Data

Enclosure No. 1
Enclosure Nos. 2 to 6

List of Abbreviations and Symbols
Record of Borehole Sheet



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.

METRIC

RECORD OF BOREHOLE NO. 1



REFERENCE 11/11/11209-F1 DATUM Geodetic LOCATION N 5159825.0 E 277008.6 - Dowling Township ORIGINATED BY JL
 PROJECT GWP 5081-06-00, Highway 144, Site No. 46-374 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY MCM
 CLIENT Triton Engineering Services Ltd. DATE (Started) 2012 March 8 TIME
 DATE (Completed) 2012 March 8 (Completed) 2:00:00 PM CHECKED BY MAM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100 WATER CONTENT (%) 20 40 60 PLASTIC LIMIT (w _p) NATURAL MOISTURE CONTENT (w) LIQUID LIMIT (w _L)	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES					
269.7	Ground Surface									
0.0	500 mm Snow cover									
	PEAT - dark brown silty organics trace fine fibres		1	AS						
			2	SS	WH					
			3	SS	WH					
267.7										
2.0	GRAVEL and SAND - grey gravel and sand trace silt (dense)		4	SS	50					51 42 (7)
			5	SS	42					
266.2										
3.5	SAND - grey sand some silt trace gravel (loose/compact)		6	SS	9					2 79 (19)
			7	SS	10					
			8	SS	7					
			9	SS	11					0 90 (10)
			10	SS	16					
260.1										
9.6	End of Sampling									
Continued Next Page										
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) 12/3/8 1:50:00 PM	0.5	1.9	
2) 12/3/9 7:20:00 AM	0.5	-								
3) 12/3/21 12:30:00 PM	0	-								

MEL-GEO 11209 - AREA 1 - BOREHOLE LOGS.GPJ MEL-GEO.GDT 13/10/4



METRIC**RECORD OF BOREHOLE NO. 1**

REFERENCE 11/11/11209-F1 DATUM Geodetic LOCATION N 5159825.0 E 277008.6 - Dowling Township ORIGINATED BY JL
 PROJECT GWP 5081-06-00, Highway 144, Site No. 46-374 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY MCM
 CLIENT Triton Engineering Services Ltd. DATE (Started) 2012 March 8 TIME
 DATE (Completed) 2012 March 8 (Completed) 2:00:00 PM CHECKED BY MAM

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L WATER CONTENT (%)	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE						
	Continued from Previous Page									
259										
258										
257										
256										
255										
254										
253										
252.3										
17.4	DCPT Refusal End of Borehole									

MEL-GEO 11209 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 13/10/4



METRIC

RECORD OF BOREHOLE NO. 2



REFERENCE 11/11/11209-F1 DATUM Geodetic LOCATION N 5159796.5 E 277007.1 - Dowling Township ORIGINATED BY JL
 PROJECT GWP 5081-06-00, Highway 144, Site No. 46-374 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY MCM
 CLIENT Triton Engineering Services Ltd. DATE (Started) 2012 March 9 TIME
 DATE (Completed) 2012 March 9 (Completed) 11:18:00 AM CHECKED BY MAM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100 WATER CONTENT (%) 20 40 60 PLASTIC LIMIT (Wp), NATURAL MOISTURE CONTENT (W), LIQUID LIMIT (Wl)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES					
269.9	Ground Surface									
0.0	300 mm Snow cover		1	AS						
	FILL - brown sand with gravel trace silt (loose)		2	SS	8					21 76 (3)
268.2			3	SS	4					
1.7	SILTY SAND - grey silty sand (loose)									
267.8			4	SS	40					
2.1	SAND - grey sand some to with gravel trace silt (dense)		5	SS	33					15 80 (5)
266.2			6	SS	9					
3.7	SAND - grey sand trace silt (loose/compact)		7	SS	11					
			8	SS	10					0 98 (2)
			9	SS	18					
			10	SS	9					
260.3	End of Sampling									
9.6										
Continued Next Page										
COMMENTS The stratification lines represent approximate boundaries. The transition may be gradual.							WATER LEVEL RECORDS			
							+ 3, × 3 : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 120 kPa ○ 3% STRAIN AT FAILURE			
							Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)	
							1) 12/3/9 11:05:00 AM	0.6	2.5	
2) 12/3/21 12:30:00 PM	0.6	-								
3) 12/3/21 2:30:00 PM	0.6	-								

MEL-GEO 11209 - AREA 1 - BOREHOLE LOGS.GPJ MEL-GEO.GDT 13/10/4



METRIC**RECORD OF BOREHOLE NO. 2**

REFERENCE 11/11/11209-F1 DATUM Geodetic LOCATION N 5159796.5 E 277007.1 - Dowling Township ORIGINATED BY JL
 PROJECT GWP 5081-06-00, Highway 144, Site No. 46-374 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY MCM
 CLIENT Triton Engineering Services Ltd. DATE (Started) 2012 March 9 TIME
 DATE (Completed) 2012 March 9 (Completed) 11:18:00 AM CHECKED BY MAM

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					
	Continued from Previous Page						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
252.8						259							
						258							
						257							
						256							
						255							
						254							
						253							
17.1	DCPT Refusal End of Borehole												

MEL-GEO 11209 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 13/10/4



METRIC

RECORD OF BOREHOLE NO. 3



REFERENCE 11/11/11209-F1 DATUM Geodetic LOCATION N 5159802.7 E 277003.9 - Dowling Township ORIGINATED BY JL
 PROJECT GWP 5081-06-00, Highway 144, Site No. 46-374 BOREHOLE TYPE Truck Mounted CME 45B - Hollow Stem Augers COMPILED BY MCM
 CLIENT Triton Engineering Services Ltd. DATE (Started) 2012 March 22 TIME
 DATE (Completed) 2012 March 22 (Completed) 2:30:00 PM CHECKED BY MAM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES								
272.1	Ground Surface												
0.0	50 mm Asphalt 150 mm Crushed gravel FILL - brown sand with gravel trace silt (very loose/compact)		1	AS									
			2	SS	26								37 55 (8)
			3	SS	7								
			4	SS	3								24 70 (6)
			5	SS	15								
268.3	150 mm dark brown silty organics SAND - grey sand with gravel some silt (compact/dense)		6	SS	40								22 61 (17)
			7	SS	28								
266.3	SAND - grey sand trace silt (loose/compact)		8	SS	11								
			9	SS	21								0 95 (5)
			10	SS	27								
262.0	SILTY SAND - grey silty sand												
10.1	Continued Next Page												
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 (dd/mm/yy)/Time Water Depth (m) Cave In (m) 1) 12/3/22 2:20:00 PM 1.8 1.9 2) - - 3) - -					

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

MEL-GEO 11209 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 13/10/4



METRIC

RECORD OF BOREHOLE NO. 3



REFERENCE 11/11/11209-F1 DATUM Geodetic LOCATION N 5159802.7 E 277003.9 - Dowling Township ORIGINATED BY JL
 PROJECT GWP 5081-06-00, Highway 144, Site No. 46-374 BOREHOLE TYPE Truck Mounted CME 45B - Hollow Stem Augers COMPILED BY MCM
 CLIENT Triton Engineering Services Ltd. DATE (Started) 2012 March 22 TIME
 DATE (Completed) 2012 March 22 (Completed) 2:30:00 PM CHECKED BY MAM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES						
	Continued from Previous Page										
261.0	SILTY SAND - grey silty sand		11	SS	16						
11.1	(compact)										
	End of Sampling										
253.2	DCPT Refusal										
18.9	End of Borehole										

MEL-GEO 11209 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 13/10/4



METRIC

RECORD OF BOREHOLE NO. 4



REFERENCE	11/11/11209-F1	DATUM	Geodetic	LOCATION	N 5159821.1 E 277027.7 - Dowling Township	ORIGINATED BY	JL
PROJECT	GWP 5081-06-00, Highway 144, Site No. 46-374			BOREHOLE TYPE	Truck Mounted CME 45B - Hollow Stem Augers	COMPILED BY	MCM
CLIENT	Triton Engineering Services Ltd.	DATE (Started)	2012 March 21	TIME		CHECKED BY	MAM
		DATE (Completed)	2012 March 21	(Completed)	1:55:00 PM		

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)			
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL						× LAB VANE		
271.6	Ground Surface																	
0.0	50 mm Asphalt 125 mm Crushed Gravel FILL - brown sand with gravel to gravelly trace to some silt (compact)		1	AS														
			2	SS	12										22 63 (15)			
			3	SS	12										41 54 (5)			
			4	SS	12													
268.7	PEAT - dark brown silty organics trace inclusions		5	SS	2								87					
268.1	SAND - grey sand with gravel some silt (dense)		6	SS	74													
			7	SS	54													
266.4	SAND - grey sand trace to some silt (loose/compact)		8	SS	11													
			9	SS	9										0 83 (17)			
263.1	SILTY SAND - grey silty sand (loose/compact)		10	SS	9													
Continued Next Page																		
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 (dd/mm/yy)/Time		Water Depth (m)		Cave In (m)				
										1) 12/3/21 1:45:00 PM		2.8		3.8				
										2) 12/3/21 4:45:00 PM		1.8		-				
										3)		-		-				
The stratification lines represent approximate boundaries. The transition may be gradual.																		

MEL-GEO 11209 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 13/10/4

METRIC**RECORD OF BOREHOLE NO. 4**

REFERENCE 11/11/11209-F1 DATUM Geodetic LOCATION N 5159821.1 E 277027.7 - Dowling Township ORIGINATED BY JL
 PROJECT GWP 5081-06-00, Highway 144, Site No. 46-374 BOREHOLE TYPE Truck Mounted CME 45B - Hollow Stem Augers COMPILED BY MCM
 CLIENT Triton Engineering Services Ltd. DATE (Started) 2012 March 21 TIME
 DATE (Completed) 2012 March 21 (Completed) 1:55:00 PM CHECKED BY MAM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES								
	Continued from Previous Page												
260.5 11.1	End of Sampling		11	SS	11		261						
250.8 20.8	DCPT Refusal End of Borehole						251						

MEL-GEO 11209 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 13/10/4



METRIC

RECORD OF BOREHOLE NO. 5



REFERENCE 11/11/11209-F1 DATUM Geodetic LOCATION N 5159827.3 E 277059.4 - Dowling Township ORIGINATED BY JL
 PROJECT GWP 5081-06-00, Highway 144, Site No. 46-374 BOREHOLE TYPE Truck Mounted CME 45B - Hollow Stem Augers COMPILED BY MCM
 CLIENT Triton Engineering Services Ltd. DATE (Started) 2012 March 21 TIME
 DATE (Completed) 2012 March 21 (Completed) 5:05:00 PM CHECKED BY MAM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES								
272.2	Ground Surface												
0.0	50 mm Asphalt 125 mm Crushed Gravel FILL - brown sand some to with gravel some to with silt (very loose/dense)		1	AS			272						
			2	SS	45		271						30 60 (10)
			3	SS	10		270						
			4	SS	2		269						13 57 (30)
269.0	PEAT - dark brown silty organics trace inclusions		5	SS	WH		268						
268.1	GRAVEL and SAND - grey gravel and sand trace silt (compact)		6	SS	21		267						
4.1			7	SS	20		266						49 47 (4)
266.1	SAND - grey sand trace to some silt (compact)		8	SS	11		265						
6.1			9	SS	19		264						
263.4	SILTY SAND - grey silty sand (loose)		10	SS	11		263						0 59 39 2
8.8							262						
Continued Next Page													
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 (dd/mm/yy)/Time 1) 12/3/21 4:50:00 PM 2) 3)						
							Water Depth (m) 2.5 - -						
							Cave In (m) 4.3 - -						

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

MEL-GEO 11209 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 13/10/4



METRIC**RECORD OF BOREHOLE NO. 5**

REFERENCE 11/11/11209-F1 DATUM Geodetic LOCATION N 5159827.3 E 277059.4 - Dowling Township ORIGINATED BY JL
 PROJECT GWP 5081-06-00, Highway 144, Site No. 46-374 BOREHOLE TYPE Truck Mounted CME 45B - Hollow Stem Augers COMPILED BY MCM
 CLIENT Triton Engineering Services Ltd. DATE (Started) 2012 March 21 TIME
 DATE (Completed) 2012 March 21 (Completed) 5:05:00 PM CHECKED BY MAM

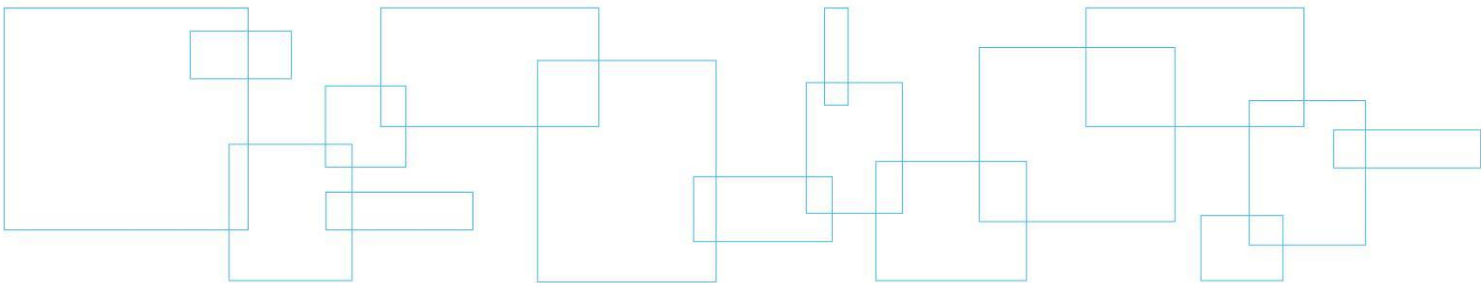
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE WATER CONTENT (%) 20 40 60 80 100	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES						
261.1	Continued from Previous Page		11	SS	9						
11.1	End of Sampling										
253.0	DCPT Refusal End of Borehole										

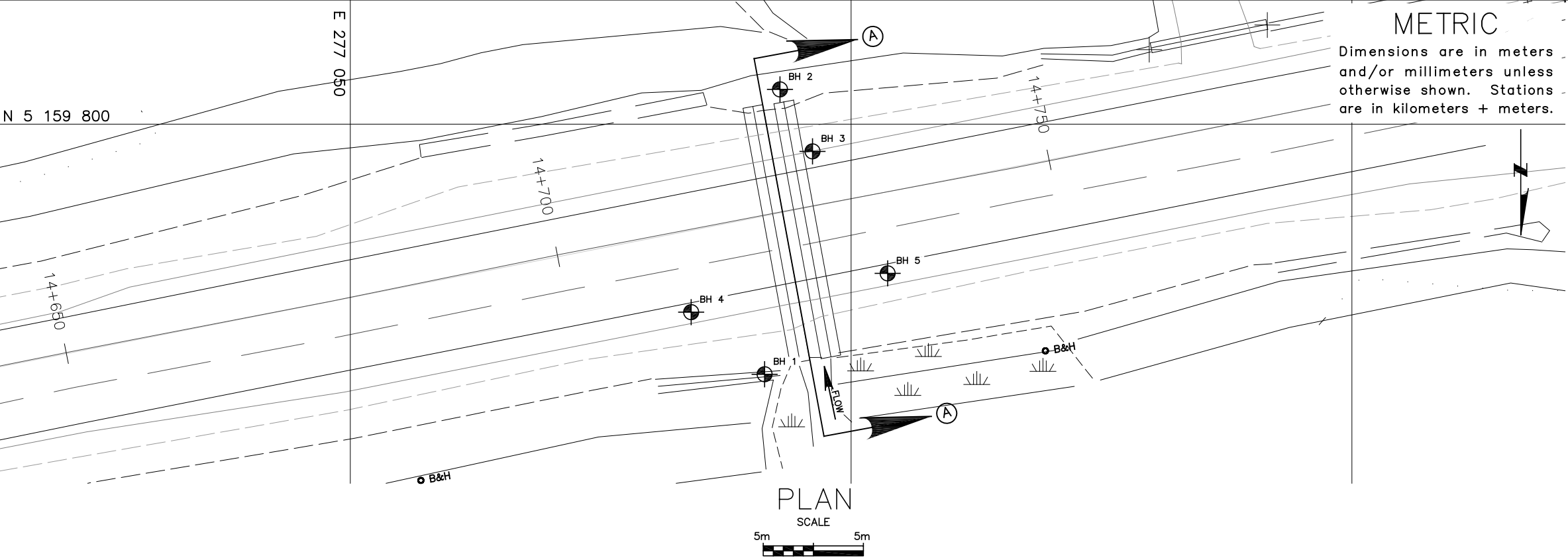
MEL-GEO 11209 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 13/10/4



Appendix 3 Lab Data

Drawing No. 2: Borehole Location and Soil Strata
Figure Nos. L-1 to L-4: Grain Size Distribution Curves
Figure No. L-5: Lab Test Summary Sheet





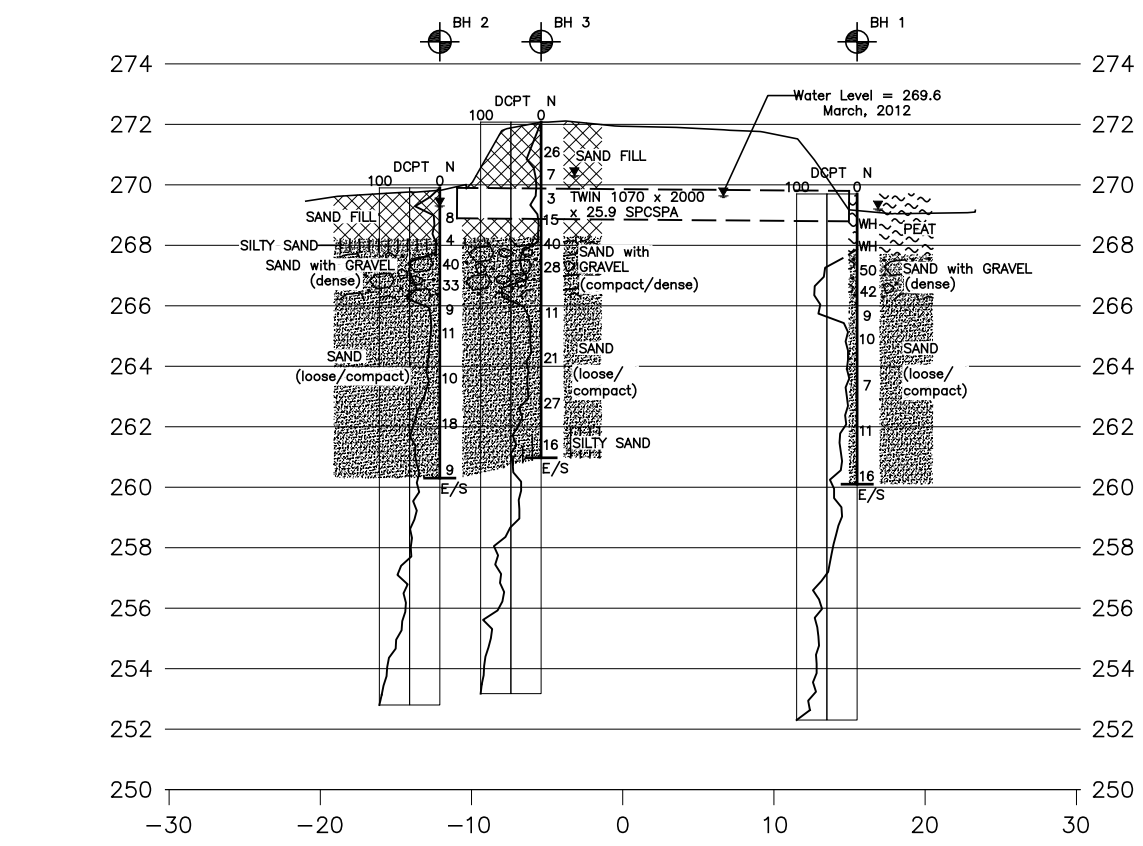
METRIC
Dimensions are in meters
and/or millimeters unless
otherwise shown. Stations
are in kilometers + meters.

CONT No
GWP No 5081-06-00

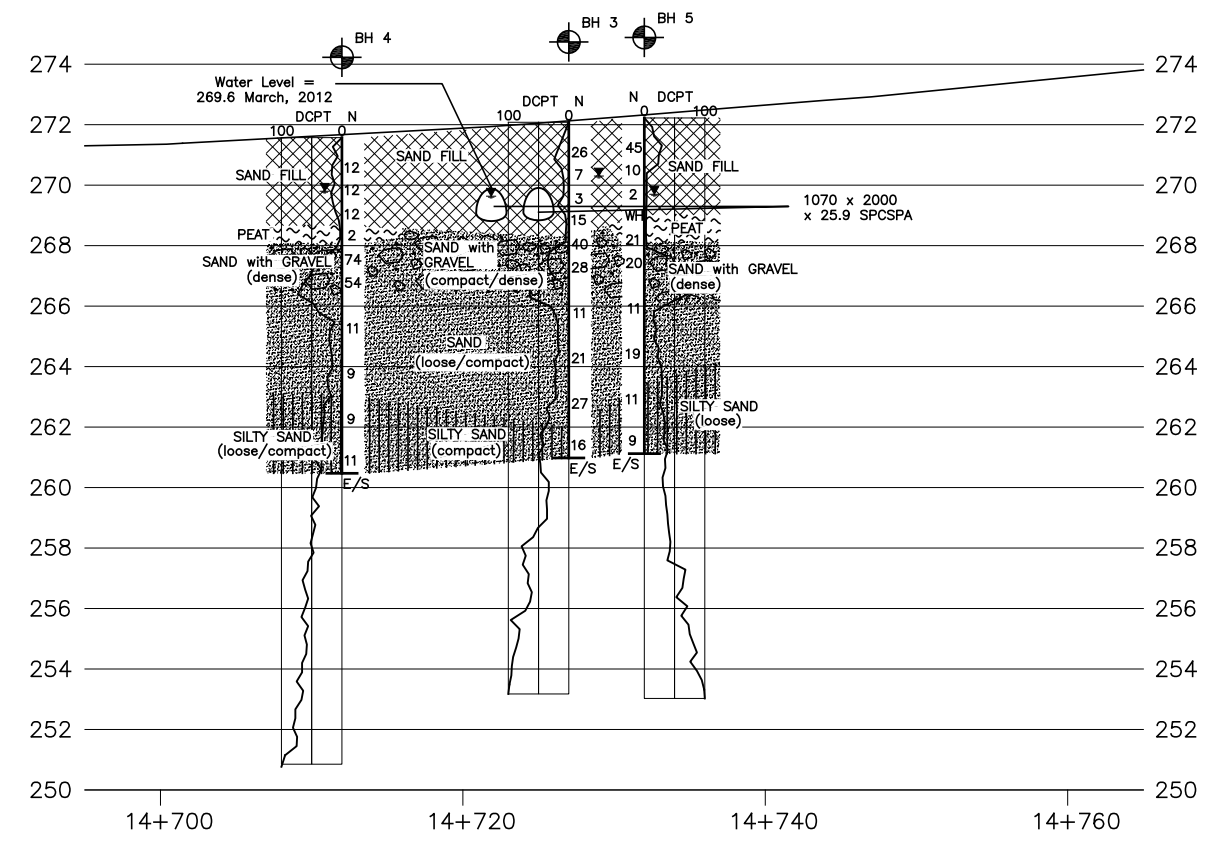
HWY NO. 144 – Township of Dowling
Drawing
2

SITE NO. 46-374
Culvert at Station 14+722
BOREHOLE LOCATIONS & SOIL STRATA

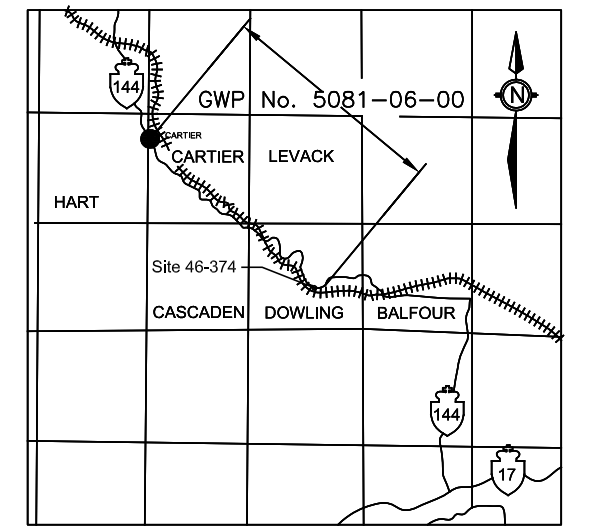
LVM | MERLEX



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



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



KEY PLAN - NOT TO SCALE
LEGEND

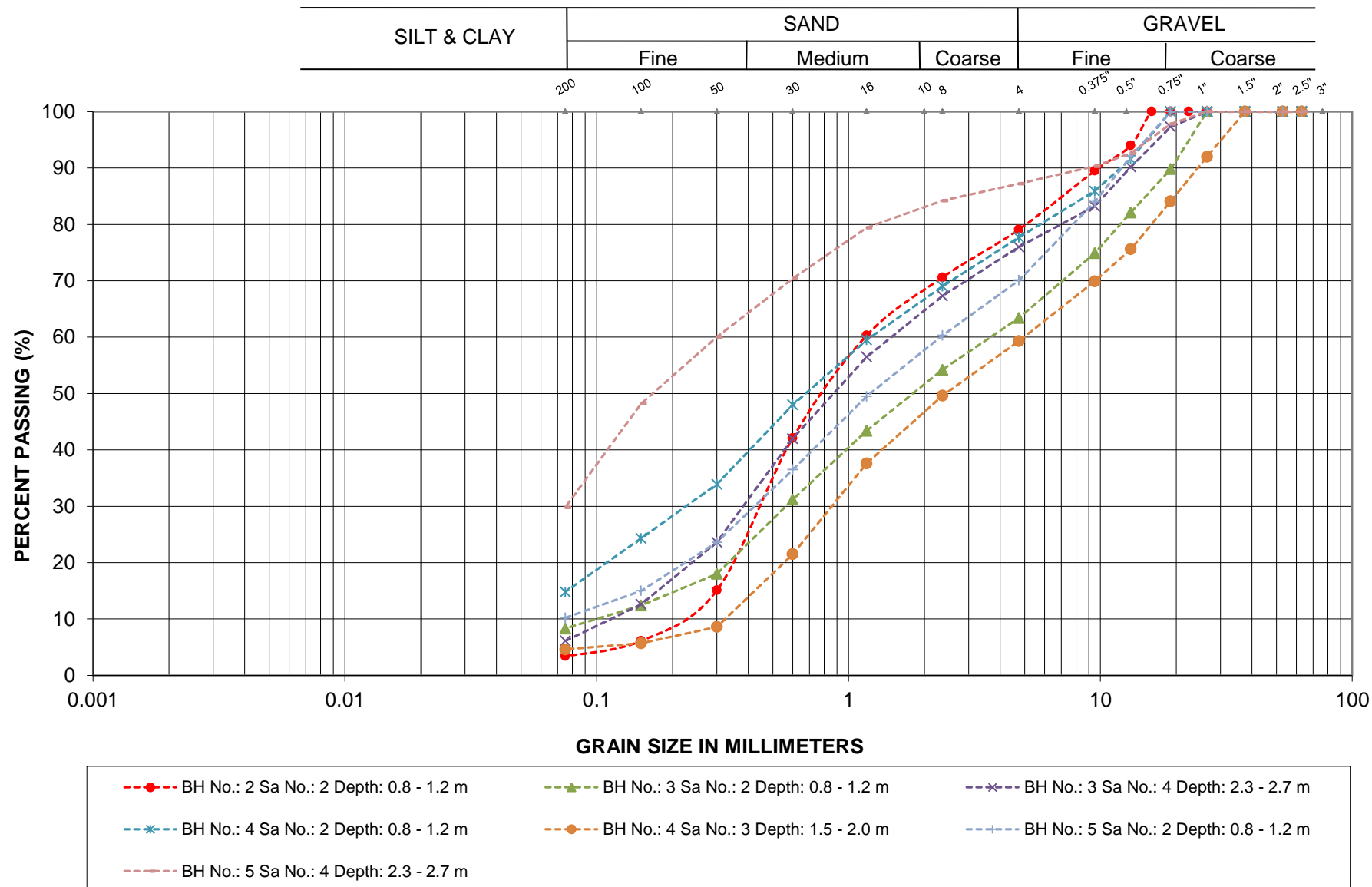
Borehole No.	Elev.	O/S	Co-ordinates	
			Northerly	Easterly
Borehole No. 1	269.7	15.5m Rt	5159825.0	277008.6
Borehole No. 2	269.9	12.1m Lt	5159796.5	277007.1
Borehole No. 3	272.1	5.0m Lt	5159802.7	277003.9
Borehole No. 4	271.6	8.5m Rt	5159821.1	277027.7
Borehole No. 5	272.2	8.5m Rt	5159827.3	277059.4

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
	Sept 2012	RG	DRAFT
	Oct 2013	RG	FINAL
HWY No. 144 – Dowling Twp – Culvert at Sta. 14+722 REF 11209-F1			
SUBM'D		GEOCRE 411-295	SITE 46-374
DRAWN RG	CHK MAM	DATE Sept 2012	FIG 2

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.

GRAIN SIZE ANALYSIS



G.W.P.: 5081-06-00

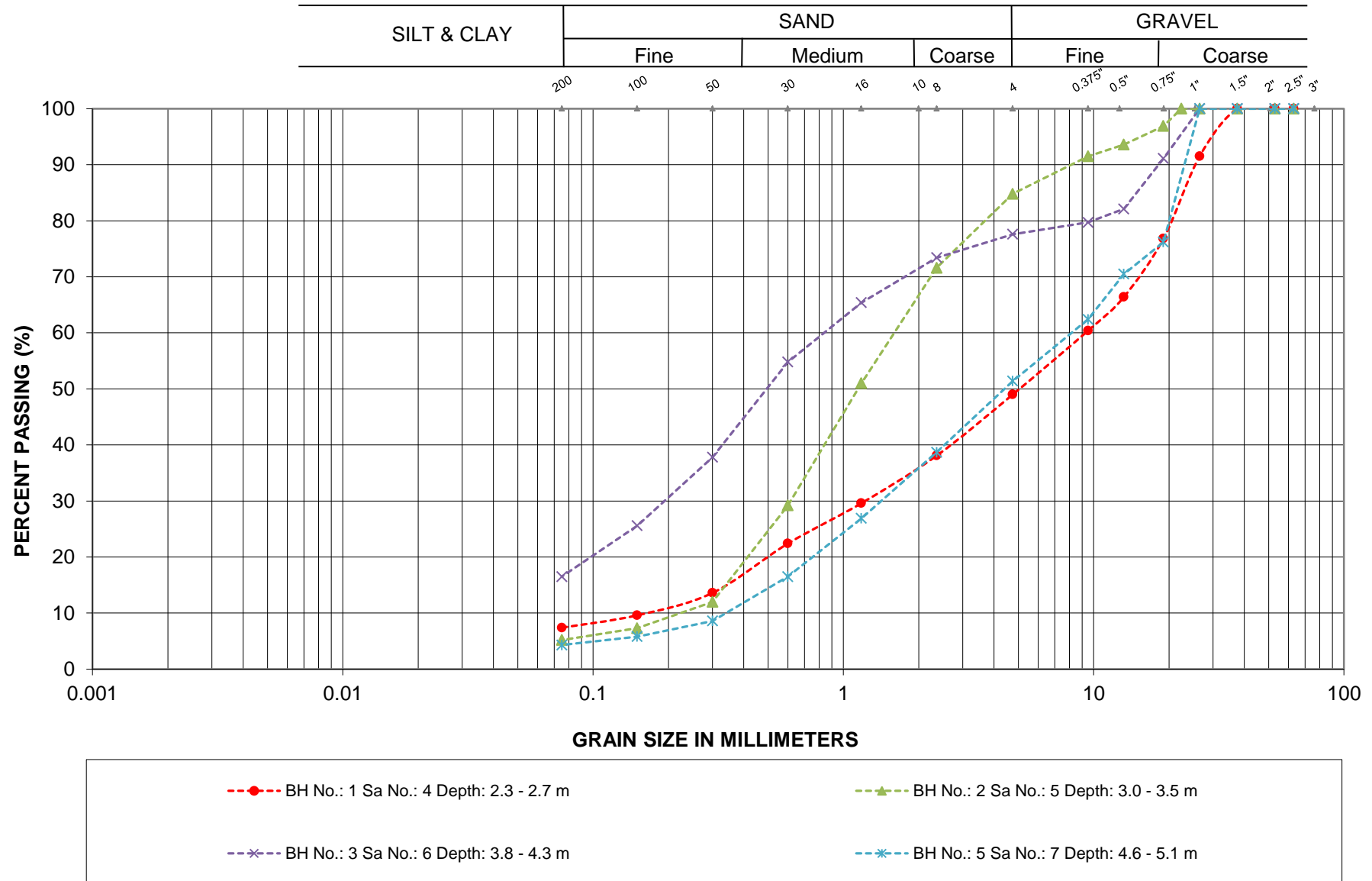
LOCATION: Hwy 144

EMBANKMENT FILL

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FIGURE L-1

GRAIN SIZE ANALYSIS



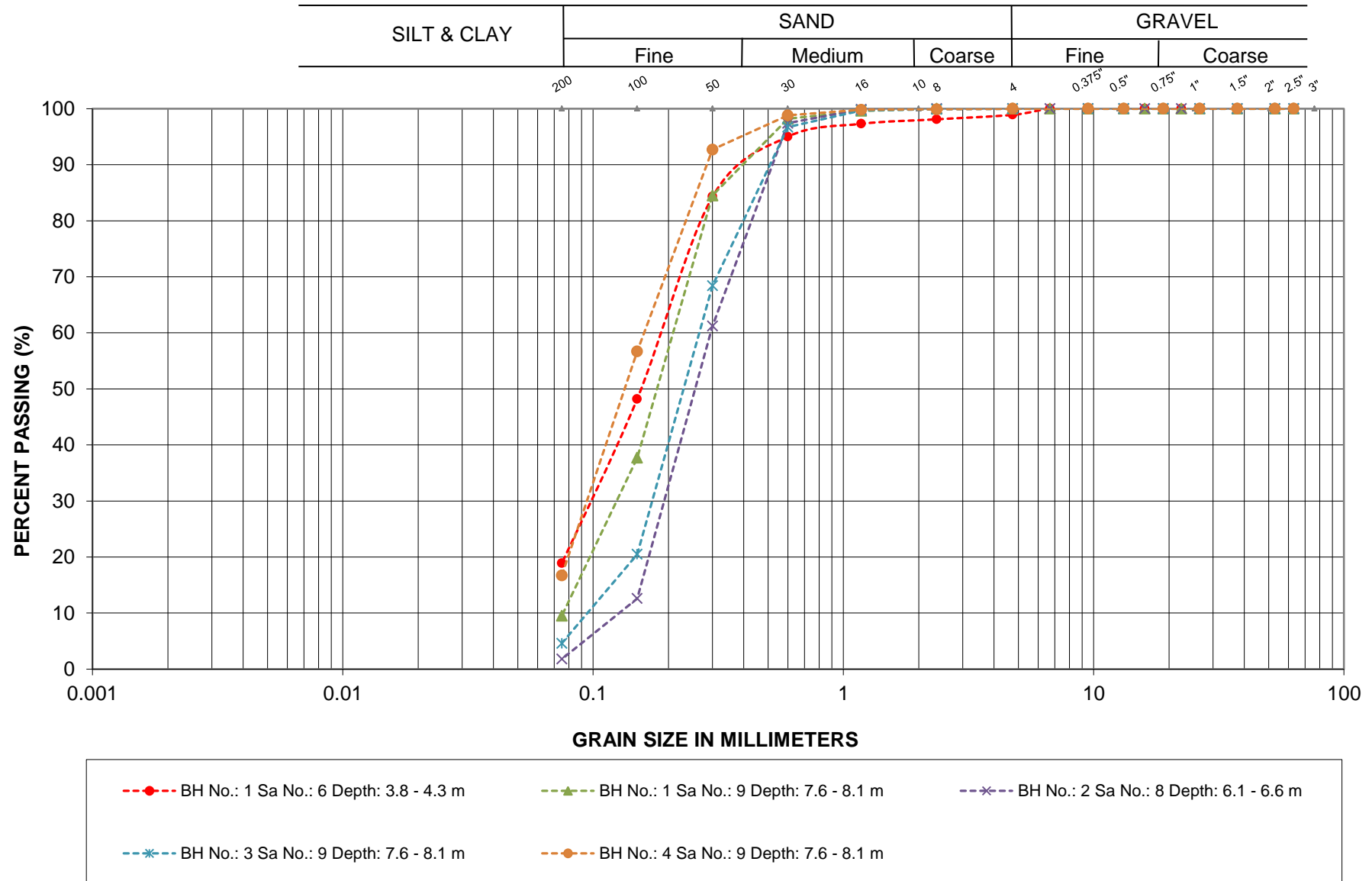
G.W.P.: 5081-06-00
LOCATION: Hwy 144

SAND AND GRAVEL

LVM | MERLEX

FIGURE L-2

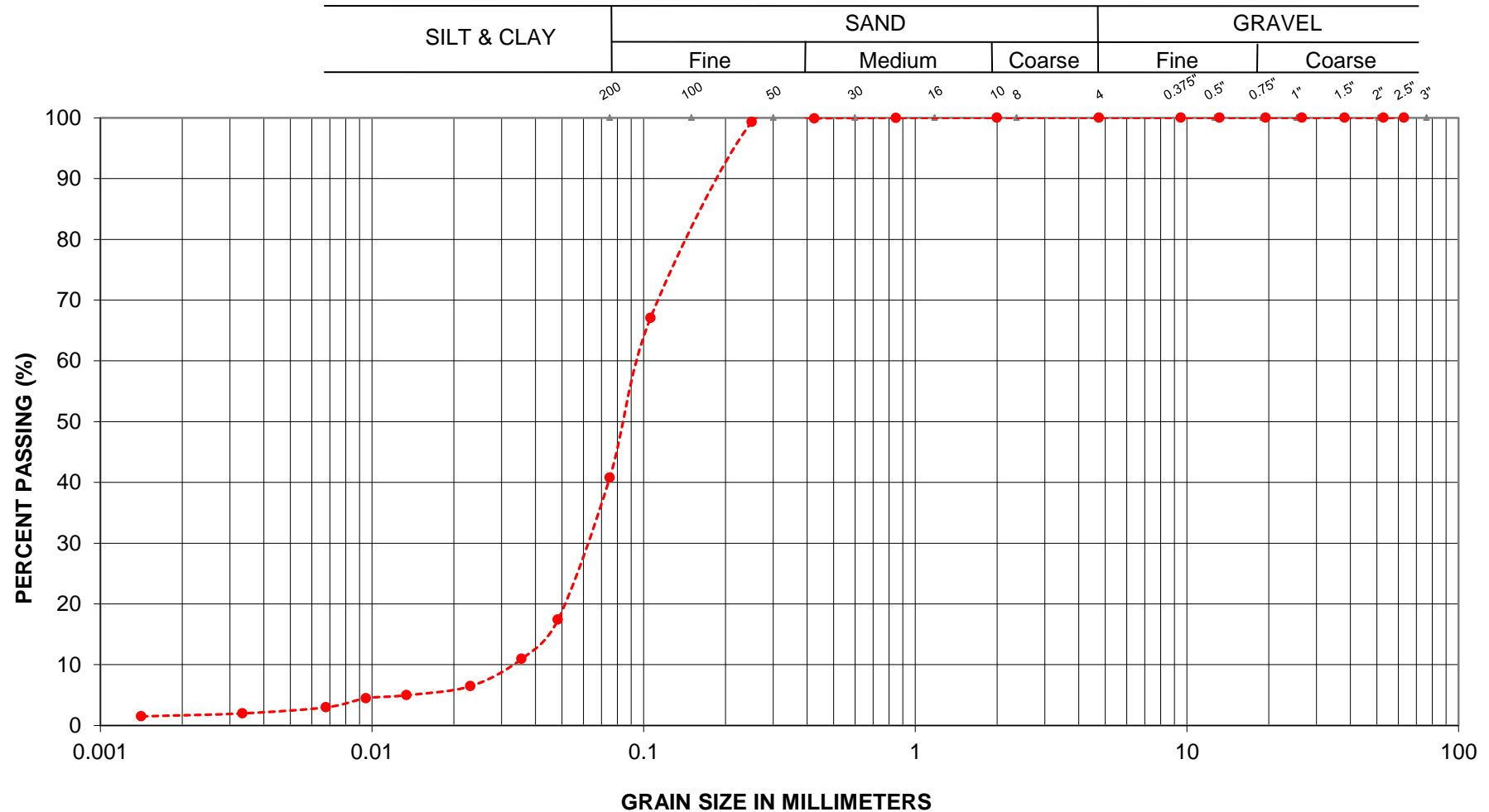
GRAIN SIZE ANALYSIS



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

SAND

GRAIN SIZE ANALYSIS



---●--- BH No.: 5 Sa No.: 10 Depth: 9.1 - 9.6 m

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

SILTY SAND

LVM | MERLEX

FIGURE L-4

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					59.4				N/A			
	2	0.8					67.6				WH			
	3	1.5					71.5				WH			
	4	2.3	51	42	7		10.0				50			
	5	3.0					12.3				42			
	6	3.8	2	79	19		25.1				9			
	7	4.6					25.6				10			
	8	6.1					27.1				7			
	9	7.6	0	90	10		23.1				11			
	10	9.1					18.1				16			
2	1	0.0					18.1				N/A			
	2	0.8	21	76	3		20.8				8			
	3a	1.5					21.8				4			
	3b	1.5					17.1				4			
	4	2.3					9.7				40			
	5	3.0	15	80	5		13.8				33			
	6	3.8					25.0				9			
	7	4.6					22.8				11			
	8	6.1	0	98	2		22.6				10			
	9	7.6					27.8				18			
	10	9.1					25.3				9			
3	1	0.0					3.5				N/A			
	2	0.76	37	55	8		4.9				26			
	3	1.5					5.9				7			
	4	2.3	24	70	6		12.2				3			
	5	3.0					14.8				15			
	6	3.8	22	61	17		24.5				40			

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 (%)				
3	7	4.6					13.9				28			
	8	6.1					18.5				11			
	9	7.6	0	95	5		21.9				21			
	10	9.1					19.5				27			
	11	10.7					24.1				16			
4	1	0.0					2.2				N/A			
	2	0.8	22	63	15		7.5				12			
	3	1.5	41	54	5		9.2				12			
	4	2.3					12.7				12			
	5	3.0					87.3				2			
	6	3.8					18.2				74			
	7	4.6					7.8				54			
	8	6.1					17.9				11			
	9	7.6	0	83	17		25.7				9			
	10	9.1					25.48				9			
	11	10.7					26				11			
5	1	0.0					3.32				N/A			
	2	0.8	30	60	10		4.31				45			
	3	1.5					7.34				10			
	4	2.3	13	57	30		19.86				2			
	5a	3.0					21.93				WH			
	5b	3.0					85.04				WH			
	6a	3.8					54.34				21			
	6b	3.8					12.19				21			
	7	4.6	49	47	4		14.56				20			
	8	6.1					22.85				11			
	9	7.6					25.81				19			

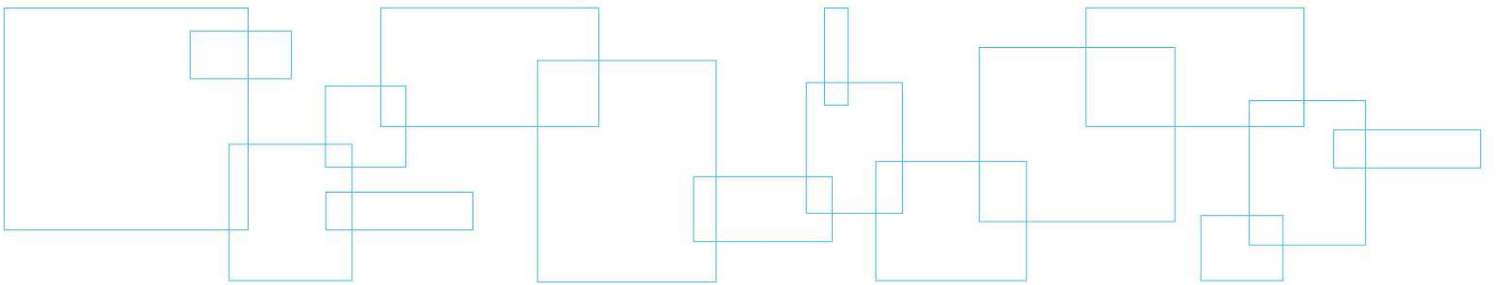
Laboratory Tests - Summary Sheet

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Appendix 4 Photo Essay

Enclosure No. 7:

Photo Essay



Existing Embankment – Existing Embankment, General Pavement Condition Looking West

Photo: 1



Existing Embankment and Culvert Inlet – Right (North) Side, Looking West

Photo: 2



Reference No. 11/11/11209-F1

Project: Hwy 144 – Station 14+722, Twp of Dowling

Photos Provided By: LVM

Date: March 2012

Culvert Inlet – Looking North

Photo: 3



Existing Embankment and Culvert Outlet – Left (South) Side, Looking West

Photo: 4



Reference No. 11/11/11209-F1

Project: Hwy 144 – Station 14+722, Twp of Dowling

Photos Provided By: LVM

Date: March 2012

Culvert Outlet – South End Looking North

Photo: 5



Culvert Outlet – Buried Culverts, South End

Photo: 6



Reference No. 11/11/11209-F1

Project: Hwy 144 – Station 14+722, Twp of Dowling

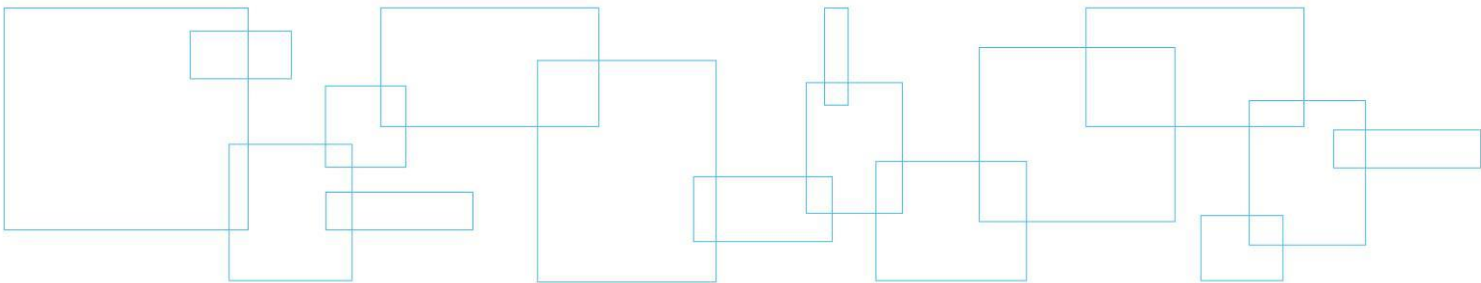
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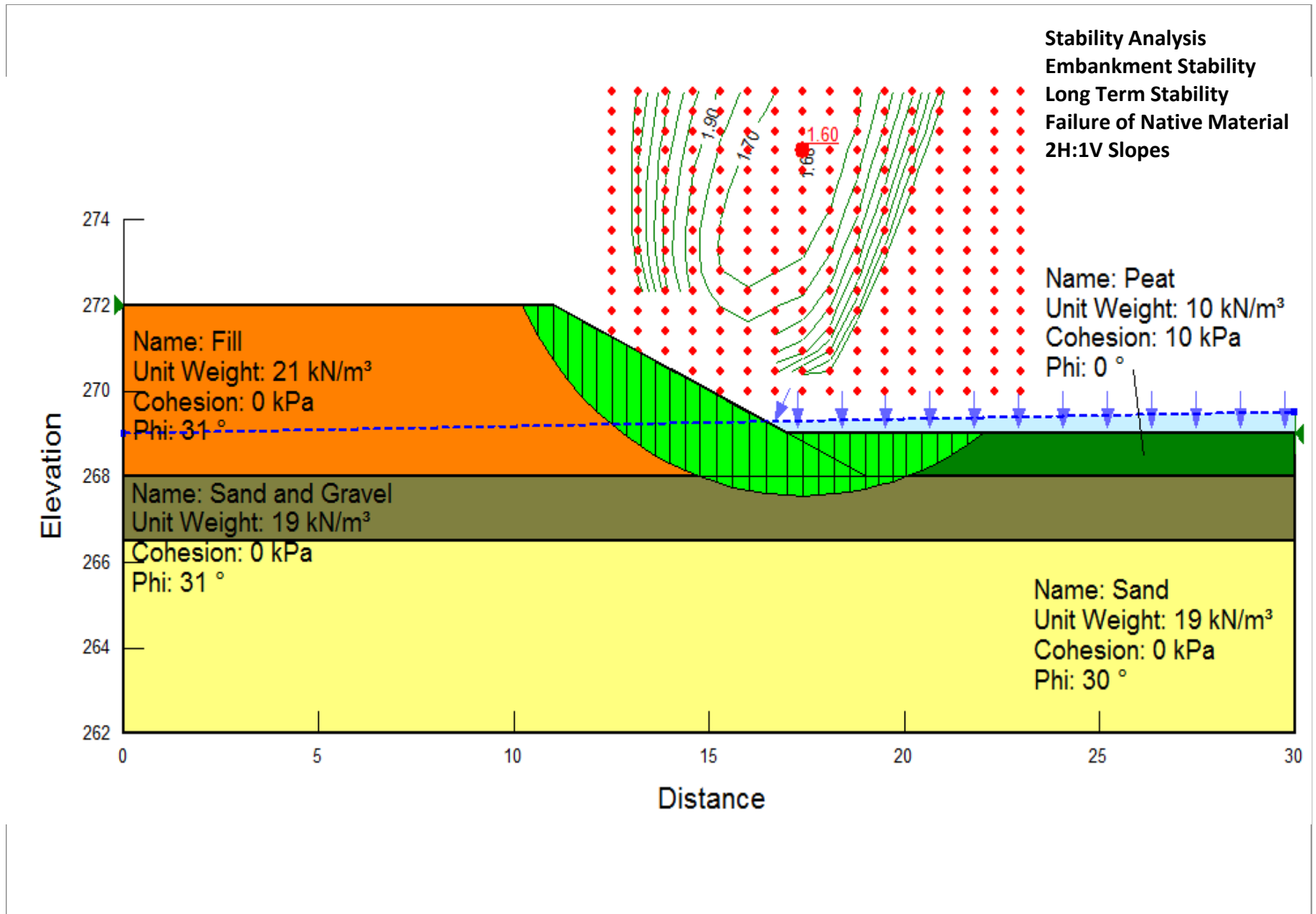
Date: March 2012

Appendix 5

Design Data

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

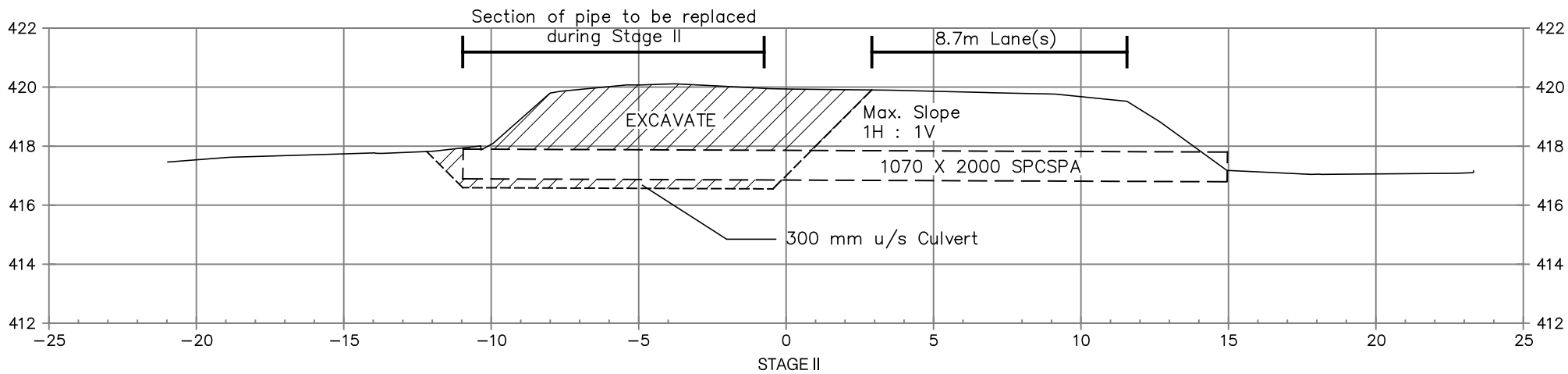
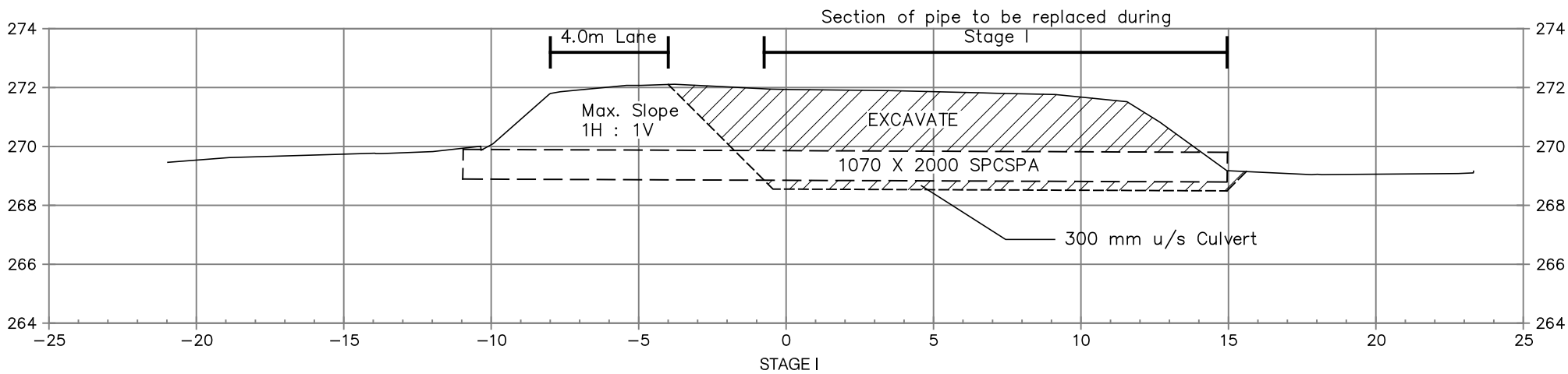




Stability Analysis
 Station 14+722
 TWP of Dowling

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

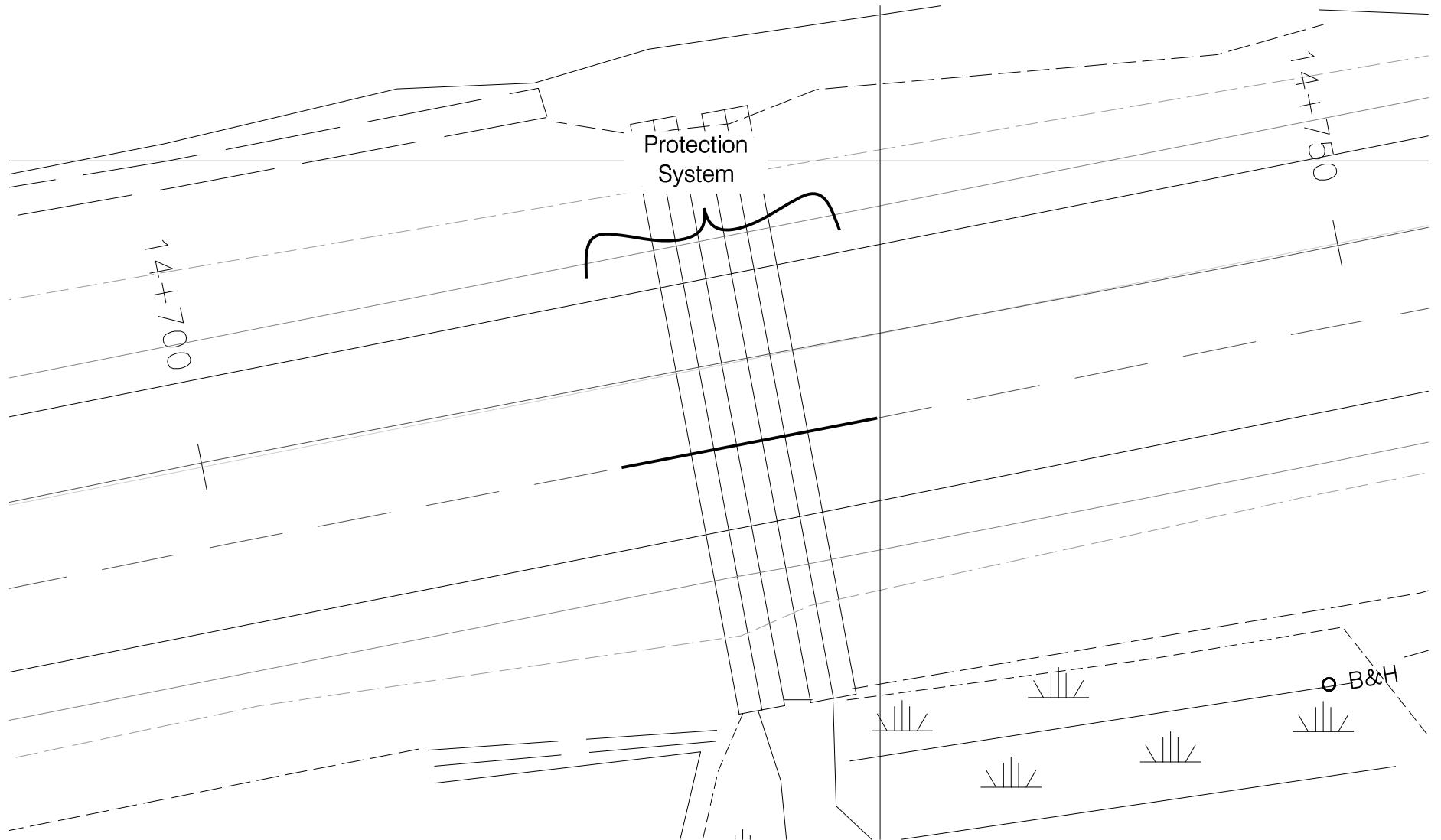


METRIC
Dimensions are in meters
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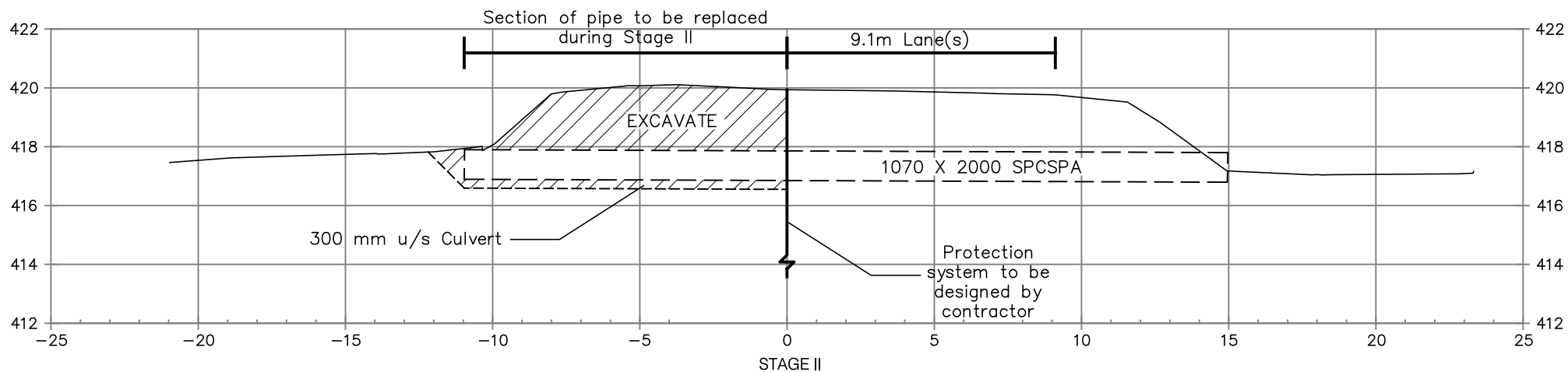
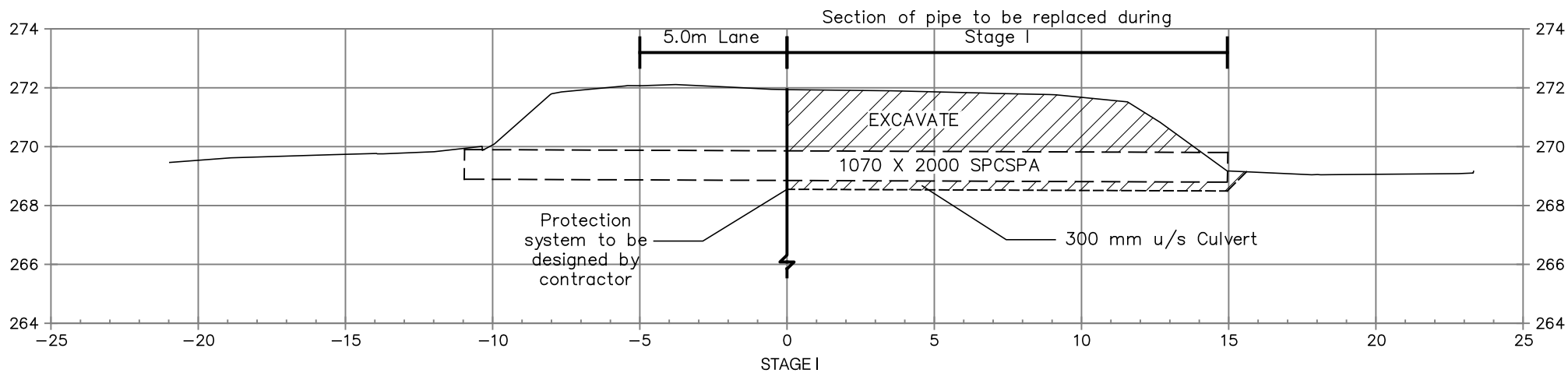
HWY 144- Township of Dowling- Culvert at Station 14+722
Conceptual Staging - Typical Sections

FIGURE SK-3



HWY 144- Township of Dowling- Culvert at Station 14+722
Conceptual Roadway Protection

FIGURE SK-4



METRIC

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