Geotechnical, Materials and Environmental Engineering

Submitted To AECOM Canada Ltd.
189 Wyld Street Suite 103, North Bay, Ontario P1B 1Z2
On Behalf of the Ontario Ministry of Transportation

Culvert Replacement
Highway 560
Seven Mile Creek Culvert – Site No. 47-314/C
GWP 5242-11-00

FINAL ADDITIONAL FOUNDATION INVESTIGATION AND DESIGN REPORT

Date: August 18, 2015
Ref. №: 13/05/13073-F5

Geocres No. 41P-59A

LVM Merlex

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Final Additional Foundation Investigation and Design Report

Prepared by:

Alexander Tepylo, P.Eng.
LVM-Merlex – Project Engineer

LICENSED PROFESSIONAL ENGINEER
S. HU
90524232
15/08/18
PROVINCE OF ONTARIO

Sen Hu, P. Eng.
LVM-Merlex – Senior Geotechnical Engineer

Reviewed by:

M.A. Merleau, P. Eng.
LVM-Merlex – Principal Engineer
MTO Designate

REGISTERED PROFESSIONAL ENGINEER
M. A. MERLEAU
15/08/18
PROVINCE OF ONTARIO

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Client:
AECOM Canada Ltd.
189 Wyld Street, Suite 103
North Bay, Ontario
P1B 1Z2
Attention: **Mr. Al Rose**

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1 INTRODUCTION

LVM-Merlex, a Division of EnGlobe Corp. (LVM-Merlex) has been retained by AECOM Canada Ltd., on behalf of the Ministry of Transportation of Ontario (MTO), to carry out an additional foundation investigation at an existing centerline culvert site. The site is located in the Township of Mickle on Highway 560, some 10.7 km west of the west junction of Highway 65 and 560.

An initial foundation investigation at this site was carried out by LVM-Merlex in 2014 to supply subsurface data and provide design recommendations for construction of a dewatering system, as required by Request for Proposal (RFP) of the project, for use in culvert rehabilitation. The results of the initial foundation investigation were supplied in a separate Final Foundation Investigation and Design Report, Geocres No. 41P-59 (LVM-Merlex Reference No. 13/05/13073-F5), dated May 21, 2014. Following submission of the final report for the initial foundation investigation, it is understood that the culvert has been reviewed and it has been decided to be replaced rather than rehabilitated the existing culvert. As such, the additional subsurface information through the existing highway embankment was required for design of a protection system.

The additional foundation investigation program was specified by the MTO in the Terms of Reference for work under Agreement No. 5013-E-0032. The terms of reference for the scope of work are outlined in LVM-Merlex's Proposal 13/05/13073-F5, dated January 27, 2015. The purpose of this investigation was to determine the subsurface conditions in the area of the existing culvert. 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 site of this foundation investigation is located on Highway 560 some 10.7 km west of the west junction of Highway 65 and 560, in the Township of Mickle. For the purposes of this project, the intersection of the highway and culvert centerlines has been given a local site chainage of station 10+000, Township of Mickle. The local topography at the site is a low wetland to the left and the right (the north and the south) of the embankment. The existing highway embankment currently supports two undivided lanes of highway, running in a west to east direction. The existing highway, at the culvert location, is constructed on an embankment some 3.8 m in height, with centerline elevation of 301.8 m at the culvert location. The culvert at this location has been described, in the RFP, as a 5.0 m diameter Corrugated Steel Pipe (CSP) culvert. However, based on inspection reports and survey data completed by others, the culvert at this site is a 4.37 x 2.87 m Structural Plate Corrugated Steel Pipe Arch (SPCSPA) culvert some 17 m in length (beveled culvert, 17 m at obvert, 24.5 m at invert).

Infrastructure at the culvert location consists of overhead wires on the left (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 560 is generally flat. Significant layers of earth overlay the bedrock. Organic terrain was also observed. Within the project area native overburden consists primarily of a layer of organic soils overlying sands within the depths investigated.

Bedrock in the area, as indicated on OGS Map 2506, is of the Late to Middle Precambrian period, Huronian Supergroup, consisting of conglomerate, sandstone, siltstone, and argillite.

3 INVESTIGATION PROCEDURES

The fieldwork for this additional foundation investigation was carried out during the period of March 18th to 19th, 2015 during which time two (2) sampled boreholes (Borehole Nos. 5 and 6), were advanced through the embankment at the location of the culvert. Borehole Nos. 1 to 4, inclusive, were previously advanced during the period of February 12th to 13th, 2014 for the initial foundation investigation described in a separate investigation report, Geocres No. 41P-59.

The additional field investigation was carried out using a truck mounted CME drilling rig equipped with hollow stem augers, standard augers, casing equipment 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. The number of blows per 300 mm penetration was recorded as the “N” value. 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. A single 19 mm diameter standpipe was installed in selected open boreholes prior to backfilling to allow for further monitoring of the shallow groundwater levels. The remaining 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 in accordance with requirements of Ontario Regulation 903. 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 fieldwork for this investigation was under the full time direction of a senior member of the LVM-Merlex 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. 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 3 (Figures Nos. L-1 and L-2 and Table No. L-3).

The locations 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. The borehole elevations are based on a survey carried out by others.

4 SUBSURFACE CONDITIONS

Details of the subsurface conditions revealed by the investigation program are presented on the enclosed Records of Borehole Logs (Appendix 2) and on Drawing 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, 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 10+000, TWP OF MICKLE

A plan and profile illustrating the borehole locations and stratigraphic sequences is shown on Drawing No. 2, Appendix 3.

During the initial exploration program, four (4) sampled boreholes were put down at this site, as follows;

- Borehole Nos. 1 and 4 were advanced in the area of the culvert outlet, and
- Borehole Nos. 2 and 3 were advanced in the area of the culvert inlet.

At the time of the initial foundation investigation, the ground surface elevations at Boreholes Nos. 1 to 4 were recorded at 299.2, 299.0, 299.3, and 299.3 m, respectively. As noted, the borehole logs for Borehole Nos. 1 to 4 have been included in this report.

During the course of the additional exploration program, two (2) sampled boreholes were put down at this site, as follows;

- Borehole No. 5 was advanced through the embankment to the east of the existing culvert;

- Borehole No. 6 was advanced through the embankment to the west of the existing culvert.

At the time of the additional subsurface investigation, the ground surface elevations at Boreholes Nos. 5 and 6 were recorded at 301.7 m and 301.6 m, respectively.

4.1.1 Pavement Structure

At ground surface, a pavement layer consisting of some 63 mm of asphalt was encountered at Borehole Nos. 5 and 6.

4.1.2 Sand Fill

Underlying the pavement layer at Borehole Nos. 5 and 6, a layer of fill consisting of brown sand trace silt to silty, trace to some gravel, was penetrated. Cobble/boulder size rock pieces were encountered below a depth of 1.0 m in this fill layer. The natural moisture content measured on samples of this deposit was in the order of 2 to 10% except a natural moisture content of 34 % encountered at Sample No. 5 recovered at the boundary of organic soil encountered in Borehole No. 6. Gradation analyses were carried out on three (3) samples of this deposit, the results of which indicated 6 to 18% gravel size particles, 59 to 71% sand size particles, and 19 to 23% silt and clay size particles (Figure No. L-1, Appendix 3). This deposit was encountered to a depth of 3.4 m below grade at Borehole Nos. 5 and 6 (elevations 298.3 and 298.2 m, respectively).

4.1.3 Organic Soils

At ground surface, at Borehole Nos. 1, 2, and 3, and underlying the granular fill at Borehole Nos. 5 and 6, a layer of organic soils was encountered. This layer was described as black silty to sandy organic soils with fine fibres. Trace gravel was encountered in this deposit at Boreholes Nos. 1 to 3. Cobbles were encountered in this deposit at Borehole Nos. 1 and 3, and a boulder was encountered in this deposit at a depth of 0.9 m below grade at Borehole No. 2. The natural moisture content measured on samples of this organic soil deposit was in the order of 25 to 144%. The layer of organic soils was encountered to depths of 1.5, 1.1, 1.1, 3.8, and 4.1 m below grade at Borehole Nos. 1, 2, 3, 5, and 6, respectively (elevations 297.7, 297.9, 298.2, 297.9, and 297.5 m, respectively).

4.1.4 Gravelly Sand to Silty Sand

Underlying the layer of organic soils at Borehole Nos. 1, 2, 3, 5, and 6, and at ground surface at Borehole No. 4, a stratum of grey sand, with varying contents of silt and gravel, trace clay was penetrated. Cobbles/boulders were encountered in this deposit. Trace organic soil was encountered in this deposit at Borehole No. 4. The natural moisture content measured on samples of this deposit was in the order of 8 to 36%. The elevated moisture contents in this deposit are likely due to the presence of organic soils. Gradation analyses were carried out on four (4) samples of this deposit, the results of which indicated 0 to 33% gravel size particles, 52 to 97% sand size particles, and 3 to 29% silt and clay size particles (Figure No. L-2, Appendix 3). Hydrometer analyses were carried out on five (5) samples of this deposit, the results of which indicated 1 to 24% gravel size particles, 50 to 70% sand size particles, 18 to 44% silt size particles, and 2 to 3% clay size particles (Figure No. L-2, Appendix 3). Atterberg Limits testing was attempted on samples of this deposit, however, the results indicated this material is non-plastic. Based on SPT 'N' values of 5 to 84 blows per 300 mm penetration and 50 blows per 50 mm penetration, the compactness of this deposit was described as loose to very dense, generally compact. Sampling was terminated in this deposit at depths of 6.1, 5.9, 6.2, 5.8, 9.6, and 9.6, m below grade at Borehole Nos. 1 to 6, respectively (elevations 293.1, 293.1, 293.1, 293.5, 292.1, and 292.0 m, respectively).

4.2 GROUNDWATER DATA

At the time of the initial investigation, the water level (ice level) at the culvert location was measured at elevation 299.4 m (February 12, 2014).

Measurements of the groundwater and cave-in levels were undertaken, where possible, in the open boreholes during the advance of the individual borings and upon completion. During the initial foundation investigation, a standpipe was installed in Borehole No. 4 to obtain post completion water levels. During the additional foundation investigation, a standpipe was installed in Borehole No. 5 to obtain post completion water levels. These levels are recorded on the individual Record of Borehole Log Sheets (Appendix 2). The water levels in Borehole Nos. 2, 3, and 4 were measured at elevations 298.7 to 299.3 m (February 12 to 13, 2014). The water levels in Borehole Nos. 5 and 6 were measured at elevations 299.2 and 296.8 m, respectively (March 19, 2015). The groundwater level at elevation 296.8 m measured in Borehole No. 6 likely had not stabilized on March 19, 2015.

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

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

An additional foundation investigation was carried for the proposed replacement of a CSP culvert as identified by the MTO.

The existing culvert is located on Highway 560 some 10.7 km west of the west junction of Highway 65 and 560, in the Township of Mickle. The existing culvert is a 4.37 x 2.87 m SPCSPA culvert some 17 m long (beveled culvert, 17 m at obvert, 24.5 m at invert). The existing culvert invert at centerline is at a depth of some 3.9 m (elevation 297.9 m). The existing highway embankment currently supports two lanes of highway, running in an east-west direction. Flow through the culvert is from the left to the right (the north to the south). Based on the subsurface information from this foundation investigation, the embankment supporting the existing pavement structure at this site has been constructed using a pavement layer structure overlying granular fills mixed with cobble/boulder size rock pieces. The native material, underlying the embankment fill, generally consisted of loose to very dense sands with cobble/boulder encountered at varying depths below the grade.

The type of culvert (concrete, CSP, or High Density Polyethylene (HDPE)) to replace the existing culverts is currently unknown. However, it is understood that the new culvert will be constructed along a similar skew and alignment and be of similar capacity. It is further understood that the final vertical alignment of the highway will remain essentially the same.

5.2 FOUNDATION CONSIDERATIONS

The founding native loose to very dense sands present below the existing embankment are considered adequate for support of a culvert and for a conventional highway embankment of this height. It should be noted that a layer of organic soils was encountered underlying the embankment fills. The organic soils, if encountered under the culvert, must be removed to native mineral soil. Bearing resistance should not be a major issue provided the natural bearing surface is not disturbed during construction and groundwater is controlled throughout construction, as discussed in Section 5.6.

Based on the characteristics of the native sand subgrade present below the culverts, the response of the existing embankment, and a founding elevation similar to that of the existing culverts, a factored bearing resistance at ULS of 500 kPa can be used for a closed culvert. In consideration of the width of the culvert, depth of overburden, and response of the existing embankment, a geotechnical reaction at SLS of 200 kPa can be used for design, in consideration of 25 mm settlement.

If open culverts (i.e. concrete frame open culverts, with wall footings, or pipe arch culverts on footings) are considered, then a factored bearing resistance at ULS of 125 kPa, and a geotechnical reaction at SLS of 80 kPa would apply for design, in consideration of 25 mm settlement and taking into consideration the limited depth of overburden and smaller footing width.

5.2.1 Slope Stability

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 2.0H:1.0V in sand fill. For the purposes of these analyses, the materials were modeled using the following parameters;

PARAMETER	MATERIAL		
	SAND FILL	SANDS	ORGANIC SOILS
Unit Weight (kN/m^3)	20.0	18.5	10
Effective Friction Angle (degrees)	32	30	-
Cohesion (kPa)	-	-	10

The unit weights and friction angles for the slope calculations are based on general representative values for the various soil types, obtained through laboratory testing and tactile analysis. The results of the analyses indicated a factor of safety for the new embankment in the order of 1.6 (see Figure No. S-1, Appendix 5). Lower factors of safety will occur during excavation and backfilling as discussed in Section 5.6. Short term stability should not be an issue if construction is carried out as described herein. The long term stability of the new embankment will not be an issue provided it is properly constructed.

5.3 CULVERT DESIGN, BEDDING, AND EMBEDMENT

The embankment consists of sand fills mixed with cobble/boulder size of rock pieces. The results of this additional investigation indicate that, below the culvert invert, the native soils consisted of a thin layer of organic soil overlying loose to very dense sands. A review of the condition of the pavement surface, at the culvert locations, revealed some minor asphalt cracking, however, in general, the embankment appears to have performed well. 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 increases 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, provided that the encountered thin organic soils are removed below the culvert invert.

5.3.1 Rigid Concrete Culvert

Concrete pipes can be considered for culvert replacement at this site. A Class B Bedding for the concrete pipes shall consist of Granular A with a thickness of 300 mm after any organic soils are removed below the culvert invert if encountered. Alternatively, specifically if construction is carried out under wet conditions, a 19 mm clear stone bedding should be used, which would aid in dewatering operations, after any organic soils are removed below the culvert invert, if encountered. 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 must be limited to a maximum 200 mm. Cover material for concrete pipes can consist of

Granular A and placed to the dimensions as shown on OPSD 802.031. If circular concrete pipes are used, compaction of the haunch is critical and should be in accordance with OPSS 501.

A precast concrete rigid frame box culvert can also be 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 after any organic soils are removed below the culvert invert, if encountered. The bedding under the middle third of the box unit base should be loosely placed and uncompacted to prevent overstressing the middle third (bottom span) as the box sides settle, in accordance with OPSS 422.07.07. 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. 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, after any organic soils are removed below the culvert invert, if encountered. 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 400 mm. The backfill material should be placed in uniform layers not exceeding uncompacted thickness of 200 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 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.

The inlet and outlet stream bed shall be protected with a rip-rap (R-50 size as per OPSS 1004) apron. The apron shall be 5 m in length, 400 mm thick and extend across the stream bed to 5 m beyond the outside edges of the culvert. Clay seals are generally used where significant head differences exist between the inlet and outlet of the culverts to prevent flow through the bedding/embedment granulars. Clay seals are not required at this culvert location.

5.3.2 Flexible Culvert

Flexible culverts (i.e. CSP/SPCSP/HDPE) can also be considered for culvert replacement at this site. If flexible pipes are used for replacement, embedment material should consist of Granular B Type I provided the maximum size of stone inclusions is limited to 25 mm or less in size and placed in accordance with OPSD 802.010 for a Type 3 soil after any organic soils are removed below the culvert invert, if encountered. 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 embedment fill should be placed in a balanced manner on the outer sides of the culvert units. The elevation difference of the backfill on either side of the culvert must be limited to a maximum 200 mm.

Considering the porous nature of the embankment fill, 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-50 size as per OPSS 1004) apron. The apron shall be 5 m in length, 400 mm thick and extend across the stream bed to 5 m beyond the outside edges of the culvert.

5.4 CULVERT INSTALLATION AND CONSTRUCTION STAGING CONSIDERATIONS

The invert elevation of the existing culvert is at 297.9 m, with the top of the embankment at elevation 301.8 m at centerline. As such, the embankment at this location is some 3.9 m in height above the culvert invert at the centerline. Therefore, a minimum 4.2 m deep excavation (i.e. to elevation 297.6 m) will be required in consideration of a 300 mm thick layer of bedding/embedment material after any organic soils are removed below the culvert invert, if encountered, and replaced by the bedding/embedment material. The present platform width at this location is some 9.5 m as shown on the cross section on Drawing No. 2. The platform width at this location, as is, will not be sufficient to carry out an open excavation using staged construction unless the temporary lowering/widening of embankment within the appropriate chainage limits is undertaken. Considering the embankment width and height of embankment, lowering/widening is not considered feasible for open cut excavations at this site. As such, consideration should be given to constructing a temporary shoring wall for use as a protection system.

5.4.1 Protection System

As noted above, consideration should be given to constructing a vertical shoring wall, along centerline, for use as a temporary protection system.

The installation of a protection system for use in the culvert replacement operation will require penetration through some 3.9 m of fills. The embankment fills are generally underlain by loose to very dense, generally compact, sands. As noted, cobbles/boulders size rocks were encountered in the embankment fills and native sands. Considering the presence of cobble/boulder size rock pieces in the embankment, advancing a temporary retaining system (i.e. driven sheet piles) through the embankment fill may be problematic. Several approaches to constructing a protection system are described in the following. See Table A in Appendix 5, for advantages and disadvantages for the different type of protection system considered for this site. A conceptual shoring location plan and a conceptual cross section are illustrated on Figure Nos. SK-2 and SK-3, respectively, in Appendix 5.

One method to construct a protection system would be to penetrate the rock fill in the embankment with H piles (soldier piles) extending into the underlying sands and install lagging. Pre-drilling may likely be required to advance the H piles through the fill and into the underlying soils, if the cobble/boulder sizes of rock pieces is encountered. The H piles would be installed at an interval of 2.5 to 3 m apart and the lagging would be installed as the excavation progresses. A waler and raker or tie-back anchor system would have to be installed as the excavation advances. The contractor must be prepared to address the large rock pieces and control groundwater as the excavation progresses, without compromising the adjacent active lane of traffic.

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):

$R = \sigma'_z * A_s * L_s * \alpha_g$ Where: σ'_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

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.

Alternatively, a caisson wall or drilled micropile system with an intermediate support system of reinforced shotcrete, to act as lagging, could be considered for the roadway protection at this site. However this shoring system is generally more costly.

The contractor's shoring/protection system design must be carried out by a geostructural engineer with appropriate experience.

The protection system can be designed using the lateral earth pressure parameters as outlines in Section 5.5.

Considering the cohesionless nature of the embankment fills (granular pavement structure overlying a granular fill and rock fill mix) 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 $0.65 * K_a * \gamma * H$, where:

K_a = active earth pressure,

γ = unit weight, and

H = height of wall above the base of excavation.

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	SAND FILL	SANDS	ORGANIC SOILS
Unit Weight (kN/m^3)	22.8	21.2	20.0	18.5	10.0
Angle of Internal Friction	34°	31°	32°	30°	-
Shear Strength (kPa)	-	-	-	-	10
Coefficient of Active Earth Pressure (K_a)	0.28	0.32	0.31	0.33	-
Coefficient of Passive Earth Pressure (K_p)	3.54	3.12	3.25	3.00	-
Coefficient of Earth Pressure at Rest (K_o)	0.44	0.48	0.47	0.50	-

For rigid structures, such as a precast concrete culvert, deflection cannot occur, as such the "at-rest" condition (K_o) applies. For flexible structures, such as CSP/HDPE culverts, 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 continuously, however, 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. Temporary open cuts with a slope of 1H:1V cannot be left unattended (i.e. overnight, during breakdowns, etc.). If work must stop for extended periods of time, the temporary slopes must be flattened to a minimum angle of 2H:1V.

The excavation backfill should consist of Select Subgrade Material (SSM) as per OPS.PROV 1010, at a minimum, up to the underside of the pavement structure. An SSM material must be used within the depth of frost penetration. Final (permanent) embankment side slopes in sand fills should be established to match the existing slopes or as per OPSD 200.010. Final slopes should be treated with a mulch and seed to prevent ravelling.

Bedrock was not encountered at the borehole locations within the anticipated depth of excavation.

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. 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 299.4 m at the time of the initial investigation (February 12, 2014) and excavations to an approximate elevation 297.6 m will be required to install the culvert and bedding. As such, dewatering will be required during excavation and culvert installation.

In order to dewater the culvert location a cofferdam will be required at the inlet and outlet. A complete cofferdam at the inlet and outlet with bypass pumping is the suggested method of controlling the creek flow. A bypass pipe could be suspended from the roof of the existing culvert, considering the culvert size, or alternately installed through the existing embankment.

A temporary gravity type cofferdam is the recommended method of controlling the creek flow at this culvert location. A gravity type cofferdam could be constructed of earth fill with a low permeable core, sand bag/metre bag, or aquadam (water filled bladder) type dam. Depending upon the base width of the cofferdam, seepage may develop below the temporary sand bag wall. This may require pumping from filtered sump holes within the dewatered area.

A sheet pile type cofferdam could also be considered for use during culvert replacement. However, it should be noted that cobbles and boulders were encountered in the existing organic soils and native sand deposits. As such, advancing a sheet pile cofferdam may be problematic during construction. Therefore, a sheet pile type cofferdam may not be appropriate at this site. For information purposes, to resist the 1.8 m hydrostatic pressure, a sheet pile wall will attain structural stability from its geometry and depth of penetration of the sheets, therefore may require minimal interior bracing. To minimize seepage below the cofferdam, the sheets should extend to a minimum depth below the inside base equal to the depth of water above the base. The depth of sheet penetration will be determined by structural and seepage considerations.

It should be noted that deposits of organic soils of significant thickness (1.3 to 1.5 m) were encountered at the borehole locations, with exception of Borehole No. 4, advanced beyond the inlet and outlet. The design of the cofferdam system must account for the presence of organic soils in and around the channel.

A conceptual cofferdam sketch has been shown on Figure SK-4 in Appendix 5.

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 construction operations cannot be stressed enough.

5.7 CONSTRUCTION CONCERNS

Considering the nature of the granular fill embankment, no major construction concerns are anticipated if construction is carried out in general conformance with the above discussion. However, the Contractor should be prepared to deal with the cobble/boulder size rock pieces in the embankment fills and native soils.   The Contractor must also be prepared to the roadway protection system and control the ground water during excavation and construction operations.

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.

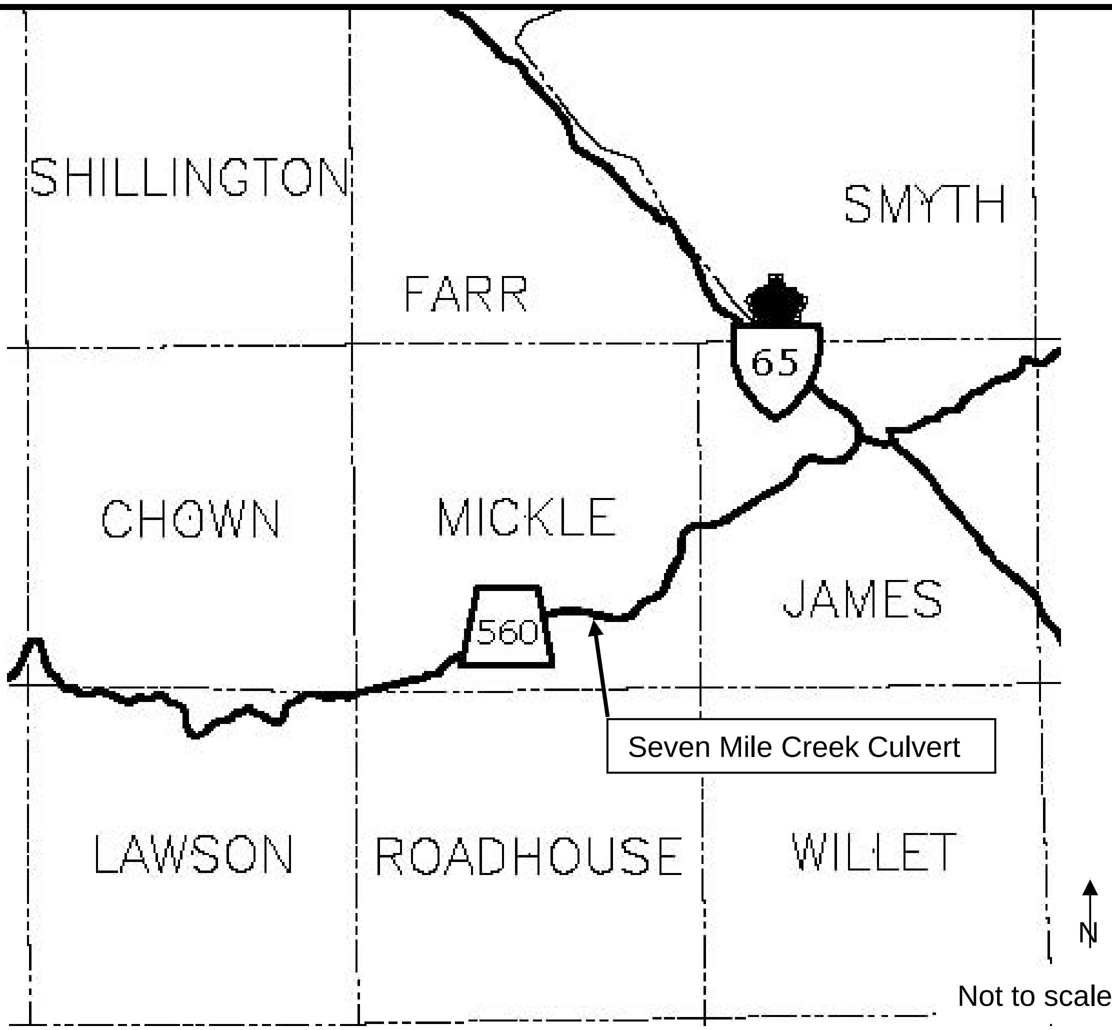
Section 5 of this reported is intended for the use of the client and the design team only and is not intended to be included in the tender documents. Inclusion of the factual information (Sections 1 to 5 inclusive) in the tender documents is furnished merely for the general information of bidders and 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 ADDITIONAL FOUNDATION INVESTIGATION AND DESIGN REPORT
GWP 5242-11-00
Highway 560

Seven Mile Creek Culvert

Reference No: 13/05/13073-F5 August 2015

LVM Merlex

Appendix 2 Subsurface Data

Enclosure No. 1	List of Abbreviations and Symbols
Enclosure Nos. 2 to 7	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
Rec % recovery from individual run of rock core
RQD Rock quality designation (%)

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) *Cohesive Soils:*

RQD (%)	*Classification*
Less than 25	Very poor quality
25 to 50	Poor quality
50 to 75	Fair quality
75 to 90	Good quality
90 to 100	Excellent quality

d) *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.

e) *Soil Moisture:*

Moisture	*Described as*
Dry	Below optimum moisture content
Moist	Near optimum moisture content
Wet	Above optimum moisture content

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 boulders is based on auger response and field observations:

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

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. 01

LVM Merlex

REFERENCE	13/05/13073-F5	DATUM	Geodetic	LOCATION	N 5283259.1 E 346463.0 - Mickle Township - Station 10+005
PROJECT	GWP 5839-05-00, Hwy 560 - Seven Mile Creek Culvert	BOREHOLE TYPE	Track Mounted CME 45B - Hollow Stem Augers		
CLIENT	AECOM Canada Inc.	DATE (Started)	12 February 2014	DATE (Completed)	12 February 2014
TIME (Completed)	2:45:00 PM				

ORIGINATED BY: JL
COMPILED BY: AT
CHECKED BY: MAM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%) (approx.)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
299.2	Ground Surface						
0.0	ORGANIC SOILS - silty to sandy organic soils with fine fibres	1	AS		299	~59	
	black	2	SS	28		~25	
	cobbles encountered between 0.5 and 1.1 m depth						
297.7		3	SS	7	298	~48	
1.5	SAND - trace silt to silty trace to with gravel trace clay						
	grey	4	SS	8	297	~27	1 52 44 3 (NP)
	(loose)	5	SS	9	296	~20	4 88 (8)
	cobbles encountered between 3.5 and 4.1 m depth	6	SS	50/50 mm		~19	
	(compact)	7	SS	29	295	~14	24 50 24 2 (NP)
					294		
293.1		8	SS	22		~16	
6.1	End of Sampling 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)		-	-
2)		-	-
3)		-	-

MEL-GEO 13073-F5 - BOREHOLE LOGS - SEVEN MILE - ADDITIONAL.GPJ MEL-GEO.GDT 12/5/15

LVM-Merlex, a Division of EnGlobe Corp.
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. 02

LVM Merlex

REFERENCE 13/05/13073-F5 DATUM Geodetic LOCATION N 5283284.5 E 346470.4 - Mickle Township - Station 10+008 ORIGINATED BY JL

PROJECT GWP 5839-05-00, Hwy 560 - Seven Mile Creek Culvert BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT

CLIENT AECOM Canada Inc. DATE (Started) 12 February 2014 DATE (Completed) 12 February 2014 TIME (Completed) 5:30:00 PM CHECKED BY MAM

ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
299.0	Ground Surface									
0.0	ORGANIC SOILS - silty to sandy organic soils with fine fibres black bouder encountered at 0.9 m depth		1	SS	2					
297.9 1.1	SAND - trace to with silt trace some gravel grey cobbles/boulders encountered between 1.1 and 5.9 m depth (compact/dense)		2	SS	14		298			
			3	SS	37		297			
			4	SS	26		296			
			5	SS	17					
			6	SS	50/75 mm		295			
			7	SS	31		294			
293.1 5.9	End of Sampling 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

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) 12/2/14 4:10:00 PM	0	0.6
2)	-	-
3)	-	-

MEL-GEO 13073-F5 - BOREHOLE LOGS - SEVEN MILE - ADDITIONAL.GPJ MEL-GEO.GDT 12/5/15

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

METRIC

RECORD OF BOREHOLE NO. 03

LVM Merlex

REFERENCE 13/05/13073-F5 DATUM Geodetic LOCATION N 5283287.9 E 346457.8 - Mickle Township - Station 9+995 ORIGINATED BY JL

PROJECT GWP 5839-05-00, Hwy 560 - Seven Mile Creek Culvert BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT

CLIENT AECOM Canada Inc. DATE (Started) 13 February 2014 DATE (Completed) 13 February 2014 TIME (Completed) 11:45:00 AM CHECKED BY MAM

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
299.3	Ground Surface							
0.0	ORGANIC SOILS - silty to sandy organic soils with fine fibres trace gravel	1	SS	10		299	144	
	black	2	SS	3	Water level / cave-in symbols		○	
298.2	cobbles encountered between 0.0 and 1.1 m depth							
1.1	SAND - trace to with silt trace to some gravel trace clay					298		
	grey	3	SS	78			○	13 63 21 3 (NP)
	cobbles encountered between 2.7 and 6.2 m depth	4	SS	61		297	○	
	(compact/very dense)	5	SS	24		296	○	10 70 18 2 (NP)
		6	SS	26		295	○	
		7	SS	31		294	○	15 53 29 3 (NP)
293.1		8	SS	50/125 mm			○	
6.2	End of Sampling End of Borehole							

Column headings: SOIL PROFILE; STRATA PLOT; SAMPLES; 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) 13/2/14 11:25:00 AM	0.6	0.7
2)	-	-
3)	-	-

MEL-GEO 13073-F5 - BOREHOLE LOGS - SEVEN MILE - ADDITIONAL.GPJ MEL-GEO.GDT 12/5/15

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

METRIC

RECORD OF BOREHOLE NO. 04

LVM Merlex

REFERENCE 13/05/13073-F5 DATUM Geodetic LOCATION N 5283261.3 E 346453.2 - Mickle Township - Station 9+995 ORIGINATED BY JL

PROJECT GWP 5839-05-00, Hwy 560 - Seven Mile Creek Culvert BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT

CLIENT AECOM Canada Inc. DATE (Started) 13 February 2014 DATE (Completed) 13 February 2014 TIME (Completed) 6:15:00 PM CHECKED BY MAM

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
299.3	Ground Surface				
0.0	SAND - trace to with silt trace gravel trace organic soil brown ------ grey (loose/compact)	1	SS	15	
		2	SS	16	
		3	SS	6	
		4	SS	12	0 97 (3)
		5	SS	7	
		6	SS	15	
		7	SS	27	
293.5 5.8	End of Sampling End of Borehole				

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRATA PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (299, 298, 297, 296, 295, 294); 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) 13/2/14 2:35:00 PM	0	-
2)	-	-
3)	-	-

MEL-GEO 13073-F5 - BOREHOLE LOGS - SEVEN MILE - ADDITIONAL.GPJ MEL-GEO.GDT 12/5/15

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

METRIC

RECORD OF BOREHOLE NO. 05

LVM Merlex

REFERENCE 13/05/13073-F5 DATUM Geodetic LOCATION N 5283276.4 E 346464.5 - Mickle Township - Station 10+003.5 ORIGINATED BY JL

PROJECT GWP 5839-05-00, Hwy 560 - Seven Mile Creek Culvert BOREHOLE TYPE Truck Mounted CME 45B - Hollow Stem Augers COMPILED BY AT

CLIENT AECOM Canada Inc. DATE (Started) 18 March 2015 DATE (Completed) 18 March 2015 TIME (Completed) 5:20:00 PM CHECKED BY MAM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	Water content (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
301.7	Ground Surface					
0.0	63 mm Asphalt					
	FILL - sand some to with silt trace to some gravel; brown, dry	1	AS		○	
	cobble/boulder size rock pieces encountered	2	AS		○	16 65 (19)
		3	AS	25/12 mm	○	
		4	AS	25/0 mm	○	
298.3		5	AS	25/0 mm	○	
3.4	ORGANICS - brown silty organics					
297.9 / 3.8	SAND - some to with silt trace gravel to gravelly; grey, moist; (compact/very dense)	6	SS	26	○	33 52 (15)
		7	SS	62	○	
	cobbles/boulders encountered below 4.5 m depth	8	SS	35	○	
		9	SS	69	○	
292.1		10	SS	84	○	
9.6	End of Sampling End of Borehole					

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRATA PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (301, 300, 299, 298, 297, 296, 295, 294, 293); 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) 18/3/15 5:20:00 PM	2.6	-
2) 19/3/15 8:05:00 AM	2.5	-
3) 19/3/15 5:00:00 PM	2.5	-

MEL-GEO 13073-F5 - BOREHOLE LOGS - SEVEN MILE - ADDITIONAL.GPJ MEL-GEO.GDT 12/5/15

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ENCLOSURE NO.: 7 (Pg. 1 of 1)

METRIC

RECORD OF BOREHOLE NO. 06

LVM Merlex

REFERENCE 13/05/13073-F5 DATUM Geodetic LOCATION N 5283271.6 E 346447.9 - Mickle Township - Station 9+988 ORIGINATED BY JL

PROJECT GWP 5839-05-00, Hwy 560 - Seven Mile Creek Culvert BOREHOLE TYPE Truck Mounted CME 45B - Hollow Stem Augers COMPILED BY AT

CLIENT AECOM Canada Inc. DATE (Started) 19 March 2015 DATE (Completed) 19 March 2015 TIME (Completed) 5:40:00 PM CHECKED BY MAM

ELEV / DEPTH (m)	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
301.6	Ground Surface					
0.0	63 mm Asphalt FILL - sand some to with silt trace to some gravel brown, dry cobble/boulder size rock pieces encountered	1	AS			
		2	AS			18 59 (23)
		3	AS	25/0 mm		
		4	AS	25/12 mm		6 71 (23)
298.2		5	AS	25/0 mm		
3.4	ORGANICS - black silty organics					
297.5		6	SS	11		
4.1	SAND - some to with silt trace gravel to gravelly grey, moist (compact/very dense)	7	SS	5	▽ (El. ~296.8)	0 71 (29)
		8	SS	9		
	cobbles/boulders encountered below 7.0 m depth	9	SS	19		
292.0		10	SS	15		
9.6	End of Sampling End of Borehole					

Elevation scale: 301, 300, 299, 298, 297, 296, 295, 294, 293, 292

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)	19/3/15 5:40:00 PM	4.8	-
2)		-	-
3)		-	-

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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 Borehole Plan and Lab Data

Drawing No. 2:	Borehole Location and Soil Strata
Figure Nos. L-1 and L-2:	Grain Size Distribution Curves
Table No. L-3:	Lab Test Summary Sheet

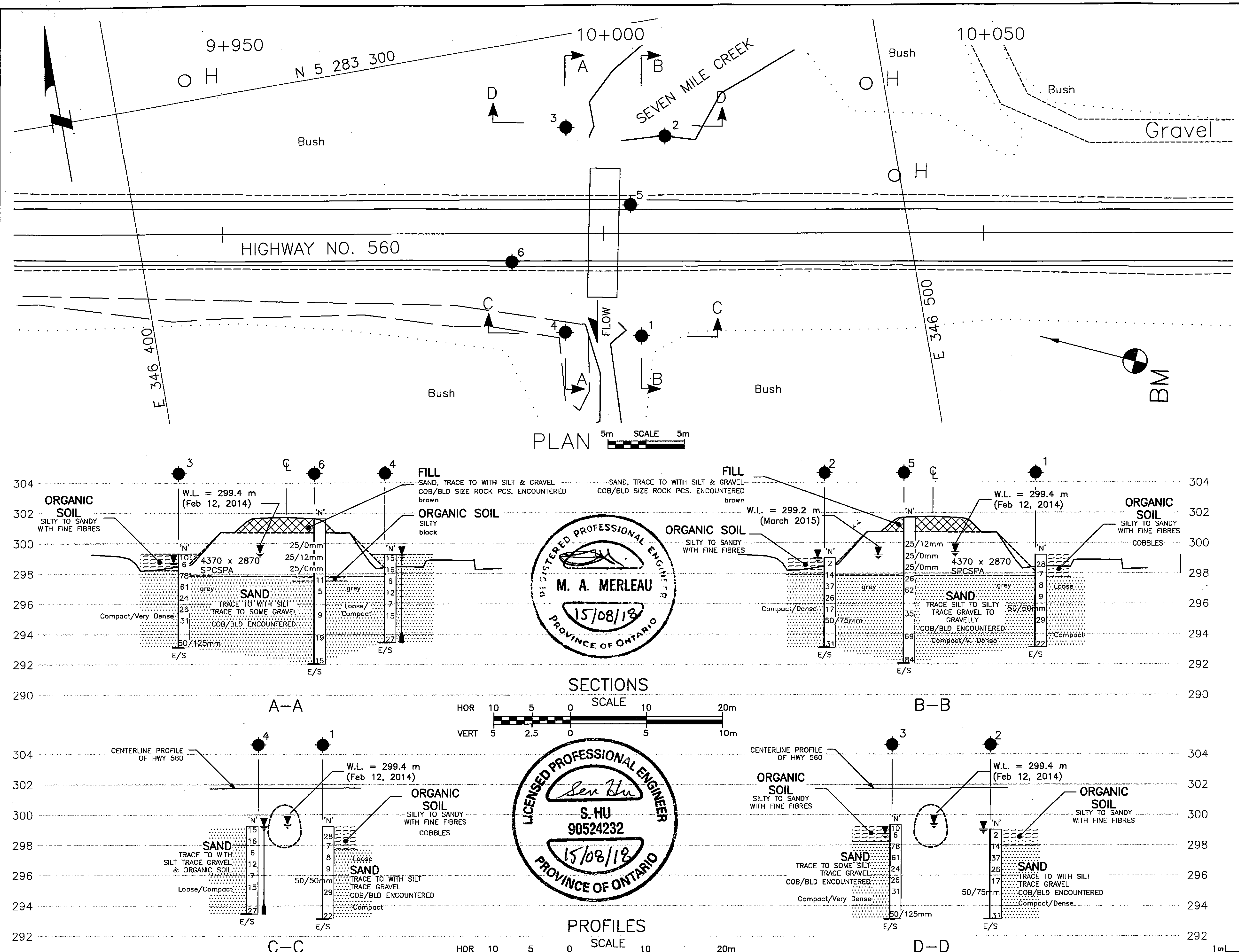
DISTRICT
CONT. No. XXXX-XXXX
GWP No. 5242-11-00

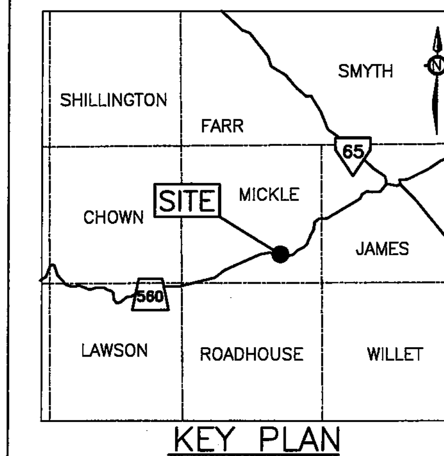
HWY 560
SEVEN MILE CREEK CULVERT
MICKLE TOWNSHIP
BOREHOLE LOCATIONS
AND SOIL STRATA

DRAWING 2

LVM Merlex

METRIC





KEY PLAN
N.T.S.

LEGEND

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

BOREHOLE No.	ELEVATION	O/S	NORTHING	EASTING
1	299.2	13.5m Rt	5283259.1	346463.0
2	299.0	13.1m Lt	5283284.5	346470.4
3	299.3	14.0m Lt	5283287.9	346457.8
4	299.3	13.0m Rt	5283261.3	346453.2
5	301.7	3.8m Lt	5283276.4	346464.5
6	301.6	3.7m Rt	5283271.6	346447.9

NOTES:

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.

2. Base plan and alignment provided in digital format by exp. on October 28, 2014.

GEOCRES No. 41P-59A

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.

DRAWING NOT TO BE SCALED
50mm ON ORIGINAL DRAWING

REVISIONS		DESCRIPTION
MAY/14	RG	INITIAL SITE INVESTIGATION
MAR/15	RG	ADDITIONAL INVESTIGATION
AUG/15	RG	FINAL

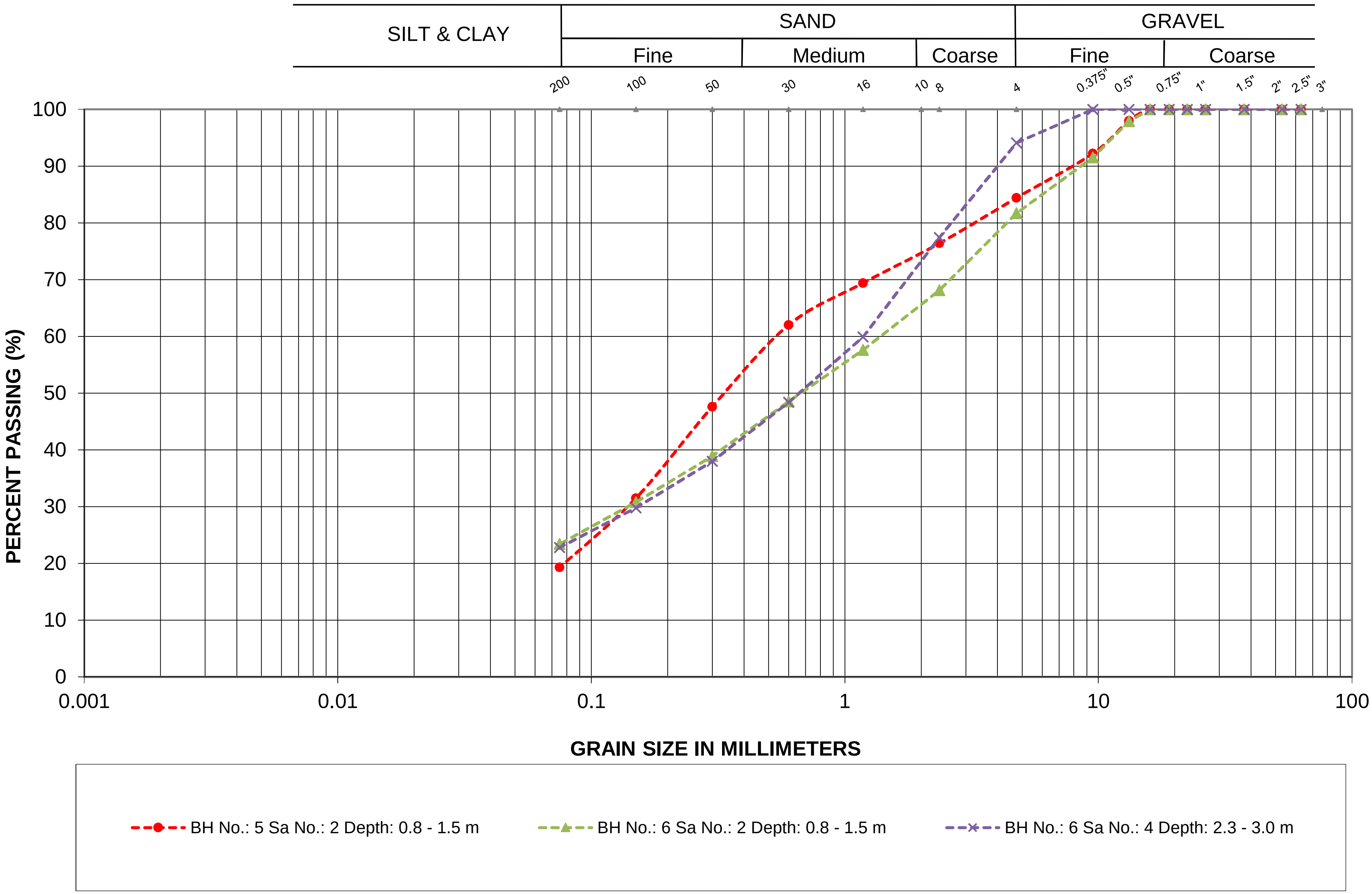
DESIGN	CHK	CODE	LOAD	DATE AUG/15
DRAWN RG	CHK AT	SITE 47-314/C	STRUCT	SCHEME	DWG 2

CAD FILE LOCATION AND NAME G:\2013\3073 - PAVE & FDN, Hwy 65 (AECOM)\FOUNDATIONS\F5-Seven Mile GWP 5242-11-00\Additional Investigation\Drawings\Working - Do not move or delete files\13073-F5 - BH PLAN - Seven Mile Creek.dwg
MODIFIED 8/14/2015 9:26:10 AM BY GRASRY
DATE PLOTTED 8/14/2015 9:26:22 AM BY: RYAN GRASSER

MINISTRY OF TRANSPORTATION, ONTARIO
PH-D-707 88-05

Reference No.: 13/05/13073-F5
Date: August 2015

GRAIN SIZE ANALYSIS



G.W.P.: 5242-11-00
LOCATION: Hwy 560, Seven Mile Creek

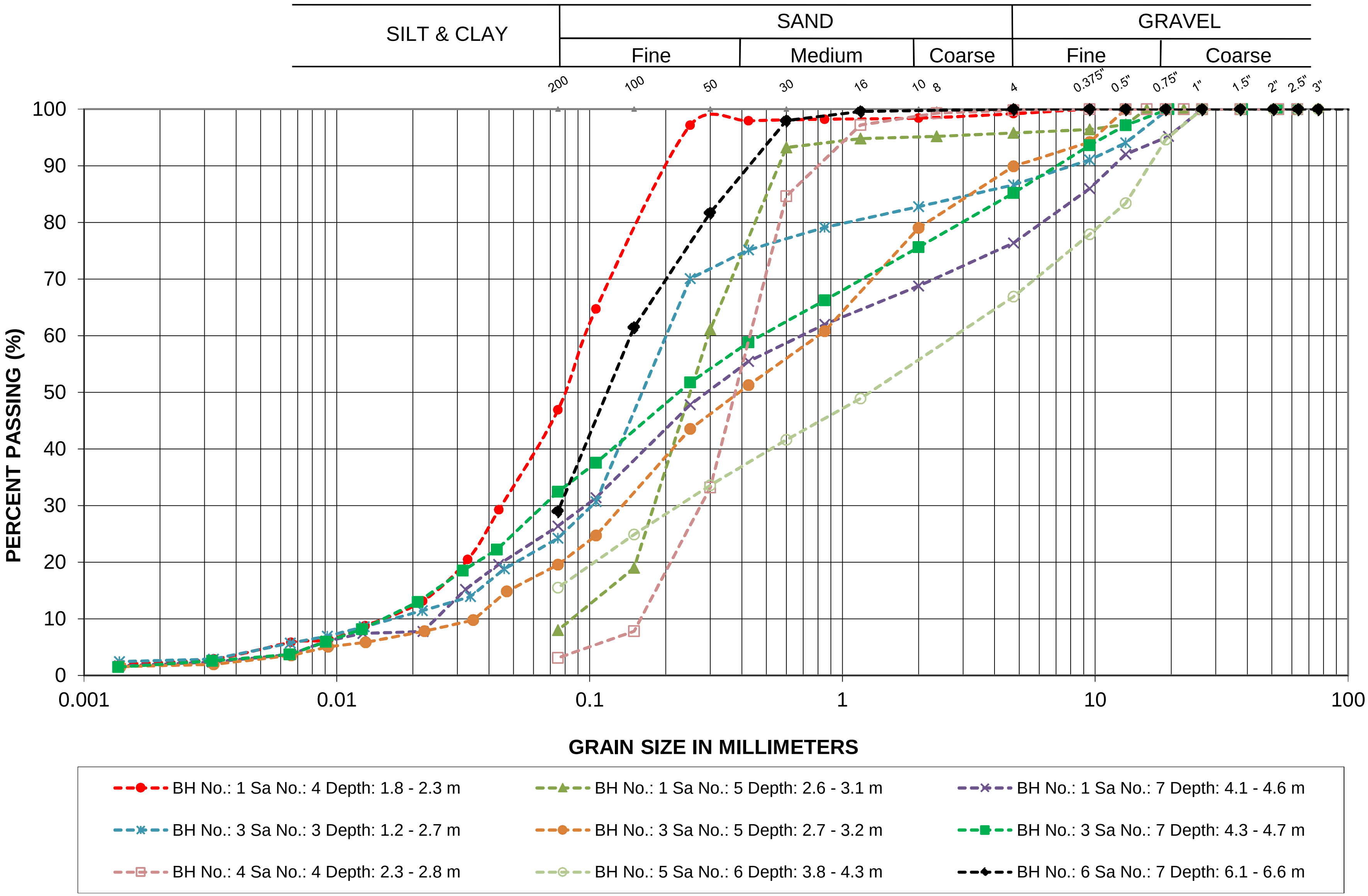
SAND FILL

LVM-MERLEX

FIGURE L-1

Reference No.: 13/05/13073-F5
Date: August 2015

GRAIN SIZE ANALYSIS



G.W.P.: 5242-11-00
LOCATION: Hwy 560, Seven Mile Creek

GRAVELLY SAND to SILTY SAND

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					57.1							
	2	0.3					24.7				28			
	3	1.1					48.2				7			
	4	1.8	1	52	44	3	28.2				8			Non-Plastic
	5	2.6	4	88	8		20.6				9			
	6	3.4					17.7				50/50mm			
	7	4.1	24	50	24	2	9.3				29			Non-Plastic
	8	5.6					12.6				22			
2	1	0.2					72.2				2			
	2	0.9					9.1				14			
	3	1.7					9.0				37			
	4	2.4					15.3				26			
	5	3.2					15.5				17			
	6	4.0					16.9				50/75 mm			
	7	5.5					12.1				31			
3	1	0.0					144.0				10			
	2	0.5					30.6				3			
	3	1.2	13	63	21	3	14.7				78			Non-Plastic
	4	2.0					10.7				61			
	5	2.7	10	70	18	2	14.2				24			Non-Plastic
	6	3.51					9.6				26			
	7	4.27	15	53	29	3	10.1				31			Non-Plastic
	8	5.8					13.2				50/125 mm			

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 (%)				
4	1	0.0					36.4				15			
	2	0.8					21.4				16			
	3	1.5					23.9				6			
	4	2.3	0	97	3		24.0				12			
	5	3.1					18.6				7			
	6	3.8					18.4				15			
	7	5.3					11.1				27			
5	1	0.0					2.6							
	2	0.8	16	65	19		6.6							
	3	1.5					9.2				25/12 mm			
	4	2.3					7.7				25/0 mm			
	5	3.1					9.7				25/0 mm			
	6	3.8	33	52	15		13.5				26			
	7	4.57					10.7				62			
	8	6.1					11.8				35			
	9	7.62					10.8				69			
	10	9.14					16.7				84			
6	1	0					2.8							
	2	0.76	18	59	23		2.3							
	3	1.52					2.8				25/0 mm			
	4	2.29	6	71	23		4.5				25/12 mm			
	5	3.05					34.4				25/0 mm			
	6a	3.81					28.4				11			
	6b	3.81					29.2							
	7	4.57	0	71	29		25.3				5			

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 (%)				
6	8	6.1					16.8				9			
	9	7.6					8.3				19			
	10	9.1					11.3				15			

Appendix 4 Photo Essay

Enclosure No. 8: Photo Essay

Culvert Inlet – Looking North	Photo: 1

Culvert Outlet – Looking South	Photo: 2

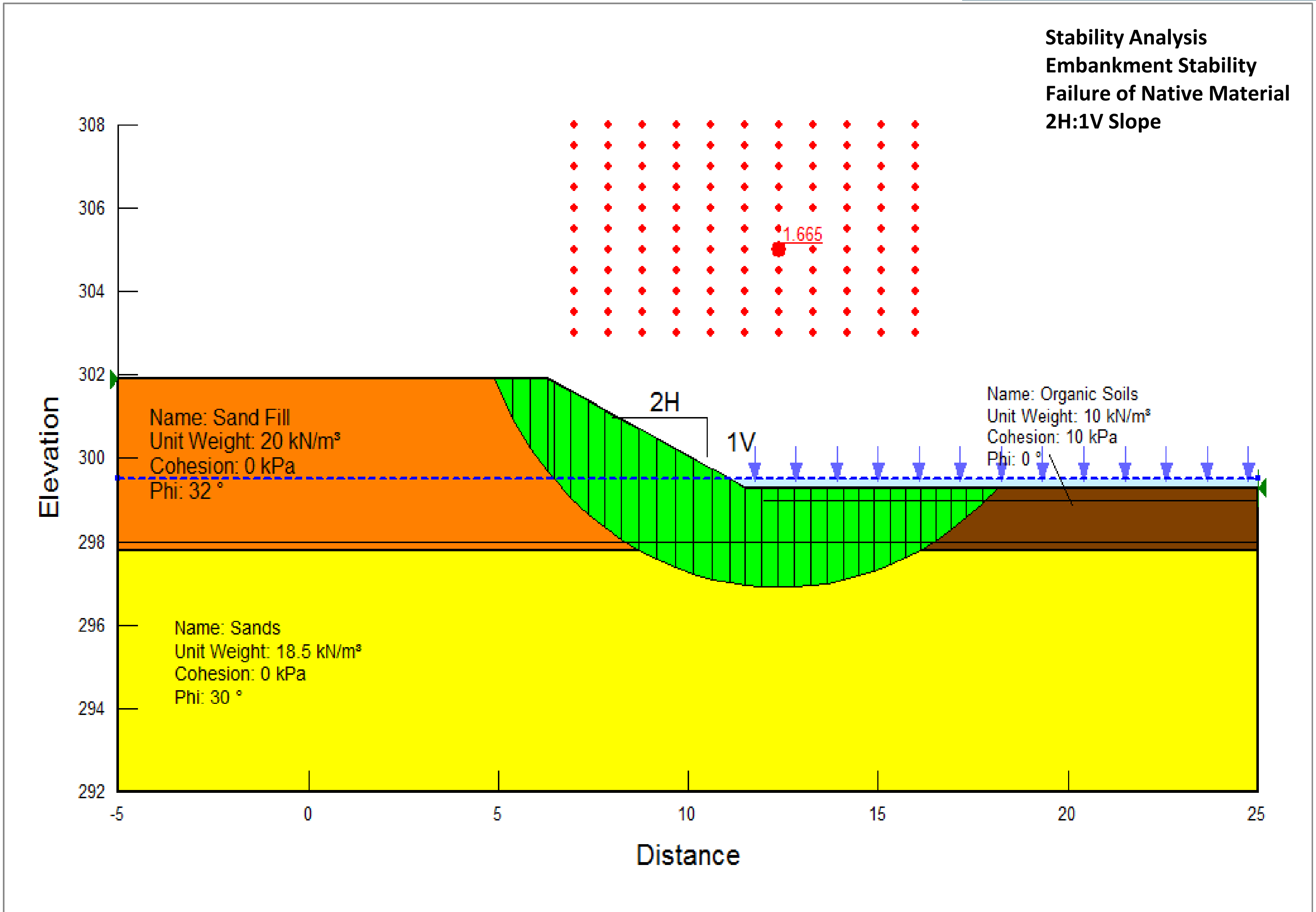
Project: Hwy 560 – Seven Mile Creek Culvert	Photos Provided By: LVM Date: July 2013

Existing Embankment at Culvert Location – Looking North	Photo: 2
	
Project: Hwy 560 – Seven Mile Creek Culvert	Photos Provided By: LVM Date: March 2015

Appendix 5 Design Data

Figure No. S-1:	Slope Stability
Table A:	Comparison of Shoring Alternatives
Figure No. SK-2:	Conceptual Shoring Locations
Figure No. SK-3:	Conceptual Shoring Sections
Figure No. SK-4:	Conceptual Cofferdam Sketch
	Notice to Contractor

Reference No.: 13/05/13073-F5
Date: August 2015



Stability Analysis
Culvert 10+000
TWP of Mickle

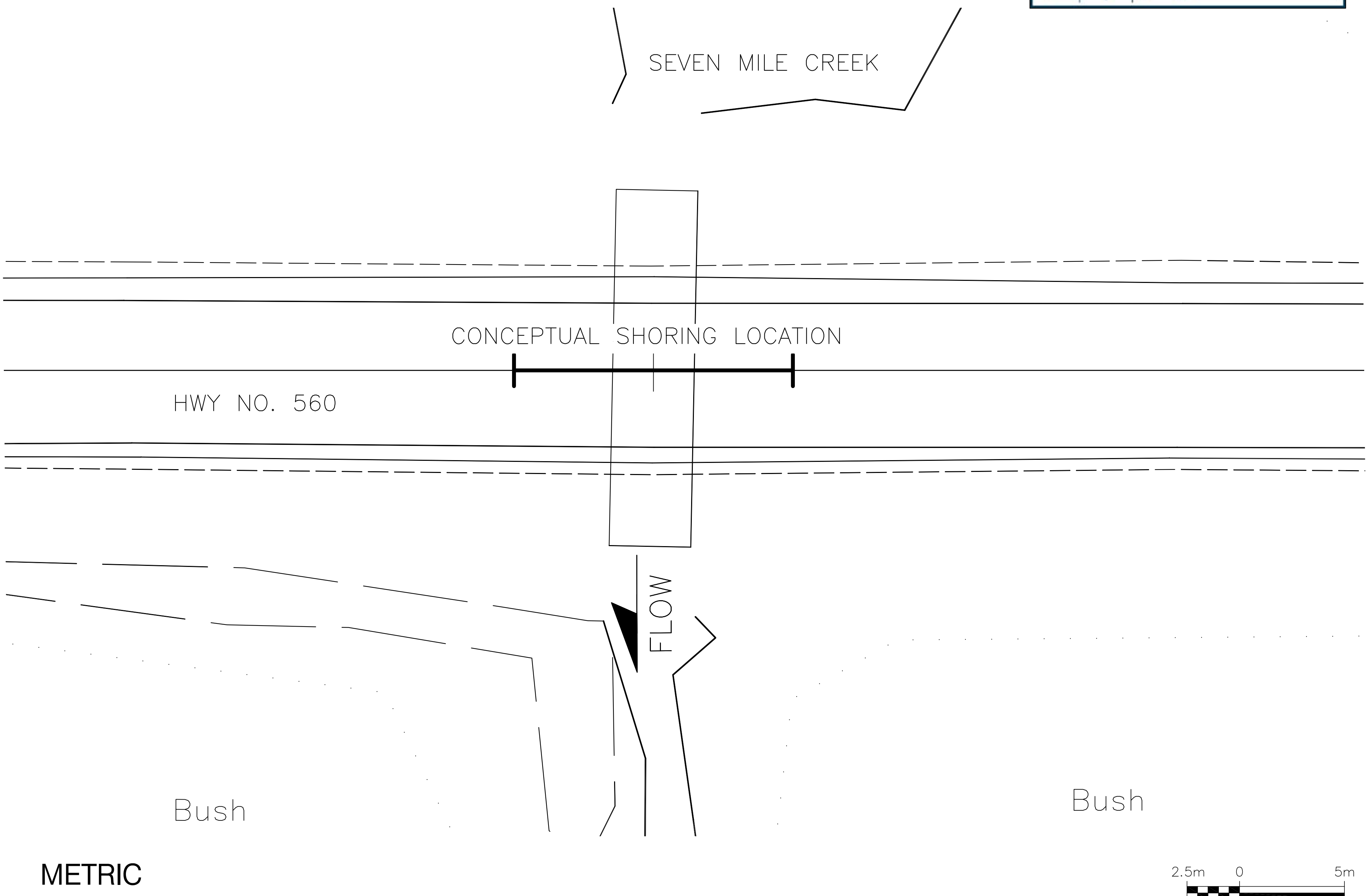
Project: G.W.P 5242-11-00
Location: Hwy 560

Figure No. S-1

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	Not considered due to rock fill embankment	$ 650/m^2
Steel Sheet Piles	5 – 21	-High strength, continuous, -Readily available	-Limited by soil conditions (i.e. obstructions)	Not considered due to rock fill embankment	$ 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	Recommended, must be carried out in conjunction with dewatering due to high ground water levels.	$ 725/m^2 Predrilling $ 1500/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	May be considered; however, higher cost	$ 1200 to 1500/m^2

REF.: 13073-F5



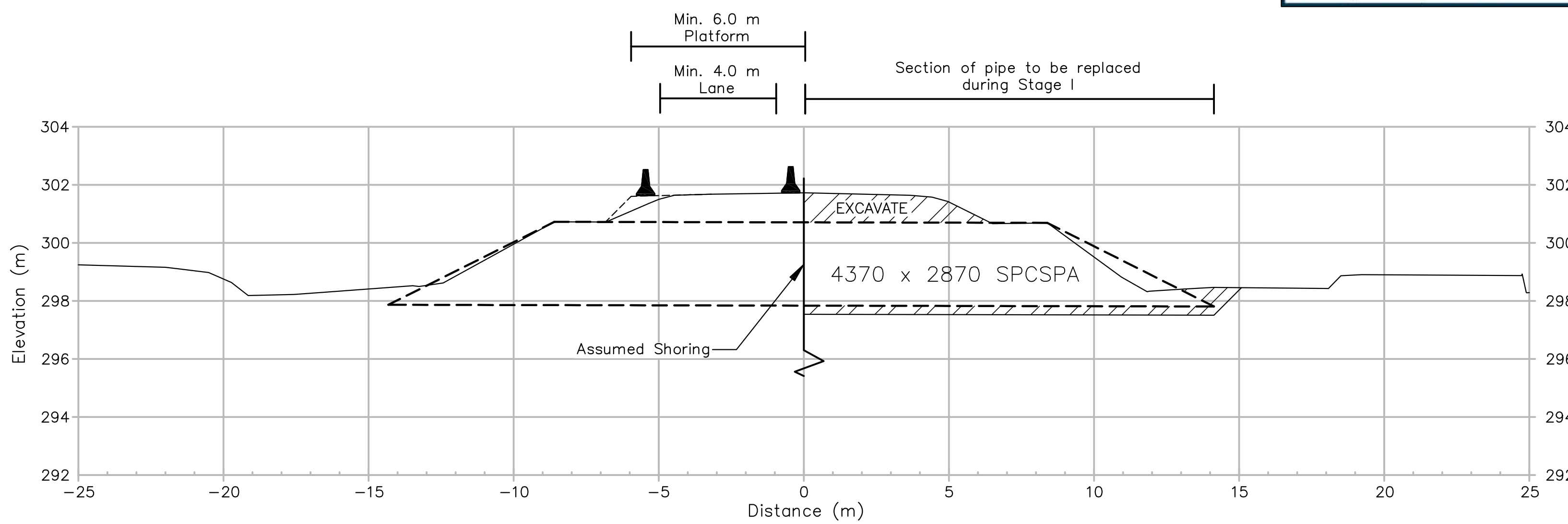
METRIC

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

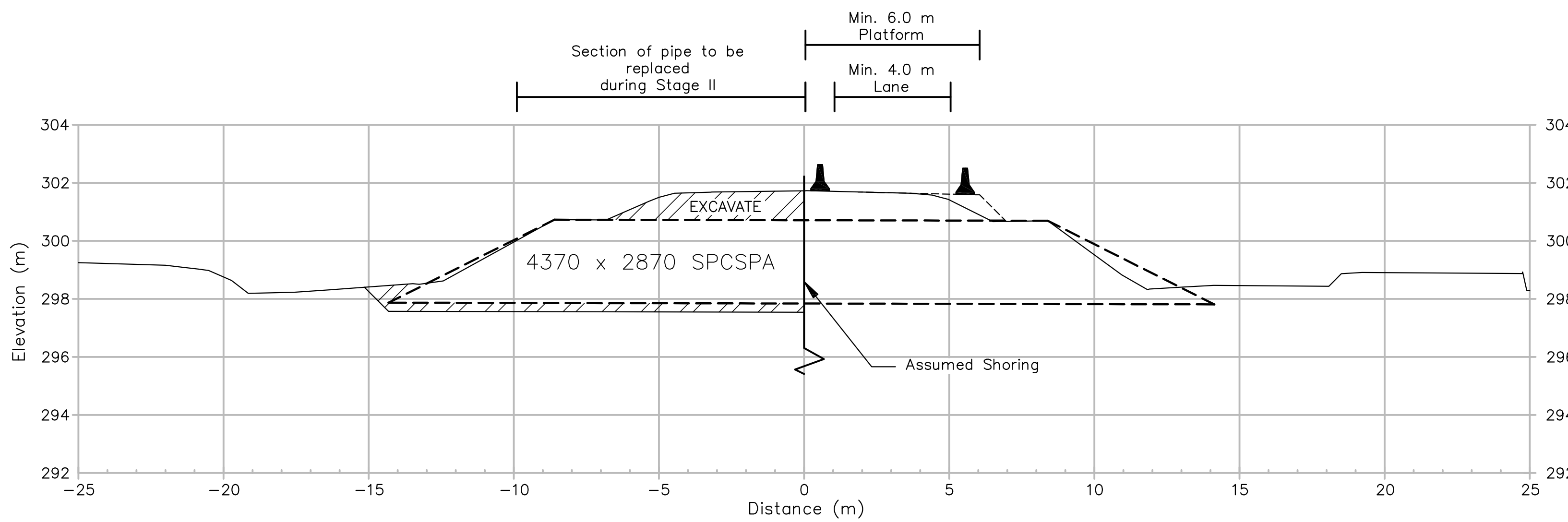
Highway 560, Township of Mickle - Culvert at Station 10+000
Conceptual Shoring Location Plan

FIGURE SK-2

REF.: 13073-F5



STAGE I



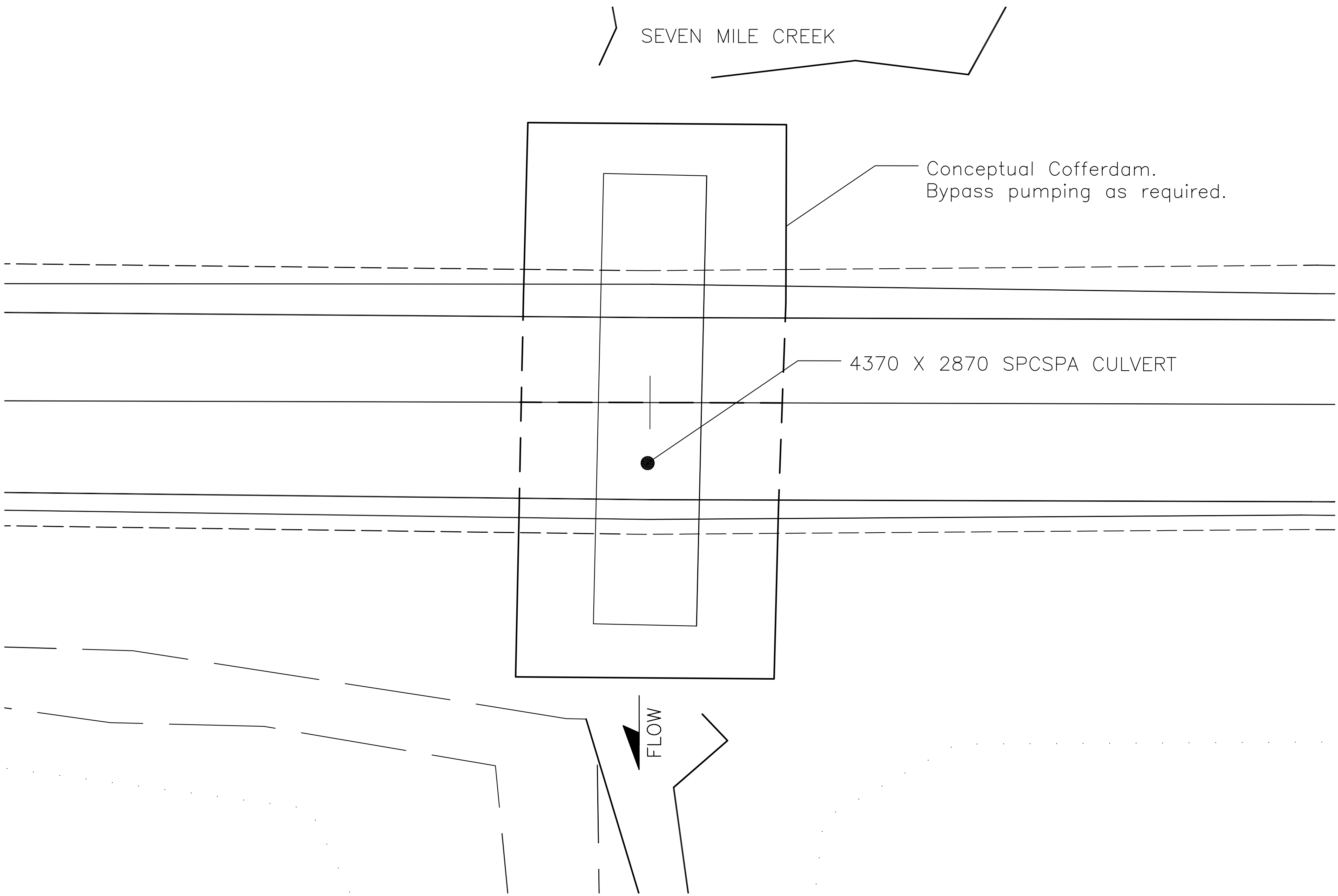
STAGE II

METRIC

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

2.5m 0 5m

Highway 560, Township of Mickle - Culvert at Station 10+000 Conceptual Shoring Cross-Section	FIGURE SK-3



HWY 560 - Township of Mickle - Sta. 10+000
Conceptual Cofferdam Sketch - Seven Mile Creek Culvert

FIGURE SK-4

NOTICE TO CONTRACTOR – Obstructions in Fills and Native Soils

Special Provision

The Contractor is notified that, during foundation field investigations for the Structural Culvert at Seven Mile Creek, on Highway 560, cobble/boulder sized rock pieces were encountered in the sand fills, and native sand deposits at varying depths. The contractor shall take into account these materials when designing and installing the Dewatering System and Protection System.