



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

**Highway 631 Rehabilitation – GWP 548-00-00  
Culvert Replacement – Mink Lake Culvert  
Station 16+584 - Twp. of Abraham  
Site No. 38C-071**

# **FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT**

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**Geocres No. 42C-31**

**LVM | MERLEX**

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## Final Foundation Investigation and Design Report

Prepared by:

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**Alexander Tepylo, P.Eng.**

LVM | Merlex – Project Engineer

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**M.A. Merleau, P. Eng.**

LVM | Merlex – Principal Engineer  
MTO Designate

Reviewed by:

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**Jake Berghamer, P. Eng.**

LVM | Merlex – Regional Manager

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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 has been retained by AECOM Canada Ltd., on behalf of the Ministry of Transportation of Ontario (MTO), to carry out a foundation investigation for the proposed replacement of an existing culvert under GWP 548-00-00. This culvert replacement is located on Highway 631, some 14.3 km north of the Junction with Hwy 17, in the Township of Abraham. The foundation investigation location was specified by the MTO in the RFP/TPM documentation Agreement No. 5011-E-0040. The terms of reference for the scope of work are outlined in LVM | MERLEX's Proposal P-12-140, dated September, 2012. 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 existing Structural Plate Corrugated Steel Pipe (SPCSP) culvert is located on Highway 631 at Station 16+584, Township of Abraham. The terrain in the area of this culvert is a low wet land/forested valley area connecting to Mink Lake to the north. Organic terrain was observed to the south (right) and north (left) of the embankment. The existing highway embankment currently supports two undivided lanes of highway, locally oriented in a west-east direction. The existing highway, at the culvert location, is constructed on an embankment consisting of granular fill mixed with rock fill, some 6.7 m in height, with centerline elevation of 421.7 m at the culvert location. The culvert at this location is a 3.05 m diameter SPCSP culvert, some 29.9 m in length. Flow through the culvert at this site is from right to left (south to north) (see Photo Essay, Appendix 4).

No above ground infrastructure was observed at this site.

### 2.1 SITE PHYSIOGRAPHY AND SURFICIAL GEOLOGY

This project is located in the Geomorphic Sub-province known as the Long Lake Rocky and Limy Drift Uplands. The topography on this section of Highway 631 is generally rolling. At many locations, significant layers of earth overburden cover the bedrock. Organic material was also observed. Within the project area the overburden consists primarily of sands containing varying amounts of silts and gravel.

Bedrock in the area, as indicated on OGS Map 2506, is of the Early Precambrian period. In the area of this culvert foundation investigation, the bedrock comprises of granitic rocks, syenite, pegmatite, and unsubdivided migmatite.

## 3 INVESTIGATION PROCEDURES

The fieldwork for this investigation was carried out during the period between July 21<sup>st</sup> and 23<sup>rd</sup>, 2013 during which time three (3) sampled boreholes were advanced. For the purposes of

foundation design for the culvert replacement, one (1) borehole was advanced at the culvert outlet, one (1) borehole was advanced through the embankment in the area of the culvert, and one (1) borehole was advanced at the culvert inlet.

The field investigation was carried out using a bombardier mounted CME drill rig equipped with hollow stem augers, standard augers, and routine geotechnical sampling equipment. Soil samples were obtained at the borehole locations at regular intervals of depth using the standard 50 mm O.D. split spoon sampler advanced in accordance with the Standard Penetration Test (SPT) procedures (ASTM D-1586). The SPT method involves advancing a 50 mm O.D. split spoon sampler with the force of a 63.5 kg hammer freely dropping 760 mm mounted in a trip (automatic) hammer. The number of blows per 300 mm penetration was recorded as the “N” value. 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 the LVM | Merlex 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 advanced through the paved portion of the roadway embankment, the upper portion of the hole 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 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 were visually examined in the LVM | Merlex North Bay laboratory for textual classification to confirm the field classification. Laboratory testing of select samples included routine testing for natural moisture contents, particle size analysis, plasticity index (Atterberg Limits), as well as specific gravity. The results of the laboratory testing are presented on the individual Record of Borehole Sheets (Appendix 2), with a summary of results presented on the laboratory sheets in Appendix C (Figures Nos. L-1 to L-5).

The locations of the individual boreholes were determined in the field using highway chainage/stationing (established by others) and offsets 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 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 Drawing No. 2 (Appendix 3). It should be noted that the stratigraphic delineations presented on the borehole logs and soil strata plot are the result of non-continuous sampling, response to drilling progress, SPT and Dynamic Cone Penetration Test (DCPT) results, plus field observations at the time of drilling. Typically such boundaries represent transitions from one zone to another and are not an exact demarcation of a specific geological unit. Additional consideration should therefore 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 16+584, TWP OF ABRAHAM

A plan and profile illustrating the borehole locations and stratigraphic sequences is provided on Drawing No. 2, Appendix 3. During the course of the exploration program, three (3) sampled boreholes were put down at this site, with Borehole No. 2 advanced through the embankment, and Borehole Nos. 1 and 3 advanced at the culvert ends. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 to 3 were recorded at 416.5, 421.6, and 415.1 m, respectively.

#### 4.1.1 Pavement Structure

At surface at Borehole No. 2, a pavement structure consisting of 50 mm of asphalt and 100 mm crushed gravel overlying 50 mm asphalt and 150 mm crushed gravel was penetrated.

#### 4.1.2 Embankment Fill

Underlying the pavement structure base at Borehole No. 2, a layer of fill consisting of brown sand trace silt and varying gravel content was penetrated. The granular fill was mixed with cobble/boulder size rock fill. The natural moisture content measured on samples of this deposit was in the order of 1 to 17%, indicating a dry to wet moisture condition, relative to optimum moisture content. Gradation analyses were carried out on two (2) samples of this deposit, the results of which indicated 15 to 48% gravel size particles, 42 to 80% sand size particles, and 5 to 10% silt and clay size particles (Figure No. L-1, Appendix 3). Based on SPT 'N' values of 4 to 43 blows per 300 mm penetration, the compactness of this deposit was described as loose to dense. This deposit was encountered to a depth of 6.1 m below grade (Elevation 415.5 m).

#### 4.1.3 Organic Soils

At surface at BH No. 3 and underlying the fill at BH No. 2, a deposit of brown silty peat trace gravel, and occasional cobbles was penetrated. The natural moisture content measured on samples of this deposit was in the order of 93 to 266%. This deposit was encountered to depths of 6.9 and 0.6 m below grade at Borehole Nos. 2 and 3, respectively (Elevations 414.7 and 414.5 m, respectively).

At surface, at BH No. 1, a layer of surficial organic soils, some 50 mm thick, was penetrated.

## 4.1.4 Fill

Underlying the surficial organic soils at Borehole No. 1, a deposit of fill described as brown sand trace silt trace gravel was penetrated. Occasional cobble/boulder size rock pieces were encountered in this deposit. The natural moisture content measured on samples of this deposit was in the order of 12%, indicating a moist moisture condition, relative to optimum moisture content. Based on SPT 'N' values of 10 blows per 300 mm penetration, the compactness of this deposit was described as compact. This deposit was encountered to a depth of 0.6 m below grade (Elevation 415.9 m).

## 4.1.5 Sand

Underlying the fill at Borehole No. 1, and underlying the organic soils at Borehole Nos. 2 and 3, a deposit of grey sand trace silt, trace gravel was penetrated. The natural moisture content measured on samples of this deposit was in the order of 17 to 29%, indicating a wet moisture condition, relative to optimum moisture content. Gradation analyses were carried out on five (5) samples of this deposit, the results of which indicated 0 to 10% gravel size particles, 81 to 97% sand size particles, and 3 to 9% silt and clay size particles (Figure No. L-2, Appendix 3). Based on SPT 'N' values of 0 (static weight of hammer) to 10 blows per 300 mm penetration, the compactness of this deposit was described as very loose to loose. This deposit was encountered to depths of 3.7, 8.8, and 2.9 m at Borehole Nos. 1, 2, and 3, respectively (Elevations 412.8, 412.8, and 412.2 m, respectively).

## 4.1.6 Sand and Silt

Underlying the sand at each borehole, a deposit of sand and silt, described as grey sand with silt to grey silt some sand, trace to some gravel was encountered. The natural moisture content measured on samples of this deposit was in the order of 9 to 27%, indicating a wet moisture condition, relative to optimum moisture content. Gradation analyses were carried out on six (6) samples of this deposit, the results of which indicated 0 to 15% gravel size particles, 14 to 72% sand size particles, 26 to 83% silt size particles, and 1 to 3% clay size particles (Figure No. L-3, Appendix 3). Atterberg Limits testing was attempted on samples of this deposit, the results indicated this material is non-plastic. Based on SPT 'N' values of 11 to 27 blows per 300 mm, the compactness of this deposit was described as compact. This deposit was encountered to a depth of 5.5 m below grade at Borehole Nos. 1 and 3 (Elevations 411.0 and 409.6 m, respectively). Sampling was terminated in this deposit at a depth of 12.6 m below grade at Borehole No. 2 (Elevation 409.0 m).

## 4.1.7 Sand

Underlying the sand and silt deposit at Borehole Nos. 1 and 3, a deposit of grey sand trace silt trace to some gravel was penetrated. The natural moisture content measured on samples of this deposit was in the order of 13 to 24%, indicating a wet moisture condition, relative to optimum moisture content. Gradation analyses were carried out on three (3) samples of this deposit, the results of which indicated 8 to 18% gravel size particles, 75 to 87% sand size



particles, and 3 to 7% silt and clay size particles (Figure No. L-4, Appendix 3). Based on SPT 'N' values of 0 (static weight of hammer) to 15 blows per 300 mm penetration, the compactness of this deposit was described as very loose to compact, generally compact. Auger refusal was encountered in this deposit at a depth of 7.7 m at Borehole Nos. 1 (Elevation 408.8 m). Sampling was terminated in this deposit at a depth of 9.6 m below grade at Borehole No. 3 (Elevation 405.5 m).

## **4.2 GROUNDWATER DATA**

The water level at the culvert outlet (left/north side) and inlet (right/south side) was measured between elevations of 415.4 and 415.7 m, respectively, at the time of this investigation.

Measurements of the groundwater level 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 Borehole Nos. 1 and 3 were measured at elevations 415.6 and 414.9 m upon completion, respectively.

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

## **5 DISCUSSION AND RECOMMENDATIONS**

### **5.1 GENERAL**

A foundation investigation was carried for the proposed culvert replacement as identified in the RFP.

The existing culvert on Highway 631 is located at Station 16+584 in the Township of Abraham, and is a 3 m diameter SPCSP culvert some 29.9 m long. The existing highway embankment currently supports two undivided lanes of highway, locally oriented in a west to east direction. Overall Highway 631 is classified as a south-north highway. Flow through the culvert is from right to left (i.e. south to north). Based on data from this foundation investigation, the embankment supporting the existing pavement structure at this site has been constructed using a granular pavement structure overlying a sand and rock fill mix. The rock fill was visible along the embankment slopes (see Photo Essay, Appendix 4). The native material, underlying the fill, generally consisted of sands underlain by sands and silt. Auger refusal was not encountered within the depth of this investigation.

The type of culvert (concrete, CSP, or High Density Polyethylene (HDPE)) to replace the existing culvert is currently unknown. However, it is understood that consideration is being given to constructing the new culvert adjacent to the existing culvert, while the existing culvert is used to maintain flow during construction. The final vertical alignment of the highway will remain essentially the same.

Following completion of the field investigation part of this project, it is understood that a culvert lining option is now being considered and is the preferred method of culvert rehabilitation at this site. As such, the following comments will apply should a new culvert be installed at this site.

### **5.2 FOUNDATION CONSIDERATIONS**

The founding native loose to compact sands present below the existing embankment are considered adequate for support of a culvert and for a conventional highway embankment of this height. The interior alignment of the culvert showed no signs of sag. Bearing resistance should not be a major issue provided the natural bearing surface is not excessively disturbed during construction and groundwater is controlled during construction, as discussed in Section 5.6.

It is noted that a layer of peat was encountered underlying the embankment fill at Borehole No. 2. Borehole No. 2 was advanced slightly up chainage from the side wall of the existing culvert, the invert of which is at an elevation of approximately 415.0 m at this location. With an allowance of 300 mm for embedment material the peat, which extends to elevation 414.7 m, would likely have been removed from below the existing culvert. All deleterious materials (i.e. peat layer, organics) must be removed from below the alignment of the new culvert down to native mineral soils.

Based on the characteristics of the native sand subgrade present below the existing culvert, the favourable response of the existing embankment, and a founding elevation similar to that of the existing culvert, a factored Geotechnical Resistance at ULS of 400 kPa can be used for design of a **closed** culvert (i.e. precast concrete frame **box** culvert or CSP/concrete pipe culvert). In consideration of the width/diameter of the culvert and the depth of overburden, a geotechnical reaction at SLS of 100 kPa can be used for design, in consideration of less than 25 mm settlement and preloading associated with the existing embankment.

If an **open** culvert (i.e. concrete frame open culvert, with wall footings, or a pipe arch culvert on footings) is considered, then a factored Geotechnical resistance value at ULS of 80 kPa, and a geotechnical reaction value at SLS of 75 kPa would apply for design, taking into consideration the limited depth of overburden and smaller footing width.

## 5.2.1 Slope Stability

The maximum height of fill above surrounding grade of the embankment at this location is some 5.4 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 stable embankment slopes of 2H:1V in granular and earth fills. The embankment was modeled as an earth fill at the culvert location, as per backfilling recommendation in Section 5.6, and inconsideration of the existing 2H:1V embankments slopes. For the purposes of these analyses, the materials were modeled using the following parameters:

PARAMETER	MATERIAL		
	EMBANKMENT FILL	SANDS	SAND AND SILTS
Unit Weight (kN/m <sup>3</sup> )	20	18.5	18.0
Effective Friction Angle (degrees)	33	30	32

The unit weights and friction angles for the slope calculations are based on general representative values for soil types, obtained through laboratory testing and tactile analysis. The results of the analysis indicated a factor of safety in the order of 1.4 against failure through the underlying native sand subgrade (as shown below on Figure No. S-1). As such, the stability of the final embankment will not be an issue provided it is properly constructed as outlined in Section 5.6.

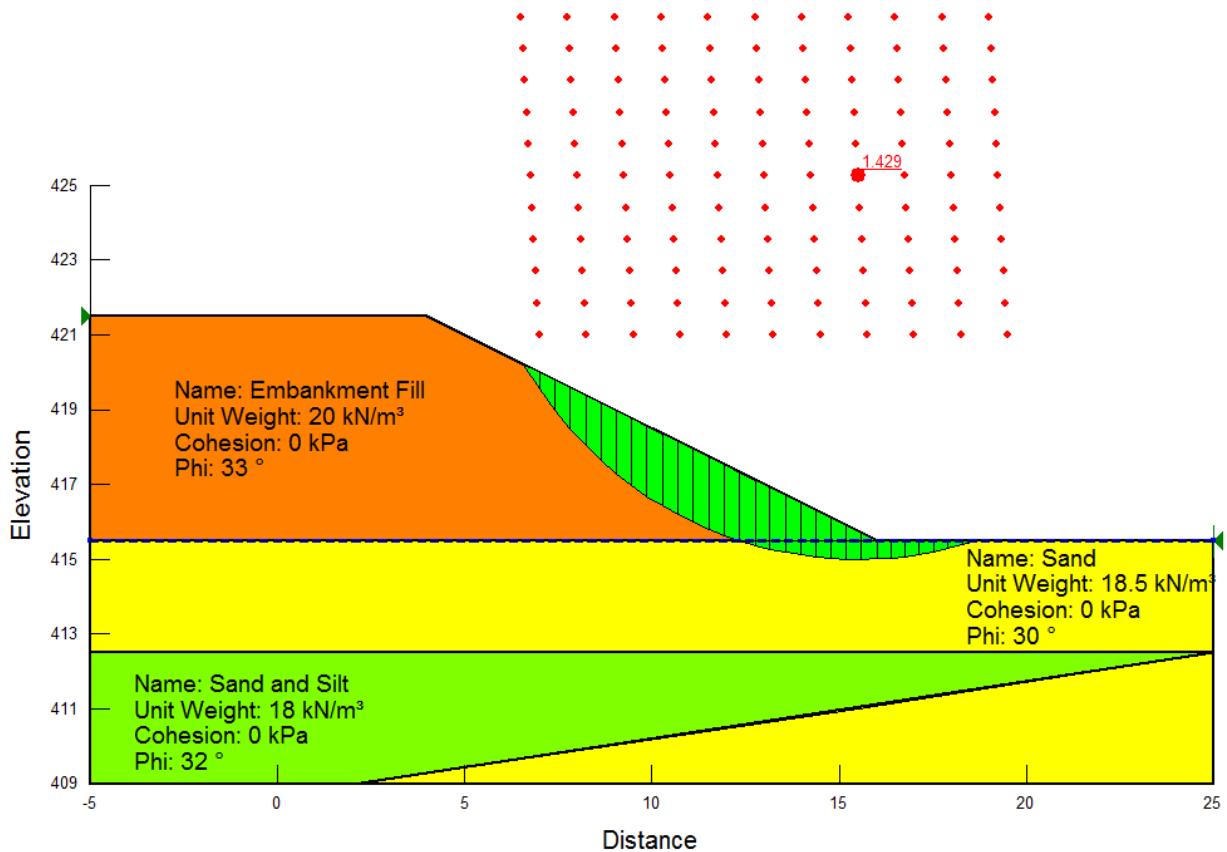


Figure 1: Slope Stability, Station 16+584, Twp of Abraham

## 5.3 CULVERT DESIGN, BEDDING, AND EMBEDMENT

The embankment consists of a granular pavement structure overlying a granular fill. The results of this investigation indicate that, below the culvert invert, the native soils at Borehole No. 2 consist of typically compact sands overlying compact sands and silt. A review of the condition of the pavement surface, at the culvert location, revealed minor asphalt cracking, however, in general, the embankment appears to have performed well. The existing embankment has preloaded the soils at the culvert location and since there will be no change in the height of the embankment, and therefore no appreciable increase in embankment load, negligible settlement of the embankment is anticipated. As such, installing a new culvert on a camber will not be required at this site.

Due to the height and composition of the embankment at the culvert location frost tapers shall not be required, as per the geotechnical report also by LVM | MERLEX, Ref No. 13/03/13042.

### 5.3.1 Rigid Concrete Culvert

A concrete pipe can be considered for culvert replacement at this site. A Class B Bedding for the concrete pipe shall consist of Granular A with a thickness of 300 mm. Alternatively, specifically if construction is carried out under wet conditions, a 19 mm clear stone bedding

could be used, which would aid in dewatering operations. During backfilling, the embedment fill should be placed in a balanced manner on each side of the pipe. Attention must be directed at compacting the embedment material within the haunch area of the pipe to 100% Standard Proctor Dry Density (SPDD). The elevation difference of the backfill on either side of the pipe must be a maximum 200 mm. Cover material for concrete pipe can consist of Granular A and placed to the dimensions as shown on OPSD 802.031.

Precast concrete rigid frame box culverts 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. The bedding below the outer one-third of the box unit base should be compacted to 100% Standard Proctor Dry Density, whereas 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 should be uncompacted throughout the length/width of the box and incorporated as the top levelling course in conformance with OPSS 422. Alternatively, specifically if construction is carried out under wet conditions, a 19 mm clear stone bedding and levelling coarse could be used, which may aid in dewatering applications. 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.

The inlet and outlet stream bed shall be protected with a full apron of Rip Rap (R-50 size as per OPSS 1004). The apron shall extend 3 m beyond the culvert opening, 500 mm thick and extend across the stream bed and up the embankment to 500 mm above the high water level mark. Clay seals are generally used where significant head differences exist between the inlet and outlet of a culvert to prevent flow through the embankment. Considering the anticipated culvert slope, at this location, clay seals are not required.

### 5.3.2 Flexible Steel Culvert

A flexible culvert (i.e. CSP/SPCSP/HDPE) can also be considered for culvert replacement at this site. If a flexible pipe is used for replacement, embedment material could consist of Granular B Type I provided the maximum size of stone inclusions is limited to 25 mm or less in size and placed in accordance with OPSD 802.010 for a Type 3 soil. The material in the haunch area must be compacted to 100% Standard Proctor Dry Density prior to placing the remainder of the embedment material. During backfilling, the embedment fill should be placed in a

balanced manner on the outer sides of the culvert unit. The elevation difference of the backfill on either side of the culvert must be a maximum 200 mm.

The inlet and outlet stream bed shall be protected with a Rip Rap (R-50 size as per OPSS 1004) apron. The apron shall extend 3 m beyond the culvert opening, be 500 mm thick and extend across the width of the stream bed and up the foreslope to 500 mm above the high water level. Considering the porous nature of the embankment fill and Rip Rap apron, inlet clay seals along the culvert or outlet cut-off walls are not considered necessary.

## 5.4 CULVERT INSTALLATION AND CONSTRUCTION STAGING CONSIDERATIONS

The invert elevation of the existing culvert is at 415.0 m, with the top of the embankment at elevation 421.7 m at centerline. As such, the embankment at this location is some 6.7 m in height above the culvert invert at the centerline. Therefore, a minimum 7.0 m deep excavation (i.e. to elevation 414.7 m) will be required in consideration a layer of bedding/embedment material some 300 mm thick. The present platform width at this location is some 9 m as can be seen on the cross section on Drawing No. 2. The platform width at this location, as is, will not be sufficient in width to carry out an open excavation using staged construction without lowering the platform or sliver widening. Consideration could be given to constructing a vertical wall for use as a protection system, however, due to the rock fill mixed with granular fill in the embankment at this culvert location, installing a protection system may be problematic. It is understood that the preferred method of replacing the culvert under consideration is to locally lower of the embankment to allow an open cut excavation for culvert replacement.

### 5.4.1 Staged Construction

The present platform width, at this location, is some 9 m as can be seen on the cross section on Figure No. 2. The culvert is located on a tangent section of the highway and there is some 3.7 m of granular fill above the culvert obvert. As such, a staged construction operation carried out by locally lowering the grade, using open cut methods, staged sequencing, and a 24/7 operation for traffic control while limiting traffic flow to one lane is being considered for culvert replacement at this location (see Figure No. SK-3, Appendix 5).

A possible staging plan, for a continuous open cut excavation under 24/7 traffic control, is shown on Figure No. SK-3, Appendix 5. The sequencing is as follows:

- Locally lower the platform grade by a minimum 2.5 m.
- Limit traffic to a single lane on the left, with a minimum platform width of 5 m, 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 5 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.

## 5.5 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	EMBANKMENT FILL	NATIVE SANDS	NATIVE SILTS AND SANDS
Unit Weight (kN/m <sup>3</sup> )	23.0	21.0	19.0	18.0	18.5
Angle of Internal Friction	35°	33°	33°	30°	32°
Shear Strength (kPa)	-	-	-	-	-
Coefficient of Active Earth Pressure (Ka)	0.27	0.29	0.29	0.33	0.31
Coefficient of Passive Earth Pressure (Kp)	3.69	3.39	3.39	3.00	3.25
Coefficient of Earth Pressure at Rest (Ko)	0.43	0.46	0.46	0.50	0.47

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

## 5.6 EXCAVATION, DEWATERING, AND EMBANKMENT RECONSTRUCTION

All excavations greater than 1.2 m in depth must, at a minimum, be sloped or shored in accordance with the Occupational Health and Safety Act Regulations for Construction Projects. The embankment material, above the water table, is considered a Type 3 soil as defined in the Occupational Health and Safety Act and Regulations for Construction Projects. Temporary open excavations, above the groundwater table, could be cut back at an angle of 1H:1V, provided they are monitored continuously. However, below the groundwater table, the side slopes will have to be cut back to a more stable angle of 2H:1V, possibly shallower, depending 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), 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 granular fills should be established to match the existing slopes or as per OPSS 200.010. Final slopes should be treated with a mulch and seed to prevent ravelling.

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

Excavations must be maintained in a dewatered condition during excavation and foundation construction and every reasonable effort must be made to prevent disturbing (piping/boiling) at the founding subgrade. 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 elevations 415.4 to 415.7 m at the time of this investigation and excavations to an approximate elevation 414.7 m will be required to install the culvert and bedding. As such dewatering will be required during excavation and culvert installation.

During construction, installation of filtered sumps and pumping from the base of the excavation will, at a minimum, be required to maintain the excavation in a dewatered condition during subgrade preparation and culvert installation. To provide a stable working surface the water level must be controlled to below the base of excavation. When wet, silty subgrades can become easily disturbed, and can lose a significant portion of its natural bearing capacity.

A sand bag cofferdam, aquadam, or possibly a temporary sheet pile type cofferdam can be considered for controlling stream flow depending upon anticipated flow at time of construction. Considering the limited head of water to be controlled, a sand bag cofferdam or aquadam is recommended. By-pass pumping can be carried out to divert the stream flow at the time of construction. Since the new culvert may be constructed adjacent to the existing culvert, by-pass pumping/diversion through the existing culvert would be possible, while the new culvert is being constructed. It would also be possible to install a second smaller by-pass culvert, through the embankment, during grade adjustments. Another alternate to supply by-pass capacity, if the anticipated flow is low during the construction period, would be to install a smaller pipe inside the existing culvert to accommodate the by-pass flow.

Ultimately, the method of excavation, dewatering, and stream flow diversion will be the choice of the contractor; however the importance of maintaining the subgrade in a dewatered stable condition during excavation and foundation construction cannot be stressed enough.



**5.7 CONSTRUCTION CONCERNS**

Considering the nature of the granular fill embankment, 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.

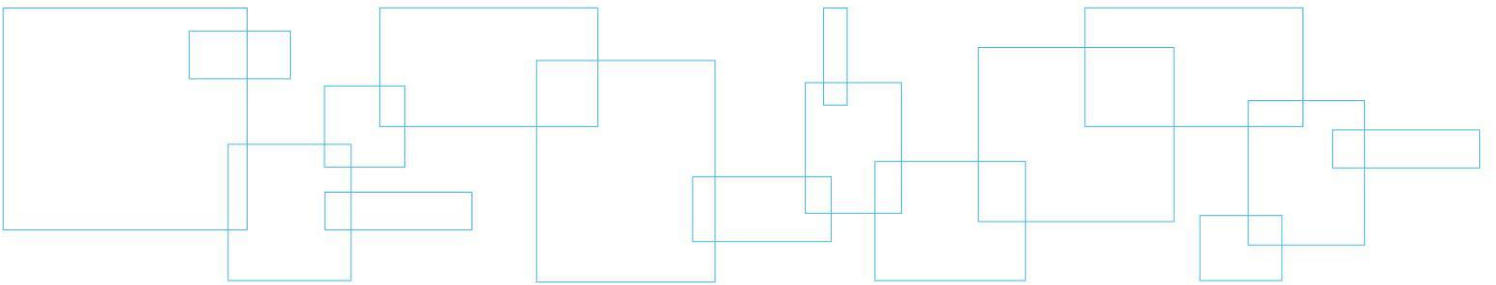
The comments in this report are intended solely for the guidance of the design engineer and address the geotechnical conditions only. The number of boreholes required to determine the localized conditions between boreholes directly affecting construction costs, equipment, scheduling, etc. would in fact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

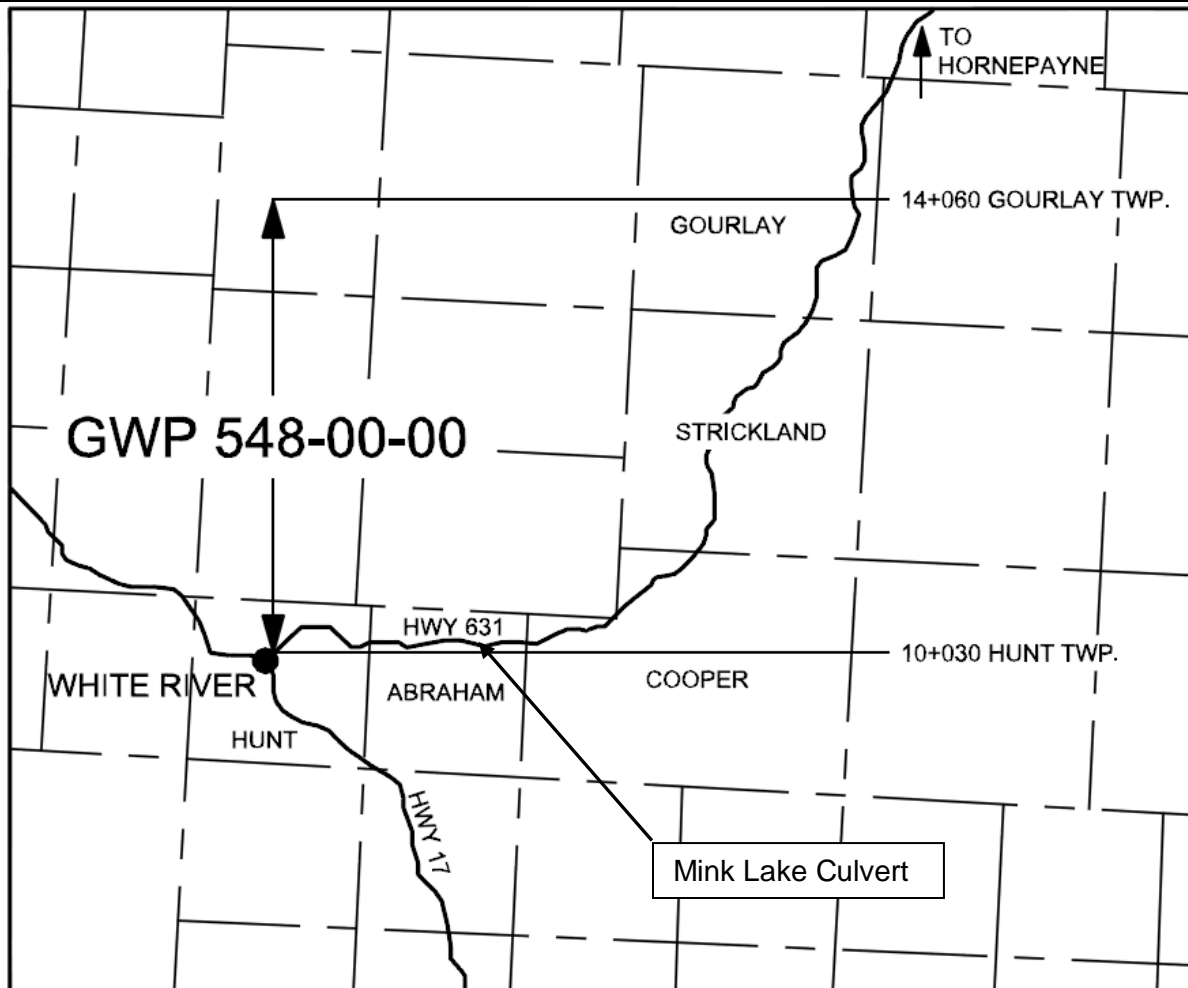
Key Plan



# KEY PLAN

Drawing No. 1

NOT TO SCALE



## FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

**GWP 548-00-00**

Highway 631

Mink Lake Culvert

**LVM | MERLEX**

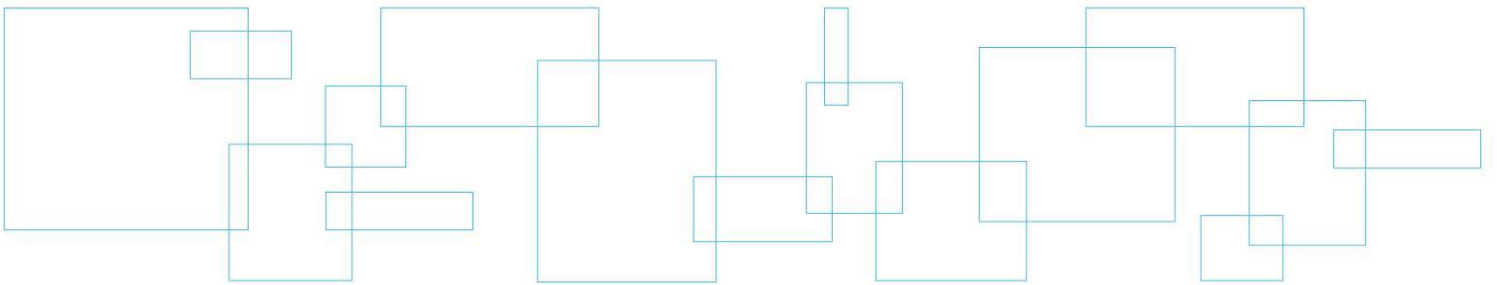
Reference No: 13/03/13042-F2

March 2014

## Appendix 2    Subsurface Data

Enclosure No. 1  
Enclosure Nos. 2 to 4

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
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.

## METRIC

## RECORD OF BOREHOLE NO. 1



REFERENCE 13/03/13042-F2 DATUM Geodetic LOCATION N 5386243.0 E 223342.9 - Abraham Township - Mink Lake Culvert ORIGINATED BY JL  
 PROJECT GWP 548-00-00, Highway 631 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY MCM  
 CLIENT AECOM DATE (Started) 2013 July 21 TIME   
 DATE (Completed) 2013 July 21 (Completed) 1:30:00 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 20 40 60 80 100	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W <sub>p</sub> W W <sub>L</sub> WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)		
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES								
416.5	Ground Surface												
0.0	50 mm Forest Root Mat		1	SS	10								
415.9	FILL - sand trace silt trace gravel occasional cobbles/boulders brown, moist												
0.6	(loose) SAND - trace silt trace gravel brown, wet (very loose/loose)		2	SS	8						0 97 (3)		
			3	SS	2								
	grey		4	SS	WH						1 96 (3)		
			5	SS	1								
412.8	SAND AND SILT												
3.7	grey, wet (compact)		6	SS	12						2 72 (26)		
			7	SS	12						0 45 54 1		
411.0	SAND - trace silt some gravel												
5.5	grey, wet (very loose)												
			8	SS	WH						13 84 (3)		
408.8	Auger Refusal												
7.7	End of Borehole												
			9	SS	25/50 mm								
COMMENTS								+ 3, × 3 : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 120 kPa ○ 3% STRAIN AT FAILURE					
The stratification lines represent approximate boundaries. The transition may be gradual.								WATER LEVEL RECORDS					
								Date (dd/mm/yy)/Time		Water Depth (m)		Cave In (m)	
								1) 13/7/21 1:30:00 PM		0.9		1.8	
								2) -		-		-	
3) -		-		-									

MEL-GEO 13042 - BOREHOLE LOGS - SITE B.GPJ MEL-GEO.GDT 14/3/11





## METRIC

## RECORD OF BOREHOLE NO. 2



REFERENCE 13/03/13042-F2 DATUM Geodetic LOCATION N 5386258.3 E 223338.3 - Abraham Township - Mink Lake Culvert ORIGINATED BY JL  
 PROJECT GWP 548-00-00, Highway 631 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY MCM  
 CLIENT AECOM DATE (Started) 2013 July 22 TIME   
 DATE (Completed) 2013 July 23 (Completed) 5:00:00 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	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W <sub>p</sub> W W <sub>L</sub> WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES						
421.6	Asphalt Surface										
0.0	50 mm Asphalt 100 mm Crushed Gravel 50 mm Asphalt 150 mm Crushed Gravel		1	AS							
	FILL - sand trace silt varying gravel content, mixed with cobble/boulder size rock fill		2	SS	43						48 42 (10)
	brown, dry										
	(loose/dense)		3	SS	33						
			4	SS	43						
			5	SS	50/75 mm						
			6	SS	18						15 80 (5)
	wet		7	SS	4						
			8	SS	12						
415.5	PEAT - silty peat trace gravel		9	SS	1					93	
6.1	brown										
414.7	SAND - trace silt trace gravel		10	SS	10						
6.9	grey, wet										
	(loose/compact)		11	SS	8						10 81 (9)
412.8	SAND AND SILT										
8.8	grey, moist		12	SS	19						15 50 34 1
	(compact)										
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) 13/7/23 5:00:00 PM 2) 3)			
The stratification lines represent approximate boundaries. The transition may be gradual.											

MEL-GEO 13042 - BOREHOLE LOGS - SITE B.GPJ MEL-GEO.GDT 14/3/11





## METRIC

## RECORD OF BOREHOLE NO. 3



REFERENCE 13/03/13042-F2 DATUM Geodetic LOCATION N 5386279.0 E 223336.5 - Abraham Township - Mink Lake Culvert ORIGINATED BY JL  
 PROJECT GWP 548-00-00, Highway 631 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY MCM  
 CLIENT AECOM DATE (Started) 2013 July 21 TIME   
 DATE (Completed) 2013 July 21 (Completed) 4:50:00 PM CHECKED BY MAM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			20	40	60					
415.1	Ground Surface														
0.0	PEAT - silty peat with rootlets occasional cobbles		1	SS	2										
414.5	brown														
0.6	SAND - trace silt trace gravel														
	grey, wet		2	SS	4										
	(very loose/compact)														
			3	SS	5										
			4	SS	5										
412.2	SAND AND SILT														
2.9	grey, wet		5	SS	7										
	(loose)														
			6	SS	2										
			7	SS	7										
409.6	SAND - trace silt trace to some gravel														
5.5	grey, wet		8	SS	11										
	(compact)														
			9	SS	13										
			10	SS	15										
405.5	End of Sampling														
9.6	End of Borehole														
COMMENTS								+ 3, × 3 : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 120 kPa			WATER LEVEL RECORDS				
								○ 3% STRAIN AT FAILURE			Date (dd/mm/yy)/Time				
											Water Depth (m)				
											Cave In (m)				
											1) 13/7/21 4:50:00 PM				
											2) -				
											3) -				

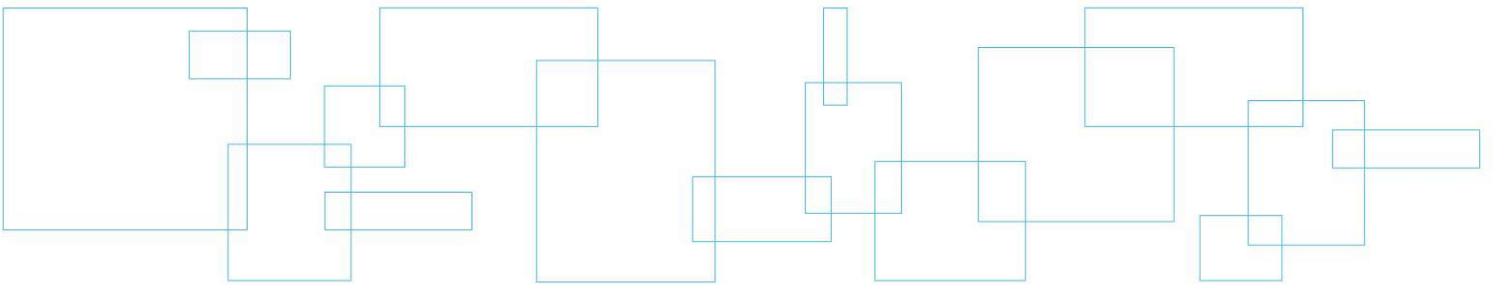
The stratification lines represent approximate boundaries. The transition may be gradual.

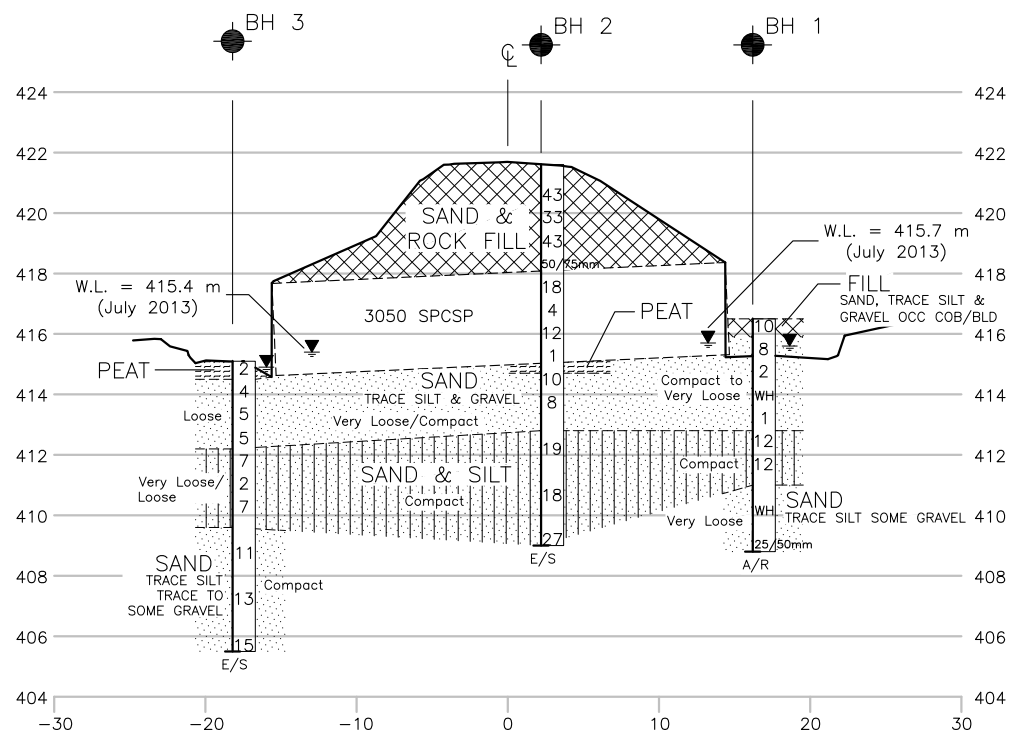
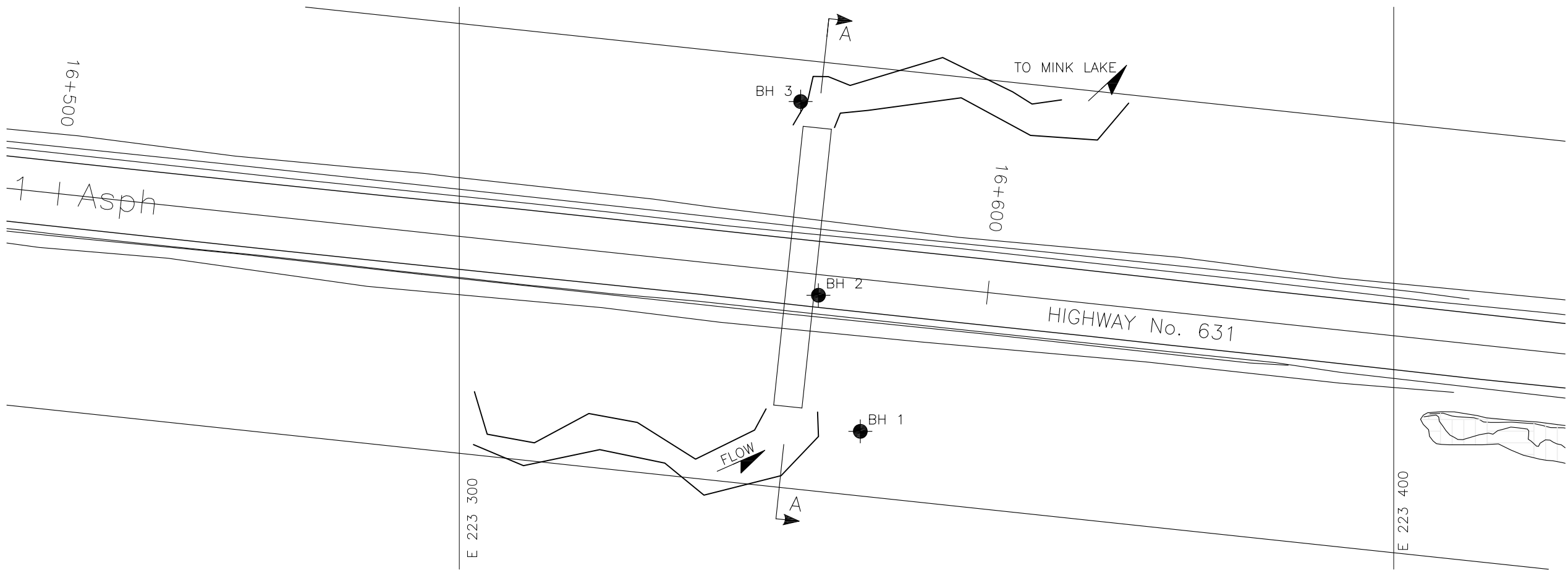
MEL-GEO 13042 - BOREHOLE LOGS - SITE B.GPJ MEL-GEO.GDT 14/3/11



## Appendix 3    Borehole Plan and 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





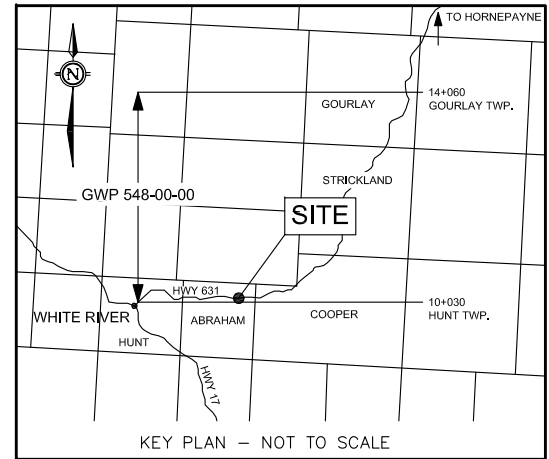
CONT. No.  
XXXX-XXXX

GWP. No.  
548-00-00

N

DRAWING  
2

HWY 631  
MINK LAKE CULVERT (SITE 38C-071)  
ABRAHAM TOWNSHIP  
BOREHOLE LOCATIONS & SOIL STRATA



LEGEND

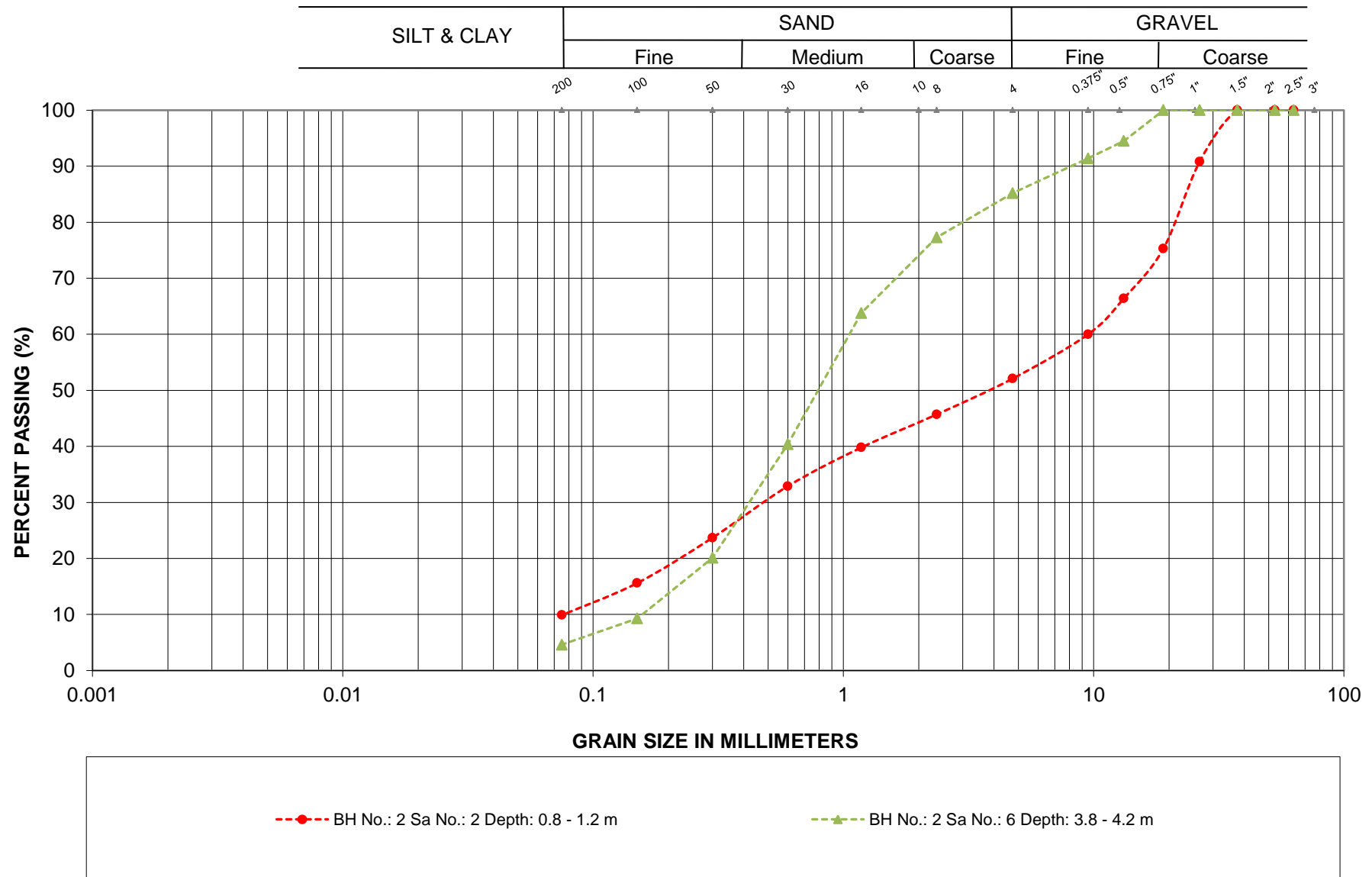
- Borehole
- N Blows/0.3 m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3 m (60° Cone, 475 J/blow)
- Water Level at Time of Investigation
- A/R Auger Refusal at Elevation
- E/S End of Sampling

Borehole No.	Elev.	O/S	Co-ordinates	
			Northerly	Easterly
Borehole No. 1	416.5	16.2 m Rt	5386243.0	223342.9
Borehole No. 2	421.6	2.2 m Rt	5386258.3	223338.3
Borehole No. 3	415.1	18.2 m Lt	5386279.0	223336.5

NOTE 1: 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.

NOTE 2: 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
	FEB 2014	RG	Revisions for Final, Add GEOCREs #
HWY NO. 631 – ABRAHAM TOWNSHIP			
GEOCREs NO.: 42C-31			
L V M REFERENCE NO.: 13/13/13042			
DRAWN: RG		CHECKED: AT	DATE: NOVEMBER 2013

**GRAIN SIZE ANALYSIS**

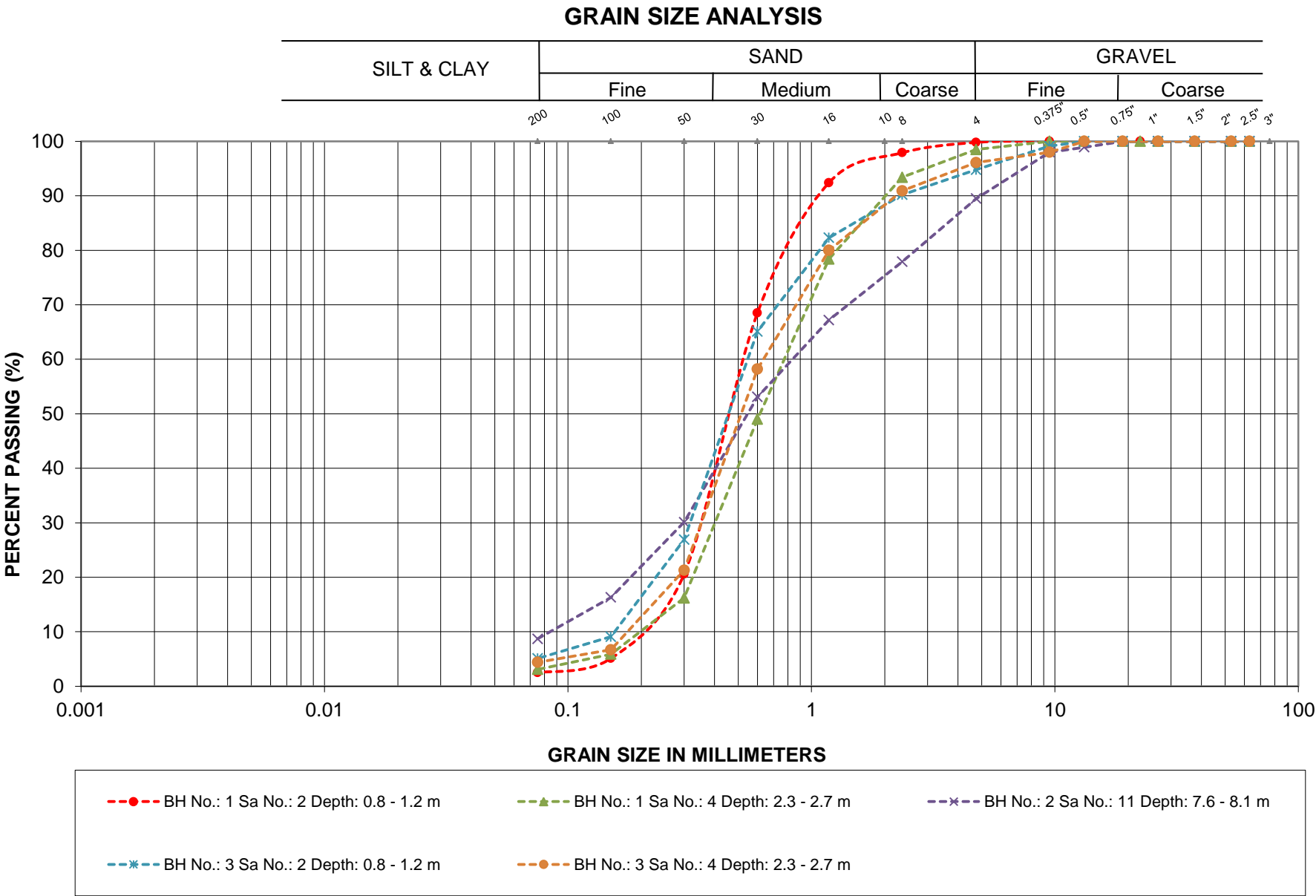
G.W.P.: 548-00-00

LOCATION: Hwy 631, Mink Lake Culvert

EMBANKMENT FILL

LVM | MERLEX

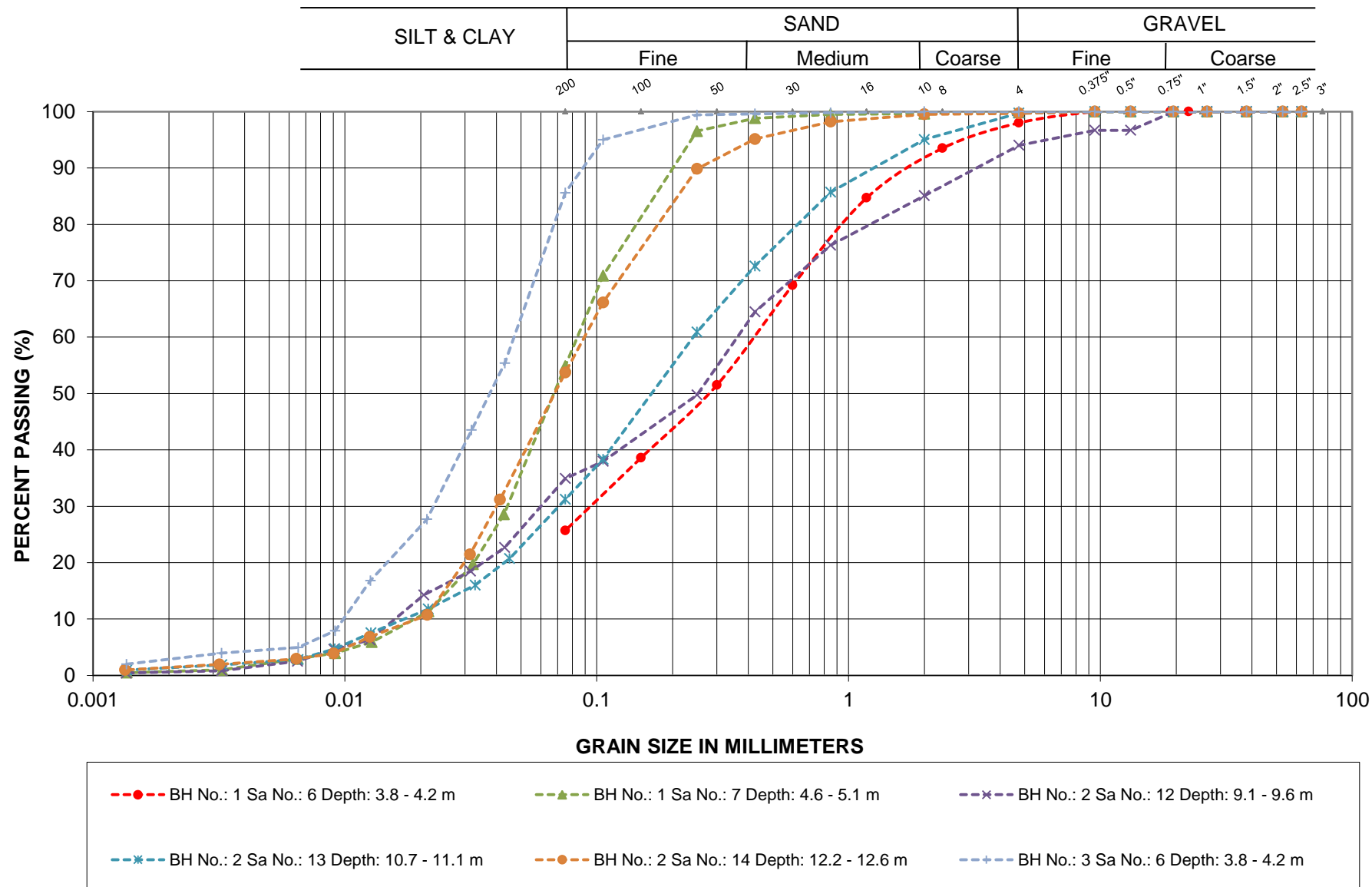
FIGURE L-1



G.W.P.: 548-00-00  
LOCATION: Hwy 631, Mink Lake Culvert

SAND

## GRAIN SIZE ANALYSIS



G.W.P.: 548-00-00

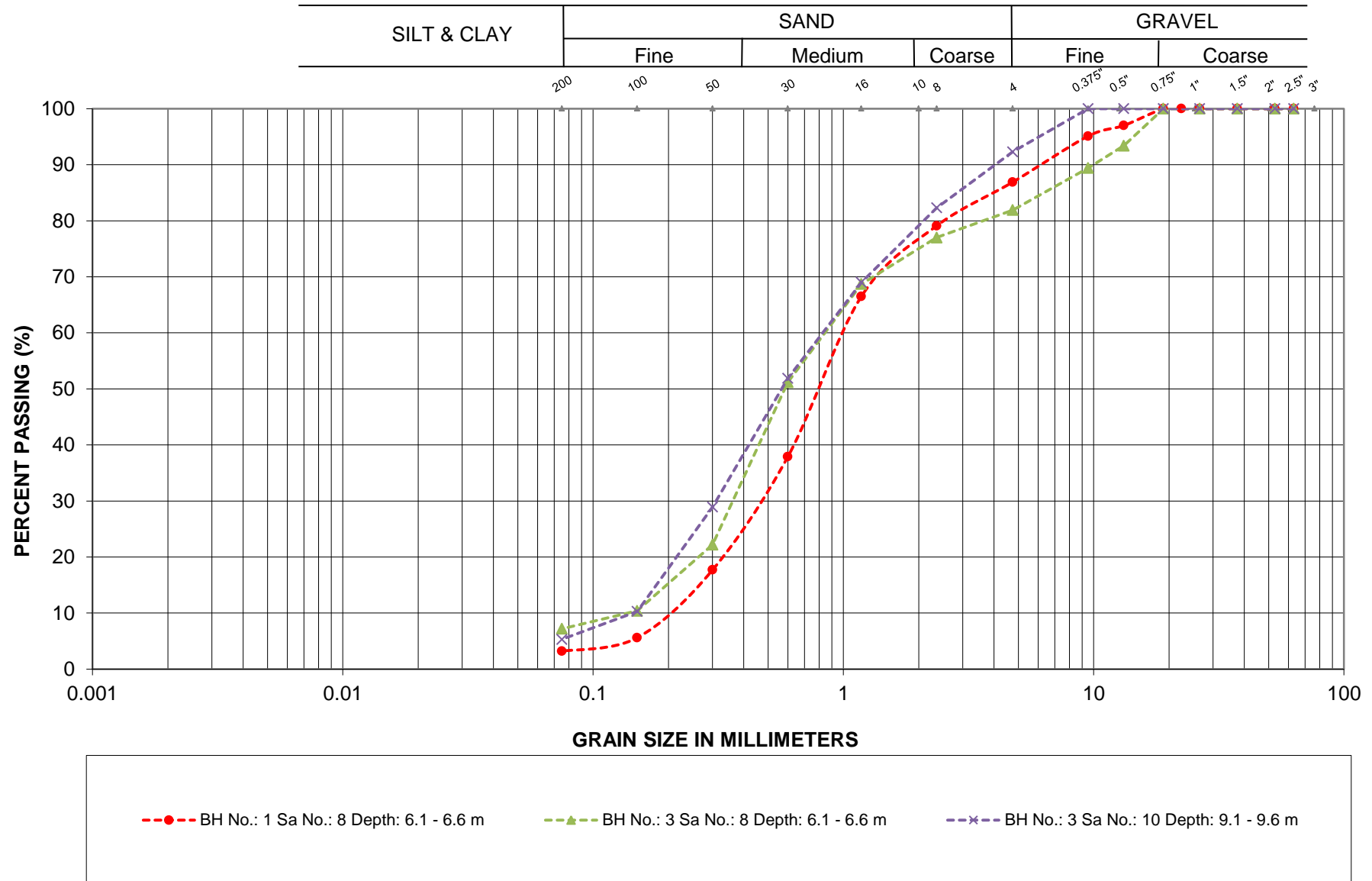
LOCATION: Hwy 631, Mink Lake Culvert

SAND AND SILT

LVM | MERLEX

FIGURE L-3



**GRAIN SIZE ANALYSIS**

G.W.P.: 548-00-00

LOCATION: Hwy 631, Mink Lake Culvert

SAND

## Laboratory Tests - Summary Sheet

Borehole No.	Sample No.	Depth	Grain Size Analysis				NMC	Atterberg Limits			SPT 'N'	USCS	Unit Weight (kN/m <sup>3</sup> )	Remarks
			Gravel Size (%)	Sand Size (%)	Silt Size (%)	Clay Size (%)		LL (%)	PL (%)	IP (%)				
1	1	0.0					11.5				10			
	2	0.8	0	97		3	25.8				8			
	3	1.5					27.5				2			
	4	2.3	1	96		3	29.9				WH			
	5	3.0					21.4				1			
	6	3.8	2	72		26	26.1				12			
	7	4.6	0	45	54	1	16.8				12			
	8	6.1	13	84		3	24.2				WH			
	9	7.6					11.7				25/50 mm			
2	1	0.0					3.7							
	2	0.8	48	42		10	2.7				43			
	3	1.5					5.4				33			
	4	2.3					0.7				43			
	5	3.0					1.2				50/75 mm			
	6	3.8	15	80		5	11.3				18			
	7	4.6					16.9				4			
	8	5.3									12			
	9	6.1					93.0				1			
	10	6.9					23.4				10			
	11	7.6	10	81		9	18.5				8			
	12	9.1	15	50	34	1	9.0				19			
	13	10.7	5	64	29	2	14.9				18			
	14	12.2	0	46	51	2	18.7				27			
3	1	0.0					265.6				2			
	2	0.8	5	90		5	26.9				4			

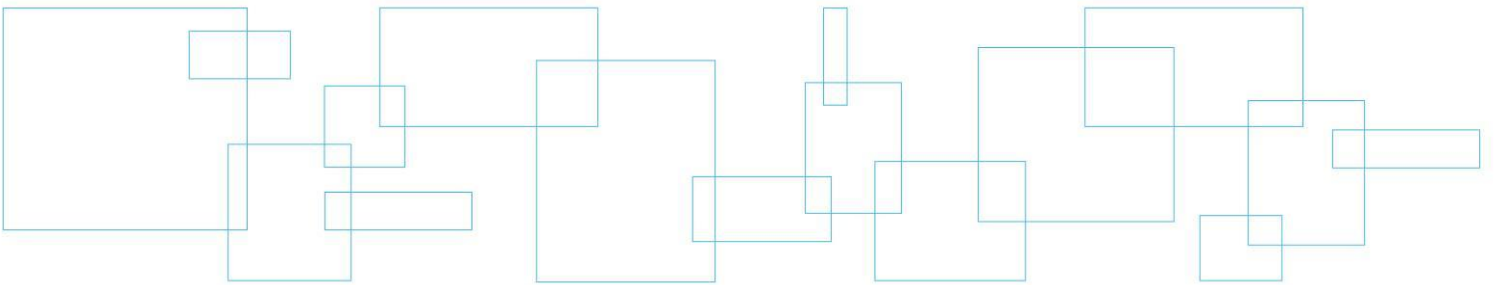
## Laboratory Tests - Summary Sheet

[illegible]

## Appendix 4    Photo Essay

Enclosure No. 5:

Photo Essay



Culvert Outlet – Looking North

Photo: 1



Embankment at Outlet – Looking South

Photo: 2



Project: Hwy 631 – Mink Lake Culvert

Photos Provided By: LVM

Date: June 2013



Culvert Inlet – Looking South

Photo: 3



South (Right) side of Embankment – Looking West

Photo: 4



Project: Hwy 631 – Mink Lake Culvert

Photos Provided By: LVM

Date: June 2013

View Through Culvert – Looking South

Photo: 5



Project: Hwy 631 – Mink Lake Culvert

Photos Provided By: LVM

Date: June 2013

## Appendix 5      Design Data

Figure SK-3:                      Conceptual Staging Plan

