

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

**Highway 144  
Vermillion River Tributary Culvert – Site No. 46-408/C  
Station 16+945 - Twp. of Balfour  
GWP 5580-04-00**

## **FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT**

Date: October 21, 2014  
Ref. N<sup>o</sup>: 12/11/12218-F2

**Geocres No. 41I-319**





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## **Final Foundation Investigation and Design Report**

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## 1 INTRODUCTION

LVM-Merlex, a division of Englobe Corp., has been retained by AECOM Canada Ltd., on behalf of the Ministry of Transportation of Ontario (MTO), to carry out a foundation investigation at the site of an existing centerline culvert. The site is located on Highway 144, some 24.5 km north of Highway 17, in the Township of Balfour.

The foundation investigation location was specified by the MTO in the Terms of Reference for additional work under Agreement No. 5011-E-0030. The terms of reference for the scope of work are outlined in LVM | Merlex Ltd.'s Proposal 12/11/12218-144, dated November, 2013. The purpose of this investigation was to determine the subsurface conditions in the area of the 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 144 some 24.5 km north of Highway 17, in the Township of Balfour. The local topography at the site is a low wetland to the left and right of the embankment. The existing highway embankment currently supports two undivided lanes of highway, locally running in a west to east direction. The existing highway, at the culvert location, is constructed in a granular fill embankment some 3.6 m in height above the stream bed, with centerline elevation of 267.0 m at the culvert location. The culvert at this location has been described as a 4.6 x 2.4 m reinforced concrete rigid frame open (RFO) culvert, some 22.7 m in length. The depths of the existing culvert foundations are unknown at this time. However, old DHO Standard DD-801 indicates that RFO culverts would have a minimum depth of footing at 1.2 m below creek bottom, which would put the underside of footing at approximately elevation 262.2 m. Flow through the culvert is from north to south (right to left) (see Photo Essay, Appendix 4).

Infrastructure at the culvert location consists of overhead wires and underground infrastructure on the left and right (south and north) sides of the highway and overhead wire were crossing the highway directly at the culvert location, which impacted boring locations. This infrastructure must be taken into consideration during construction.

### 2.1 SITE PHYSIOGRAPHY AND SURFICIAL GEOLOGY

This project is located in the Geomorphic Sub-province known as the Eastern Sandy Uplands. The topography along this section of Highway 144 is generally flat to slightly rolling. Within the specific project area overburden consists primarily of sands with silts overlying silty clays overlying bedrock.

Bedrock in the area, as indicated on OGS Map 2506, is of the Middle Precambrian Animikie Group which consists of sandstone, shale, argillite, iron formation, tuff, basalt, and limestone.

### 3 INVESTIGATION PROCEDURES

The field work for this investigation was carried out between March 11<sup>th</sup>, 2014 and June 17<sup>th</sup>, 2014. Three (3) boreholes were advanced through the embankment, one located adjacent to the culvert, and the other two located up and down chainage from the culvert location. One borehole was advanced at each of the inlet and outlet ends of the existing culvert.

The field investigation was carried out using a Truck and Bombardier mounted CME drilling rig equipped with hollow stem augers, standard augers, and routine geotechnical sampling equipment. Soil samples were obtained at the borehole locations at regular intervals of depth using the standard 50 mm O.D. split spoon sampler advanced in accordance with the Standard Penetration Test (SPT) procedures (ASTM D-1586). The SPT method involves advancing a 50 mm O.D. split spoon sampler with the force of a 63.5 kg hammer freely dropping 760 mm mounted in a trip (automatic) hammer. The number of blows per 300 mm penetration was recorded as the “N” value. 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. Standpipes were installed in select open boreholes prior to backfilling. 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 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 surface treatment.

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 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, an Atterberg Limits Testing, as well as specific gravity testing. The results of the laboratory testing are presented on the individual Record of Borehole Sheets (Appendix 2), with a summary of results presented on the laboratory sheets in Appendix 3 (Figures Nos. L-1 to L-7 and Table L-8).

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

## **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). 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 16+945, TWP OF BALFOUR**

A plan and profile illustrating the borehole locations and stratigraphic sequences is shown on Drawing No. 2, Appendix 3. During the course of the exploration program, five (5) sampled boreholes were put down at this site, with Borehole Nos. 1 and 2 advanced at the culvert ends (inlet (right/north) and outlet (left/south), respectively), and Borehole Nos. 3, 4, and 5 advanced through the embankment. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 to 5 were recorded at 264.6, 264.8, 266.9, 266.9, and 267.0 m, respectively.

#### **4.1.1 Pavement Structure**

Borehole Nos. 3, 4, and 5 were advanced through the embankment where a layer of asphalt some 100 to 300 mm thick was penetrated. The asphalt layer was underlain by some 300 mm of crushed gravel at Borehole Nos. 4 and 5.

#### **4.1.2 Sand Fill**

Underlying the pavement structure, at Borehole Nos. 3, 4, and 5, a layer of brown granular fill consisting of sand some gravel, trace silt was penetrated. The cobble size rock was encountered at shallow depths in this deposit at Borehole No. 3, 4, and 5. The natural moisture content measured on samples of this deposit was in the order of 3 to 16%. A gradation analyses was carried out on one (1) sample of this deposit, the results of which indicated 18% gravel size particles, 72% sand size particles, and 10% silt and clay size particles (Figure No. L-1, Appendix 3). Based on SPT 'N' values of 7 to 32 blows per 300 mm penetration, the compactness of this deposit was described as loose to dense. This deposit was encountered to depths of 1.1, 2.1, and 1.4 m below ground surface at Borehole Nos. 3, 4, and 5, respectively (elevations 265.8, 264.8, and 265.6 m, respectively).

#### **4.1.3 Sand and Gravel Fill**

Underlying the sand fill at Borehole No. 3, a layer of granular fill consisting of brown to grey sand and gravel, trace silt was penetrated. The natural moisture content measured on samples of this deposit was in the order of 2 to 3%. A gradation analysis was carried out on one (1) sample of this deposit, the results of which indicated 51% gravel size particles, 43% sand size

particles, and 6% silt and clay size particles (Figure No. L-2, Appendix 3). Based on SPT 'N' values of 21 to 36 blows per 300 mm penetration, the compactness of this deposit was described as compact to dense. This layer was encountered to a depth of 2.9 m below grade at Borehole No. 3 (elevation 264.0 m).

#### 4.1.4 Silt Fill

At surface, at Borehole Nos. 1 and 2, underlying the sand and gravel fill at Borehole No. 3, and underlying the sand fill at Borehole Nos. 4 and 5, a layer of fill consisting of silt, trace to with sand, trace gravel, trace clay, mixed with organic soils was penetrated. Shattered rock was encountered at various depths in this deposit at Borehole Nos. 3, 4, and 5. The natural moisture content measured on samples of this deposit was in the order of 4 to 57%. Hydrometer analyses were carried out on four (4) samples of this deposit, the results of which indicated 0 to 10% gravel size particles, 1 to 25% sand size particles, 59 to 92% silt size particles, and 5 to 7% clay size particles (Figure No. L-3, Appendix 3). Atterberg Limits Testing was carried out on four (4) samples of this fill layer, however the majority of the samples were generally found to be non-plastic (NP) except at one (1) sample of this layer, which indicated a Plastic Limit in the order of 43% and a Liquid Limit in the order of 58%, indicating a plastic silt (MH) (Figure No. L-6, Appendix 3). Based on SPT 'N' values of 3 to 54 blows per 300 mm penetration, the compactness of this deposit was described as very loose to very dense, generally loose. This layer was encountered to depths of 2.1, 2.1, 5.6, 4.0, and 2.9 m below grade at Borehole Nos. 1 to 5, respectively (elevations 262.5, 262.7, 261.3, 262.9, and 264.1 m, respectively).

#### 4.1.5 Silt

Underlying the silt fill at Borehole Nos. 1, 3, 4, and 5, a deposit of grey silt trace to some clay was penetrated. The natural moisture content measured on samples of the silt deposit was in the order of 23 to 28%. Hydrometer analyses were carried out on three (3) samples of this deposit, the results of which indicated 0% gravel size particles, 0% sand size particles, 93 to 94% silt size particles, and 6 to 7% clay size particles (Figure No. L-4, Appendix 3). Atterberg Limits Testing was attempted on samples of this fill layer, however samples were generally found to be non-plastic (NP). Based on SPT 'N' values of 4 to 17 blows per 300 mm penetration, this deposit was described as loose to compact, generally compact. This deposit was encountered to depth of 4.4, 7.1, 7.1, and 7.1 m below grade at Borehole Nos. 1 to 5, respectively (elevations 260.2, 259.8, 259.8, and 259.9 m, respectively).

#### 4.1.6 Clayey Silt to Silty Clay

Underlying the silt at Borehole Nos. 1, 3, 4, and 5, and underlying the silt fill at Borehole No. 2, a deposit of grey clayey silt to silty clay was penetrated. The clay content generally increased with depth in this deposit. The natural moisture content measured on samples of the sand deposit was in the order of 29 to 53%. Hydrometer analyses were carried out on seven (7) samples of this deposit, the results of which indicated 0% gravel size particles, 0 to 2% sand size particles, 51 to 88% silt size particles, and 12 to 47% clay size particles (Figure No. L-5,



Appendix 3). Atterberg Limits testing carried out on six (6) samples of this deposit, the results of which indicated a Plastic Limit in the order of 17 to 22% and a Liquid Limit in the order of 27 to 33%, indicating a clayey silt to silty clay of low plasticity (ML-CL to CL) (Figure No. L-6, Appendix 3). Based on in-situ shear strengths of 62 to greater than 100 kPa, the consistency of this deposit was described as stiff to very stiff. Sampling was terminated in this deposit at depths of 8.4, 8.4, 16.0, and 16.0 m below grade at Borehole Nos. 1 to 4, respectively (elevations 256.2, 256.4, 250.9, and 250.9 m, respectively).

Based on auger response, the silty clay deposit was encountered to a depth of 14.3 m below grade at Borehole No. 5 (elevation 252.7 m), where a dense deposit, likely sands was encountered. Auger refusal was encountered at a depth of 15.2 m below grade (elevation 251.8 m).

#### **4.1.7 Dynamic Cone Penetration Tests**

Dynamic cone penetration tests (DCPT) were advanced from the surface at the location of Borehole Nos. 1 and 2. DCPT refusal was encountered at depths of 15.2 and 14.2 m below grade at Borehole Nos. 1 and 2, respectively (elevations 249.4 and 250.6 m, respectively).

## **4.2 GROUNDWATER DATA**

At the time of this investigation, the water level at the culvert outlet was measured at elevation 263.5 m on June 17, 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. These levels are recorded on the individual Record of Borehole Log Sheets (Appendix 2). The water levels in Borehole Nos. 1 to 5 were measured at elevations 259.5 to 264.7 m. It should be noted that water levels may not have stabilized at the time of measurement.

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

## 5 DISCUSSION AND RECOMMENDATIONS

### 5.1 GENERAL

A foundation investigation was carried for the proposed replacement of the existing Vermillion River Tributary Culvert on Highway 144, as identified in the Terms of Reference for additional work under Agreement No. 5011-E-0030.

The existing culvert, located at Station 16+945 in the Township of Balfour, has been described as a 4.6x2.4 m reinforced concrete rigid frame open (RFO) culvert some 22.7 m long. At this time, no information of the type or depth of existing foundations was available. However, old DHO Standard DD-801 indicates that RFO culverts of similar dimension would have a minimum depth of footing at 1.2 m below creek bottom, which would put the underside of footing at approximately elevation 262.2 m. Flow through the culvert is from north to south (right to left) (see Photo Essay, Appendix 4).

The existing highway embankment currently supports two undivided lanes of highway, running in a west to east direction. Flow through the culvert is from right to left (north to south). 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 typically earth fill. The native material, underlying the embankment fill, generally consisted of loose to compact silts overlying stiff to very stiff clayey silts to silty clays.

As noted, the existing culvert is reported as a rigid frame open culvert. However, it is understood that installing a new precast concrete box culvert, with a 6.0 m span and 2.44 m rise, is the preferred method of culvert replacement. It is understood that the new culvert will be constructed on a similar alignment and skew as the existing culvert. The final vertical alignment of the highway will remain essentially the same.

### 5.2 FOUNDATION CONSIDERATIONS

It is understood that old DHO standards for foundations for rigid frame open footings stated that footings should be established a minimum 1.2 m below the stream bed. At this location this would result in the underside of existing footing varying between about elevation 262.3 to 262.2 m. The average elevation of the native compact silt subgrade, below the existing embankment fill is about elevation 262.7 m, however was encountered to an elevation of 261.3 m at Borehole No. 3.

The new RFB culvert will be established with an invert elevation of 263.0 m. Allowing for a 300 mm thick concrete slab bottom and a minimum of 300 mm bedding this would require an excavation to about elevation 262.4 m.

The existing foundations must be removed, at a minimum, to the underside of the bedding layer of the new culvert, approximately elevation 262.4 m. Consideration could also be given to removing the foundations (and backfill) down to the native subgrade, if the underside of footing is only 100 to 200 mm below the underside of bedding. This would be the case if the footings

were established at the minimum 1.2 m depth. However since the exact depth of the existing foundations is unknown, the depth of potential excavation is also unknown. To avoid disturbing the fills and native subgrade below the culvert, it is recommended that, if it is proven during construction that the footings extend to a substantial depth, the fill material and footing be left in place at the underside of the bedding material and the footing be cut off at the underside of bedding depth. Groundwater control (dewatering) will be critical during excavations.

Based on the characteristics of the native undisturbed compact silts and clayey silts to silty clays subgrade present below the culvert, the response of the existing embankment, and a founding elevation at or below the existing culvert invert, a factored bearing resistance at ULS of 600 kPa can be used for a closed culvert (i.e. precast concrete frame box culvert with 6.0 m span or SPCSPA culvert) founded on a bedding layer at elevation 262.4 m. In consideration of the width of the culvert, and response of the existing embankment, a geotechnical reaction at SLS of 110 kPa can be used for design, in consideration of less than 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 geotechnical resistance at ULS of 100 kPa, and a geotechnical resistance at SLS of 100 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

The maximum height of fill above surrounding grade of the embankment at this location is some 3.6 m above the stream bed. 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 existing embankment slopes of 2.0H:1.0V in granular fills. For the purposes of these analyses, the materials were modeled using the following parameters;

PARAMETER	MATERIAL					
	SAND FILL	SAND AND GRAVEL FILL	SILT FILL	SILT	CLAYEY SILT TO SILTY CLAY	
					SHORT TERM	LONG TERM
Unit Weight (kN/m <sup>3</sup> )	18.5	23.0	18.0	18.0	16.5	16.5
Effective Friction Angle (degrees)	30	34	28	29	-	28
Effective Cohesion (kPa)	-	-	-	-	0	5
Undrained Shear Strength (kPa)	-	-	-	-	70	-

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 1.5 (see Figure Nos. S-1 and S-2, 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 granular fills. The results of this investigation indicate that, below the culvert inverts, the native soils at Borehole Nos. 1 and 2 consist of generally compact silts, at elevations 262.5 and 262.7 m, respectively, overlying stiff to very stiff clayey silts. At Borehole No. 3 the fill extended to elevation 261.3 m, which is some 2.2 m below the steam bed. This greater depth of fill could represent backfill to the footings or potentially backfill to an old channel or by-pass used during construction. 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 no increase in embankment load; therefore no appreciable settlement of the embankment is anticipated. As such, installing the culvert on a camber will not be required at this site.

#### **5.3.1 Rigid Concrete Culvert**

Bedding for a rigid frame box (RFB) culvert shall consist of Granular A with a thickness of 300 mm. The bedding under the middle third of the box unit base should be loosely placed and uncompacted. The upper 75 mm portion of the Granular A bedding should be uncompacted throughout the length/width of the box and incorporated as the top levelling course in conformance with OPSS 422. Alternatively, specifically if construction is carried out under wet conditions, as anticipated at this site, a 19 mm clear stone, as per OPSS.Prov 1004, bedding and levelling coarse should be used, which would 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 of stream bed shall be protected with a full apron of Rip Rap (R-50 size as per OPSS.PROV 1004). The apron shall extend 3 m beyond the sides of the culvert, be 500 mm thick and extend across the stream bed and up the embankment to 500 mm above the design high water level. Clay seals are generally used where a significant head differences exists between the inlet and outlet of a culvert to prevent flow through the embankment. Since

this culvert will be installed essentially level clay seals are not considered necessary at this location.

### 5.3.2 Flexible 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 embedment material, on either side of the culvert, must be a maximum 200 mm.

The inlet and outlet of stream bed shall be protected with a Rip Rap (R-50 size as per OPSS.PROV 1004) apron. The Rip Rap apron a minimum 500 mm thickness shall extend 3 m beyond the sides of the culvert installation, be 500 mm thick and extend across the width of the stream bed and up the embankment to 500 mm above the design high water level.

## 5.4 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	SILT FILL	NATIVE SILT
Unit Weight (kN/m <sup>3</sup> )	23.0	21.0	18.5	18.0	18.0
Angle of Internal Friction	34°	31°	30°	28°	29°
Coefficient of Active Earth Pressure (Ka)	0.28	0.32	0.33	0.36	0.35
Coefficient of Passive Earth Pressure (Kp)	3.54	3.12	3.00	2.77	2.88
Coefficient of Earth Pressure at Rest (Ko)	0.44	0.48	0.50	0.53	0.52

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

## 5.5 CULVERT INSTALLATION AND CONSTRUCTION STAGING CONSIDERATIONS

The invert elevation of the existing culvert is at approximately 263.4 m, with the top of the embankment at elevation 267.0 m at centerline. As such, the embankment at this location is some 3.6 m in height above the existing stream bed at the centerline. The depth of the existing culvert foundations is not known. Therefore, a minimum 4.6 m deep excavation (i.e. to

elevation 262.4 m) will be required in consideration a 300 mm thick box, 300 mm thick layer of bedding/embedment material below the proposed invert of 263.0 m. The present platform width at this location is some 13.5 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 to carry out an open excavation using staged construction unless local lowering of the grade and/or temporary embankment widening is undertaken. Consideration can be given to constructing a vertical wall for use as a protection system.

#### 5.5.1 Staged Construction

As noted, the platform at this location, as is, is of insufficient width to carry out an open excavation using staged construction, unless temporarily lowering the vertical alignment is carried out. To carry out an open cut excavation, locally lowering the grade to allow for staged construction using staged sequencing and limiting traffic flow to one lane would be required (see Figure No. SK-3, Appendix 5).

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

- Locally lower the grade at the culvert to an elevation of approximately 266.2 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 11 m of new culvert.
- Reconstruct the embankment on the right. Allow 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 back to two lanes when sufficient width permits.

#### 5.5.2 Protection System

As noted above, consideration could also be given to constructing a vertical 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 3.6 m of granular and earth fills. The embankment fill is generally underlain by loose to compact silts underlain by stiff clayey silts. The embankment generally consists of granular fill, as such, the recommended method of constructing a temporary vertical wall for a protection system along the centreline of the highway alignment would be to drive steel sheet piles through the embankment fill into the underlying native soils. Conceptual shoring locations and sections are illustrated on Figure Nos. SK-4 and SK-5, Appendix 5.

Based on the results of this investigation, the embankment fill including sand fill, sand and gravel fill, silt fill and native materials generally do not contain major obstructions; however the layers of embankment fill(s) appearing to contain minor quantities of cobble/boulder size rock in the sand fill and silt fill deposits were encountered at various depths below ground surface at locations of Borehole Nos. 3, 4, and 5. As obstructions were not encountered at Borehole Nos. 1 and 2 located at the areas of inlet and outlet of the existing culvert, the sheet piles are also considered acceptable for use in temporary shoring for cofferdam construction. However, if the cobble/small boulder size rock is encountered during driving of a sheet section, the individual sheet section could be left high and the cobble/small boulder removed during excavation advance, followed by continued driving of the sheet will be required. The contractor must select a sufficiently robust sheet section to penetrate minor cobble/small boulder size obstructions. A Notice to Contractor is included in Appendix 6.

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

$K_a$  = active earth pressure,

$\gamma$  = unit weight, and

$H$  = height of wall above the base of excavation.

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

A table outlining the possible temporary excavation protection/flexible retaining systems and their relative advantages, disadvantages, and costs, as well as comments on the viability of the methods is provided in Table A, Appendix 5. Conceptual shoring location is illustrated on Figure No. SK-4, Appendix 5.

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

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.

## **5.6 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), 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 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, 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 elevation 263.5 m at the outlet at the time of this investigation and excavations to an approximate elevation 262.4 m would be required to install the culvert and bedding. As such dewatering will be required during excavation and culvert installation.

It is anticipated that excavations will be advanced to a depth some 1.0 m below the groundwater level, depending on the water level at the time of construction. To provide a stable working surface the water level must be lowered to below the base of excavation. When wet, the silt subgrade can become easily disturbed, and can lose a significant portion of its native bearing capacity. Temporary construction groundwater control in silty soils, similar to those encountered on this site, can generally be carried out to a depth of approximately 750 mm to 1.0 m below the prevailing groundwater table using the conventional construction dewatering methods of using a sufficient number of strategically placed filtered sump holes located in the base of the excavation outside the area of influence of engineered fill and/or foundations. It is noted that the efficiency of conventional sump holes to control the groundwater depends highly upon the number of sumps, the depth of their base below the ultimate subgrade level, method of construction (i.e. cased and filtered sump hole versus a pump at the base of the excavation), and their spacing. Where greater draw down is required, a more sophisticated dewatering system, such as vacuum well points, will have to be used to maintain an unwatered, stable subgrade.

A sand (metre) bag cofferdam, earth fill cofferdam, aquadam, or possibly temporary sheet pile type cofferdam can also be considered for controlling stream flow depending upon anticipated



flow at time of construction. By-pass pumping through a temporary culvert can be carried out to divert the stream flow at the time of construction.

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. However, the presence of the overhead wires extending diagonally above the culvert site must be addressed in the Contractor's operation plan.

## Appendix 1 Key Plan

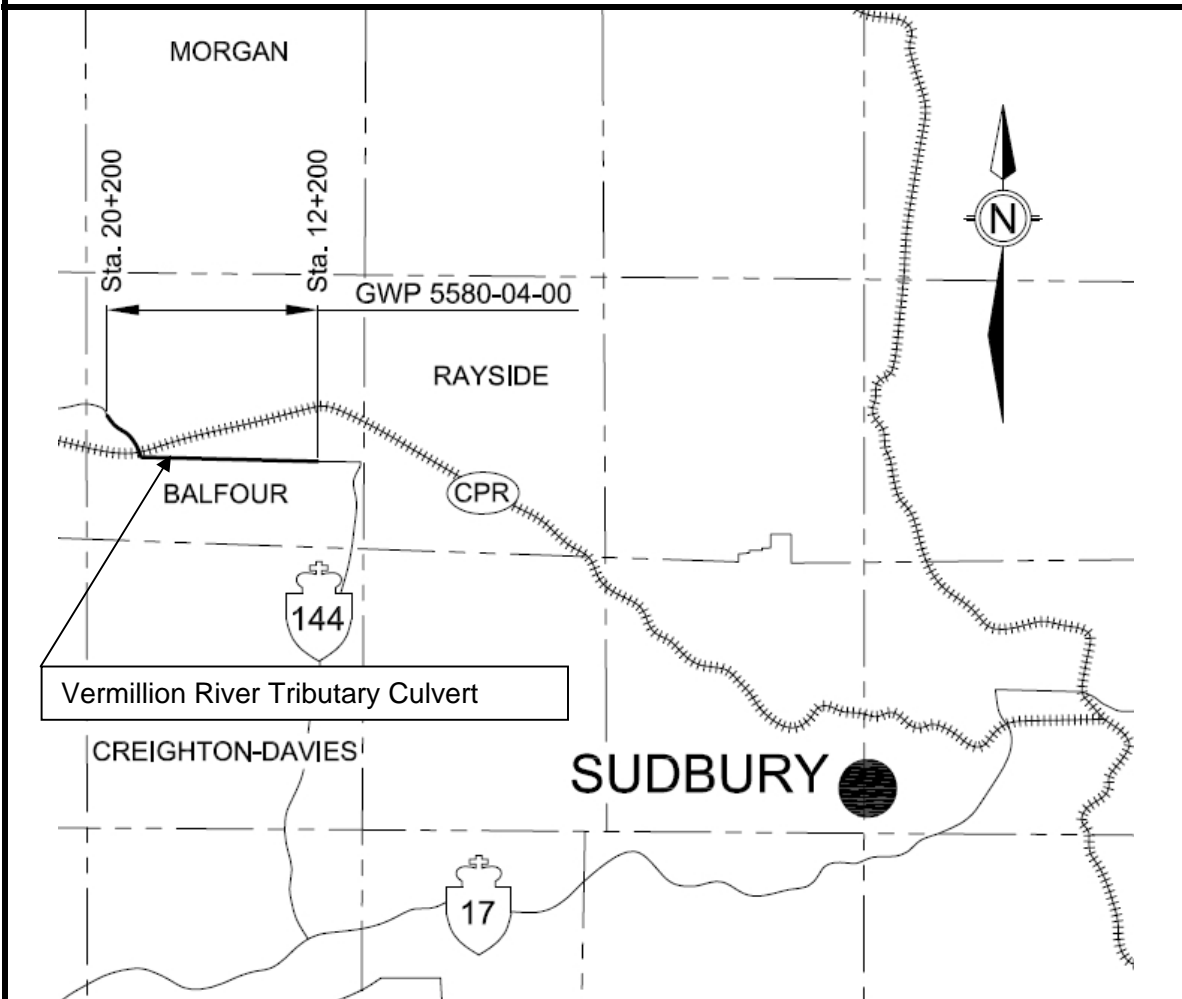
Drawing No. 1

Key Plan

# KEY PLAN

Drawing No. 1

NOT TO SCALE



**FINAL  
FOUNDATION INVESTIGATION  
AND DESIGN REPORT**

**GWP 5580-04-00**

Highway 144

Vermillion River Tributary Culvert



Reference No: 12/11/12218-F2

October 2014

## Appendix 2    Subsurface Data

Enclosure No. 1	List of Abbreviations and Symbols
Enclosure Nos. 2 to 6	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
WH	Sampler advanced by static weight of hammer and/or rods
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.

**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

**METRIC****RECORD OF BOREHOLE NO. 1**

REFERENCE 12/11/12218-F2 DATUM Geodetic LOCATION N 5158970.2 E 283922.0 - Balfour Twp, Station 16+935, 15.0 m Rt ORIGINATED BY JL  
 PROJECT GWP 5580-04-00, Highway 144, Site No. 46-408/C BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT  
 CLIENT AECOM Inc. DATE (Started) 2014 March 11 TIME   
 DATE (Completed) 2014 March 11 (Completed) 11:50:00 AM CHECKED BY MAM

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	PLASTIC LIMIT $w_p$ NATURAL MOISTURE CONTENT $w$ LIQUID LIMIT $w_L$	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE						
	Continued from Previous Page									
249.4										
15.2	DCPT Refusal End of Borehole									

MEL-GEO 12218 - BOREHOLE LOGS - VERMILLION RIVER.GPJ MEL-GEO.GDT 14/9/18



**METRIC****RECORD OF BOREHOLE NO. 2**

REFERENCE 12/11/12218-F2 DATUM Geodetic LOCATION N 5158939.9 E 283904.8 - Balfour Twp, Station 16+931, 16.0 m Lt ORIGINATED BY JL  
 PROJECT GWP 5580-04-00, Highway 144, Site No. 46-408/C BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT  
 CLIENT AECOM Inc. DATE (Started) 2014 March 11 TIME   
 DATE (Completed) 2014 March 11 (Completed) 4:25:00 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								
264.8	Ground Surface												
0.0	FILL - silt, trace to with sand trace gravel trace clay trace decayed wood  brown/grey, moist  (loose)		1	SS	3								
			2	SS	5								
			3	SS	4								
262.7	CLAYEY SILT												
2.1	grey, wet (very stiff)  dark grey clay varves <5 mm thick		4	SS	13								0 12 81 7
			5	SS	13								0 0 88 12
			6	SS	10								
			7	SS	10								
	clay content generally increases with depth												0 0 70 30 (NP)
			8	SS	8								0 0 69 31
	(stiff)												
			9	SS	5								
256.4	End of Sampling												
8.4													
Continued Next Page													
COMMENTS  The stratification lines represent approximate boundaries. The transition may be gradual.								WATER LEVEL RECORDS					
								+ 3, × 3 : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 120 kPa ○ 3% STRAIN AT FAILURE					
								Date (yy/mm/dd)/Time 1) 14/3/11 4:25:00 PM 2) 3)					
								Water Depth (m) 5.3 - -					
								Cave In (m) 7.5 - -					

MEL-GEO 12218 - BOREHOLE LOGS - VERMILLION RIVER.GPJ MEL-GEO.GDT 14/9/18

**METRIC****RECORD OF BOREHOLE NO. 2**

REFERENCE 12/11/12218-F2 DATUM Geodetic LOCATION N 5158939.9 E 283904.8 - Balfour Twp, Station 16+931, 16.0 m Lt ORIGINATED BY JL  
 PROJECT GWP 5580-04-00, Highway 144, Site No. 46-408/C BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT  
 CLIENT AECOM Inc. DATE (Started) 2014 March 11 TIME (Completed) 4:25:00 PM CHECKED BY MAM  
 DATE (Completed) 2014 March 11

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					
	Continued from Previous Page												
250.6 14.2	DCPT Refusal End of Borehole					251							

MEL-GEO 12218 - BOREHOLE LOGS - VERMILLION RIVER.GPJ MEL-GEO.GDT 14/9/18

**METRIC**

## RECORD OF BOREHOLE NO. 3



REFERENCE	12/11/12218-F2	DATUM	Geodetic	LOCATION	N 5158959.9 E 283903.6 - Balfour Twp, Station 16+953, 4.0 m Rt	ORIGINATED BY	JL
PROJECT	GWP 5580-04-00, Highway 144, Site No. 46-408/C			BOREHOLE TYPE	Truck Mounted CME 45 - Hollow Stem Augers	COMPILED BY	RG
CLIENT	AECOM Inc.	DATE (Started)	2014 June 11	TIME		CHECKED BY	MAM
		DATE (Completed)	2014 June 11	(Completed)	12:30:00 PM		

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)			
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa					WATER CONTENT (%)		
						PLASTIC LIMIT W <sub>p</sub>			NATURAL MOISTURE CONTENT W			LIQUID LIMIT W <sub>L</sub>		

MEL-GEO 12218 - BOREHOL LOGS - VERMILLION RIVER.GPJ MEL-GEO.GDT 14/9/18

**METRIC****RECORD OF BOREHOLE NO. 3**

REFERENCE 12/11/12218-F2 DATUM Geodetic LOCATION N 5158959.9 E 283903.6 - Balfour Twp, Station 16+953, 4.0 m Rt ORIGINATED BY JL  
 PROJECT GWP 5580-04-00, Highway 144, Site No. 46-408/C BOREHOLE TYPE Truck Mounted CME 45 - Hollow Stem Augers COMPILED BY RG  
 CLIENT AECOM Inc. DATE (Started) 2014 June 11 TIME   
 DATE (Completed) 2014 June 11 (Completed) 12:30:00 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	SHEAR STRENGTH kPa					
	Continued from Previous Page						20 40 60 80 100						
			13	SS	PM								
			14	SS	PM								
250.9 16.0	End of Sampling End of Borehole												

MEL-GEO 12218 - BOREHOLE LOGS - VERMILLION RIVER.GPJ MEL-GEO.GDT 14/9/18

### METRIC

## RECORD OF BOREHOLE NO. 4



REFERENCE	<u>12/11/12218-F2</u>	DATUM	<u>Geodetic</u>	LOCATION	<u>N 5158950.7 E 283918.3 - Balfour Twp, Station 16+938, 4.6 m Lt</u>	ORIGINATED BY	<u>JL</u>
PROJECT	<u>GWP 5580-04-00, Highway 144, Site No. 46-408/C</u>			BOREHOLE TYPE	<u>Truck Mounted CME 45 - Hollow Stem Augers</u>	COMPILED BY	<u>RG</u>
CLIENT	<u>AECOM Inc.</u>	DATE (Started)	<u>2014 June 16</u>	TIME		CHECKED BY	<u>MAM</u>
		DATE (Completed)	<u>2014 June 16</u>	(Completed)	<u>4:30:00 PM</u>		

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	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		SHEAR STRENGTH kPa										WATER CONTENT (%)		
							○ UNCONFINED		+ FIELD VANE		● QUICK TRIAXIAL						× LAB VANE		
266.9	Asphalt Surface						20	40	60	80	100	20	40	60					
0.0	100 mm Asphalt 300 mm Crushed Gravel  FILL - sand some gravel trace silt cobble encountered  brown, dry  (loose/compact)		1	AS	N/A							○							
			2	SS	13							○							
			3	SS	7							○							
264.8																			
2.1	FILL - silt, trace to with sand trace gravel trace clay  brown/grey, moist  (loose/compact) shattered rock encountered at 3.0 m depth		4	SS	5							○				0 18 77 5 (NP)			
			5	SS	21							○							
262.9			6	SS	10								○						
4.0	SILT  grey, wet  (compact)  clay content generally increases with depth		7	SS	12							○				0 0 94 6 (NP)			
			8	SS	11							○							
259.8																			
7.1	CLAYEY SILT to SILTY CLAY - trace sand  grey, wet  (very stiff)  dark grey clay varves <15 mm thick   clay content generally increases with depth  (stiff)		9	SS	6							○							
			10	SS	4							○							
			11	SS	3							○							
			12	SS	WH							○				0 2 51 47			
Continued Next Page							254												
COMMENTS   The stratification lines represent approximate boundaries. The transition may be gradual.							+ 3, × 3 : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 120 kPa ○ 3% STRAIN AT FAILURE					WATER LEVEL RECORDS							
												Date (yy/mm/dd)/Time		Water Depth (m)		Cave In (m)			
												1)		-		-			
												2)		-		-			
												3)		-		-			

MEL-GEO 12218 - BOREHOL LOGS - VERMILLION RIVER.GPJ MEL-GEO.GDT 14/9/18

**METRIC****RECORD OF BOREHOLE NO. 4**

REFERENCE 12/11/12218-F2 DATUM Geodetic LOCATION N 5158950.7 E 283918.3 - Balfour Twp, Station 16+938, 4.6 m Lt ORIGINATED BY JL  
 PROJECT GWP 5580-04-00, Highway 144, Site No. 46-408/C BOREHOLE TYPE Truck Mounted CME 45 - Hollow Stem Augers COMPILED BY RG  
 CLIENT AECOM Inc. DATE (Started) 2014 June 16 TIME   
 DATE (Completed) 2014 June 16 (Completed) 4:30:00 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	SHEAR STRENGTH kPa					
	Continued from Previous Page												
			13	SS	PM								
			14	SS	PM								
250.9													
16.0	End of Sampling End of Borehole												

MEL-GEO 12218 - BOREHOLE LOGS - VERMILLION RIVER.GPJ MEL-GEO.GDT 14/9/18

## METRIC

## RECORD OF BOREHOLE NO. 5



REFERENCE	12/11/12218-F2	DATUM	Geodetic	LOCATION	N 5158951.7 E 283898.3 - Balfour Twp, Station 16+958, 4.4 m Lt	ORIGINATED BY	JL
PROJECT	GWP 5580-04-00, Highway 144, Site No. 46-408/C			BOREHOLE TYPE	Truck Mounted CME 45 - Hollow Stem Augers	COMPILED BY	RG
CLIENT	AECOM Inc.			DATE (Started)	2014 June 17	TIME	
				DATE (Completed)	2014 June 17	(Completed) 2:30:00 PM	CHECKED BY
							MAM

[illegible]

MEL-GEO 12218 - BOREHOL LOGS - VERMILLION RIVER.GPJ MEL-GEO.GDT 14/9/18

**METRIC****RECORD OF BOREHOLE NO. 5**

REFERENCE 12/11/12218-F2 DATUM Geodetic LOCATION N 5158951.7 E 283898.3 - Balfour Twp, Station 16+958, 4.4 m Lt ORIGINATED BY JL  
 PROJECT GWP 5580-04-00, Highway 144, Site No. 46-408/C BOREHOLE TYPE Truck Mounted CME 45 - Hollow Stem Augers COMPILED BY RG  
 CLIENT AECOM Inc. DATE (Started) 2014 June 17 TIME   
 DATE (Completed) 2014 June 17 (Completed) 2:30:00 PM CHECKED BY MAM

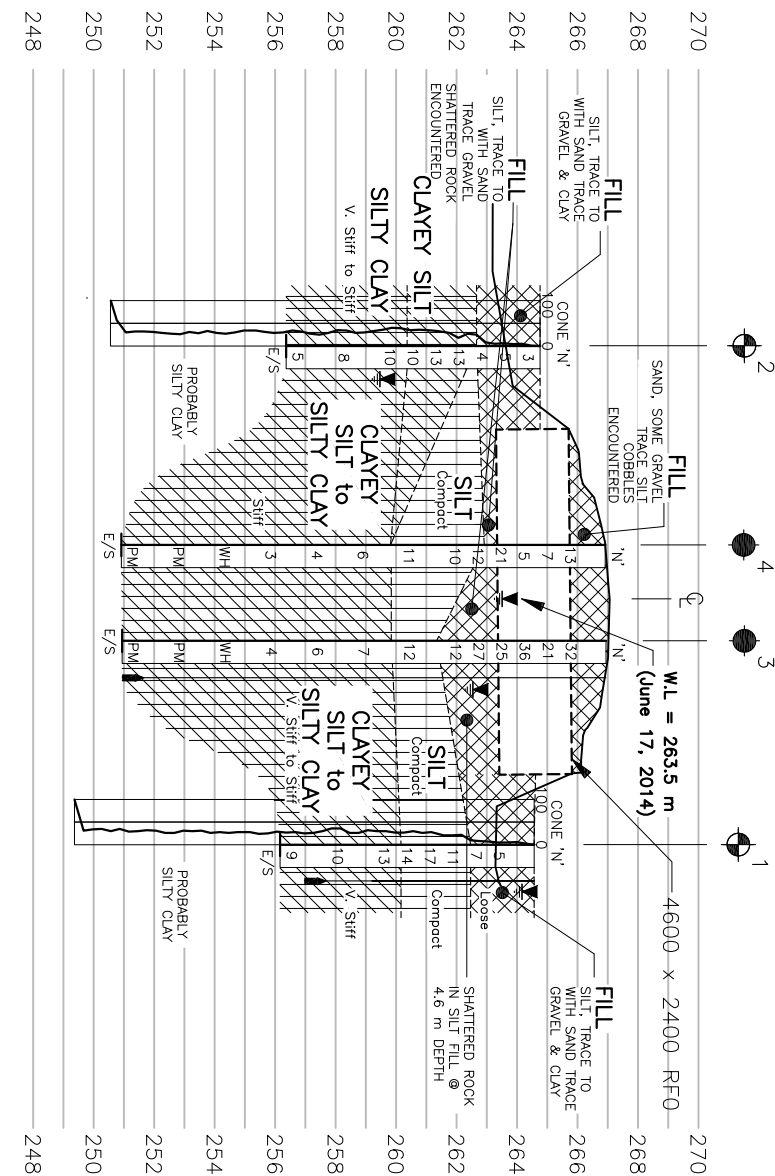
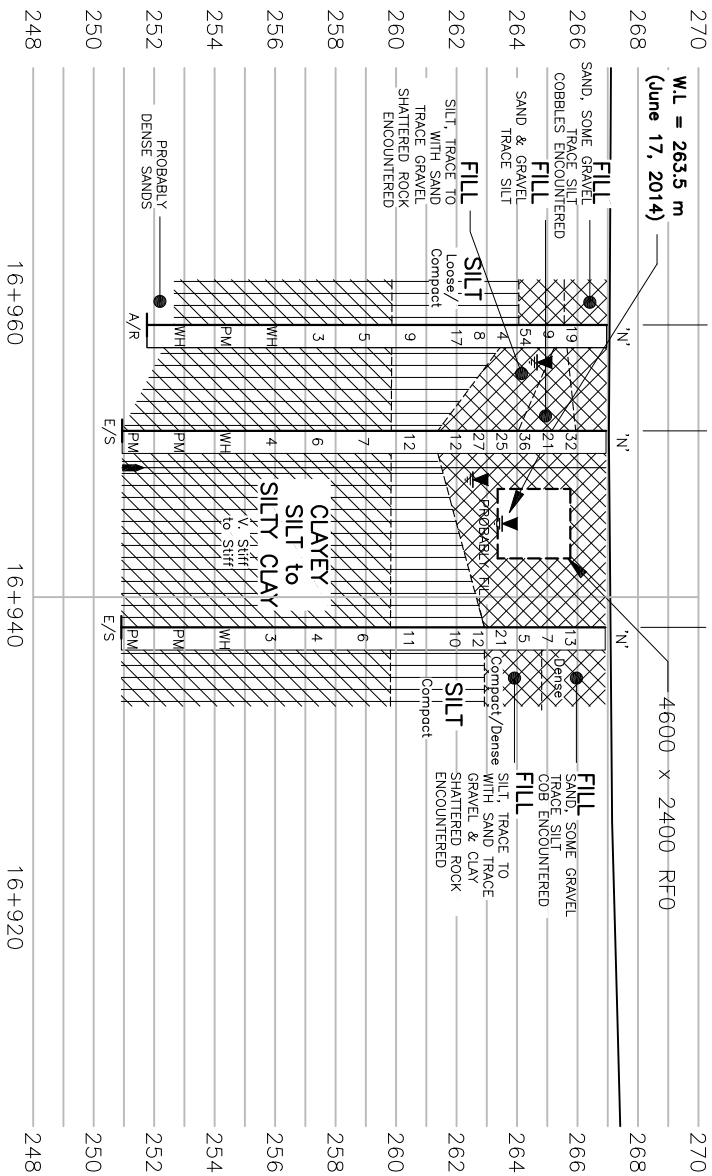
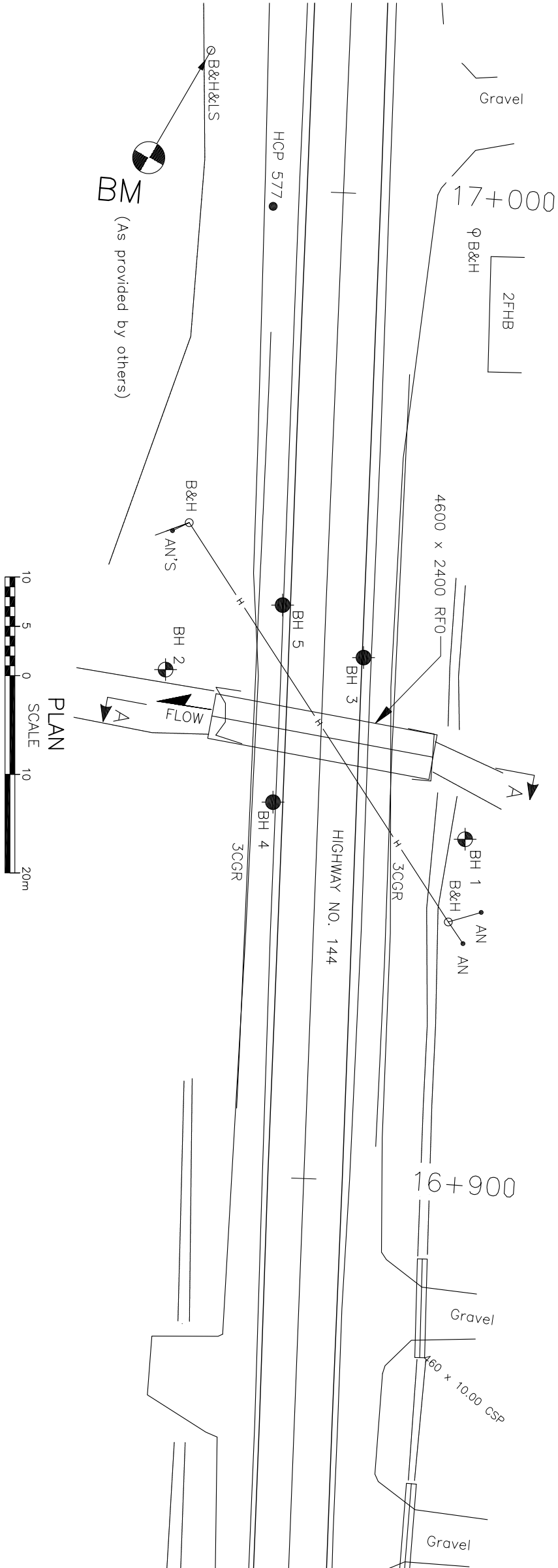
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	Continued from Previous Page																
252.7			13	SS	WH												
14.3	Augers grinding - likely dense sands																
251.8																	
15.2	Auger Refusal End of Borehole																

MEL-GEO 12218 - BOREHOLE LOGS - VERMILLION RIVER.GPJ MEL-GEO.GDT 14/9/18



### **Appendix 3 Borehole Plan and Laboratory Data**

Drawing No. 2:	Borehole Location and Soil Strata
Figure Nos. L-1 to L-5:	Grain Size Distribution Curves
Figure No. L-6:	Atterberg Limits Summary
Figure No. L-7:	Shear Strength Summary
Table No. L-8:	Lab Test Summary Sheet

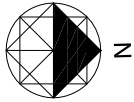


CONT. No.

XXXX-XXXX

GWP. No.

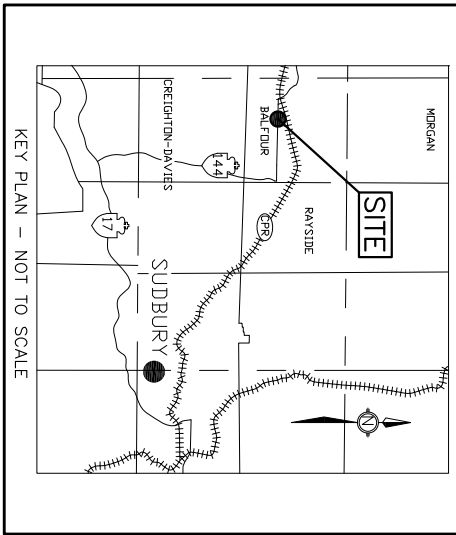
5580-04-00



DRAWING

2

HWY 144  
VERMILLION CREEK TRIBUTARY CULVERT  
(SITE 46-408/C)  
TOWNSHIP OF BALFOUR  
BOREHOLE LOCATIONS & SOIL STRATA



#### LEGEND

- Borehole
- Borehole with Dynamic Cone Penetration Test (DCPT)
  - 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
- Piezometer
- A/R Auger Refusal at Elevation
- E/S End of Sampling

Borehole No.	Elev.	O/S	Co-ordinates
			Northerly Easterly
Borehole No. 1	264.6	15.0 m Rt	5158970.2 283922.0
Borehole No. 2	264.8	16.0 m Lt	5158939.9 283904.8
Borehole No. 3	266.9	4.0 m Rt	5158959.9 283903.6
Borehole No. 4	266.9	4.6 m Lt	5158950.7 283918.3
Borehole No. 5	267.0	4.4 m Lt	5158951.7 283898.3

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.

NO	DATE	BY	DESCRIPTION
----	------	----	-------------

5	AUG 2014	RG	DRAFT
6	OCT 2014	AT	FINAL

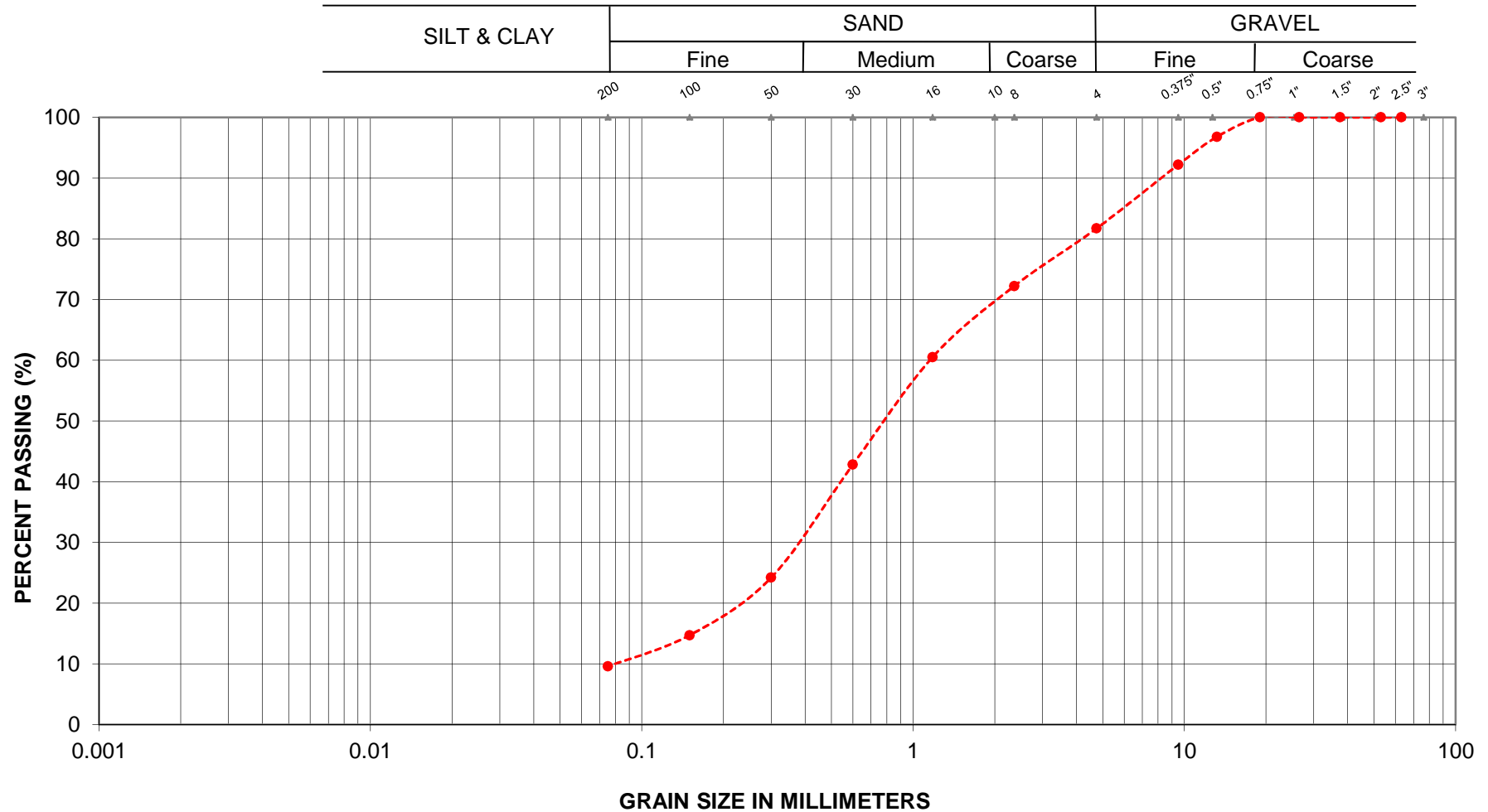
HWY NO. 144 – BALFOUR TOWNSHIP

GEOCRES NO.: 411–319

LVM REF. NO.: 12/11/12218

DRAWN: RG CHECKED: AT DATE: OCTOBER 2014

# GRAIN SIZE ANALYSIS



---●--- BH No.: 3 Sa No.: 1 Depth: 0.0 - 0.8 m

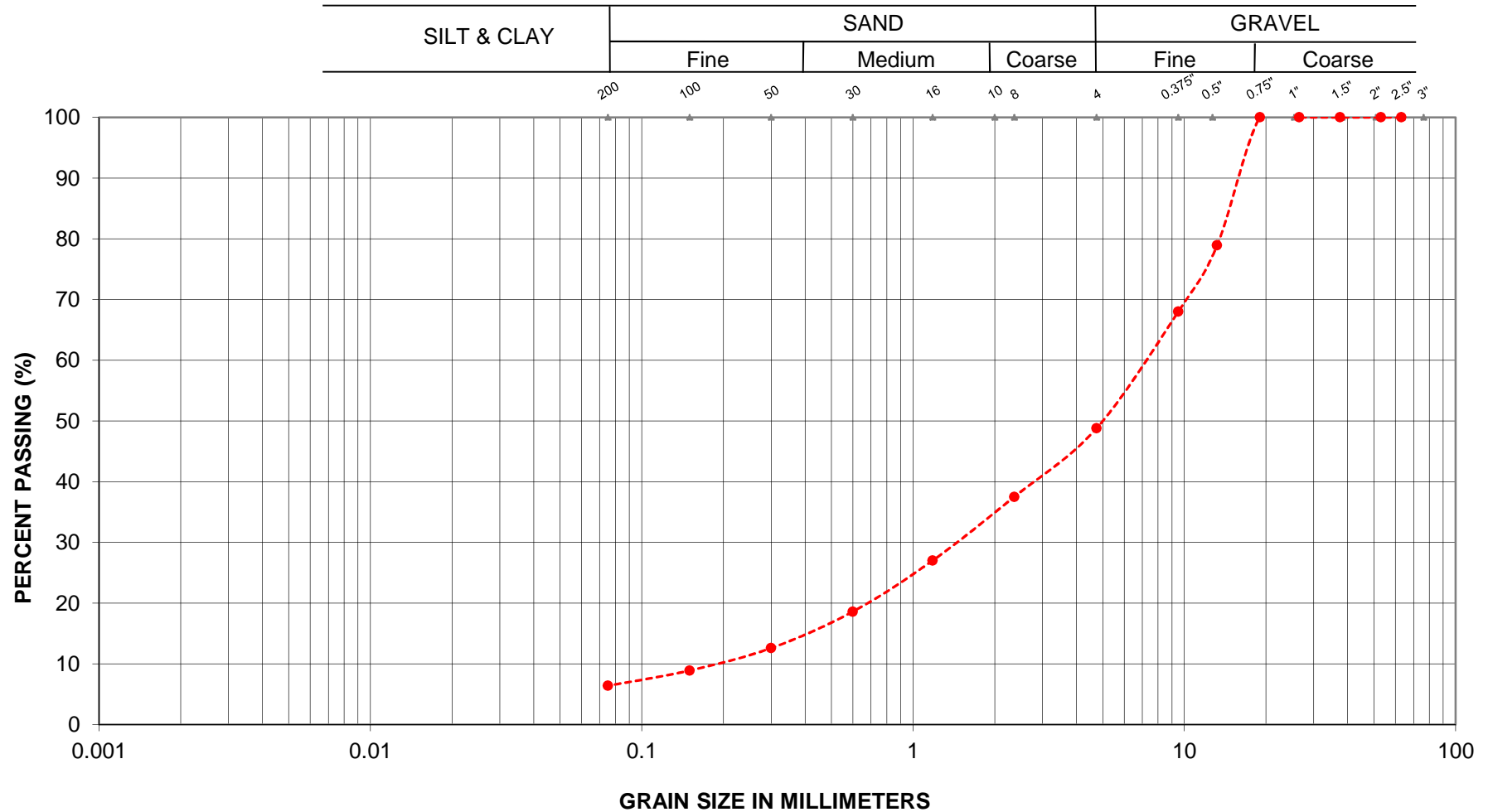
G.W.P.: 5580-04-00  
LOCATION: Hwy 144, Vermillion River Tributary Culvert

SAND FILL

LVM | MERLEX

FIGURE L-1

# GRAIN SIZE ANALYSIS

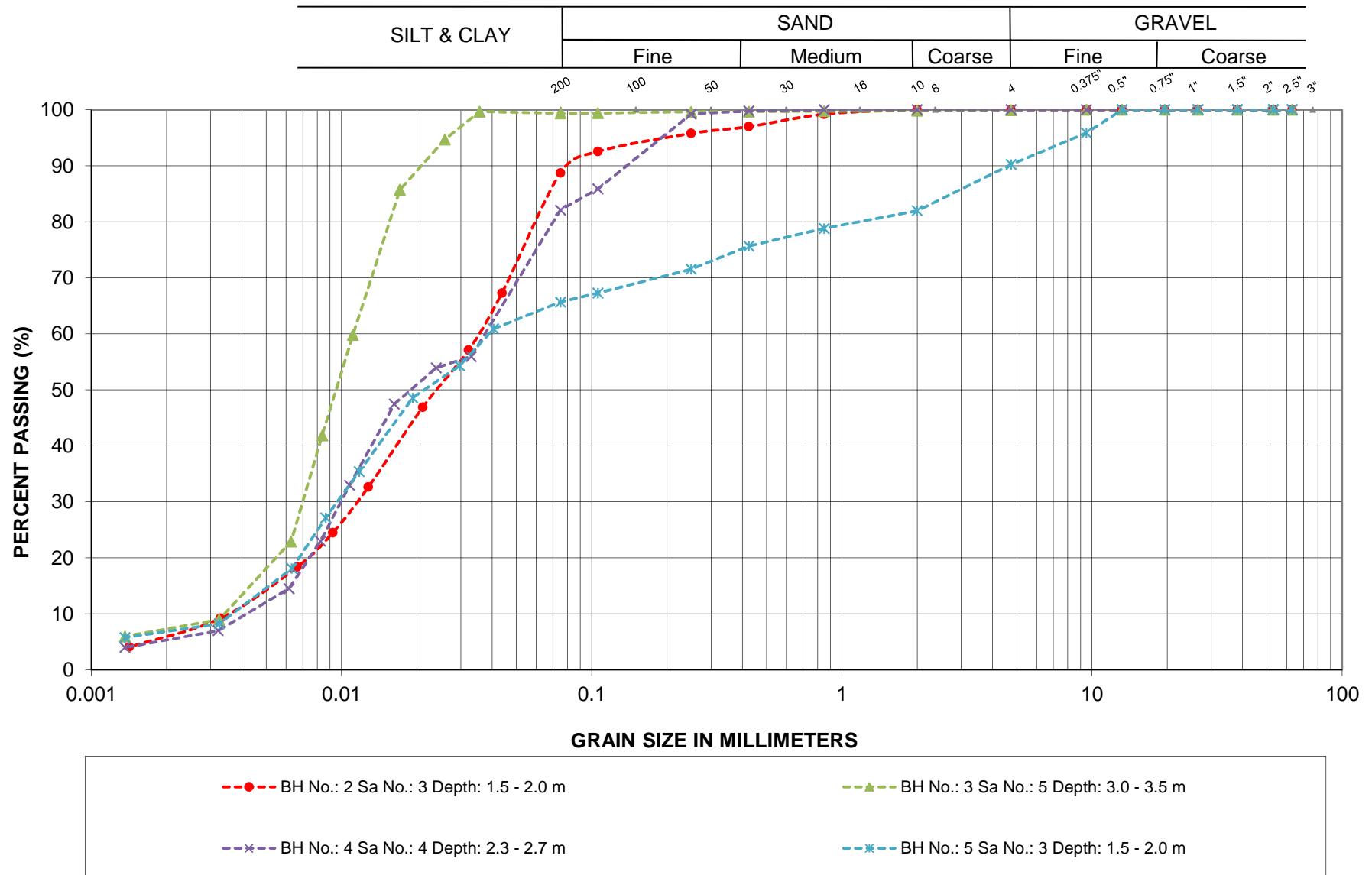


---●--- BH No.: 3 Sa No.: 4 Depth: 0.0 - 0.8 m

G.W.P.: 5580-04-00  
LOCATION: Hwy 144, Vermillion River Tributary Culvert

SAND AND GRAVEL FILL

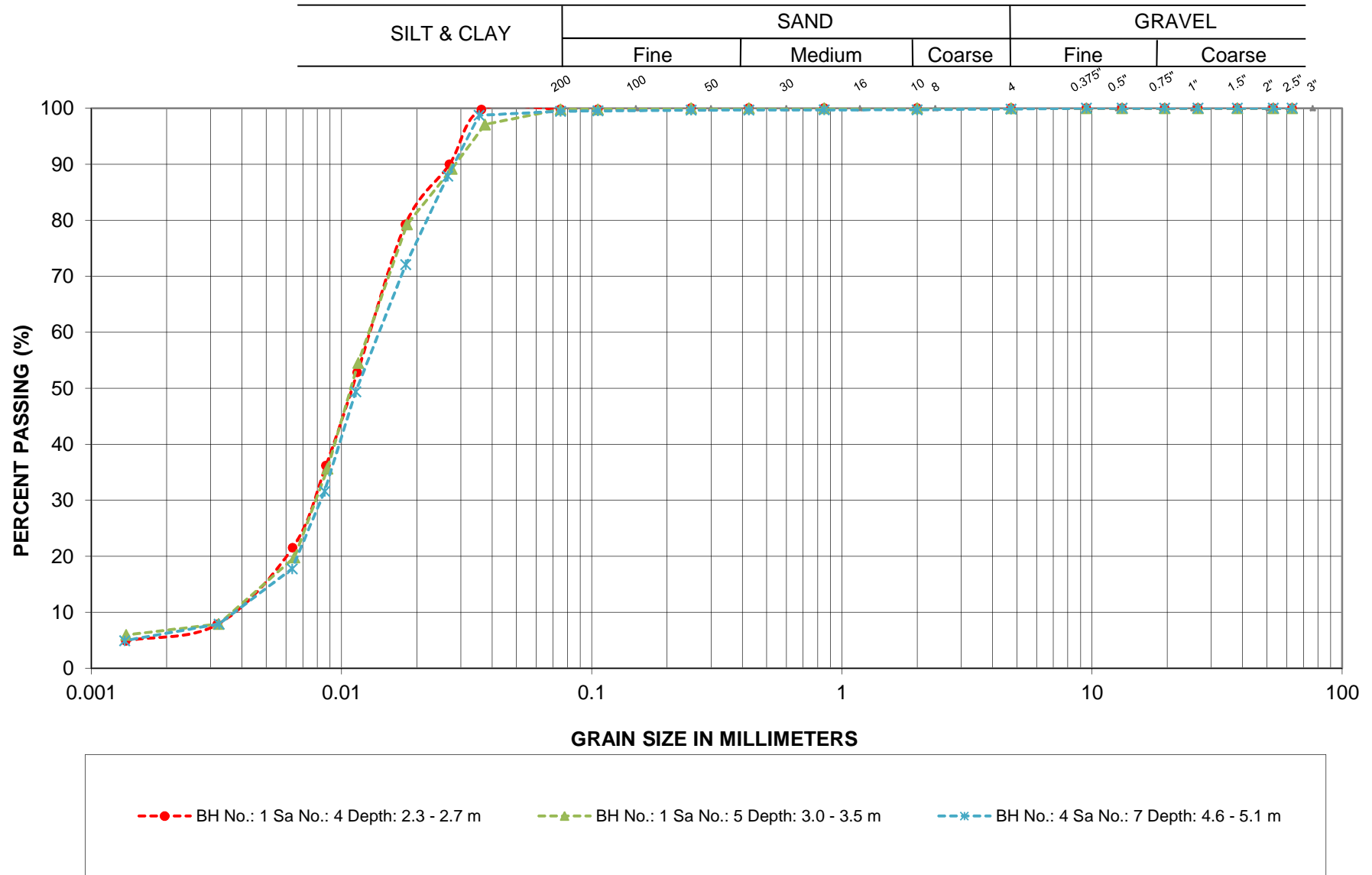
### GRAIN SIZE ANALYSIS



G.W.P.: 5580-04-00  
LOCATION: Hwy 144, Vermillion River Tributary Culvert

SILT FILL

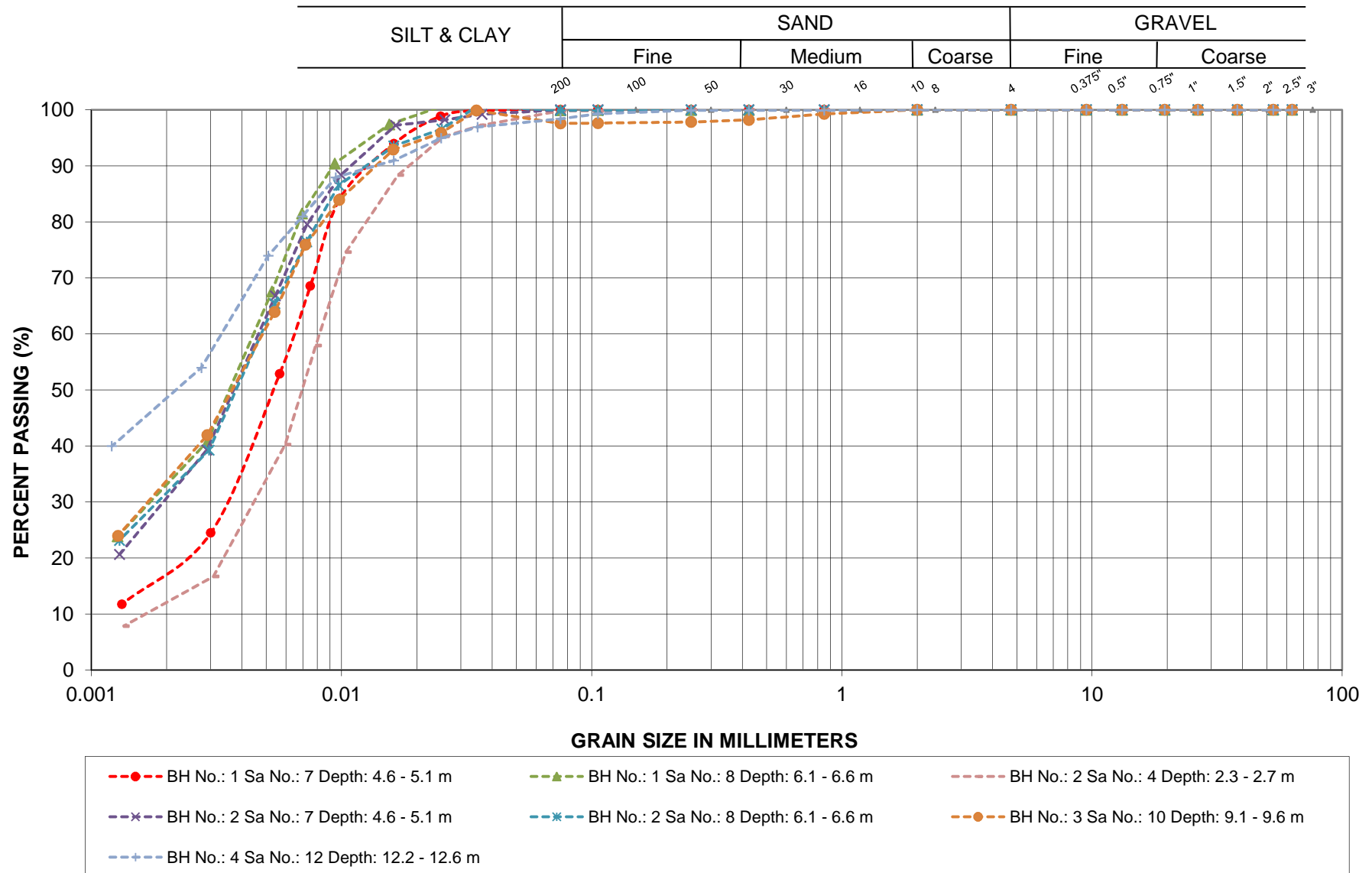
# GRAIN SIZE ANALYSIS



G.W.P.: 5580-04-00  
LOCATION: Hwy 144, Vermillion River Tributary Culvert

SILT

# GRAIN SIZE ANALYSIS

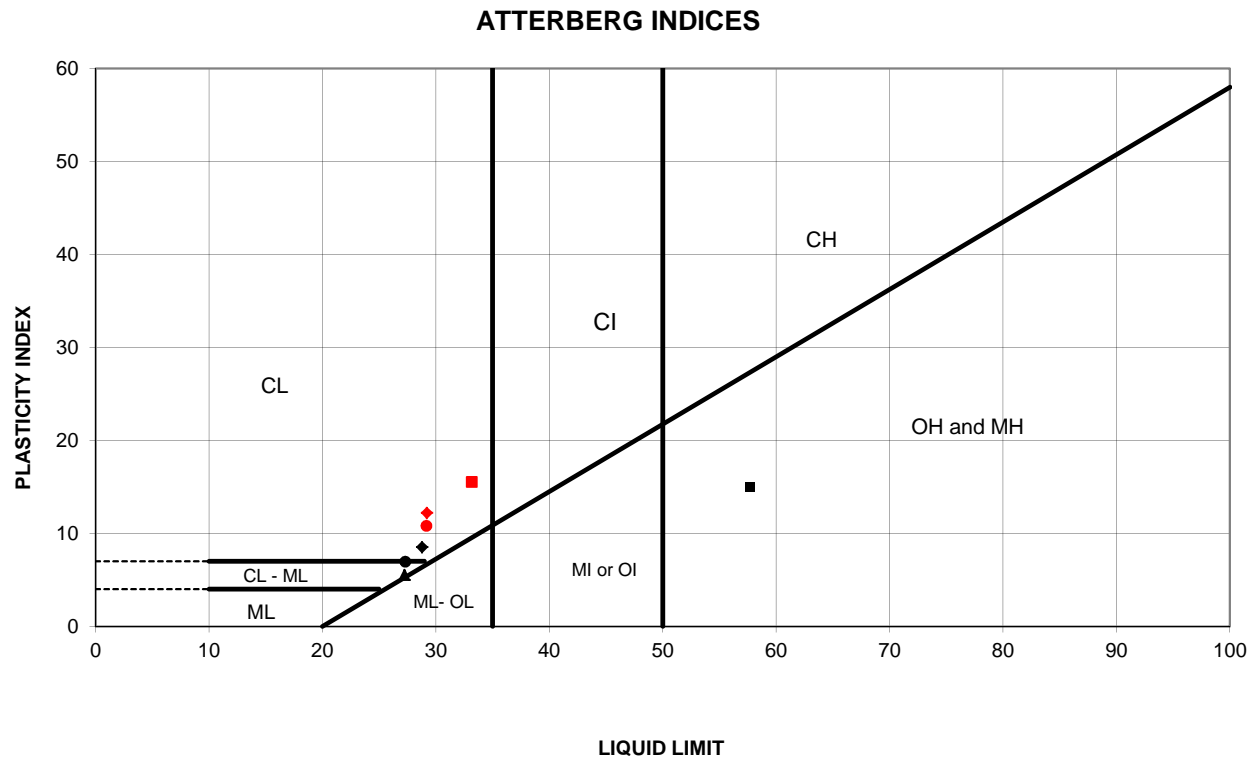


G.W.P.: 5580-04-00  
LOCATION: Hwy 144, Vermillion River Tributary Culvert

CLAYEY SILT to SILTY CLAY

# ATTERBERG LIMITS TEST RESULTS

FIGURE L-6



SYMBOL	BH	Sa. No.	Depth(m)	Elev.(m)	Liquid Limit	Plastic Limit	Plasticity Index	NMC %
●	1	7	4.6	260.0	27.3	20.3	7.0	28.7
◆	1	8	6.1	258.5	28.8	20.2	8.5	30.0
■	2	3	1.5	263.3	57.8	42.8	15.0	57.3
▲	2	4	2.3	262.5	27.2	21.7	5.5	26.1
●	2	8	6.1	258.7	29.2	18.4	10.8	31.5
◆	3	10	9.1	257.8	29.2	17.0	12.2	33.3
■	4	12	12.2	254.7	33.2	17.7	15.5	37.4

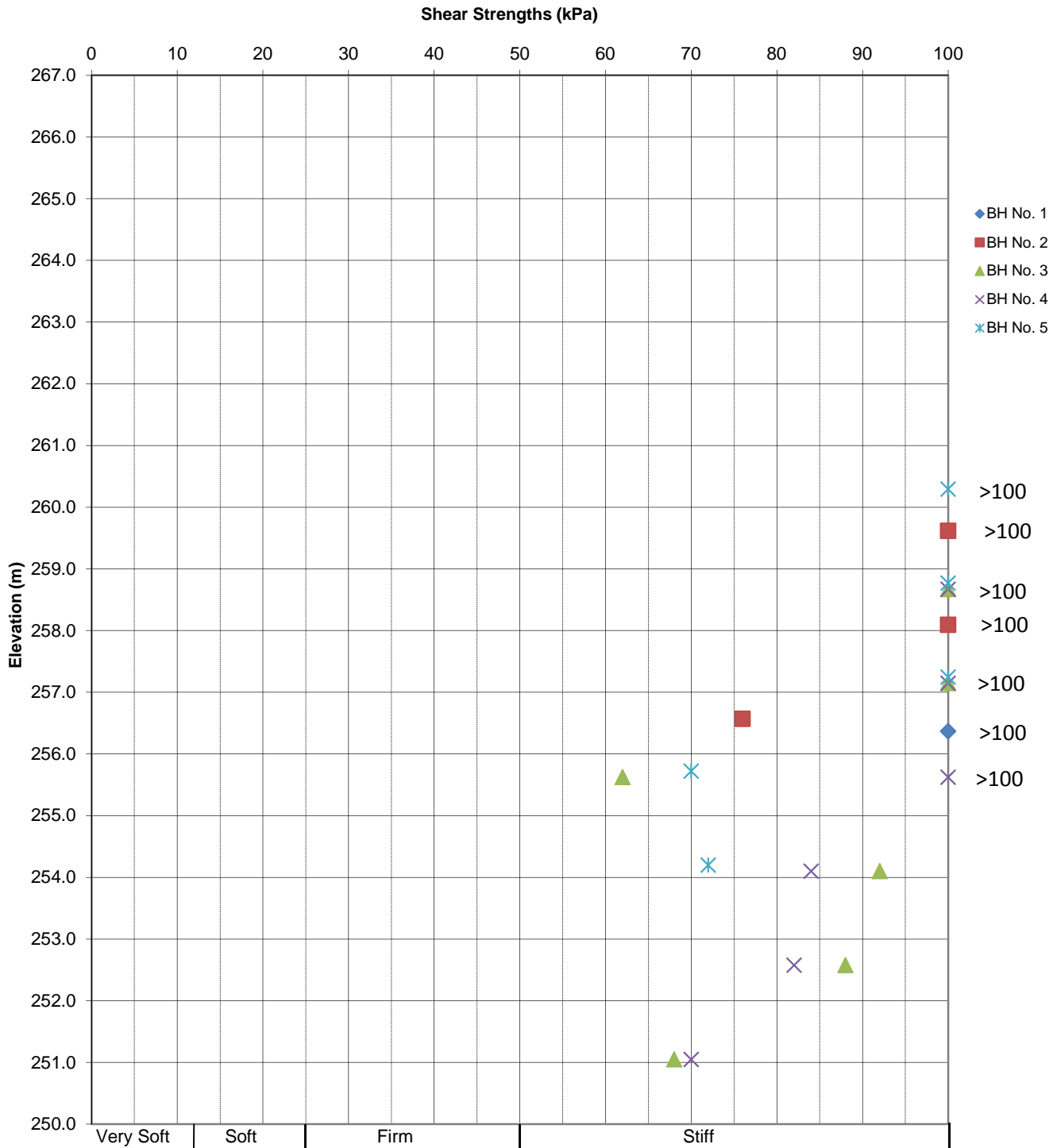
Date: Oct-14  
 Project: Hwy 144, Vermillion River Tributary  
 G.W.P: 5580-04-00

Prep'd: AT  
 Chkd: MAM  
 Ref. No.: 12/11/12218-F2

LVM-MERLEX, a division of EnGlobe corp.



## In-Situ Shear Strengths vs. Depth



## 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					28.5							
	2	0.8					22.7				5			
	3	1.5					46.7				7			
	4	2.3	0	0	94	6	27.7				11			Non Plastic (NP)
	5	3.1	0	0	93	7	23.4				17			Non Plastic (NP)
	6	3.8					28.2				14			
	7	4.6	0	0	83	17	28.7	27.3	20.3	7.0	13			
	8	6.1	0	0	67	33	30.0	28.8	20.2	8.6	10			
	9	7.6					33.5				9			
2	1	0.0					45.7				3			
	2	0.8					50.0				5			
	3	1.5	0	12	81	7	57.3	57.8	42.8	15.0	4			
	4	2.3	0	0	88	12	26.1	27.2	21.7	5.5	13			
	5	3.1					27.4				13			
	6	3.8					28.2				10			
	7	4.6	0	0	70	30	30.8				10			Non Plastic (NP)
	8	6.1	0	0	69	31	31.5	29.2	18.4	10.8	8			
	9	7.6					33.2				5			
3	1	0.0	18	72	10		4.2							
	2	0.8					10.6				32			
	3	1.52					2.9				21			
	4	2.29	51	43	6		2.1				36			
	5	3.1	0	1	92	7	24.0				25			Non Plastic (NP)
	6	3.8					21.3				27			
	7	4.6					4.2				12			

## Laboratory Tests - Summary Sheet

Borehole No.	Sample No.	Depth	Grain Size Analysis				NMC	Atterberg Limits			SPT 'N'	USCS	Unit Weight (kN/m3)	Remarks
			Gravel Size (%)	Sand Size (%)	Silt Size (%)	Clay Size (%)		LL (%)	PL (%)	IP (%)				
3	8	6.1					26.6				12			
	9	7.6					30.4				7			
	10	9.1	0	2	65	33	33.3	29.2	17.0	12.2	6			
	11	10.7					35.8				4			
	12	12.2					35.4				WH			
	13	13.7					53.6				PM			
	14	15.2					34.0				PM			
4	1	0.0					3.3							
	2	0.8					16.0				13			
	3	1.5					10.5				7			
	4	2.3	0	18	77	5	23.6				5			Non Plastic (NP)
	5	3.1					22.3				21			
	6	3.8					36.8				12			
	7	4.57	0	0	94	6	22.8				10			Non Plastic (NP)
	8	6.1					25.9				11			
	9	7.62					31.1				6			
	10	9.14					31.9				4			
	11	10.67					35.2				3			
	12	12.19	0	2	51	47	37.4	33.2	17.7	15.5	WH			
	13	13.72					47.7				PM			
	14	15.24					52.6				PM			
5	1	0					3.5							
	2	0.76					5.3				19			
	3	1.52	10	25	59	6	17.3				9			Non Plastic (NP)
	4	2.29					3.6				54			

## Appendix 4 Photo Essay

Enclosure No. 7:

Photo Essay

Existing Embankment – Looking West

Photo: 1



Existing Embankment – Looking East

Photo: 2



Project: Hwy 144 – Vermillion River Tributary Culvert

Photos Provided By: LVM

Date: June 2014

Culvert Inlet – Looking North

Photo: 3



Culvert Outlet – Looking North

Photo: 4



Project: Hwy 144 – Vermillion River Tributary Culvert

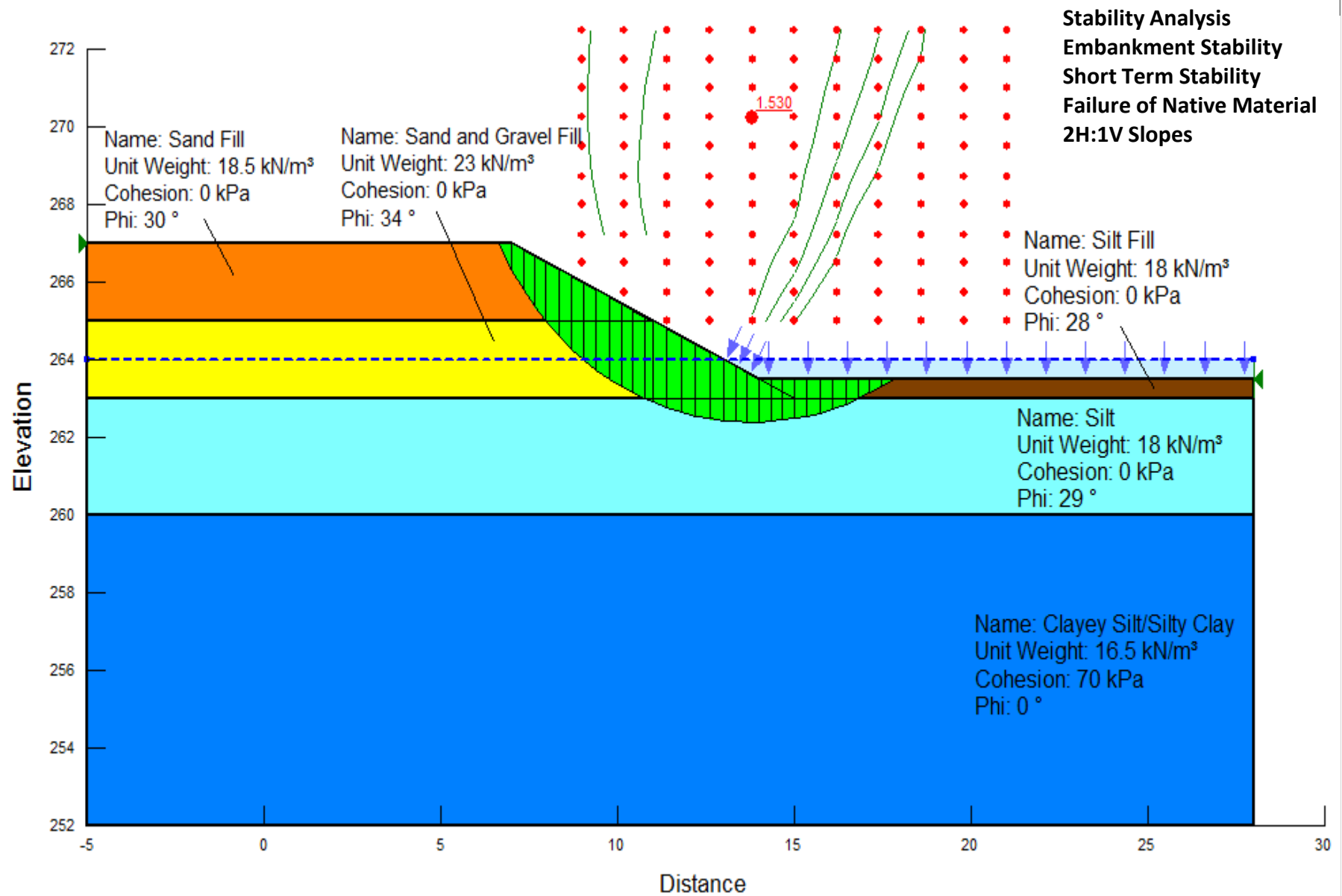
Photos Provided By: LVM

Date: June 2014

## Appendix 5 Design Data

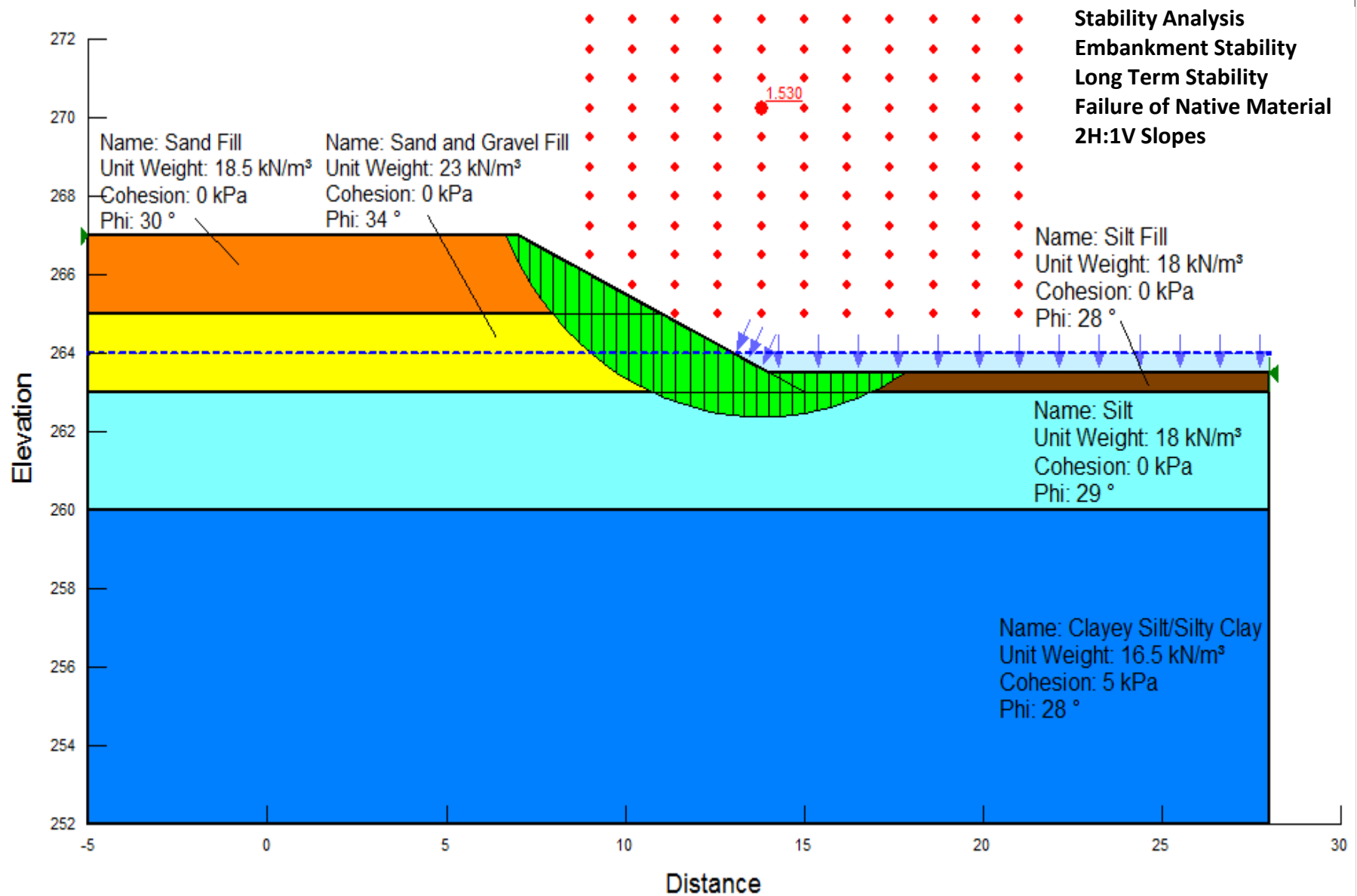
Figure No. S-1 and S-2:	Slope Stability
Table A:	Comparison of Shoring Alternatives
Figure No. SK-3	Conceptual Staging Plan
Figure No. SK-4:	Conceptual Shoring Locations
Figure No. SK-5:	Conceptual Shoring Sections





Stability Analysis  
Station 16+945  
TWP of Balfour

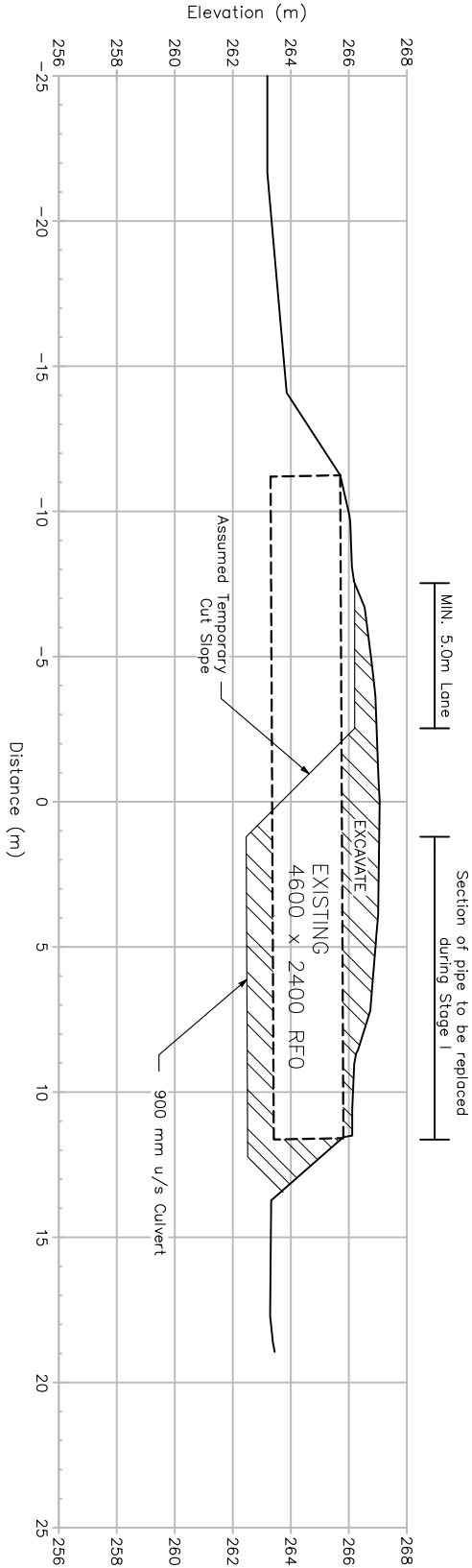




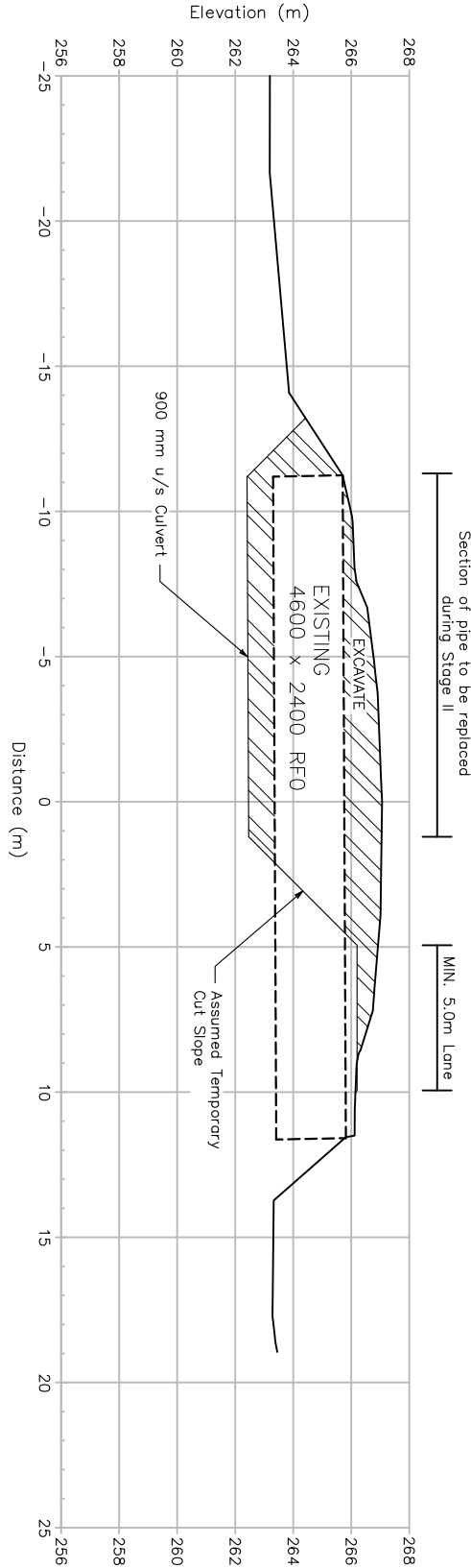
Stability Analysis  
 Station 16+945  
 TWP of Balfour

**Table A – Comparison of Shoring Alternatives**

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



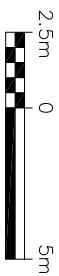
STAGE I



STAGE II

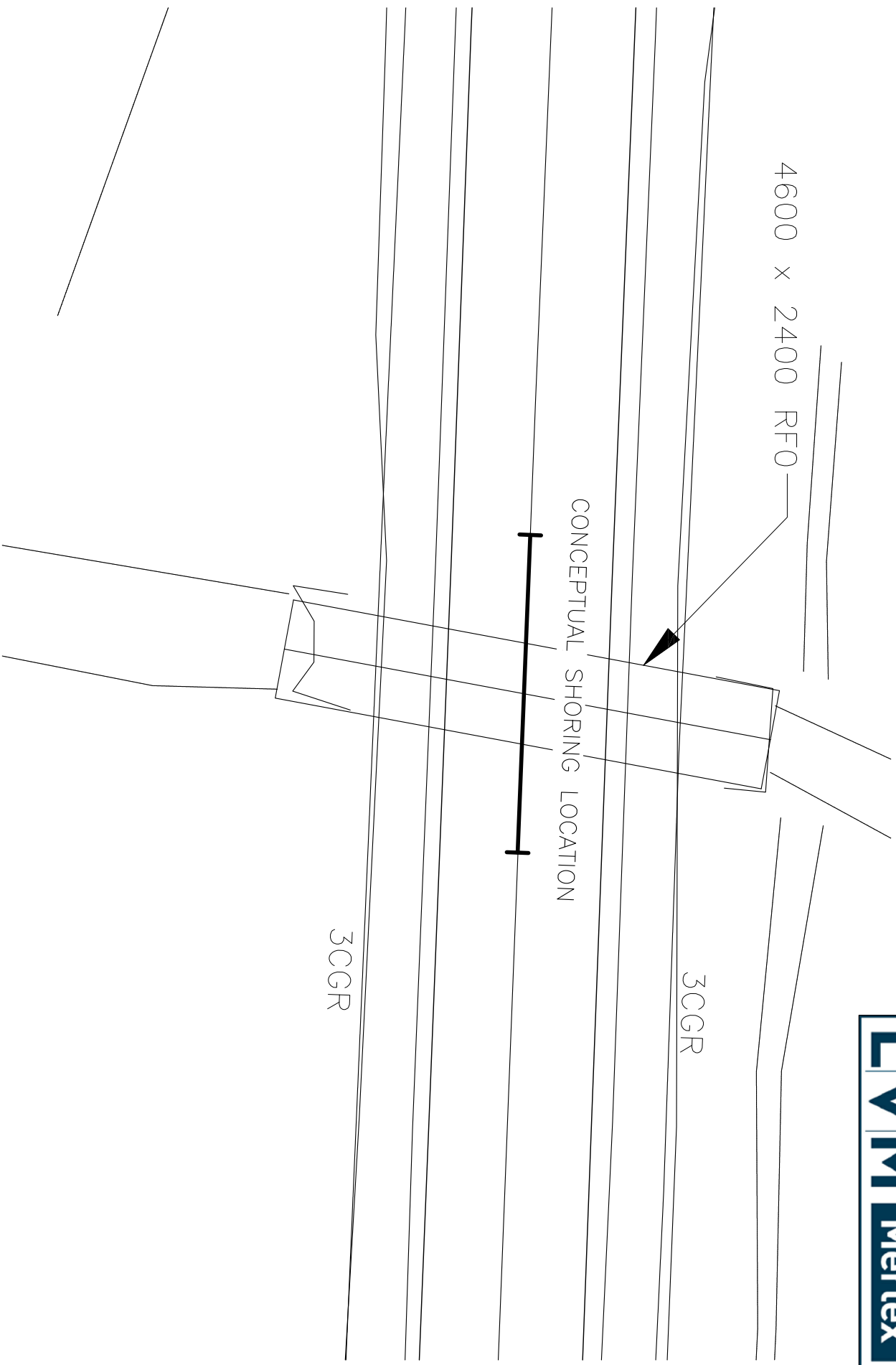
METRIC

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



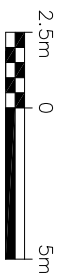
Highway 144, Township of Balfour- Vermillion Creek Tributary Culvert  
Conceptual Staging Section

FIGURE SK-3



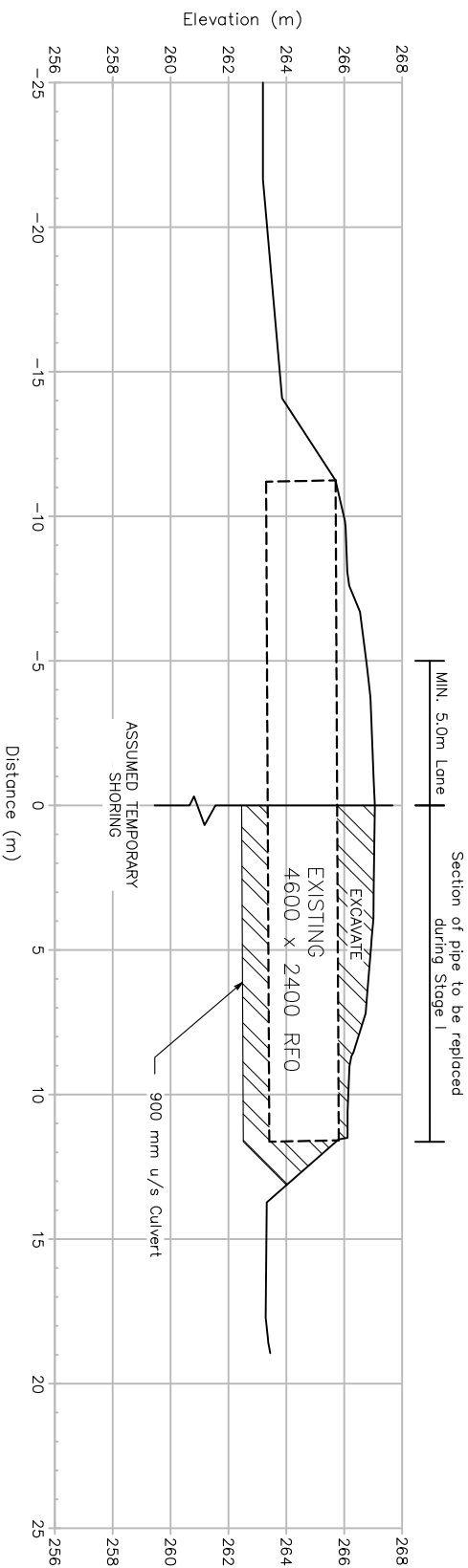
METRIC

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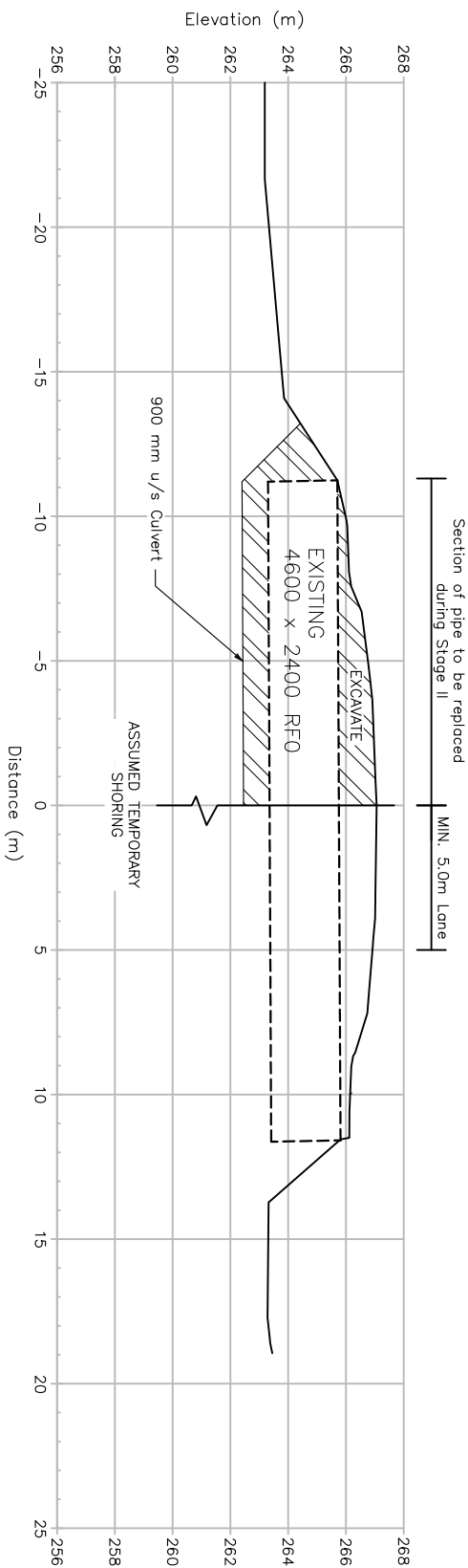


Highway 144, Township of Balfour- Vermillion Creek Tributary Culvert  
Conceptual Shoring Locations

FIGURE SK-4



STAGE I



STAGE II

METRIC

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



## **Appendix 6    Notice to Contractor**

Notice to Contractor

**NOTICE TO CONTRACTOR – Obstructions in Embankment Fill Soils**

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Special Provision

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The Contractor is advised that the embankment fill material(s) includes sand, sand and gravel, silt and contains a mix of cobble/boulder size rock in the sand fill and silt fill deposits at various depths below ground surface. The contractor should be prepared to deal with these materials.