

**FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT REPLACEMENT AT KESAGAMI RIVER
SITE NO. 39N-011
HIGHWAY 652
COCHRANE DISTRICT, ONTARIO
G.W.P. No. 5193-13-00, W.P. No. 5038-12-01**

GEOCRES Number: 42H-59

Report to

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TABLE OF CONTENTS

SECTION	PAGE
PART 1 FACTUAL INFORMATION	
1 INTRODUCTION.....	1
2 SITE DESCRIPTION.....	1
3 SITE INVESTIGATION AND FIELD TESTING	2
4 LABORATORY TESTING	3
5 DESCRIPTION OF SUBSURFACE CONDITIONS	3
5.1 General.....	3
5.2 Asphalt and Topsoil.....	4
5.3 Fill.....	4
5.4 Peat	5
5.5 Sand and Silty Sand	5
5.6 Silt, Sandy Silt and Clayey Silt.....	5
5.7 Sand and Silt, Sandy Silt to Clayey Silt Till.....	7
5.8 Bedrock.....	7
5.9 Groundwater Conditions.....	8
6 MISCELLANEOUS.....	9
PART 2 ENGINEERING DISCUSSION AND RECOMMENDATIONS	
7 GENERAL	11
8 CULVERT FOUNDATIONS	11
8.1 General.....	11
8.2 Foundation Alternatives.....	12
8.3 Foundation Design.....	12
8.3.1 Concrete Box Culverts	13
8.3.2 Retaining Walls	13
8.3.3 Settlements	13
8.3.4 Subgrade Preparation	14
8.3.5 Frost Depth.....	14
8.4 Construction Considerations.....	14
9 CULVERT BACKFILL AND LATERAL EARTH PRESSURES	15
10 EMBANKMENT DESIGN AND RECONSTRUCTION	16
11 EROSION CONTROL	16

12	EXCAVATION AND GROUNDWATER CONTROL	17
12.1	General.....	17
12.2	Foundations	17
12.3	Excavations.....	17
12.4	Groundwater Control.....	18
13	ROADWAY PROTECTION SYSTEMS	18
14	CONSTRUCTION CONCERNS.....	19
15	CLOSURE.....	19

Appendices

Appendix A	Record of Borehole Sheets
Appendix B	Laboratory Test Results
Appendix C	Borehole Locations and Soil Strata Drawings
Appendix D	Foundation Alternatives Comparison
Appendix E	Suggested Wording for NSSP
Appendix F	Selected Photographs of Existing Culvert Area

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) at the location of a culvert site on Highway 652 over the Kesagami River tributary, located approximately 144 km north of Highway 579 in Cochrane District.

The purpose of this investigation was to obtain subsurface information at the culvert location and, based on the data obtained, to provide a borehole location plan, stratigraphic profiles, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber was retained by URS Canada Inc. (URS) to carry out this foundation investigation under the MTO Agreement Number 5012-E-0033. The foundations terms of reference indicates that there is no record of any previous foundation investigation carried out at or near the subject culvert.

2 SITE DESCRIPTION

The culvert site is located on Highway 652, 144 km North of Highway 579 and to the northeast of the Town of Cochrane in Cochrane District, Ontario. This culvert carries a tributary of the Kesagami River under Highway 652.

The existing culvert is a 4.6 m span by 4.0 m high by 36 m long steel plate pipe arch (SPPA) constructed in 1982. According to the terms of reference, the structure is in fair condition with deterioration of several elements. The embankment fill height at the culvert is approximately 3.0 m.

The grade of the existing Highway 652 in the vicinity of the culvert ranges between approximately Elevations 298.5 and 299 m, with ground surface at the culvert inlet and outlet areas varying between approximately 295 and 297 m.

The site is located in a rural area adjacent to swamps, creeks and other watercourses. The surrounding area is heavily forested with low-lying areas featuring tall grasses and shrubs. Local topography is generally of low relief with no visible bedrock outcrops. The Detour Lake Gold Mine is located approximately 20 km northeast of the site along Highway 652.

The terrain in the general vicinity of the site is moderately sloping moderately towards the river. Soil cover generally consists of glaciofluvial deposits of sands and silts with varying amounts of gravel overlying glacial tills. The underlying bedrock consists of mafic metavolcanic rocks. Rockfill, presumably used for erosion protection, is visible on the ground surface surrounding the culvert at its inlet and outlet areas.

3 SITE INVESTIGATION AND FIELD TESTING

This borehole investigation and field testing program was carried out between October 1st and 8th, 2013. The program consisted of drilling and sampling eight boreholes (numbered KR13-01 to KR13-08) to depths ranging from 6.7 m to 22.2 m (Elevations 290.5 to 276.5 m). Of the eight boreholes, two were located at the culvert inlet (KR13-07 and 13-08), two were located at the culvert outlet (KR13-01 and 13-02), two were located at the embankment crest adjacent to the culvert (KR13-04 and 13-05), and two were located some distance away from the culvert (KR13-03 and 13-06).

DCPT's were conducted in four boreholes. In Boreholes KR13-01, KR13-02, KR13-07 and KR13-08, the DCPT was extended beyond the depth of sampling.

The borehole locations were staked in the field and utility clearances were obtained prior to commencement of drilling operations. The co-ordinates and elevations of the as-drilled boreholes were subsequently provided by Callon Dietz utilizing Digital Terrain Model (DTM), based on borehole location sketches provided by Thurber. The approximate locations and elevations of the boreholes are shown on the attached Borehole Locations and Soil Strata Drawing included in Appendix C.

A truck-mounted drill rig was used to drill and sample the boreholes on the highway and shoulder, and a track-mounted drill rig was used to drill and sample the boreholes at the culvert inlet and outlet. Hollow stem augers and NW casing were used to advance the boreholes. Soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT). Borehole KR13-06 was further advanced into bedrock using NQ size coring equipment in conjunction with NW casings. Two standpipe piezometers were installed, one at the culvert inlet and one at the culvert outlet. In addition, groundwater conditions in the open boreholes were observed throughout the drilling operations. The details of monitoring well installations and borehole completion are summarized in Table 3.1.

Two members of Thurber's technical staff, one at each rig, supervised the drilling and sampling operations on a full time basis. The supervisors logged the boreholes, secured the recovered soil samples in labelled containers, stored the rock core samples in wooden boxes, and transported the samples to Thurber's laboratory for further examination and testing.

Table 3.1
Borehole Completion and Monitoring Well Installation Details

Borehole Number	Monitoring Well Installations			Completion Details
	Screen Depth (m)	Screen Elevation (m)	Filter Stratum	
KR13-01	None Installed			Auger cuttings to surface
KR13-02	4.8 – 6.7	290.4 - 288.6	Sand	Bentonite above sand screen to surface
KR13-03	None Installed			Bentonite to 0.9 m, sand and asphalt to surface
KR13-04	None Installed			Bentonite to 0.9 m, sand to 0.1 m, asphalt to surface
KR13-05	None Installed			Bentonite to 1.2 m, sand to 0.1 m, asphalt to surface
KR13-06	None Installed			Bentonite mixed with cuttings to 1.8 m, bentonite to 0.6 m, sand to 0.1 m, asphalt to surface
KR13-07	2.4 – 6.7	293.3 - 289.0	Sand	Bentonite above sand screen to surface
KR13-08	None Installed			Bentonite to 2.4 m, bentonite mixed with cuttings to surface

Results of field drilling and sampling are presented on the Record of Borehole sheets in Appendix A.

4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and to natural water content determination. Selected soil samples were subjected to grain size distribution analyses (sieve and hydrometer). Point load testing was carried out on selected rock cores for unconfined compressive strength correlation. The results of this laboratory testing program are shown on the Record of Borehole sheets in Appendix A and on the figures in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

5.1 General

Reference is made to the Record of Borehole sheets in Appendix A for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile and selected cross-sections for this culvert site are presented on the Borehole Locations and Soil Strata Drawings in Appendix C for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the record of boreholes governs any interpretation of the site conditions.

In general, the subsurface conditions encountered in the boreholes located on the highway and shoulder consist of asphalt and/or cohesionless fill overlying native sand, silt, and till deposits. The native soils are underlain by proven bedrock at one of the borehole locations. Boreholes located at the culvert inlets and outlets encountered topsoil or rockfill overlying native sand and silt deposits. More detailed descriptions of the individual stratum are presented below.

5.2 Asphalt and Topsoil

A layer of asphalt between 25 and 40 mm in thickness was encountered at ground surface in Boreholes 13-03, 13-04, 13-05, and 13-06.

Topsoil 50 mm in thickness was encountered in Boreholes KR13-01, KR13-02, and KR13-08. The topsoil thickness may vary between and beyond the borehole locations, and the limited data is not suitable for estimating topsoil quantities. A 0.3 m thick rockfill was present at the surface of Borehole 13-07.

5.3 Fill

Embankment fill was encountered below the asphalt in Boreholes KR13-01, KR13-03, KR13-04, KR13-05, and KR13-06. This fill typically consists of layers of brown gravelly sand, sand and sandy silt. Where encountered, the fill was found extending to depths of 0.8 m to 4.4 m (Elevations 296.4 to 294.3 m).

SPT N-values measured in the cohesionless fill typically ranged from 8 to 100 blows per 0.3m penetration, with typical values ranging between 10 and 100 per 0.3 m penetration, indicating a compact to very dense state. Occasional loose to dense zones indicated by N-values of 7 to 8 blows 50 blows for less than 0.3 m penetration, were encountered in Boreholes KR-13-03 and KR13-04, respectively. Measured water contents of the recovered fill samples ranged between 2% and 25%. Results of grain size analyses conducted on samples of the fill are presented on Figures B1 to B3 in Appendix B and are summarized in the following table:

Soil Particles	%
<u>Sand to Gravelly Sand Fill</u>	
Gravel	20 to 30
Sand	55 to 62
Silt and Clay	12 to 20
<u>Silt to Sandy Silt Fill</u>	
Gravel	0 to 6
Sand	9 to 21
Silt	65 to 82
Clay	8 to 14

5.4 Peat

A layer of peat 50 mm in thickness was encountered in Borehole KR13-03 at Elevation 295.7 m beneath the embankment fill. Water content of the peat sample was found to be 52%. The peat was fibrous, wet, and black in colour.

5.5 Sand and Silty Sand

Deposits of brown to grey sand to silty sand containing trace to some gravel, occasional cobbles and trace clay were encountered in all boreholes except Borehole KR13-06. These deposits were encountered near the ground surface (below topsoil or fill) within the culvert inlet/outlet boreholes, and beneath the embankment fill within the highway and shoulder boreholes. Where fully penetrated, the thickness of these deposits ranged between 3.9 and 7.5 m in thickness, with base elevations varying from 290.5 to 287.0 m. Boreholes KR13-01 and KR-13-02 were terminated within the sand.

In Boreholes KR13-01, 13-02, 13-07 and 13-08 located at the inlet and outlet areas, most SPT N-values ranged between 0 and 8 blows per 0.3 m penetration indicating a typically very loose to loose state, with compact to dense zones present at depth as indicated by N-values of 14 to 33 blows. For Boreholes KR13-03, 13-04 and 13-07 through the embankment, SPT N-values generally varied from 4 to 52 blows indicating a loose to very dense state. The measured water contents of samples of these soils generally ranged from 10% to 30%.

Grain size analyses conducted on samples of the sand and silty sand are presented on Figures B4, B5 and B6 in Appendix B. The results are summarized in the following table.

Soil Particles	%
<u>Sand</u>	
Gravel	0 to 35
Sand	61 to 95
Silt and Clay	2 to 15
<u>Silty Sand</u>	
Gravel	0
Sand	71
Silt	24
Clay	5

5.6 Silt, Sandy Silt and Clayey Silt

Brown to grey silt, sandy silt and clayey silt deposits were encountered in all eight boreholes. These soils are generally interlayered with the sand to silty sand or present just above the underlying glacial till. Where fully penetrated, the thickness of these deposits ranged between

0.3 and 2.9 m in thickness, with base elevations varying from 295.3 to 289.4 m. Borehole KR13-07 was terminated within the clayey silt.

SPT N-values measured within the silt and sandy silt deposits at shallow depths ranged from 5 to 14 blows per 0.3 m penetration indicating loose to compact conditions. In Borehole KR13-06, an N-value of 67 blows was measured for a silt layer below the sand deposit indicating a very dense state. The water contents of the silt and sandy silt samples were typically in the order of 18 % to 22 %.

SPT N-values measured within the clayey silt layers ranged from 4 to 57 blows per 0.3 m penetration indicating a soft to hard consistency. Measured water contents of the clayey silt samples were in the order of 20 %.

Grain size analyses conducted on samples of these soils are presented in Figures B7 to B9 of Appendix B. These results are summarized in the following table.

Soil Particles	%
<u>Silt and Clayey Silt</u>	
Gravel	0 to 2
Sand	0 to 13
Silt	73 to 84
Clay	9 to 23

Grain size analyses conducted on two samples of these soils are presented in Figures B9 and B10 of Appendix B. These results are summarized in the following table.

Soil Particles	%
<u>Sandy Silt</u>	
Gravel	0 to 3
Sand	22 to 27
Silt	64 to 65
Clay	8 to 11

A 0.6 m thick layer of gravelly sand was encountered underlying the sandy silt layer in Borehole KR13-06. The base elevation of this layer is at Elevation 289.4 m. The measured water content of a sample was 16%. Results of grain size analyses conducted on a sample of this soil are presented in Figure B10 of Appendix B. These results are summarized in the following table.

Soil Particles	%
<u>Gravelly Sand</u>	
Gravel	25
Sand	62
Silt and Clay	13

5.7 Sand and Silt, Sandy Silt to Clayey Silt Till

Grey sand and silt to sandy silt glacial till deposits were encountered in all but Boreholes KR13-01, KR13-02 and KR13-07. Borehole KR13-06 was advanced through the till into bedrock. The till layer was found to be 9.5 m thick with its base elevation at 279.9 m. Boreholes KR13-03, 13-04 and 13-08 were all terminated within the till. A 1.5 m thick layer of clayey silt till was encountered in Borehole KR13-05 at 10.1 m depth.

SPT N-values measured within the till deposits ranged from 40 blows per 0.3 m penetration to greater than 100 blows for less than 0.3 m penetration, indicating dense to very dense conditions. Some of the higher 'N'-values may be attributed to the presence of cobbles or boulders. Measured water contents of the till samples were typically in the order of 6% to 20%.

Grain size analyses conducted on samples of the tills are presented in Figure B11 of Appendix B. These results are summarized in the following table.

Soil Particles	%
<u>Sand and Silt Till</u>	
Gravel	3 to 4
Sand	33 to 50
Silt	36 to 53
Clay	10 to 15
<u>Clayey Silt Till</u>	
Gravel	0
Sand	0 to 2
Silt	85 to 87
Clay	12 to 13

5.8 Bedrock

Bedrock was encountered and proven by coring in Borehole KR13-06 at a depth of 18.8m, or Elevation 279.9 m. The soils in Borehole KR13-06 were found to be underlain by granite, an Archean rock formation occurring as a felsic intrusive contact as part of the Pre-Cambrian

Canadian Shield. The rock cores are generally in a fresh state with slight weathering at the joints. No exposed bedrock was observed in the general vicinity of the site.

The measured Total Core Recovery (TCR) was 100% in all three runs of the granite. The Rock Quality Designation (RQD) values ranged from 92 to 100% indicating excellent rock quality. The Fracture Indices (FI) were typically between 0 and 2 fractures per 0.3 m core run.

The estimated Unconfined Compressive Strength (UCS) for the cores ranged from 123 to 197 MPa indicating a very strong rock. These estimated rock strength values are based on point load tests that were conducted on selected rock cores recovered from Borehole KR13-06.

5.9 Groundwater Conditions

Free water was not observed in most of the boreholes upon completion of drilling. Standpipe piezometers were installed in Boreholes KR13-02 and 13-07. Water levels observed in the open boreholes and those measured in the two installed standpipe piezometers are presented below.

Borehole (screen location)	Date of Reading	Water Level Depth (m)	Water Level Elevation (m)
KR13-01	-	-	-
KR13-02 (sand)	October 2, 2013	1.4	293.8
	November 1, 2013	1.2	294.0
	November 7, 2013	1.1	294.1
KR13-03	October 8, 2013	4.2	295.0
KR13-04	October 7, 2013	5.4	293.5
KR13-05	-	-	-
KR13-06	-	-	-
KR13-07 (sand/clayey silt)	October 3, 2013	1.3	294.4
	November 1, 2013	1.0	294.7
	November 7, 2013	1.0	294.7
KR13-08	-	-	-

It is noted that all groundwater observations at this site are short term and the levels are expected to fluctuate seasonally and after heavy rainfalls. Based on the above readings, the groundwater level at this site ranges between 294 and 295 m. Local high water levels, spring snowmelt and periods of significant and/or prolonged precipitation events will affect the groundwater level.

6 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Callon Dietz obtained and provided the northing and easting coordinates, and ground surface elevations of the borehole locations from the DTM, based on borehole location sketches prepared by Thurber.

Downing Drilling of Hawkesbury, Ontario, supplied and operated a truck-mounted CME 75 rig, and a track-mounted CME 55 drill rig to carry out the drilling, sampling and in-situ testing operations.

The drilling and sampling operations in the field were supervised on a full time basis by Mr. Stephane Loranger and Ms. Katrina Young of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratory.

Overall project management was provided by Mr. Alastair Gorman, P.Eng. Direction of the field program was provided by Dr. Sydney Pang, P.Eng. Interpretation of the field data and preparation of this report was jointly completed by Ms. Katrina Young, E.I.T. and Dr. Sydney Pang, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and provides foundation recommendations for design of the replacement of the existing culvert carrying the Kesagami River tributary under Highway 652, located approximately 144 km north of Highway 579.

Based on the terms of reference, the existing structure is a 4.6 m span by 4.0 m high by 36 m long Steel Plate Pipe Arch (SPPA) culvert. It is understood that the structure is in fair condition with deterioration of the culvert barrel. The embankment along this section of highway is approximately 4.5 m in height.

The discussions and recommendations presented in this report are based on information provided by URS and on the factual data obtained during the course of this investigation.

An archived drawing shows the general topography of the subject area prior to construction of the culvert and the highway. Selected photographs showing the culvert area are included in Appendix F for reference.

8 CULVERT FOUNDATIONS

8.1 General

Preliminary information from URS indicates that current project requirements involve replacement of the existing single culvert with twin concrete box culverts of which one will be along the original culvert alignment. Temporary embankment widening of approximately 2.0 m will be required on the north and south sides during construction. Physical dimensions of the proposed culverts obtained from a preliminary General Arrangement (GA) drawing and other design information provided by URS are presented in Table 8.1. Boreholes drilled at the culvert site are also identified in this table for reference.

Table 8.1 Physical Data of Proposed Replacement Culverts

Culvert #	Borehole Numbers	Approx. Invert Elevations (m)		Length (m)	Width (m)	Height (m)
		Inlet	Outlet			
C01	KR13-01 and 13-02 near outlet	291.909	291.873	36.0	3.0	3.4
	KR13-04 and 13-05 through embankment adjacent to existing culvert					
	KR13-03 and 13-06 through highway for roadway protection					
	KR13-07 and 13-08 near inlet					

Note: All dimensions are preliminary and subject to changes

8.2 Foundation Alternatives

This section presents discussions on alternate types of replacement culverts and foundation alternatives, and provides recommendations on a feasible and/or preferred foundation option.

Several culvert types that may be considered for this site are listed as follows:

- Concrete box (closed) culvert
- Concrete, open footing, culvert
- Circular pipes (concrete, steel, HDPE)

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix D.

The existing culvert is a Steel Plate Pipe Arch (SPPA). Preliminary design information indicates that consideration is being given to using precast twin concrete box culverts as replacements. Given the subsurface conditions and anticipated construction sequencing, we consider the box culvert to be the preferred option from a foundation engineering standpoint. Precast sections can be installed rapidly with less potential for disturbance of the founding soils during installation.

From a foundation engineering standpoint, concrete open footing culverts as well as concrete, steel and HDPE pipes are also technically feasible alternatives, provided that other design issues including flow capacity, hydraulic properties and durability can also be satisfied.

The report herein focuses on providing foundation recommendations on the design and construction of box culverts and the associated wingwalls. Recommendations for other culvert options will be provided upon request.

8.3 Foundation Design

It is understood that the inverts of the replacement culverts are approximately the same as those of the existing culvert. Foundation design aspects for the replacement culverts include

subgrade conditions, geotechnical resistances for the wingwall foundation soils, settlement of founding soils, lateral earth pressures, erosion control, protection system design, groundwater control and staged excavation.

8.3.1 Concrete Box Culverts

Since one of the replacement culverts will be installed along the same alignment as the existing culvert, it is anticipated that the subgrade soils within the existing culvert footprint will not be subjected to significant additional loading.

In order to provide a more uniform foundation subgrade condition, a minimum 300 mm thick layer of bedding material conforming to OPSS 1010 Granular A requirements should be provided under the base of the box culverts as per OPSD 803.010. The bedding material should be placed as soon as practical for protecting the subgrade from disturbance during construction following its inspection and approval. Construction equipment must not be allowed to travel on the bedding or the prepared subgrade.

Based on the borehole information, the underside of the Granular A pad may be founded on the undisturbed, typically compact sand at or below Elevation 292 m. The recommended geotechnical resistances for this founding elevation, under the existing culvert footprints, are as follows:

- Factored Geotechnical Resistance at ULS of 225 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 150 kPa

Resistance to lateral forces / sliding resistance between the concrete slab and the underlying Granular A should be calculated assuming an ultimate coefficient of friction of 0.4.

It is recommended that the culverts be designed to resist external loadings including frost forces, lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

8.3.2 Retaining Walls

Preliminary design information provided by URS indicates that there will be no requirement for any retaining wall as part of this culvert replacement project.

8.3.3 Settlements

It is understood that there is no grade raise at this site. The existing SPPA culvert is to be replaced with twin concrete box culvert of which one box will be installed along the original culvert alignment. The opening sizes of the new and existing culverts are approximately similar. Taking into consideration the proposed construction sequencing for this site, it is anticipated that rebound of the subgrade after removal of the existing culvert and the surrounding fill will be negligible. Given the compact sand subgrade, any settlement that might occur would be completed by the end of construction.

8.3.4 Subgrade Preparation

After the excavation and removal of the existing SPPA and surrounding soils are completed to the design founding elevation, any remaining fill, topsoil, loose riverbed deposits, disturbed soils, and any deleterious materials within the culvert replacement footprint must be sub-excavated to the undisturbed native compact sand. The exposed surface must be inspected to confirm that the subgrade is suitable and uniformly competent. The sub-excavated area should be backfilled with well compacted Granular A or Granular B Type II material.

Construction of the culvert replacement must be carried out in the dry. This work should be carried out in accordance with OPSS 902.

8.3.5 Frost Depth

The frost penetration depth for this site is 2.6 m.

8.4 Construction Considerations

Staged open cutting will be employed to construct the replacement culverts at the Kesagami River tributary. It is understood that all works are to be carried out within the existing highway platform.

URS has developed a set of construction staging plans. The main features outlined in these plans are as follows:

- One lane of traffic will be maintained at all times during construction
- Temporary widening of the highway platform will be carried out on both sides
- Cofferdams are required to be installed at the inlet and outlet areas to facilitate diversion of creek flow and surface water
- Sump pumping may be required within the cofferdams
- Creek flow will be maintained in one culvert at all times
- Roadway protection will be required during various stages of construction
- Excavation and removal of the existing culvert, installation of the new twin culverts and backfilling will be carried out within the protection systems

Protection systems (temporary shoring) such as the use of interlocking steel sheetpiles will be required. Foundation recommendations for design of such a system are provided in a subsequent section of this report. Sump pumping will be required at all locations to permit construction in the dry. Positive dewatering such as the use of vacuum well points may be required. Diversion of river and surface water using sandbag and/or sheetpile cofferdam will also be required.

A Permit To Take Water (PTTW) should be obtained for this project.

9 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

It is recommended that backfill to the culvert and wingwalls consists of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS 1010. Reference should be made to the backfill arrangements stipulated in OPSD 803.01 as appropriate.

All fills must be placed in regular lifts and be compacted in accordance with OPSS 501. The backfill must be placed and compacted in simultaneous lifts on both sides of a culvert, and the top of backfill elevation should be the same on both sides of the culvert at all times. Heavy compaction equipment must not be used adjacent to the walls and roofs of the culverts.

Earth pressures acting on the culvert walls may be assumed to impose a triangular distribution. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2010 but are generally given by the expression:

$$p_h = K (\gamma h + q)$$

where

- p_h = horizontal pressure on the culvert wall at depth h (kPa)
- K = earth pressure coefficient (see table below)
- γ = bulk unit weight of retained soil (see table below)
- h = depth below top of fill where pressure is computed (m)
- q = value of any surcharge (kPa)

If full drainage is not achievable, the culvert walls must be designed to withstand full hydrostatic pressure assuming a water level at least equal to the design river water level.

Earth pressure coefficients for backfill to the retaining walls are dependent on the material used as backfill. Recommended unfactored values are shown in the following Table 9.1. Active pressures should be used for any wingwall or unrestrained wall.

Table 9.1
Earth Pressure Coefficients (K)

Wall Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ$; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (modified) $\phi = 32^\circ$; $\gamma = 21.2 \text{ kN/m}^3$		Embankment Fill $\phi = 30^\circ$; $\gamma = 20.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54

At rest (Restrained Wall)	0.43	0.62	0.47	0.70	0.50	0.76
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	3.0	-

For rigid structures such as concrete box culverts, it is recommended that at-rest horizontal earth pressures be used for design.

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I, or at a depth of 1.7 m for Granular A or Granular B Type II.

10 EMBANKMENT DESIGN AND RECONSTRUCTION

The existing embankment along this section of the highway is approximately 4.5 m in height. The fill cover above the crown of the culvert is in the order of 2.0 m. It is understood that there is no planned grade raise at this site.

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS 206. The embankment material should consist of either the excavated granular fill if they meet the moisture and gradation requirements, or imported Granular A or B Type II material meeting OPSS 1010 requirements.

Provided that the granular material is placed and compacted as recommended, it is anticipated that the existing slope inclination of 2H : 1V or flatter should remain stable. Where applicable, benching of the existing earth slope surface should be carried out as per OPSD 208.010 in order to enhance the keying in of the new fill.

In general, surface vegetation, peat, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlet and outlet, and within the embankment footprints. Inspection and approval of the foundation surfaces by qualified geotechnical personnel is recommended.

11 EROSION CONTROL

Erosion protection should be provided at the culvert inlet and/or outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field.

Typically, rock protection should be provided over all surfaces with which river water is likely to be in contact. Treatment at the outlets should be in accordance with OPSD 810.010. A vegetation cover

should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS 804.

A clay seal or a concrete cut-off wall may be used to minimize the potential for piping through the backfill. The clay seal must extend to the order of 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS 1205. A geosynthetic clay liner may be used as a clay seal.

12 EXCAVATION AND GROUNDWATER CONTROL

12.1 General

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native sand at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Surficial alluvial deposits that are anticipated in the inlet and outlet areas are classified as Type 4 soils.

12.2 Foundations

Excavation and backfilling for culvert construction must be carried out in accordance with OPSS 902.

Excavated sand to gravelly sand fill may be reused as backfill provided the following conditions are satisfied.

- There is sufficient space to stockpile on site and control the moisture content within acceptable limits for compaction
- Gradation (OPSS Granular A or B requirements) and compaction characteristics are confirmed prior to reuse as backfill

Excavated silty clay, organics and debris such as wood fibres should not be reused and should be segregated and removed from site.

12.3 Excavations

Excavations for culvert replacement will typically be carried out through the existing embankment fill and extended into the native sand. The work will be carried out within a protection system.

Any protection system should be designed by licensed Professional Engineers experienced in such designs. OPSS 539 “Construction Specification for Protection Systems” will have to be included in the contract documents. It is recommended that Performance Level 2 as per

Clause 539.04.02.01 (maximum horizontal displacement of 25 mm) be specified for this culvert replacement site.

12.4 Groundwater Control

The subgrade of the new culvert will be below the groundwater level. The groundwater level is expected to be largely governed by the water level in the river. Given the presence of predominantly cohesionless soils at this site, positive dewatering measures such as vacuum well points for localized groundwater lowering may be required in conjunction with cofferdams (sheetpiles) in order to maintain reasonably dry excavations during the course of staged construction. Suggested wordings of an NSSP alerting the Contractor of potential obstructions such as cobbles and boulders in the fill and native glacial tills are included in Appendix E.

In addition, groundwater perched within the embankment fill will seep into the excavations during culvert replacement. Surface runoff will also tend to accumulate in these excavations. In addition to positive dewatering, creek water diversion, protection systems such as sheetpiled enclosures and pumping from filtered sumps will be required.

13 ROADWAY PROTECTION SYSTEMS

Roadway protection will be required during various stages of construction. The design of roadway protection should be the responsibility of the Contractor. However, an option that may be considered for use at this site is steel interlocking sheetpile walls which are also anticipated to provide a partial groundwater cutoff. It is anticipated that the sheetpiles will need to be extended into the very dense sandy silt till to develop the required toe resistance.

An interlocking sheetpiled wall may be designed using the parameters given below:

$$\begin{aligned}\gamma &= 20 \text{ kN/m}^3 \\ \gamma_w &= 10 \text{ kN/m}^3 \\ K_a &= 0.33 \text{ (road embankment fill)} \\ K_p &= 3.0 \text{ (road embankment fill/native sand)}\end{aligned}$$

Full hydrostatic pressure should be considered assuming a water level at least equal to the design creek water level.

The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors must be considered when designing the shoring system. Typically, a triangular earth pressure distribution similar to the one used for culvert lateral pressure design should be used for a cantilevered sheetpiled wall.

The designer of the roadway protection system should check whether the penetration depth is sufficiently deep to provide base fixity. Suggested wordings of an NSSP alerting the Contractor of

potential obstructions such as cobbles and boulders in the fill and native glacial tills are included in Appendix E.

All shoring systems should be designed by a Professional Engineer experienced in such designs.

14 CONSTRUCTION CONCERNS

During construction, the Contract Administrator should employ experienced geotechnical staff to observe construction activities related to foundation construction, and to inspect and approve the culvert subgrade.

Potential construction concerns include, but are not necessarily limited to, the following:

- Impact of excavation on the existing pavement surface

Daily visual inspection of the pavement surface must be carried out in the vicinity of the culvert replacement. If cracks form in the pavement or settlement is observed to occur, these matters must immediately be brought to the attention of the C.A. for determining as to whether remedial action is required.

- Adequate dewatering of the temporary excavations to install the new culvert,
- removal of peat, organics, soft soils and alluvial deposits near river channels,
- disturbance of the soil subgrade within the culvert foundation footprints,
- confirmation that the culvert backfills and approach fills are adequately placed and compacted to specifications.

It is recommended that provision(s) be included in the contract requiring the QVE to confirm that the above issues are adequately addressed. Should there be any doubts about issues such as depth of sub-excavation, these provisions should require the QVE to alert the CA.

15 CLOSURE

Preparation of this foundation design report was carried out by Dr. Sydney Pang, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng.

THURBER ENGINEERING LTD.

Sydney Pang, P.Eng.
Senior Foundations Engineer



Alastair Gorman, P.Eng.
Project Manager, Senior Foundations Engineer



P.K. Chatterji, P.Eng.
Principal, Designated MTO Contact



Appendix A

Record of Borehole Sheets

19-4406-9

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$



Water Level

C_{pen}

Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

EXPLANATION OF ROCK LOGGING TERMS






ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
	(MPa)	(psi)	
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

RECORD OF BOREHOLE No KR13-01

1 OF 1

METRIC

GWP# 5193-13-00 LOCATION Kesagami River N 5 524 175.7 E 363 264.2 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.02 - 2013.10.02 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								<div><div>20406080100</div><div>○ UNCONFINED + FIELD VANE</div><div>● QUICK TRIAXIAL × LAB VANE</div></div>			<div><div>PLASTIC LIMIT</div><div>NATURAL MOISTURE CONTENT</div><div>LIQUID LIMIT</div><div>W_P W W_L</div><div>WATER CONTENT (%)</div><div>204060</div></div>					
297.2	GROUND SURFACE															
0.0	TOPSOIL: (50 mm)		1	SS	8		297									
	SAND, trace rootlets Loose Dark Brown Moist															
296.4	(FILL)		2	SS	10											
0.8	SILT, some sand and clay, trace gravel Compact Brown Moist															
			3	SS	8											
295.3																
1.9	SAND, some gravel, trace silt Loose to Very Loose Light Brown Saturated		4	SS	3											
			5	SS	9											
			6	SS	6											
292.7	Compact		7	SS	14											
4.5																
	Trace gravel, trace cobbles		8	SS	14											
290.5	END OF SAMPLING AND START OF DCPT AT 6.7 m.															
6.7																
289.0	END OF DCPT AND BOREHOLE AT 8.2 m. BOREHOLE BACKFILLED WITH AUGER CUTTINGS UPON COMPLETION.															
8.2																

+³, ×³: Numbers refer to Sensitivity
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 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KR13-02

1 OF 1

METRIC

GWP# 5193-13-00 LOCATION Kesagami River N 5 524 190.6 E 363 278.7 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.01 - 2013.10.01 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
295.2	GROUND SURFACE											
0.0	TOPSOIL: (50 mm)											
	SAND Loose Light Brown Moist		1	SS	9		295					
294.4												
0.8	Sandy SILT, trace clay											
294.1	Loose Light Brown Moist		2	SS	5		294					0 27 65 8
1.1												
	Silty SAND, trace clay Very Loose Grey/Brown Wet											
	With organics		3	SS	2		293					
			4	SS	5		292					0 71 24 5
			5	SS	4		291					
291.3												
	Clayey SILT, trace sand Soft Light Brown		6	SS	4		290					0 4 73 23
290.6												
4.6	SAND, trace silt, trace gravel Loose Brown to Grey Saturated		7	SS	7		289					
			8	SS	5		288					3 92 5 (SI+CL)
288.5												
6.7	END OF SAMPLING AND START OF DCPT AT 6.0 m.											
287.6												
7.6	END OF DCPT AND BOREHOLE AT 7.6 m. Piezometer installation consists of 19 mm diameter Schedule 40 PVC pipe with a 1.52 m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Oct. 2/13 1.4 293.8 Nov. 1/13 1.2 294.0 Nov. 7/13 1.1 294.1											

+³, ×³: Numbers refer to
Sensitivity

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(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KR13-03

1 OF 3

METRIC

GWP# 5193-13-00 LOCATION Kesagami River N 5 524 164.8 E 363 251.5 ORIGINATED BY SLL
 HWY 652 BOREHOLE TYPE NW Casing/NQ Core Barrel COMPILED BY AN
 DATUM Geodetic DATE 2013.10.07 - 2013.10.08 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
299.2	GROUND SURFACE												
0.0	ASPHALT: (40 mm)		1	SS	50/ 0.150		299						25 55 20 (SI+CL)
298.6	Gravelly SAND Very Dense Brown Moist (FILL)		2	SS	84		298						
0.6	SAND, some silt Very Dense to Compact Brown Moist (FILL)		3	SS	25		297						
297.0	SILT, trace sand and clay Loose Brown Moist (FILL)		4	SS	8		296						0 9 82 9
295.7	PEAT, black (50 mm)		5	SS	10		295						
295.8	SILT, some clay, trace sand and gravel Compact Brown Wet		6	SS	14		294						1 8 73 18
3.6			7	SS	14		293						
293.6	SAND, trace silt and gravel Compact Brown Wet		8	SS	27		292						
5.6			9	SS	25		291						
290.2	Gravelly SAND, trace silt		10	SS	28		290						35 61 4 (SI+CL)
9.0													

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

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(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KR13-03

2 OF 3

METRIC

GWP# 5193-13-00 LOCATION Kesagami River N 5 524 164.8 E 363 251.5 ORIGINATED BY SLL
 HWY 652 BOREHOLE TYPE NW Casing/NQ Core Barrel COMPILED BY AN
 DATUM Geodetic DATE 2013.10.07 - 2013.10.08 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				W _p W W _L				
								20 40 60 80 100 20 40 60 80 100				20 40 60				
	Continued From Previous Page															
287.0	SAND , trace silt and gravel, occasional cobbles Very Dense Grey Wet		11	SS	52		289									
							288									
12.2	SILT and SAND , some clay, trace gravel, inferred cobbles and boulders Very Dense Grey Moist (TILL)		12	SS	100/ 0.275		287								3 38 45 14	
							286								Used NQ Core Barrel for retrieving cobble/boulder fragments out of casing	
			13	SS	100/ 0.175		285									
							284								4 33 53 10	
			14	SS	82		283									
							282									
			15	SS	100/ 0.125		281									
	Occasional cobbles						280									
			16	SS	100/ 0.150											
			17	SS	100/ 0.125											

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KR13-03

3 OF 3

METRIC

GWP# 5193-13-00 LOCATION Kesagami River N 5 524 164.8 E 363 251.5 ORIGINATED BY SLL
 HWY 652 BOREHOLE TYPE NW Casing/NQ Core Barrel COMPILED BY AN
 DATUM Geodetic DATE 2013.10.07 - 2013.10.08 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								20 40 60 80 100							
								<div><div><div></div><div></div><div></div><div></div><div></div></div><div>20406080100</div></div> <div>○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE</div>					<div><div>PLASTIC LIMIT</div><div>NATURAL MOISTURE CONTENT</div><div>LIQUID LIMIT</div></div> <div><div>W_P</div><div>W</div><div>W_L</div></div> <div>WATER CONTENT (%)</div>		
279.1	Continued From Previous Page				0.125										
20.1	END OF BOREHOLE AT 20.1 m. BOREHOLE OPEN TO 4.4 m AND WATER LEVEL AT 4.2 m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.9 m, THEN SAND AND ASPHALT TO SURFACE.														

RECORD OF BOREHOLE No KR13-04

1 OF 2

METRIC

GWP# 5193-13-00 LOCATION Kesagami River N 5 524 174.7 E 363 278.1 ORIGINATED BY SLL
 HWY 652 BOREHOLE TYPE NW Casing/NQ Core Barrel COMPILED BY AN
 DATUM Geodetic DATE 2013.10.03 - 2013.10.07 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
								20 40 60 80 100				W _P W W _L					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
298.9	GROUND SURFACE					▽	298								GR SA SI CL		
0.0	ASPHALT: (25 mm)		1	SS	50/ 0.125												30 57 13 (SI+CL)
	Gravelly SAND, some silt Very Dense to Dense Brown Moist (FILL)		2	SS	45												
297.5																	
1.4	Sandy SILT, trace clay and gravel Compact Brown Moist to Wet (FILL)		3	SS	20				297								6 21 65 8
296.7																	
2.2	SAND, trace to some silt Compact Brown Moist (FILL)		4	SS	18				296								
			5	SS	23												Split spoon wet
295.2																	
3.7	SAND, trace to some silt Loose Brown to Grey Wet		6	SS	9				295								
			7	SS	4		294										
							293										
			8	SS	7									0 92 8 (SI+CL)			
							292										
291.7	Compact		9	SS	13		291										
7.2							290										
	Trace gravel		10	SS	30												
288.9							289										

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
 20
 15 10 5 0
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KR13-04

2 OF 2

METRIC

GWP# 5193-13-00 LOCATION Kesagami River N 5 524 174.7 E 363 278.1 ORIGINATED BY SLL
 HWY 652 BOREHOLE TYPE NW Casing/NQ Core Barrel COMPILED BY AN
 DATUM Geodetic DATE 2013.10.03 - 2013.10.07 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)					
								○ UNCONFINED + FIELD VANE							● QUICK TRIAXIAL × LAB VANE					
								20	40	60	80	100			20	40	60	80	100	
Continued From Previous Page																				
10.0	SILT , some clay Very Dense Grey Moist (TILL)		11	SS	93		288								0	0	87	13		
287.3																				
11.6			SAND and SILT , some clay, trace gravel, inferred cobbles and boulders Very Dense Grey Moist (TILL)		12	SS	81		287											
								286												
					13	SS	100		285								3	50	36	11
					14	SS	100/ 0.250		284											Used NQ Core Barrel for retrieving cobble/boulder fragments out of casing
							283													
			15	SS	51		282													
							281													
280.5			16	SS	100/															
18.4	END OF BOREHOLE AT 18.4 m. BOREHOLE OPEN TO 5.6 m AND WATER LEVEL AT 5.4 m UPON COMPLETION. BORHEOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.9 m, SAND TO 0.1 m, THEN ASPHALT TO SURFACE.				0.100															

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KR13-05

1 OF 2

METRIC

GWP# 5193-13-00 LOCATION Kesagami River N 5 524 163.9 E 363 271.6 ORIGINATED BY SLL
 HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.01 - 2013.10.01 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)							
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE										
298.8	GROUND SURFACE							20	40	60	80	100	20	40	60	GR	SA	SI	CL
0.0	ASPHALT: (35 mm)																		
	Gravelly SAND, some silt Dense Brown Moist (FILL)		1	SS	47								○			29	59	12 (SI+CL)	
			2	SS	30								○						
297.4																			
1.4	Sandy SILT, some clay Compact Brown Moist (FILL)		3	SS	17								○			0	15	71	14
296.2			4	SS	13								○						
2.6	SAND, trace to some silt Compact Brown Moist																		
			5	SS	18								○			0	95	5 (SI+CL)	
			6	SS	20								○						
			7	SS	10								○						
			8	SS	16								○			0	94	6 (SI+CL)	
			9	SS	10								○						
290.0																			
8.8	Some gravel, occasional cobbles Very Dense Grey Wet		10	SS	100/ 0.175								○						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity 20
15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KR13-05

2 OF 2

METRIC

GWP# 5193-13-00 LOCATION Kesagami River N 5 524 163.9 E 363 271.6 ORIGINATED BY SLL
 HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.01 - 2013.10.01 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE										
								● QUICK TRIAXIAL × LAB VANE										
288.7	Continued From Previous Page						20	40	60	80	100	20	40	60				
10.1	Clayey SILT , trace sand, occasional cobbles Hard Grey Moist (TILL)		11	SS	100/ 0.275	288							○		0 2 85 13			
287.2																		
11.6	SAND , some silt, occasional cobbles and gravel Compact Grey Wet (TILL)					287												
286.3			12	SS	39								○					
12.5	SAND and SILT , trace gravel, inferred cobbles and boulders Very Dense Grey Moist (TILL)					286							○					
						285							○					
			13	SS	68													
						284												
			14	SS	100/ 0.150								○					
						283												
						282							○					
			15	SS	100/ 0.075													
						281												
280.3			16	SS	100/ 0.075								○					
18.5	END OF BOREHOLE AT 18.5 m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.2 m, THEN SAND TO 0.1 m, THEN ASPHALT TO SURFACE.				0.075													

ONTMT4S 4069.GPJ 2012TEMPLATE(MTO).GDT 1/7/15

RECORD OF BOREHOLE No KR13-06

1 OF 3

METRIC

GWP# 5193-13-00 LOCATION Kesagami River N 5 524 169.0 E 363 286.4 ORIGINATED BY SLL
 HWY 652 BOREHOLE TYPE NW Casing/NQ Core Barrel COMPILED BY AN
 DATUM Geodetic DATE 2013.10.02 - 2013.10.03 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P W W L									
								20 40 60 80 100				20 40 60									
298.7	GROUND SURFACE							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%)									
0.0 0.1	ASPHALT: (30 mm)							20	40	60	80	100		20	40	60		GR	SA	SI	CL
	Gravelly SAND, some silt Very Dense to Dense Brown Moist (FILL)		1	SS	100		298							○				20	62	18 (SI+CL)	
			2	SS	33									○							
			3	SS	37		297														
296.0							296														
2.7	SILT, some sand, trace clay Compact to Loose Grey Wet (FILL)		4	SS	19		295							○							
			5	SS	7									○				0	15	76	9
294.3							294							○							
4.4	Clayey SILT, some sand Firm Grey Moist to Wet		6	SS	6									○							
293.1							293														
5.6	Stiff		7	SS	16		292							○							
291.4							291														
7.3	Sandy SILT, trace gravel Very Dense Grey Moist		8	SS	67		290							○							
290.0																					
8.7	Gravelly SAND, trace silt Dense Grey Wet																				
289.4														○							
9.3	SAND and SILT, some clay, trace gravel Hard Grey		9	SS	100/ 0.275		289							○				25	62	13 (SI+CL)	
																		2	41	40	17

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KR13-06

2 OF 3

METRIC

GWP# 5193-13-00 LOCATION Kesagami River N 5 524 169.0 E 363 286.4 ORIGINATED BY SLL
 HWY 652 BOREHOLE TYPE NW Casing/NQ Core Barrel COMPILED BY AN
 DATUM Geodetic DATE 2013.10.02 - 2013.10.03 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P			NATURAL MOISTURE CONTENT W			LIQUID LIMIT W _L			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)										GR	SA	SI	CL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
								20	40	60	80	100	20	40	60																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
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Used NQ Core
Barrel for
retrieving
cobble/boulder
fragments out of
casing

3 47 39 11

RUN #1
TCR=100%
SCR=100%
RQD=100%
UCS=192MPa

 RUN #2
TCR=100%
SCR=100%
RQD=92%
UCS=152MPa

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity 20
15 5
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KR13-06

3 OF 3

METRIC

GWP# 5193-13-00 LOCATION Kesagami River N 5 524 169.0 E 363 286.4 ORIGINATED BY SLL
 HWY 652 BOREHOLE TYPE NW Casing/NQ Core Barrel COMPILED BY AN
 DATUM Geodetic DATE 2013.10.02 - 2013.10.03 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20	40	60	80					
	Continued From Previous Page															
	Sub-vertical joint (50 mm) at 20.2 m														1	RUN #3 TCR=100% SCR=100% RQD=97% UCS=142MPa
	Horizontal joint at 20.7 m, 21.4 m					278									2	
			3	RUN		277									0	
276.5															0	
22.2	END OF BOREHOLE AT 22.2 m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG MIXED WITH CUTTINGS TO 1.8 m, THEN BENTONITE HOLEPLUG TO 0.6 m, THEN SAND TO 0.1 m, THEN ASPHALT TO SURFACE.															

RECORD OF BOREHOLE No KR13-07

1 OF 1

METRIC

GWP# 5193-13-00 LOCATION Kesagami River N 5 524 156.0 E 363 274.7 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.02 - 2013.10.02 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P W W _L	20 40 60					
295.7	GROUND SURFACE														
0.0	ROCKFILL														
295.4															
0.3	SAND, some silt Very Loose Brown Saturated		1	SS	7		295								
			2	SS	3										
			3	SS	0		294								
			4	SS	0		293								0 86 14 (SI+CL)
			5	SS	0		292								
292.0															
3.7	Trace gravel Loose		6	SS	4		291								
			7	SS	8		290								
289.5															
6.2	Clayey SILT Hard Light Brown Saturated		8	SS	57										0 0 84 16
289.0															
6.7	END OF DCPT AND BOREHOLE AT 6.7 m. Piezometer installation consists of 19 mm diameter Schedule 40 PVC pipe with a 1.52 m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Oct. 3/13 1.3 294.4 Nov. 1/13 1.0 294.7 Nov. 7/13 1.0 294.7														

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KR13-08

1 OF 1

METRIC

GWP# 5193-13-00 LOCATION Kesagami River N 5 524 157.0 E 363 286.5 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.02 - 2013.10.02 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P W W _L	WATER CONTENT (%)				
								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
295.1	GROUND SURFACE													
0.0	TOPSOIL: (50 mm)						295							
	Sandy SILT, some clay, trace gravel		1	SS	5									3 22 64 11
294.4	Very Loose													
	Brown													
0.7	Moist													
	SAND, some silt		2	SS	1		294							
	Very Loose													
	Brown													
	Wet													
			3	SS	1		293							
			4	SS	0									
292.1	Dense to Compact		5	SS	33		292							
3.0														
			6	SS	24		291							0 85 15 (SI+CL)
290.5														
4.6	SAND and SILT, some clay, trace gravel		7	SS	48		290							3 40 42 15
	Dense													
	Grey to Brown													
	Wet (TILL)													
	END OF DCPT AT 6.4 m		8	SS	40		289							
288.4														
6.7	END OF BOREHOLE AT 6.7 m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 2.4 m, THEN BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.													

ONTMT4S 4069.GPJ 2012TEMPLATE(MTO).GDT 1/7/15

Appendix B

Laboratory Test Results

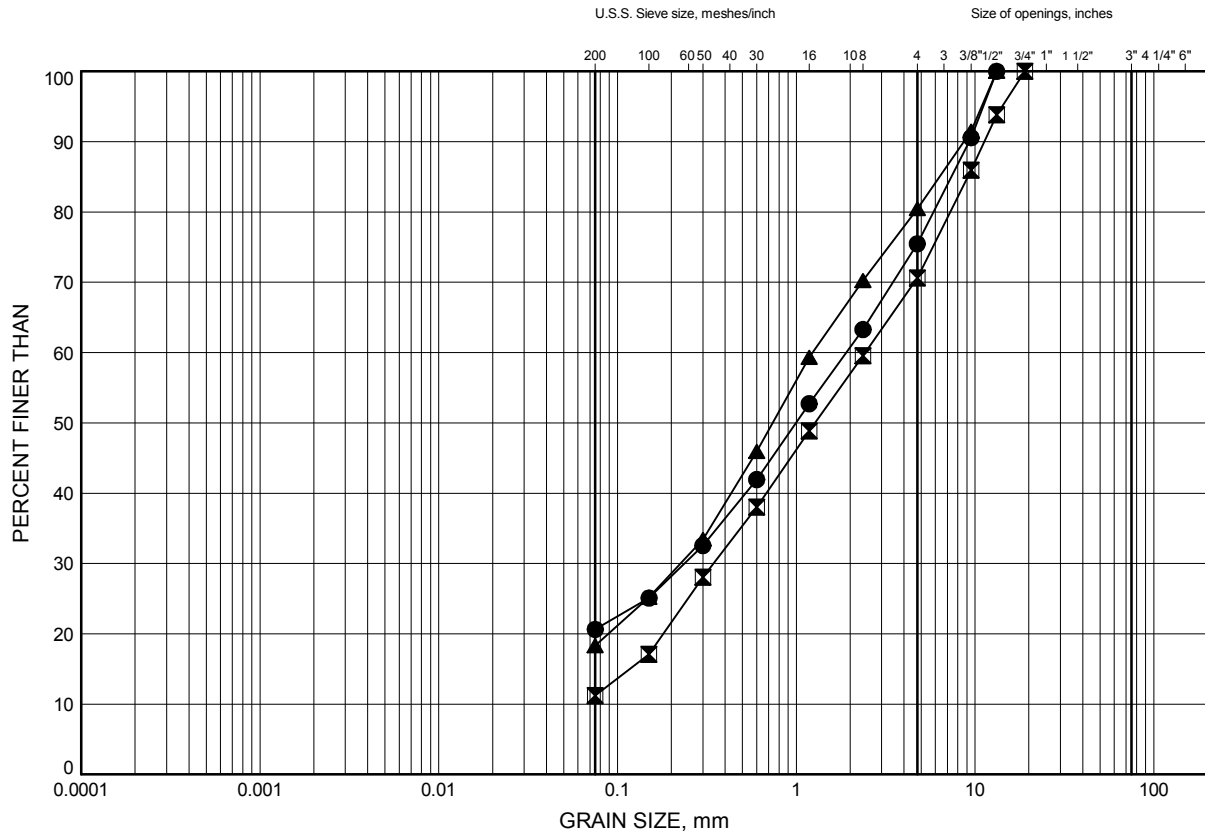
19-4406-9

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B1

GRAVELLY SAND FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KR13-03	0.30	298.90
⊠	KR13-05	0.46	298.34
▲	KR13-06	0.30	298.40

Date December 2013

GWP# 5193-13-00



Prep'd AN

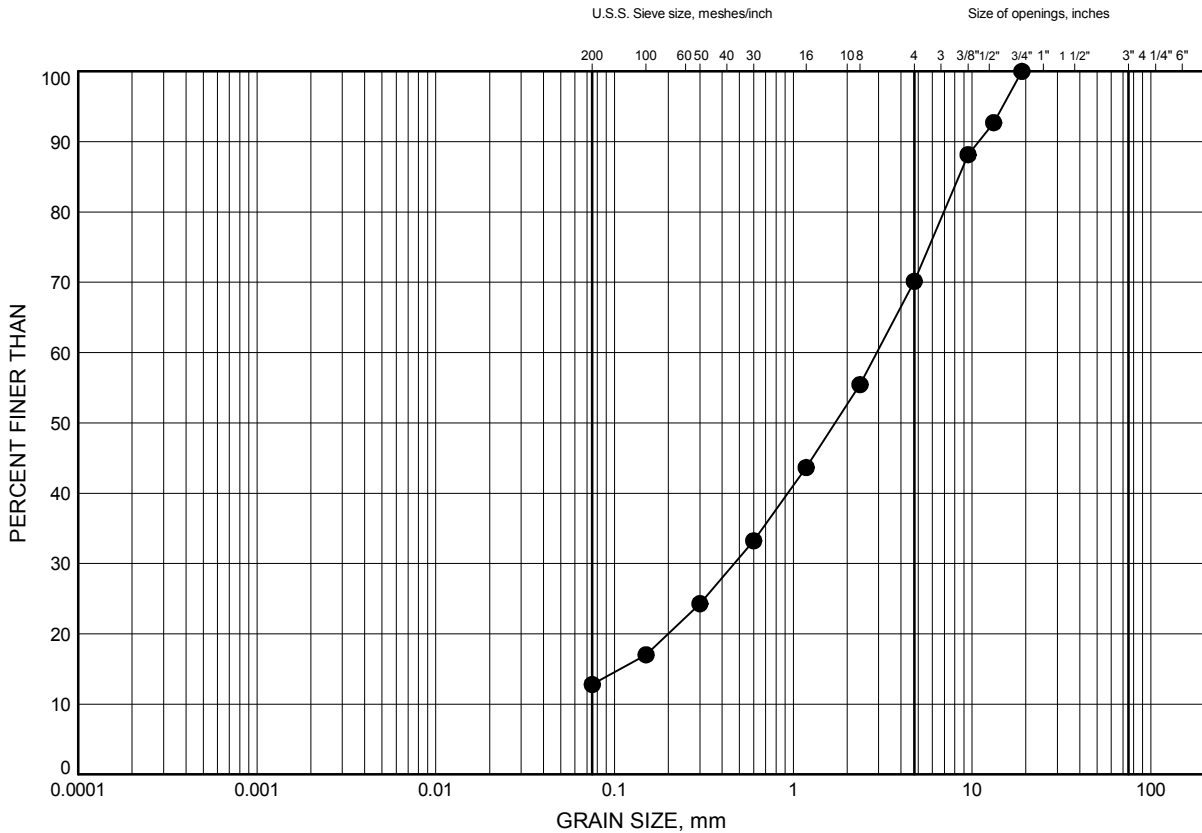
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B2

SAND FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KR13-04	0.30	298.60

Date December 2013
GWP# 5193-13-00



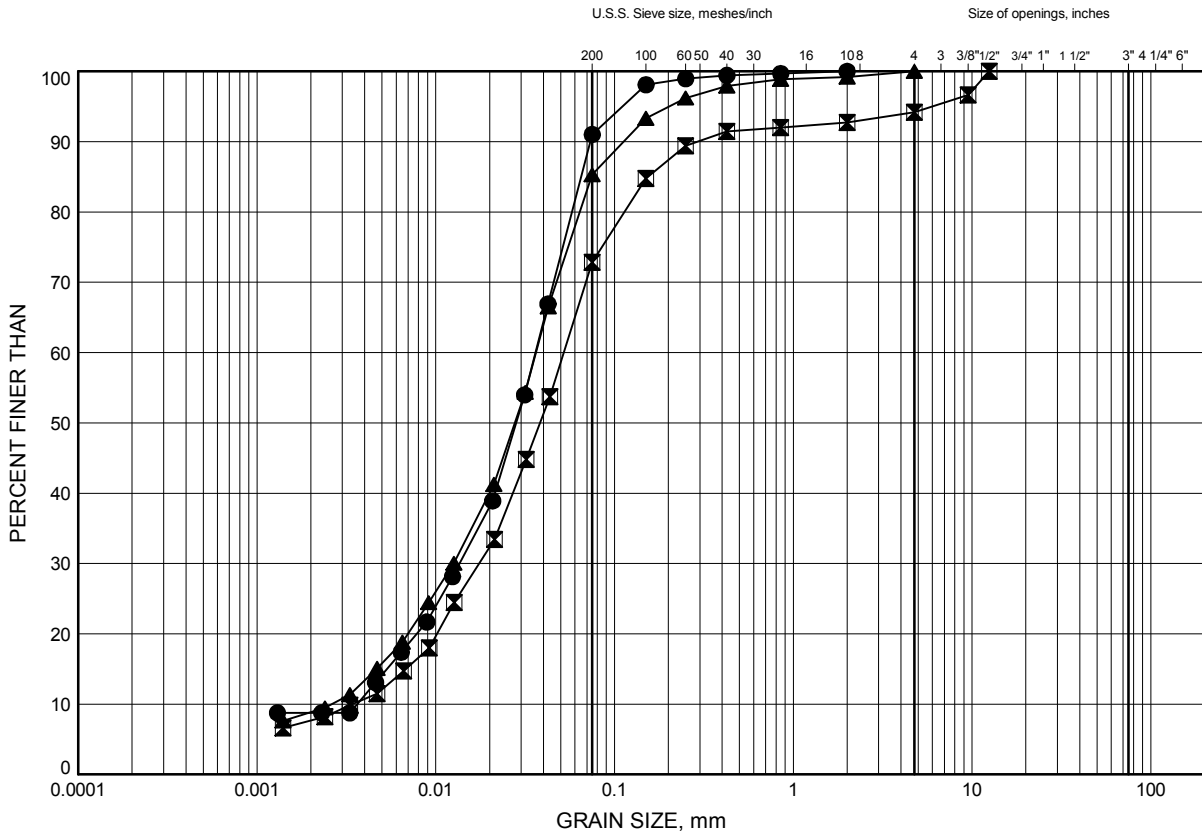
Prep'd AN
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILT TO SANDY SILT FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KR13-03	2.59	296.61
⊠	KR13-04	1.83	297.07
▲	KR13-06	4.11	294.59

Date December 2013

GWP# 5193-13-00



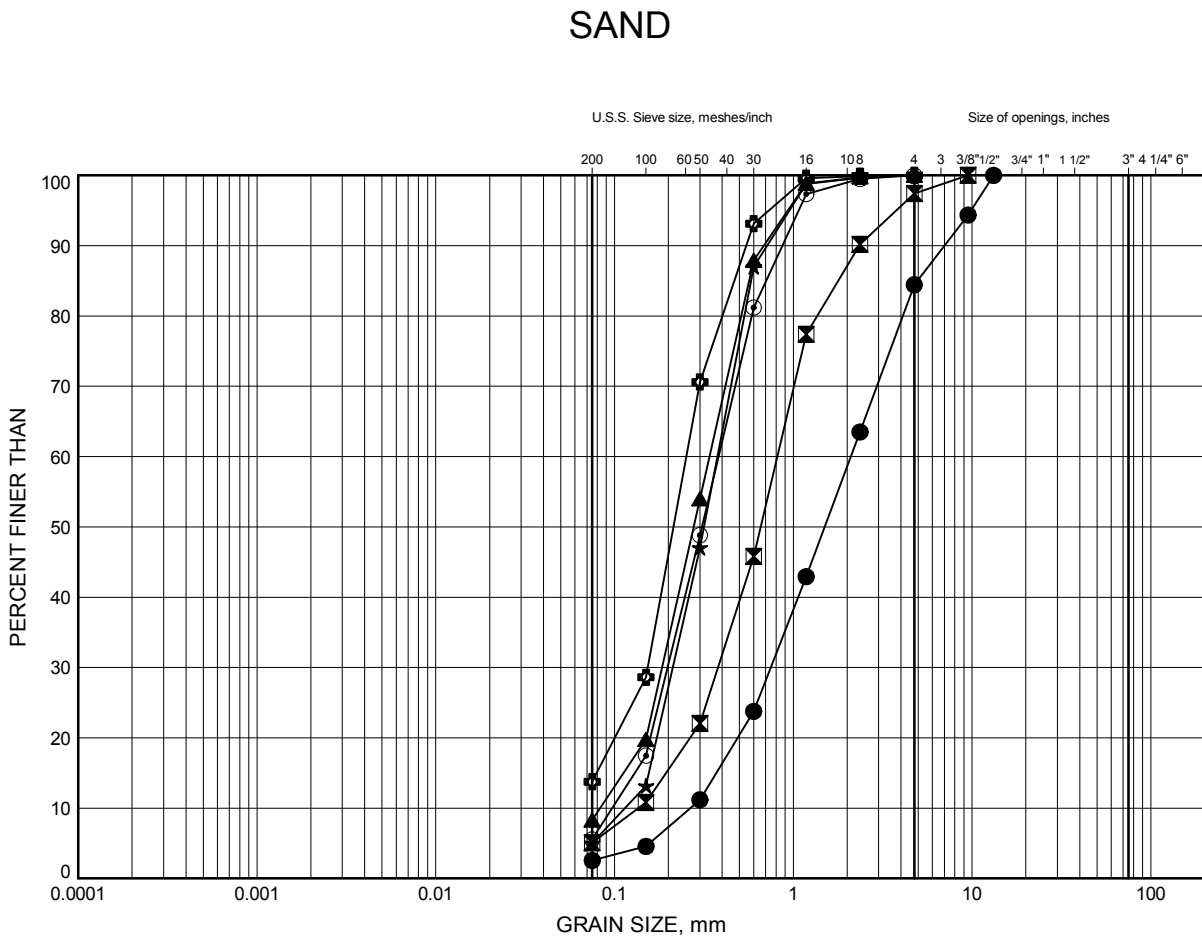
Prep'd AN

Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B4



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KR13-01	4.88	292.32
⊠	KR13-02	6.28	288.92
▲	KR13-04	6.40	292.50
★	KR13-05	3.35	295.45
⊙	KR13-05	6.40	292.40
⊕	KR13-07	2.59	293.11

Date December 2013

GWP# 5193-13-00



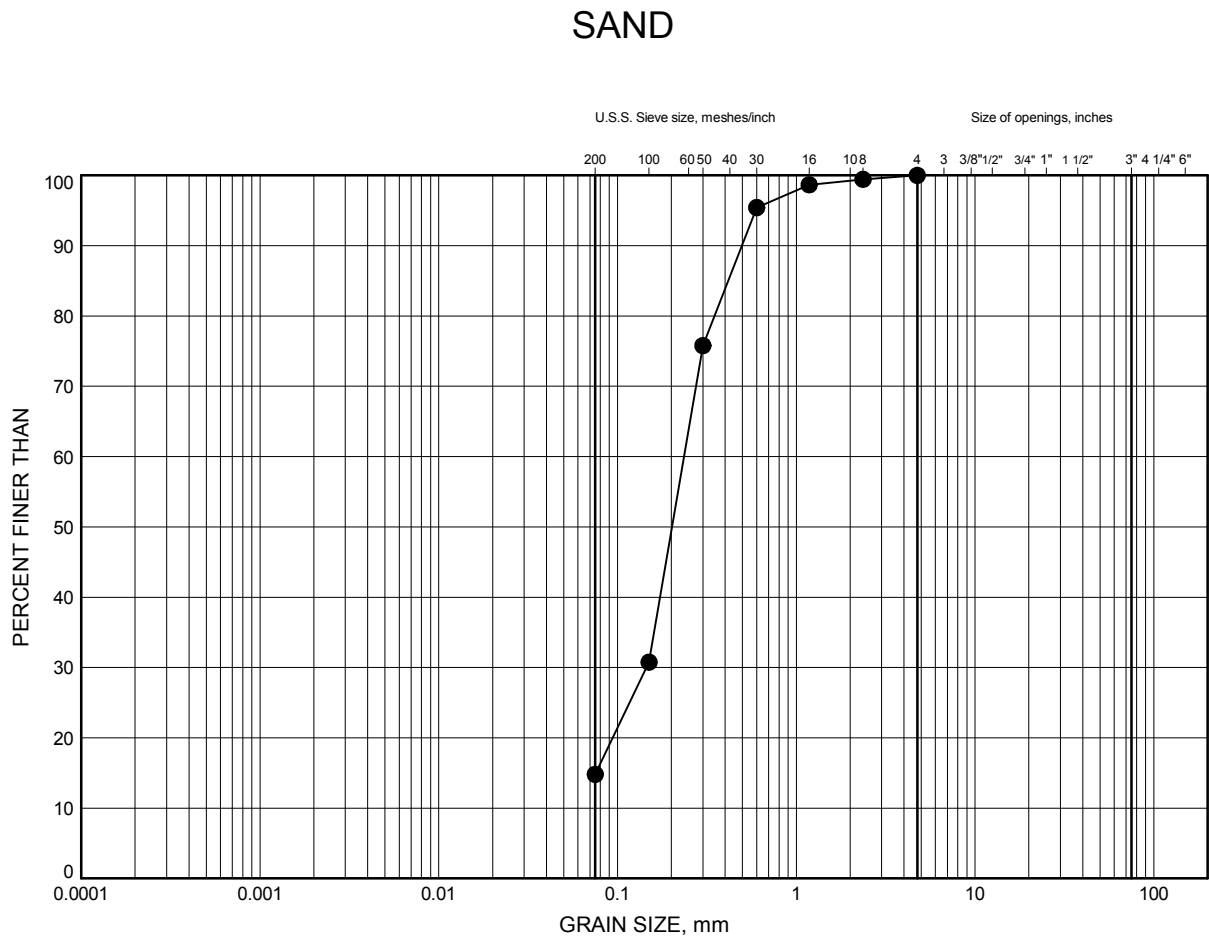
Prep'd AN

Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B5



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KR13-08	4.11	290.99

Date December 2013

GWP# 5193-13-00



Prep'd AN

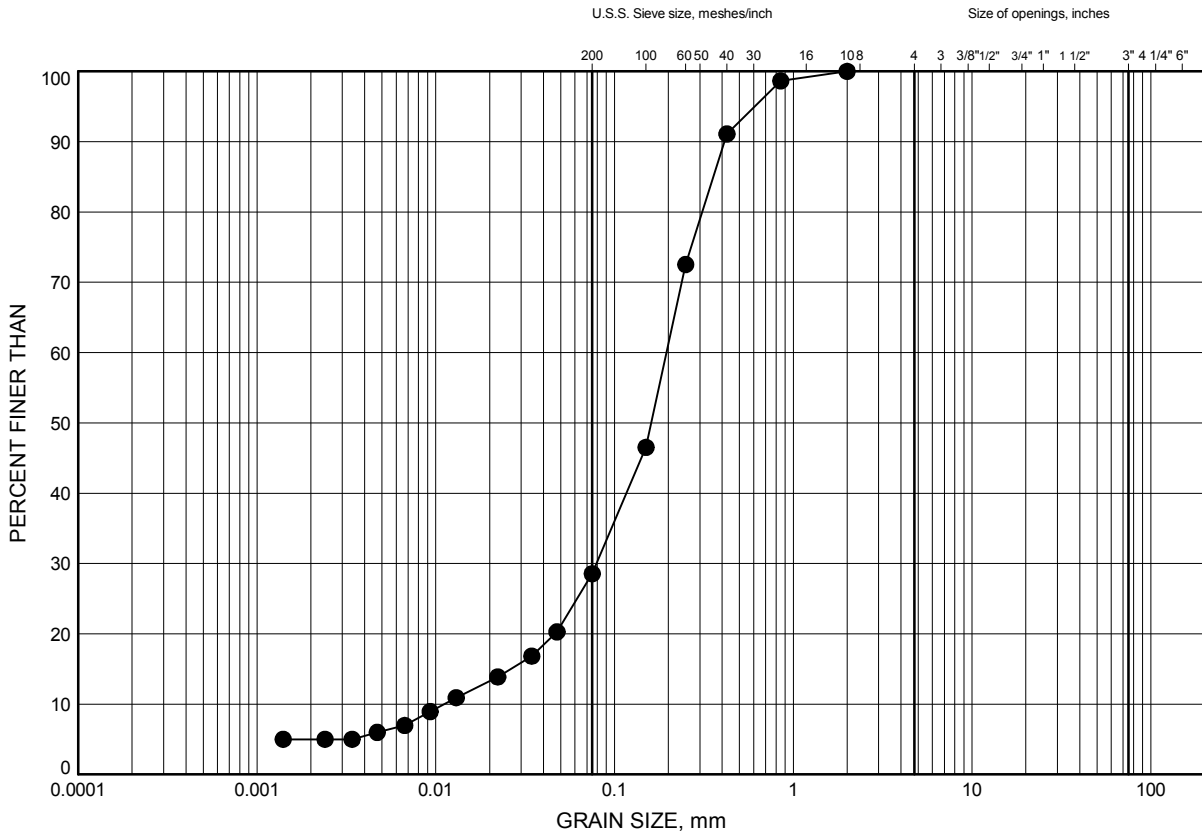
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B6

SILTY SAND



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KR13-02	2.59	292.61

Date December 2013

GWP# 5193-13-00



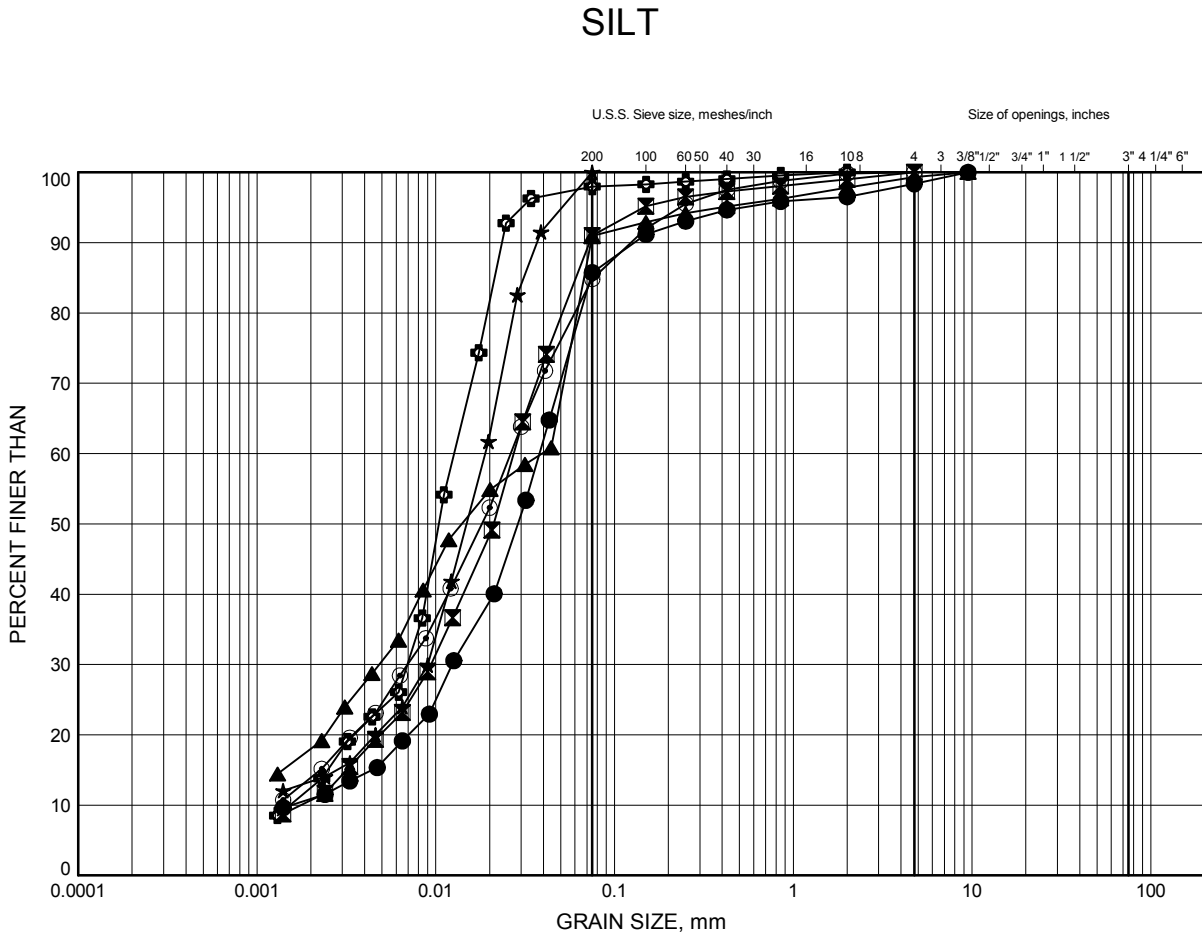
Prep'd AN

Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B7



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KR13-01	0.94	296.26
⊠	KR13-01	1.70	295.50
▲	KR13-03	4.88	294.32
★	KR13-04	10.97	287.93
⊙	KR13-05	1.83	296.97
⊕	KR13-05	10.90	287.90

Date December 2013

GWP# 5193-13-00



Prep'd AN

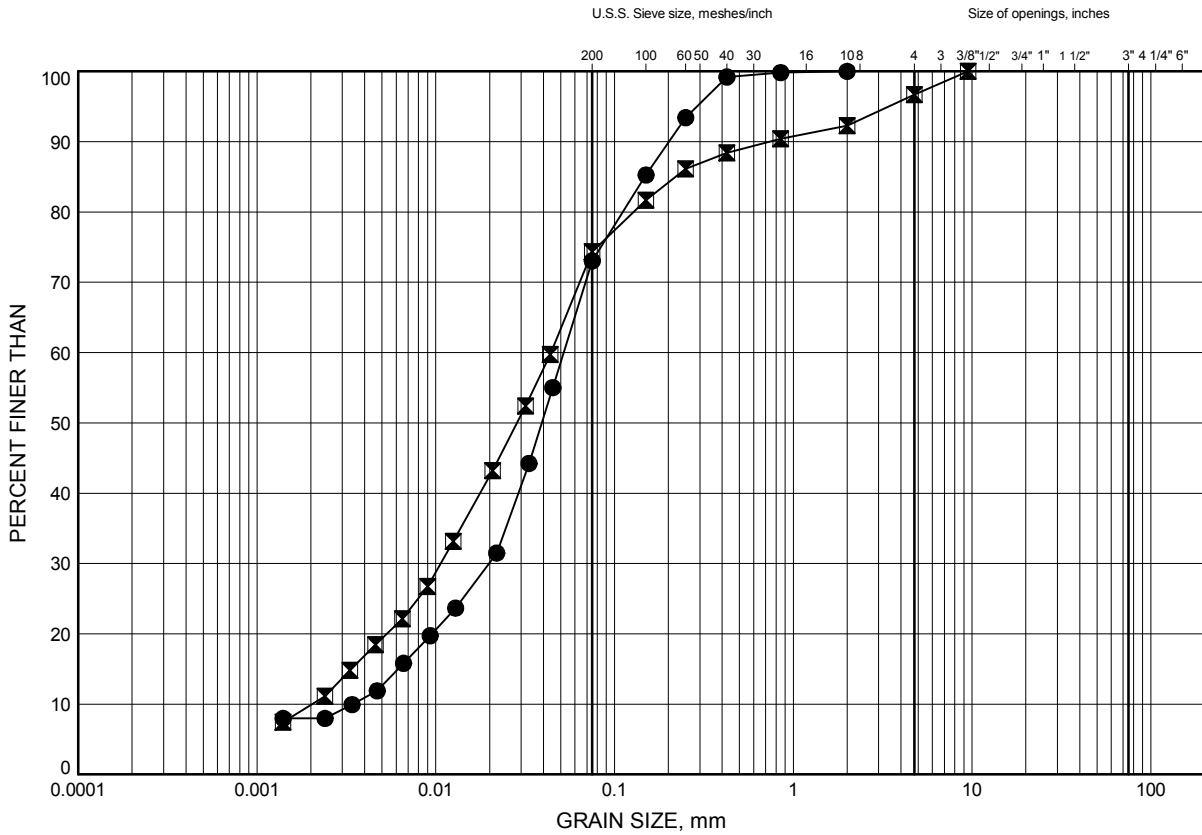
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B8

SANDY SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KR13-02	0.91	294.29
⊠	KR13-08	0.48	294.62

Date December 2013

GWP# 5193-13-00



Prep'd AN

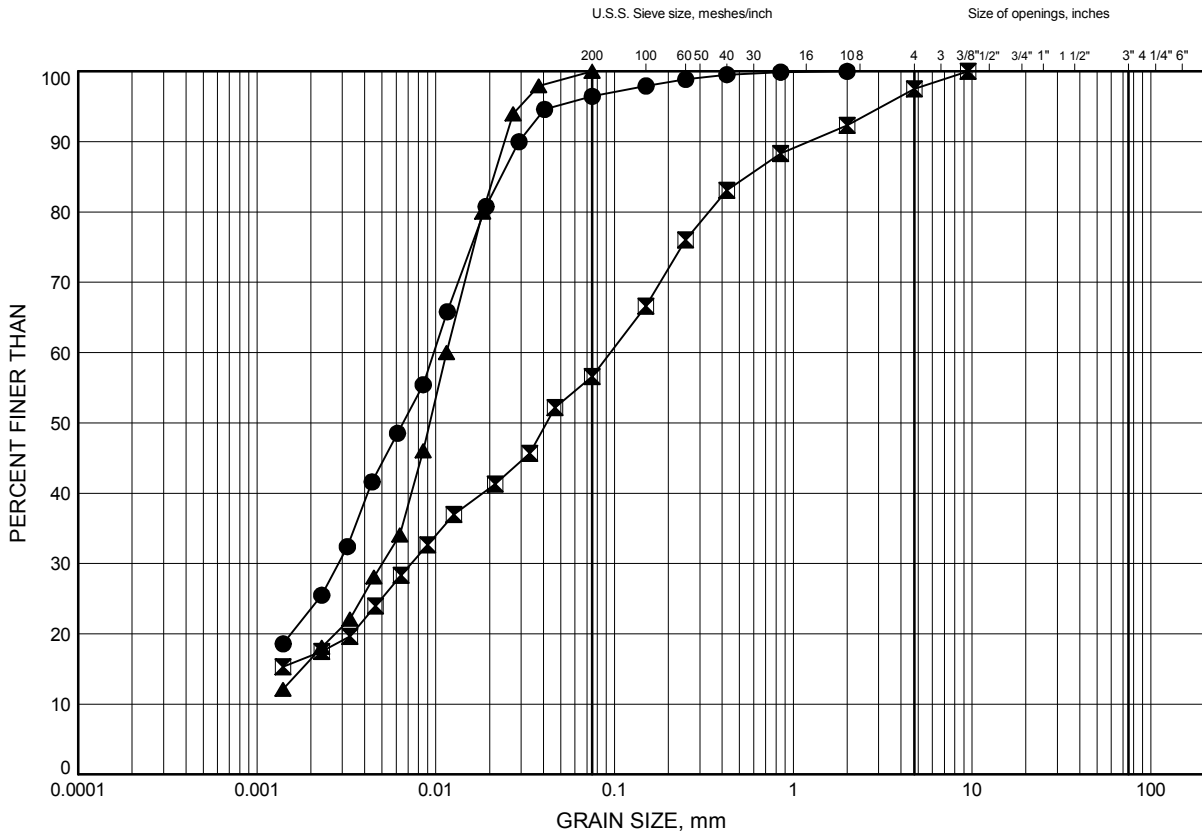
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B9

CLAYEY SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KR13-02	4.00	291.20
⊠	KR13-06	9.46	289.24
▲	KR13-07	6.34	289.36

Date December 2013

GWP# 5193-13-00



Prep'd AN

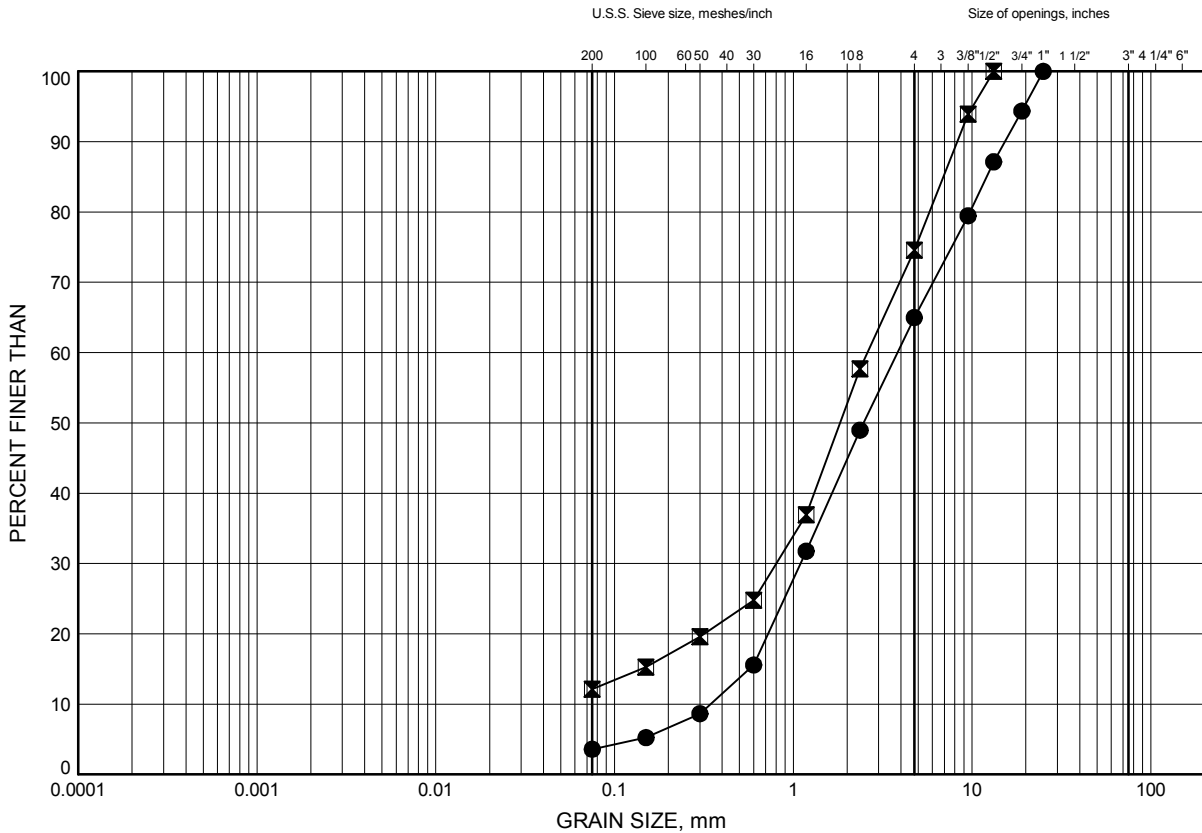
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B10

GRAVELLY SAND



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KR13-03	9.45	289.75
⊠	KR13-06	9.24	289.46

Date December 2013

GWP# 5193-13-00



Prep'd AN

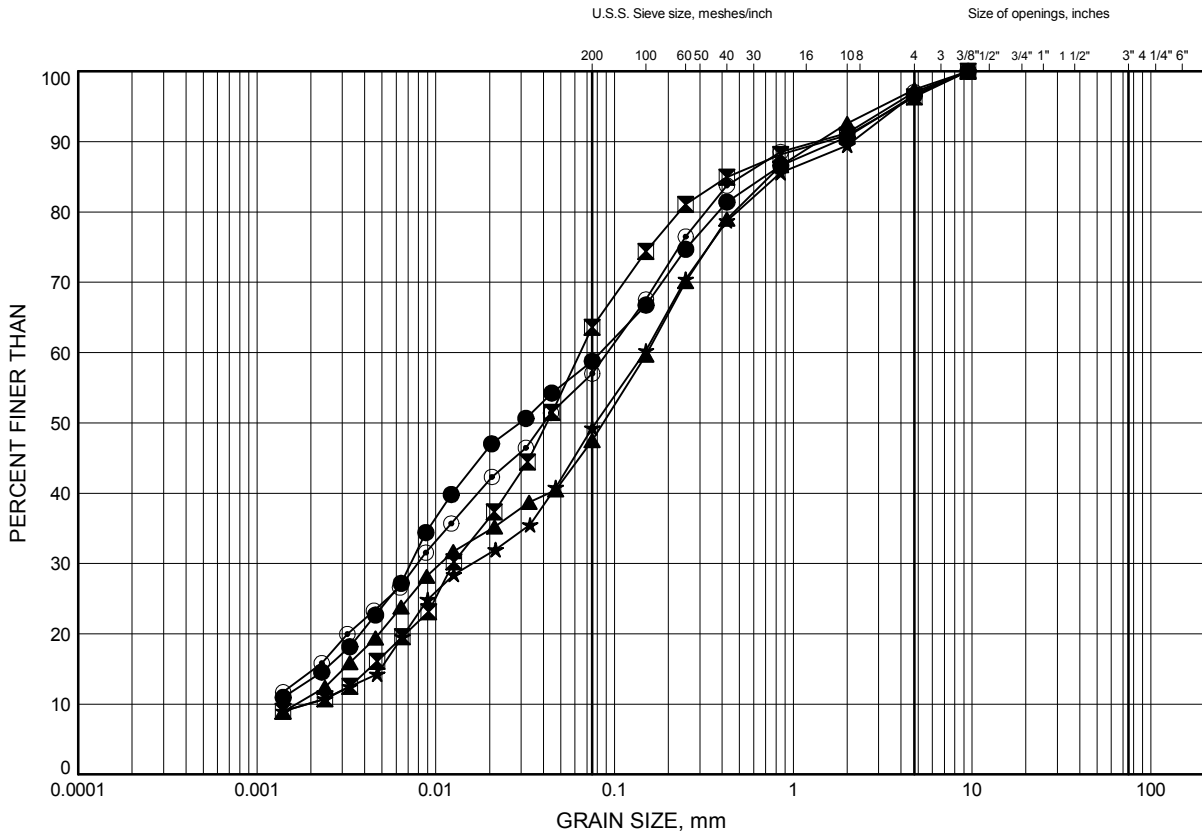
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B11

SAND & SILT TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KR13-03	12.41	286.79
⊠	KR13-03	15.54	283.66
▲	KR13-04	13.94	284.96
★	KR13-06	14.02	284.68
⊙	KR13-08	4.88	290.22

Date December 2013

GWP# 5193-13-00



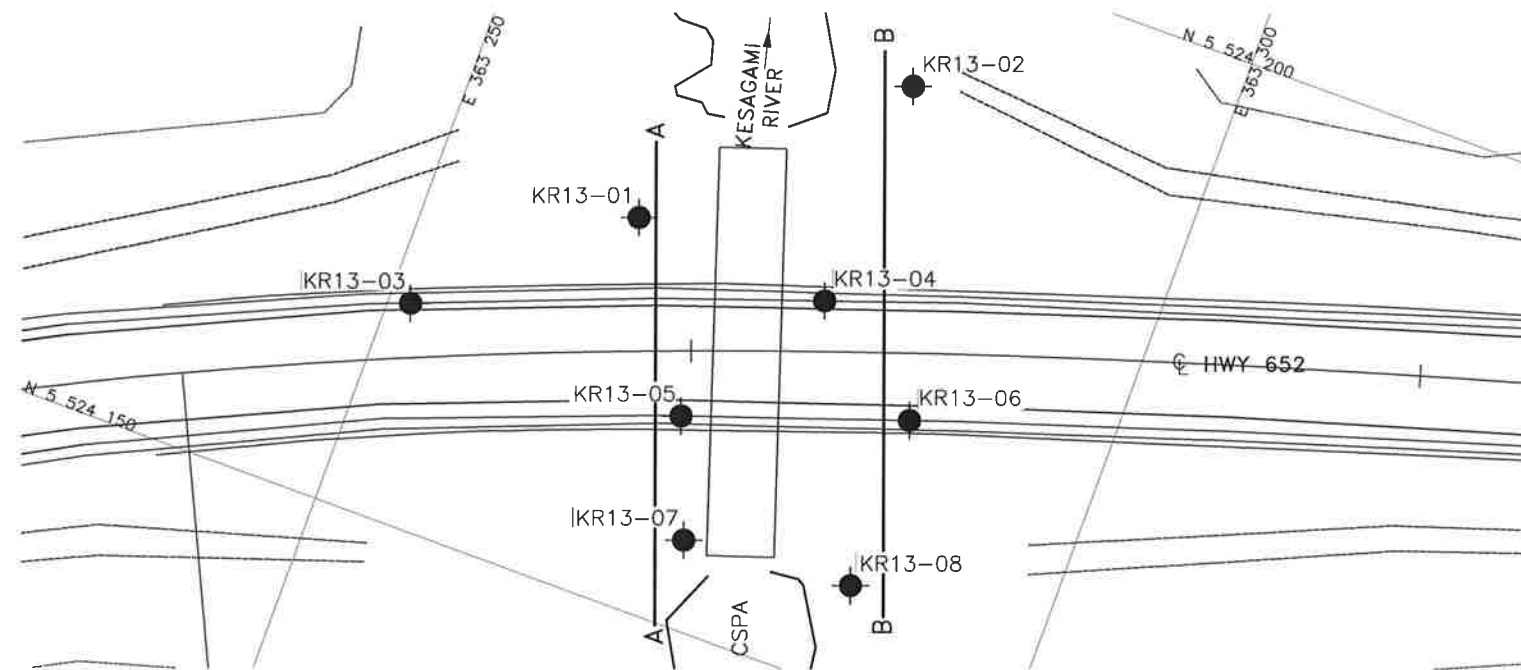
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Chkd. SKP

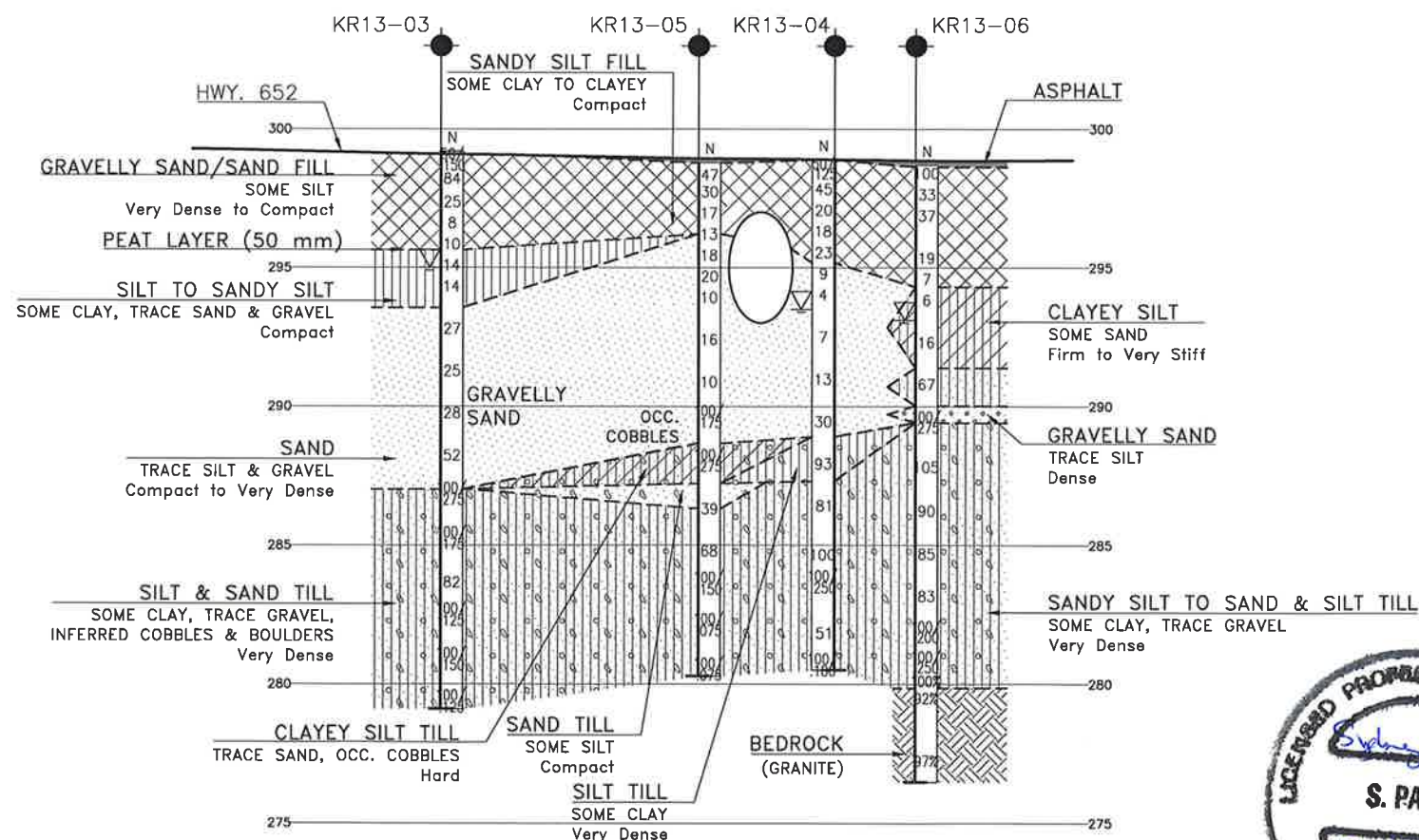
Appendix C

Borehole Locations and Soil Strata Drawings

19-4406-9



PLAN
SCALE 1:500



PROFILE ALONG C HWY 652

SCALE 1:500
V 1:250

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

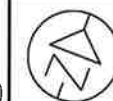
CONT No
GWP No 5193-13-00

HIGHWAY 652
KESAGAMI RIVER
CULVERT REPLACEMENT I
BOREHOLE LOCATIONS AND SOIL STRATA

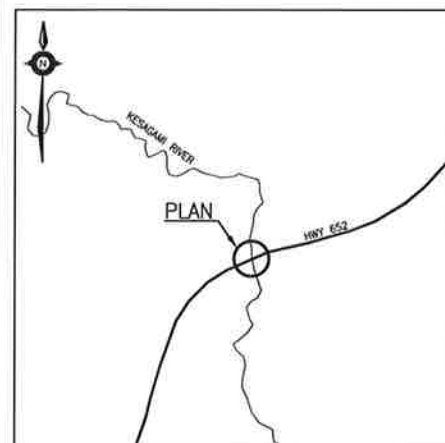
URS



THURBER ENGINEERING LTD.



SHEET



KEYPLAN

LEGEND

●	Borehole
⊕	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
W	Water Level
W	Head Artesian Water
—	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
KR13-01	297.2	5 524 175.7	363 264.2
KR13-02	295.2	5 524 190.6	363 278.7
KR13-03	299.2	5 524 164.8	363 251.5
KR13-04	298.9	5 524 174.7	363 278.1
KR13-05	298.8	5 524 163.9	363 271.6
KR13-06	298.7	5 524 169.0	363 286.4
KR13-07	295.7	5 524 156.0	363 274.7
KR13-08	295.1	5 524 157.0	363 286.5

NOTES

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRE No. 42H-59



DATE	BY	DESCRIPTION
DESIGN	SKP	CHK SKP
DRAWN	AN	CHK AEG
		SITE 39N-011C
		STRUCT
		DWG 2

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
GWP No 5193-13-00

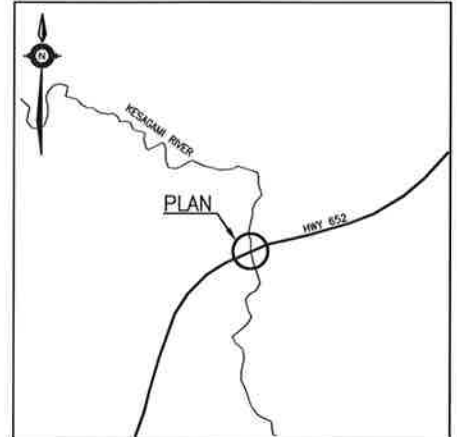
HIGHWAY 652
KESAGAMI RIVER
CULVERT REPLACEMENT II
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

URS



THURBER ENGINEERING LTD.



KEYPLAN LEGEND

●	Borehole
⊕	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
⊕	Water Level
⊕	Head Artesian Water
⊕	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

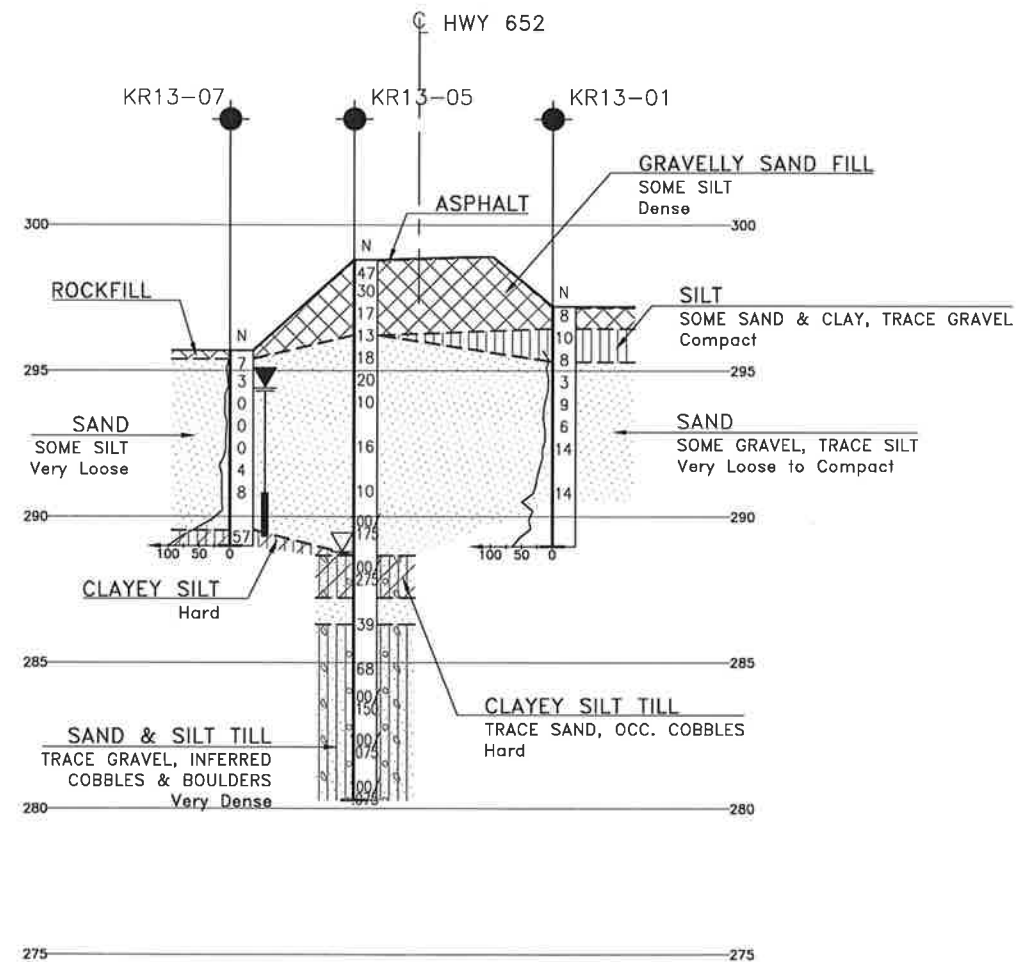
NO	ELEVATION	NORTHING	EASTING
KR13-01	297.2	5 524 175.7	363 264.2
KR13-02	295.2	5 524 190.6	363 278.7
KR13-03	299.2	5 524 164.8	363 251.5
KR13-04	298.9	5 524 174.7	363 278.1
KR13-05	298.8	5 524 163.9	363 271.6
KR13-06	298.7	5 524 169.0	363 286.4
KR13-07	295.7	5 524 156.0	363 274.7
KR13-08	295.1	5 524 157.0	363 286.5

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 42H-59

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	SKP	CHK	SKP
DRAWN	AN	CHK	AEG
SITE	39N-011C	STRUCT	DWG 3
DATE	NOV 2014		

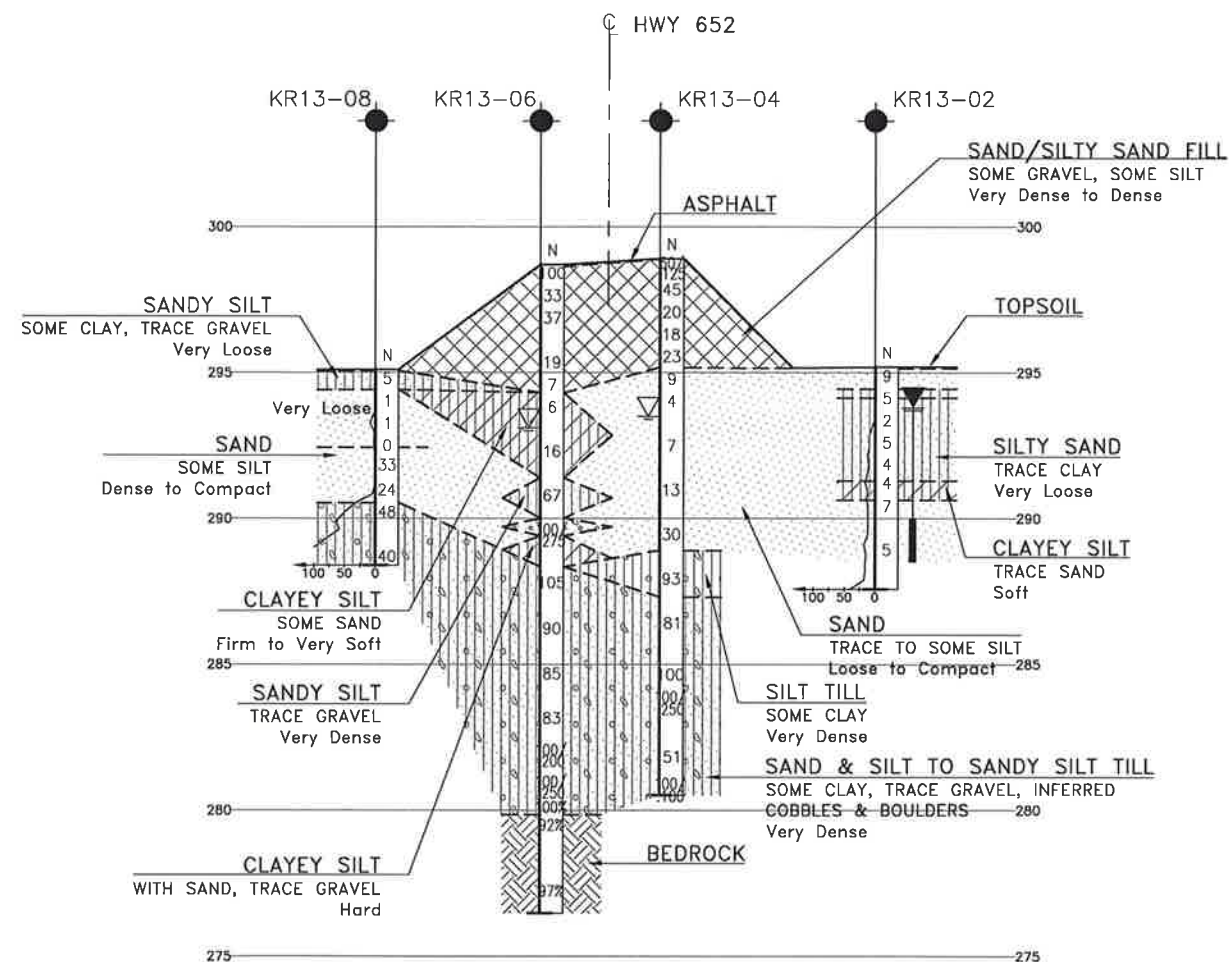


SECTION ALONG A-A



H 1:500

V 1:250



SECTION ALONG B-B



Appendix D

Foundation Alternatives Comparison

19-4406-9

COMPARISON OF ALTERNATIVE CULVERT TYPES

Location	Concrete Open Footing Culvert	Concrete Rigid Box Culvert	Circular Pipe Culvert (concrete, CSP, HDPE)
Culvert Replacement	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Relatively expedient installation if precast units are used. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Requires deeper sub-excavation than box culverts. ii. Relatively higher post construction settlement than box culverts. <p style="text-align: center;">NOT RECOMMENDED</p>	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade. ii. Relatively expedient installation if precast units are used. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Requires compacted granular pad on subgrade. <p style="text-align: center;">RECOMMENDED</p>	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts. ii. Lower cost than concrete (rigid frame) culverts. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. CSP and HDPE pipes not as durable as concrete culverts. ii. Feasibility also depends on flow capacity and other hydraulic properties. <p style="text-align: center;">GENERALLY FEASIBLE</p>

Appendix E

Suggested Wording for NSSP

1. Suggested Text for NSSP on “Obstructions”

“Installation of cofferdams and roadway protection systems could encounter obstructions such as cobbles and boulders embedded in the fill and native glacial tills. Such obstructions may impede sheetpile installation and prohibit the sheetpiles from reaching the design depth of installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the sheetpiles to the design depths.”

Appendix F

Selected Photographs of Culvert Extension Locations



Photo 1: Kesagami River Inlet



Photo 2: Kesagami River Outlet