Foundation Investigation Report
Replacement of Jackfish Creek Culvert, Highway 11
Site No. 45-274/C

Rehabilitation/Replacement of 17 Structures along various Highways in Northwestern Region

G.W.P. 6212-14-00

Geocres No. 52B-30

Prepared for:
Ministry of Transportation Ontario

Prepared by:
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Project No. 165000958

December 2016

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For
G.W.P 6212-14-00

Highway 11 – Replacement of Jackfish Creek Culvert

Site No. 45-274/C
Unsurveyed Territory of Thunder Bay

1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by the Ministry of Transportation, Ontario (MTO), to undertake the detail design for the proposed replacement of the Jackfish Creek Culvert. This culvert is located on Highway 11 approximately 13 km west of Junction Highway 11B in an unsurveyed territory of Thunder Bay.

Stantec previously completed a preliminary foundation investigation and design report for the Jackfish Creek Culvert titled "Preliminary Foundation Investigation and Design Report, Replacement of Jackfish Creek Culvert, Highway 11, Site No. 42-274/C, Geocress No. 52B-23" dated January 2015.

The purpose of this investigation was to document the subsurface conditions at the site and, to provide a borehole locations plan and soil strata drawing with a stratigraphic profile and cross-sections, records of boreholes, laboratory test results and a written description of the subsurface conditions, based on the data obtained, in accordance with MTO standards and requirements.

This Foundation Investigation Report has been prepared specifically and solely for the proposed replacement of the Jackfish Creek Culvert.

Project Number: 165000958

Project Location: Hwy 11 Jackfish Creek Culvert Replacement, 13 km west of Jct. Hwy 11B

G.W.P.: 6212-14-00

Agreement Number: 3014-E-0025

2.0 SITE DESCRIPTION AND GEOLOGY

Site Location

The site location is shown on the Key Plan inset to Drawing No. 1, provided in Appendix A. The existing Jackfish Creek Culvert crosses beneath Highway 11, approximately 13 km west of Junction Highway 11B near the town of Atikokan.

General Site Description

General site photographs showing the highway and culvert are provided in Appendix A.

Highway 11 runs approximately east-west at the project location with chainage increasing from west to east. In the vicinity of the culvert, Highway 11 has a two-lane rural cross-section with narrow shoulders (see Photograph 1 in Appendix A). The paved Highway 11 surface is approximately 7.3 m wide with approximately 1.8 m wide shoulders. The embankment has approximate side slopes of 2H:1V or flatter. Both the inlet and outlet ends of the culverts were partially submerged at the time of the 2014 drilling investigation.

Existing Culvert

The existing Jackfish Creek culvert is a two-cell timber culvert with a total span of 4.2 m (2.1 m each cell). The culvert is approximately 25.0 m long. The year built is unknown. The fill cover is approximately 2.0 m high. The total embankment height is approximately 4.0 m.

Physiographic Description

The site is located within the Atikokan-Lumby Lake Area of northwestern Ontario. The Quaternary Geology of the area has been compiled in Map 2554 of the Ontario Geological Survey (Barnett et al. 1991). Surficial materials within this area consist predominantly of a thin, discontinuous veneer of drift (till) over bedrock. Modern fluvial deposits occupy major river valleys, such as along the Seine River. Glaciolacustrine sand, silt and clay occur locally. The generalized geology of the area indicates that the bedrock is dominated by the Marmion Lake batholith (OGS, 1999) and includes metasedimentary rocks.

Drainage in the area is generally north and northwest toward the Seine River. In the immediate vicinity of the site, drainage is provided via ditches leading to the culvert. At the culvert location, Jackfish Creek flows towards the north.

3.0 DRILLING INVESTIGATION

A field investigation consisting of four boreholes was carried out by Stantec on May 15, 27 and 28, 2014 for the replacement of the proposed Jackfish Creek culvert (Site No. 45-274/C) during the preliminary design stage. The boreholes were designated BH14-1 through BH14-4 and their locations are shown on the Borehole Location Plan, Drawing No.1 in Appendix A.

During the detailed design stage one additional borehole (BH15-5) was advanced by Stantec's sub-consultant, Amec Foster Wheeler, on December 7, 2015. The borehole location is shown on the Borehole Location Plan, Drawing No.1 in Appendix A.

Prior to carrying out the investigations, Stantec and Amec Foster Wheeler contacted the public utility authorities to clear the borehole locations of public utilities. Boreholes BH14-1, BH14-2, and BH15-5 were advanced through the gravel shoulders and asphalt surface of the Highway 11 with

hollow-stem augers using a truck mounted drill rig equipped for soil and bedrock sampling (HQ casing). Boreholes BH14-3 and BH14-4 were advanced near the culvert inlet and outlet using portable drilling casing (NQ casing).

The subsurface stratigraphy encountered in each borehole was recorded in the field by Stantec or Amec Foster Wheeler representatives. Split spoon samples were collected at regularly spaced intervals (typically every 760 mm) during the course of Standard Penetration Testing (ASTM D1586). Bedrock was cored with HQ size coring equipment in BH14-1 & BH14-2 and NQ size in BH14-3 & BH14-4. All samples recovered were returned to Stantec's Ottawa laboratory for detailed classification and testing.

Boreholes were backfilled with auger cuttings mixed with bentonite and road holes were topped with cold patch asphalt as required. Groundwater depth was inferred from open boreholes during drilling.

3.1 SURVEY

The elevation and coordinates (northing and easting) of boreholes BH14-1 through BH14-4 were determined using a Global Positioning System (GPS) apparatus, Trimble Geo XH, capable of decimeter accuracy.

The coordinates of borehole BH15-5 were interpreted from the site plan based on off-set measurements from the existing culvert and edge of asphalt. The elevation of the borehole was surveyed relative to a temporary benchmark on the southwest corner of the culvert. The temporary benchmark was determined to have an elevation of 391.95 m Geodetic by Amec Foster Wheeler.

The ground surface elevations and coordinates of the borehole locations are provided in Drawing 1 of Appendix A and on the Borehole Records included in Appendix B. Summary information pertaining to the boreholes included in this report is given in Table 3.1.

Table 3.1: Borehole Summary

	Boreholes				
	14-1	**14-2**	**14-3**	**14-4**	**15-5**
MTM Zone 16 Coordinates Northing Easting	 5400395 394874	 5400386 394880	 5400377 394867	 5400406 394881	 5400388 394872
Ground Surface Elevation, m	394.4	394.4	391.0	390.9	394.4
Total Depth Drilled, m	8.2	7.7	2.9	3.0	5.1
End of Borehole Elevation, m	386.2	386.7	388.1	387.9	389.3
Depth Augered, m	5.2	5.7	1.4	2.0	5.1
Number of Soil Samples	7	8	2	3	6
Depth Cored, m	3.0	2.0	1.5	1.0	-

3.2 LABORATORY TESTING

All samples were taken to Stantec's Ottawa laboratory where they were subjected to a detailed visual examination by a Geotechnical Engineer.

The geotechnical laboratory testing program for the borehole samples is summarized in Table 3.2.

Table 3.2: Geotechnical Laboratory Testing Program

Test Description	Number of Tests
Moisture Content	27
Atterberg Limits	2
Grain Size Distribution	8
Unconfined Compression (rocks)	2

Two soil samples were tested for pH, soluble sulphate content, chloride content, and resistivity.

Samples remaining after testing will be placed in storage for a period of one year after issuance of the final report. After the storage period, the samples will be discarded.

4.0 SUBSURFACE CONDITIONS

The details of the subsurface conditions observed in the five boreholes in the vicinity of the culvert are presented in the Borehole Records provided in Appendix B. An explanation of the symbols and terms used to describe the Borehole Records is also provided in Appendix B.

The borehole location plan and stratigraphic section of the soils encountered within the boreholes is provided in Drawing No. 1 of Appendix A.

In general, the subsurface stratigraphy encountered at the boreholes consisted of pavement structure over embankment fill, or topsoil with organics overlying a thin layer of till; the till layer is underlain by graphite schist bedrock.

4.1 OVERBURDEN

4.1.1 Asphalt

A layer of asphalt with a thickness of 150 mm was encountered in borehole BH15-5.

4.1.2 Embankment Fill

Embankment fill material was encountered at the ground surface in BH14-1 and BH14-2 and beneath the asphalt layer in BH15-5. The thickness of the embankment fill was approximately 3.8 m to 4.6 m and extended to approximate base elevation of 390.6 m and 389.8 m.

The embankment fill consisted predominantly of silty sand with gravel in boreholes BH14-2 and BH15-5. Within BH14-1 the fill consisted of gravel with silt and sand over sand with silt and gravel. Occasional cobbles and boulders were encountered within the embankment fill.

The Standard Penetration Test (SPT) blow counts (N-values) measured within the fill ranged between 10 and greater than 100 blows per 0.3 m.

Index tests carried out on representative samples of the embankment fill material indicated the following results:

Gravel:	18 to 50%
Sand:	43 to 58%
Fines (Silt & Clay):	7 to 25%
Silt Size:	18 to 22%
Clay Size:	3 to 5%
Moisture Content:	4 to 13%

Atterberg limits test carried out on sample BH14-1 SS4 of the fill material indicated a non-plastic material.

Representative grain size distribution plots for the embankment fill material are provided in Figure 1 of Appendix C. According to USCS, the group symbol for the embankment fill material is SM (silty sand with gravel); SW-SM (well-graded sand with silt and gravel), and GW-GM (well-graded gravel with silt and sand).

4.1.3 Topsoil with Organics

Approximately 0.8 and 1.4 m thick layer of topsoil with organic material with some sand and gravel were encountered at the ground surface in BH14-3 and BH14-4. The base elevation of the layer was 389.6 and 390.1 m. These materials also contained some sand and gravel. The moisture content of this layer ranged between 28 and 45%.

4.1.4 Till

A till layer was encountered beneath the embankment fill in BH14-1, BH14-2 and BH15-5 and beneath the topsoil with organics layer in BH14-4. This layer consisted predominantly of sand and gravel size materials. A boulder within the till soil material was cored in borehole BH14-4 between elevation 388.9 m and 389.5 m. The thickness of the till layer ranged approximately between 0.6 and 1.4 m. The base of the layer terminated on bedrock between elevations 388.7 m and 389.6 m.

The SPT N-values measured within the till layer were from 12 to greater than 100 blows per 0.3 m, suggesting a compact to very dense state.

Index tests carried out on representative samples of the till layer indicated the following results:

Gravel:	12 to 65%
Sand:	31 to 48%
Fines (Silt & Clay):	4 to 43%
Silt Size:	11 to 35%
Clay Size:	1 to 8%
Moisture Content:	8 to 23%

Atterberg limits tests carried out on sample BH14-4 SS2 of the till material indicated a non-plastic material.

Representative grain size distribution plot for the silty sand layer is provided in Figure 2 of Appendix C. The USCS group symbol for the till layer is SM (silty sand with gravel), GM (well-graded gravel with sand) and GW-GM (well graded gravel with silt and sand).

4.2 BEDROCK

Grey to dark grey graphite schist bedrock with quartz intrusions was encountered in boreholes BH14-1 to BH14-4. The weathering of the bedrock was described as fresh to slightly weathered. Bedrock was inferred from auger refusal at borehole BH15-5. The top of bedrock elevations ranged between 388.7 and 389.6 m. The Rock Quality Designation (RQD) values were between 57% and 100%, indicating a fair to excellent rock quality. RQD value of 0% was measured in BH14-3, this low value is attributed to the very short coring length. The Total Core Recovery (TCR) was 100%. A detailed description of the rock core is provided in Field Core Logs in Appendix B. Rock core photographs are provided in Appendix B.

Unconfined compressive strength (UCS) tests were carried out on two bedrock samples (one each from BH14-2 and BH14-3). The results of these tests are summarized in Table 4.1.

Table 4.1: Unconfined Compressive Strength of Rock Cores

Borehole No	Test Elevation (m)	Unconfined Compressive Strength (MPa)
BH14-2	386.9	163
BH14-3	389.3	177

Based on the rock UCS test results presented above, the tested bedrock samples may be described as very strong.

4.3 GROUNDWATER

Groundwater was observed in the open boreholes at the time of drilling, between May 15 and 28, 2014 as well as December 7, 2015. The observed groundwater levels are summarized in Table 4.2 as “inferred” groundwater level.

Table 4.2: Inferred Groundwater Levels (time of drilling)

Borehole No	Ground Surface Elevation (m)	Groundwater	
		Depth (m)	Elevation (m)
BH14-1	394.4	3.8	390.6
BH14-2	394.4	3.7	390.7
BH14-3	391.0	0.5	390.5
BH14-4	390.9	0.5	390.4
BH15-5	394.4	3.7	390.7

Fluctuations in the groundwater and culvert water level due to seasonal variations or in response to a particular precipitation event should be anticipated.

The water level in the creek was observed (by others) at elevation 390.9 m on June 4, 2013. The inferred water level in the creek, during drilling in May 2014, was approximately 390.5 m.

4.4 CCEMICAL TEST RESULTS

Two samples of the native material were tested for pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis results are provided in Table 4.3.

Table 4.3: Results of Chemical Analysis

Borehole No	Sample No.	Depth (m)	pH	Chloride (µg/g)	Sulphate (µg/g)	Resistivity (Ohm-m)
BH14-1	SS-5	3.05 to 3.66	7.8	110	35	35
BH14-2	SS-4	2.29 to 2.90	7.7	9	58	51

5.0 MISCELLANEOUS

The field work for the Preliminary Foundation Investigation was supervised by Mr. Jason Hopwood-Jones, Geotechnical Engineering Technician, under the direction of Mr. Chris McGrath, P.Eng. The supplemental borehole drilled as part of the Detailed Foundation Investigation was supervised by Amec Foster Wheeler representative Mr. Tyler Renaud, P.Eng.

USL-1 of Ottawa, Ontario, carried out the private and public utility locates for the boreholes.

The drilling equipment used for the investigation was supplied and operated by Paddock Drilling Ltd. of Brandon, Manitoba and TBT Engineering Limited, Thunder Bay. The portable drilling equipment was supplied and operated by Landcore Drilling of Chelmsford, Ontario.

Location and elevation survey of the boreholes BH14-1 to BH14-4 was carried out by Stantec while borehole BH15-5 was carried out by Amec Foster Wheeler.

Geotechnical laboratory testing was carried out at Stantec's Ottawa laboratory. Chemical testing for pH, soluble sulphate, and chloride content, and resistivity was carried out by Paracel Laboratories of Ottawa.

This report was prepared by Marjan Oboudi, and reviewed by Chris McGrath and Raymond Haché.

6.0 CLOSURE

A subsurface investigation is a limited sampling of a site. The subsurface conditions given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information.

Respectfully Submitted;

STANTEC CONSULTING LTD.

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Geotechnical Engineering

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Designated Principal MTO Foundation Contact

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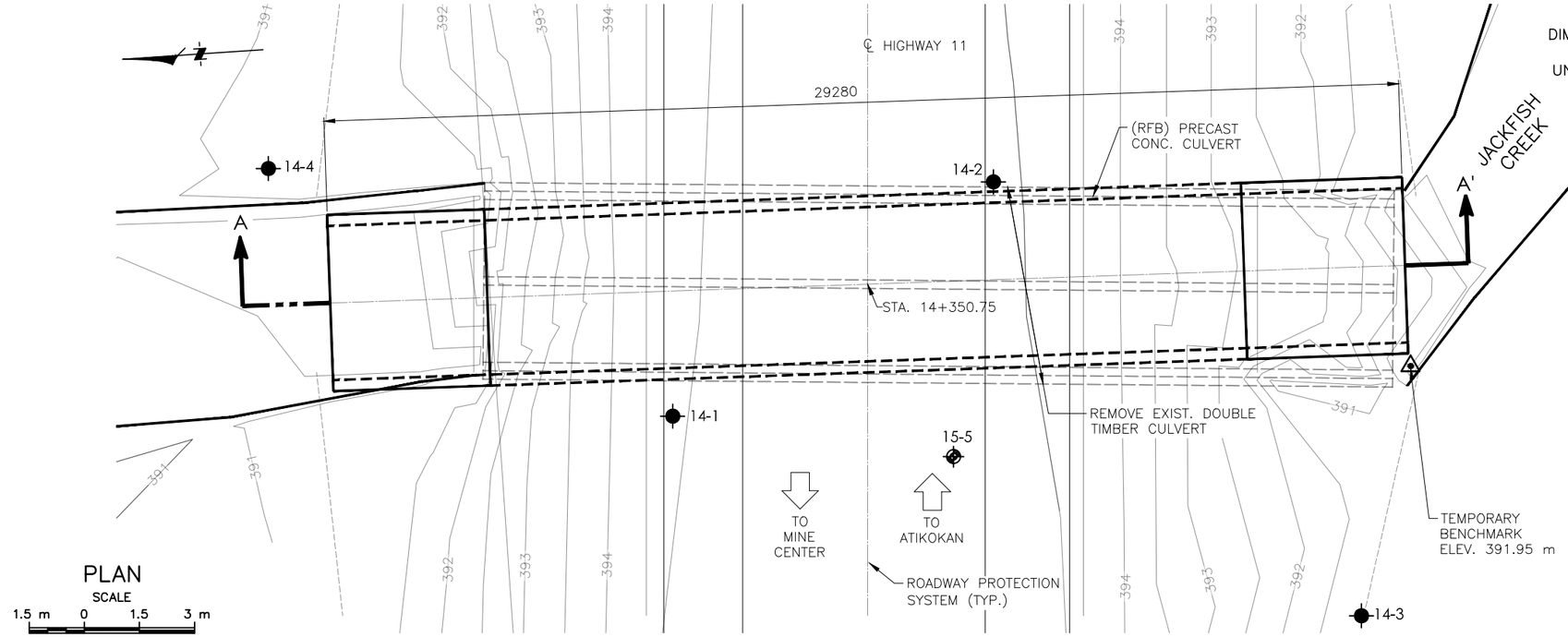
APPENDIX A

Drawing No. 1 – Borehole Location Plan and Soil Strata Plot

Site Photos



PLAN

SCALE

1.5 m 0 1.5 3 m

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

LICENSED PROFESSIONAL ENGINEER
C. MCGRATH
2016-12-02
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
J.G.A.R. HACHÉ
2016-12-02
PROVINCE OF ONTARIO

PLATE No

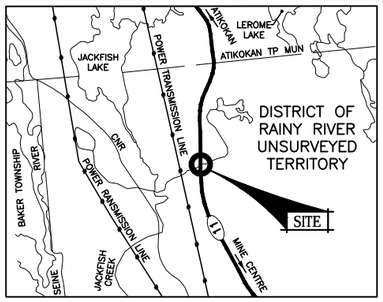
CONT 2016–6008

WP 6212–14–00

HIGHWAY 11
JACKFISH CREEK CULVERT REPLACEMENT
BOREHOLE LOCATIONS & SOIL STRATA

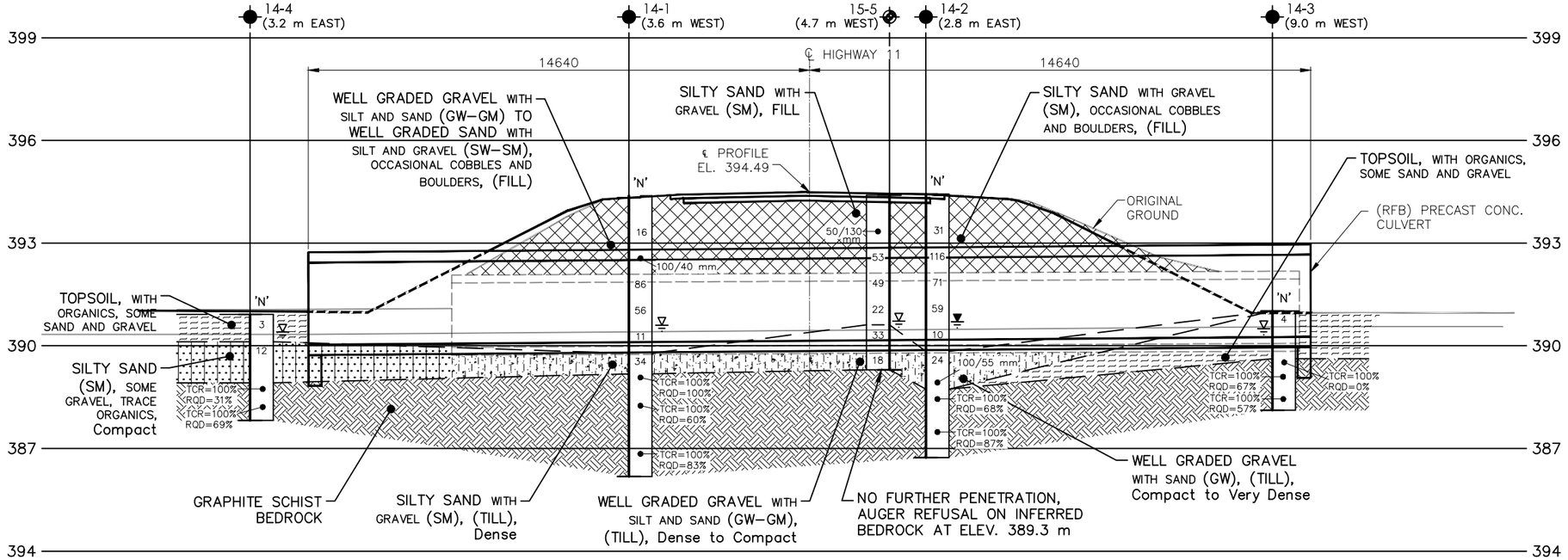
SHEET

Stantec



KEY PLAN

1 km 0 1 2 km



CROSS SECTION A–A'

SCALE

1.5 m 0 1.5 3 m

LEGEND

- Borehole
- Borehole by Others
- N — Blows/0.3m (Std Pen Test, 475 J/blow)
- WL at Time of Investigation May 2014
- WL at Time of Investigation Dec 2015
- (x.x m) — Offset from Cross Section Line in meters

No	ELEV	MTM ZONE 16 COORDINATES NORTH	EAST
14–1	394.4	5 400 395.3	394 873.7
14–2	394.4	5 400 386.1	394 879.5
14–3	391.0	5 400 376.9	394 867.0
14–4	390.9	5 400 405.8	394 881.2
15–5	394.4	5 400 387.7	394 872.1

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.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102–2 of Form 100.

REVISIONS			
	DATE	BY	DESCRIPTION

GEOCRES No 52B–30

HWY No 11					DIST
SUBM'D MO	CHECKED CM	DATE 2016–12–02		SITE	45–274C
DRAWN GBB	CHECKED CM	APPROVED		DWG	2

DRAWING NAME: 165000958–45–273c–p1_Jackfish Creek_Final.dwg
CREATED BY: GBB
MODIFIED:
T:\Autocad\Drawings\Project Drawings\2016\165000958\45–274 Jackfish Creek Culvert (Hwy 11)\Final\165000958_45–274c–p1_Jackfish Creek_Final.dwg (Plan & CS)
Printed: Dec 02, 2016
PR–D–707 88–05
MINISTRY OF TRANSPORTATION, ONTARIO

Stantec	Project No.: 165000958	GWP: 6212-14-00	Site Photographs
	Project Name: Highway 11 Replacement of Jackfish Creek Culvert, District of Rainy River, ON		Date: May 15, 2014

Site Photo No.: 1	Looking east at the south end of culvert (inlet)

Site Photo No.: 2	Looking west at the north end of culvert (outlet)

Stantec	Project No.: 165000958	GWP: 6212-14-00	Site Photographs
	Project Name: Highway 11 Replacement of Jackfish Creek Culvert, District of Rainy River, ON		Date: May 15, 2014

Site Photo No.: 3	Looking south at the inlet

Site Photo No.: 4	Looking north at the outlet

APPENDIX B

Symbols and Terms Used on Borehole Records

Borehole Records

Rockcore Records

Rockcore Photographs

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

Topsoil	-	mixture of soil and humus capable of supporting vegetative growth
Peat	-	mixture of visible and invisible fragments of decayed organic matter
Till	-	unstratified glacial deposit which may range from clay to boulders
Fill	-	material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

Desiccated	-	having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.
Fissured	-	having cracks, and hence a blocky structure
Varved	-	composed of regular alternating layers of silt and clay
Stratified	-	composed of alternating successions of different soil types, e.g. silt and sand
Layer	-	> 75 mm in thickness
Seam	-	2 mm to 75 mm in thickness
Parting	-	< 2 mm in thickness

Terminology describing soil types:
The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488). The classification excludes particles larger than 76 mm (3 inches). The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):
Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present:

Trace, or occasional	Less than 10%
Some	10-20%
Frequent	> 20%

Terminology describing compactness of cohesionless soils:
The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test N-Value (also known as N-Index). A relationship between compactness condition and N-Value is shown in the following table.

Compactness Condition	SPT N-Value
Very Loose	<4
Loose	4-10
Compact	10-30
Dense	30-50
Very Dense	>50

Terminology describing consistency of cohesive soils:
The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests.

Consistency	Undrained Shear Strength	
	kips/sq.ft.	kPa
Very Soft	<0.25	<12.5
Soft	0.25 - 0.5	12.5 - 25
Firm	0.5 - 1.0	25 - 50
Stiff	1.0 - 2.0	50 – 100
Very Stiff	2.0 - 4.0	100 - 200
Hard	>4.0	>200

ROCK DESCRIPTION

Terminology describing rock quality:

RQD	Rock Mass Quality
0-25	*Very Poor*
25-50	*Poor*
50-75	*Fair*
75-90	*Good*
90-100	*Excellent*

Rock quality classification is based on a modified core recovery percentage (RQD) in which all pieces of sound core over 100 mm long are counted as recovery. The smaller pieces are considered to be due to close shearing, jointing, faulting, or weathering in the rock mass and are not counted. RQD was originally intended to be done on NW core; however, it can be used on different core sizes if the bulk of the fractures caused by drilling stresses are easily distinguishable from *in situ* fractures. The terminology describing rock mass quality based on RQD is subjective and is underlain by the presumption that sound strong rock is of higher engineering value than fractured weak rock.

Terminology describing rock mass:

Spacing (mm)	Joint Classification	Bedding, Laminations, Bands
> 6000	*Extremely Wide*	-
2000-6000	*Very Wide*	*Very Thick*
600-2000	*Wide*	*Thick*
200-600	*Moderate*	*Medium*
60-200	*Close*	*Thin*
20-60	*Very Close*	*Very Thin*
<20	*Extremely Close*	*Laminated*
<6	-	*Thinly Laminated*

Terminology describing rock strength:

Strength Classification	Unconfined Compressive Strength (MPa)
Extremely Weak	< 1
Very Weak	1 – 5
Weak	5 – 25
Medium Strong	25 – 50
Strong	50 – 100
Very Strong	100 – 250
Extremely Strong	> 250

Terminology describing rock weathering:

Term	Description
Fresh	No visible signs of rock weathering. Slight discolouration along major discontinuities
Slightly Weathered	Discolouration indicates weathering of rock on discontinuity surfaces. All the rock material may be discoloured.
Moderately Weathered	Less than half the rock is decomposed and/or disintegrated into soil.
Highly Weathered	More than half the rock is decomposed and/or disintegrated into soil.
Completely Weathered	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.

STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.

Boulders
Cobbles
Gravel

Sand

Silt

Clay

Organics

Asphalt

Concrete

Fill

Bedrock

SAMPLE TYPE

SS	Split spoon sample (obtained by performing the Standard Penetration Test)
ST	Shelby tube or thin wall tube
DP	Direct-Push sample (small diameter tube sampler hydraulically advanced)
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ, etc.	Rock core samples obtained with the use of standard size diamond coring bits.

WATER LEVEL MEASUREMENT

measured in standpipe, piezometer, or well

inferred

RECOVERY

For soil samples, the recovery is recorded as the length of the soil sample recovered. For rock core, recovery is defined as the total cumulative length of all core recovered in the core barrel divided by the length drilled and is recorded as a percentage on a per run basis.

N-VALUE

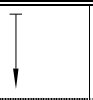
Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (64 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (305 mm) into the soil. For split spoon samples where insufficient penetration was achieved and N-values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N value corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to A size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (305 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

S	Sieve analysis
H	Hydrometer analysis
k	Laboratory permeability
γ	Unit weight
G_s	Specific gravity of soil particles
CD	Consolidated drained triaxial
CU	Consolidated undrained triaxial with pore pressure measurements
UU	Unconsolidated undrained triaxial
DS	Direct Shear
C	Consolidation
Q_u	Unconfined compression
I_p	Point Load Index (I_p on Borehole Record equals $I_p(50)$ in which the index is corrected to a reference diameter of 50 mm)

	Single packer permeability test; test interval from depth shown to bottom of borehole
	Double packer permeability test; test interval as indicated
	Falling head permeability test using casing
	Falling head permeability test using well point or piezometer

Stantec

RECORD OF BOREHOLE No BH14-1

1 OF 1

METRIC

W.P. 6212-12-02 LOCATION Highway 11 Jackfish Creek (Site 45-274/C) N: 5 400 395 E: 394 874 ORIGINATED BY JHJ

DIST HWY 11 BOREHOLE TYPE Hollow-stem Augers, Splittspoon Sampler COMPILED BY KF

DATUM Geodetic DATE 2014 05 15 - 2014 05 15 CHECKED BY SG

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED ● QUICK TRIAXIAL ✖ FIELD VANE × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
394,4	Granular Fill										
0.0	FILL: well-graded gravel with silt and sand (GW-GM) and well-graded sand with silt and gravel (SW-SM), brown Compact to very dense - occasional cobbles and boulders		1	BS	-		394				50 43 (7)
			2	SS	16						
			3	SS	100/ 40 mm		393				
			4	SS	86		392				18 59 18 5 Non-plastic
			5	SS	56		391				
			6	SS	11	▽					
389,8							390				
4,6	TILL: silty sand with gravel (SM) Grey		7	SS	34						38 48 (14)
389,2							389				
5,2	Graphite schist BEDROCK: numerous quartz intrusions; grey - fair to excellent quality - very strong - unweathered - close to moderate joint spacing (Refer to Field Bedrock Core Log)		8	HQ	-						TCR=100% RQD=100%
			9	HQ	-		388				TCR=100% RQD=60%
			10	HQ	-		387				TCR=100% RQD=83%
386,2											
8,2	End of Borehole TCR = Total core recovery										

✖ ^{3}, × ^{3}: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000873 - MTO 13 STRUCTURES_JACKFISHCK.GPJ ONTARIO MOT.GDT 10/7/16

Stantec

RECORD OF BOREHOLE No BH14-2

1 OF 1 **METRIC**

W.P. 6212-12-02 LOCATION Highway 11 Jackfish Creek (Site 45-274/C) N: 5 400 386 E: 394 880 ORIGINATED BY JHJ

DIST HWY 11 BOREHOLE TYPE Hollow-stem Augers, Splittspoon Sampler COMPILED BY KF

DATUM Geodetic DATE 2014 05 15 - 2014 05 15 CHECKED BY SG

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL ✖ FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
394,4	Granular Fill										
0.0	FILL: silty sand with gravel (SM), brown Compact to very dense - occasional cobbles and boulders		1	BS	-		394		○		
			2	SS	31				○		
			3	SS	116		393		○		29 49 (22)
			4	SS	71		392		○		
			5	SS	59	▽	391		○		
			6	SS	10				○		
389,8							390				
4,6	TILL: well-graded gravel with sand (GW) Compact to very dense Grey		7	SS	24				○		65 31 (4)
388,7			8	SS	100/ ,55 mm		389		○		
5,7	Graphite schist BEDROCK: numerous quartz intrusions; dark grey - fair to good quality - very strong - slightly weathered - close to moderate joint spacing (Refer to Field Bedrock Core Log)		9	HQ	-						TCR=100% RQD=68%
			10	HQ	-		388				TCR=100% RQD=87%
386,7							387				UCS=163 MPa
7,7	End of Borehole TCR = Total core recovery UCS = Unconfined compressive strength										

✖³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000873 - MTO 13 STRUCTURES_JACKFISHCK.GPJ ONTARIO MOT.GDT 10/7/16

Stantec

RECORD OF BOREHOLE No BH14-3

1 OF 1

METRIC

W.P. 6212-12-02 LOCATION Highway 11 Jackfish Creek (Site 45-274/C) N: 5 400 377 E: 394 867 ORIGINATED BY JHJ

DIST HWY 11 BOREHOLE TYPE Portable Drilling Equipment, Splittspoon Sampler COMPILED BY KF

DATUM Geodetic DATE 2014 05 27 - 2014 05 28 CHECKED BY SG

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ✖ FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
391,0	Topsoil										
0.0	Topsoil, with organics, some sand and gravel		1	SS	4	▽					
			2	SS	9		390		45		
389,6											
1,4	Graphite schist BEDROCK: numerous quartz intrusions; grey - very poor to fair quality - very strong - slightly weathered - close to moderate joint spacing (Refer to Field Bedrock Core Log)		3	NQ	-						TCR=100% RQD=0% UCS=177 MPa
			4	NQ	-		389				TCR=100% RQD=67%
			5	NQ	-						TCR=100% RQD=57%
388,1											
2,9	End of Borehole TCR = Total core recovery UCS = Unconfined compressive strength										

✖ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000873 - MTO 13 STRUCTURES_JACKFISHCK.GPJ ONTARIO MOT.GDT 10/7/16

Stantec

RECORD OF BOREHOLE No BH14-4

1 OF 1

METRIC

W.P. 6212-12-02 LOCATION Highway 11 Jackfish Creek (Site 45-274/C) N: 5 400 406 E: 394 881 ORIGINATED BY JHJ

DIST HWY 11 BOREHOLE TYPE Portable Drilling Equipment, Splittspoon Sampler COMPILED BY KF

DATUM Geodetic DATE 2014 05 28 - 2014 05 28 CHECKED BY SG

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL ✖ FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
390,9	Topsoil										
0.0	Topsoil, with organics, some sand and gravel		1	SS	3	▽			41		
390,1											
0,8	TILL: silty sand (SM), some gravel, trace organics Compact Dark grey to grey 1.40 to 1.98 m: cored through granite boulder		2	SS	12		390		○		12 45 35 8 Non-plastic
388,9			3	NQ	-		389				
2,0	Graphite schist BEDROCK: numerous quartz intrusions; grey - poor to fair quality - very strong - slightly weathered - close to moderate joint spacing		4	NQ	-						TCR=100% RQD=31%
			5	NQ	-						TCR=100% RQD=69%
387,9	(Refer to Field Bedrock Core Log)						388				
3,0	End of Borehole TCR = Total core recovery										

✖³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

Stantec

RECORD OF BOREHOLE No BH15-5

1 OF 1

METRIC

W.P. 6212-12-02 LOCATION Highway 11 Jackfish Creek (Site 45-274/C) N: 5 400 388 E: 394 872 ORIGINATED BY JHJ

DIST HWY 11 BOREHOLE TYPE Hollow-stem COMPILED BY MO

DATUM Geodetic DATE 2015 12 07 - 2015 12 07 CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED ● QUICK TRIAXIAL ✖ FIELD VANE × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
394,4	Asphalt										
0,0 / 394,3	Asphalt										
0,2	FILL: silty sand with gravel (SM), brown Compact to very dense - Ocassional cobbles and boulders		1	SS	50 / , 130 mm		394		○		
			2	SS	53		393		○		
			3	SS	49		392		○		21 54 22 3
			4	SS	22		391		○		
390,6						▽					
3,8	TILL: Well graded gravel with silt and sand (GW-GM), dense to compact		5	SS	33		390		○		
389,3			6	SS	18				○		51 37 11 1
5,1	End of Borehole Auger Refusal on Inferred Bedrock										

✖³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000873 - MTO 13 STRUCTURES_JACKFISHCK.GPJ ONTARIO MOT.GDT 10/7/16

Field Bedrock Core Log

Client:	Ontario Ministry of Transportation	**Project No.:**	165000958
Project:	Replacement of Jackfish Creek Culvert (Hwy 11)	**Date:**	May 15, 2014
Contractor:	Paddock Drilling Ltd	**Borehole No.:**	BH14-1
		Logger:	Simon Gudina

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES							OCCASIONAL FEATURES	DRILLING OBSERVATIONS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING		
5.21	HQ 8	100%	100%	5.41	Graphite schist BEDROCK: numerous quartz intrusions; dark grey		U	1	B	F	C	RP		T		Hardness = 3.5 to 6.5
5.41	HQ 9	100%	60%	6.86	Graphite schist BEDROCK: numerous quartz intrusions; dark grey		U	1	B	F	C-M	RP		T		Hardness = 3.5 to 6.5
6.86	HQ 10	100%	83%	8.23	Graphite schist BEDROCK numerous quartz intrusions; dark grey		U	1	B	F	C-M	RP		T		Hardness = 3.5 to 6.5

STRENGTH (MPa)

EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25
VW = Very Weak = 1-5
EW = Extremely Weak = < 1

WEATHERING

U = Unweathered = No Signs
S = Slightly = Discolored
M = Moderately < 1/2 decomposed/soil-like
H = Highly > 1/2 decomposed/soil-like
C = Completely = All decomposed/soil-like

DISCONTINUITY TYPE

B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

SPACING

VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

ORIENTATION

F = Flat = 0-20^0
D = Dipping = 20-50^0
V = n-Vertical = >50^0

ROUGHNESS

RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar

FILLING

T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
S = Sandy, Clay Free
Si = Sandy, Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay

Field Bedrock Core Log

Client:	Ontario Ministry of Transportation	**Project No.:**	165000958
Project:	Replacement of Jackfish Creek Culvert (Hwy 11)	**Date:**	May 15, 2014
Contractor:	Paddock Drilling Ltd	**Borehole No.:**	BH14-2
		Logger:	Simon Gudina

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES							OCCASIONAL FEATURES	DRILLING OBSERVATIONS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING		
5.74	HQ 9	100%	68%	6.25	Graphite SCHIST, numerous quartz intrusions; dark grey		S	1	B	F	C	RP		T		Hardness = 3.5 to 6.5
6.25	HQ 10	100%	87%	7.67	Graphite SCHIST, numerous quartz intrusions; dark grey	VS	S	1	S	F-D	M	RP		T		Hardness = 3.5 to 6.5

STRENGTH (MPa)

EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25
VW = Very Weak = 1-5
EW = Extremely Weak = < 1

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VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

ORIENTATION

F = Flat = 0-20^0
D = Dipping = 20-50^0
V = n-Vertical = >50^0

ROUGHNESS

RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar

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T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
S = Sandy, Clay Free
Si = Sandy, Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay

Field Bedrock Core Log

Client:	Ontario Ministry of Transportation	**Project No.:**	165000958
Project:	Replacement of Jackfish Creek Culvert (Hwy 11)	**Date:**	May 28, 2014
Contractor:	Landcore Drilling Ltd	**Borehole No.:**	BH14-3
		Logger:	Simon Gudina

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES							OCCASIONAL FEATURES	DRILLING OBSERVATIONS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING		
1.42	NQ 3	100%	0%	1.6	Graphite schist BEDROCK: numerous quartz intrusions; grey		S	1	S	F-D		C		T	Several fractures	Hardness = 3.5 to 6.5
1.6	NQ 4	100%	67%	2.26	Graphite schist BEDROCK: numerous quartz intrusions; grey		S	1	S	F-D	C	RP		T	Nodular features	Hardness = 3.5 to 6.5
2.26	NQ 5	100%	57%	2.92	Graphite schist BEDROCK: numerous quartz intrusions; grey		S	1	S	V	C-M	RP		T		

STRENGTH (MPa)

EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25
VW = Very Weak = 1-5
EW = Extremely Weak = < 1

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U = Unweathered = No Signs
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C = Completely = All decomposed/soil-like

DISCONTINUITY TYPE

B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

SPACING

VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

ORIENTATION

F = Flat = 0-20^0
D = Dipping = 20-50^0
V = n-Vertical = >50^0

ROUGHNESS

RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar

FILLING

T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
S = Sandy, Clay Free
Si = Sandy, Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay

Field Bedrock Core Log

Client:	Ontario Ministry of Transportation	**Project No.:**	165000958
Project:	Replacement of Jackfish Creek Culvert (Hwy 11)	**Date:**	May 28, 2014
Contractor:	Landcore Drilling Ltd	**Borehole No.:**	BH14-4
		Logger:	Simon Gudina

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES							OCCASIONAL FEATURES	DRILLING OBSERVATIONS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING		
1.4	NQ 3	88%	22%	1.98	Granite boulder, pink to light grey	NA	NA	NA								
1.98	NQ 4	100%	31%	2.39	Graphite SCHIST, quartz infills; grey		S	1		V	C	RP		T		Hardness = 3.5 to 6.5
2.39	NQ 5	100%	69%	3.05	Graphite SCHIST, quartz infills; grey		S	1		F	C-M	RP		T		Hardness = 3.5 to 6.5

STRENGTH (MPa)

EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25
VW = Very Weak = 1-5
EW = Extremely Weak = < 1

WEATHERING

U = Unweathered = No Signs
S = Slightly = Discolored
M = Moderately < 1/2 decomposed/soil-like
H = Highly > 1/2 decomposed/soil-like
C = Completely = All decomposed/soil-like

DISCONTINUITY TYPE

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J = Cross Joint
F = Fault
S = Shear Plane

SPACING

VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

ORIENTATION

F = Flat = 0-20^0
D = Dipping = 20-50^0
V = n-Vertical = >50^0

ROUGHNESS

RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar

FILLING

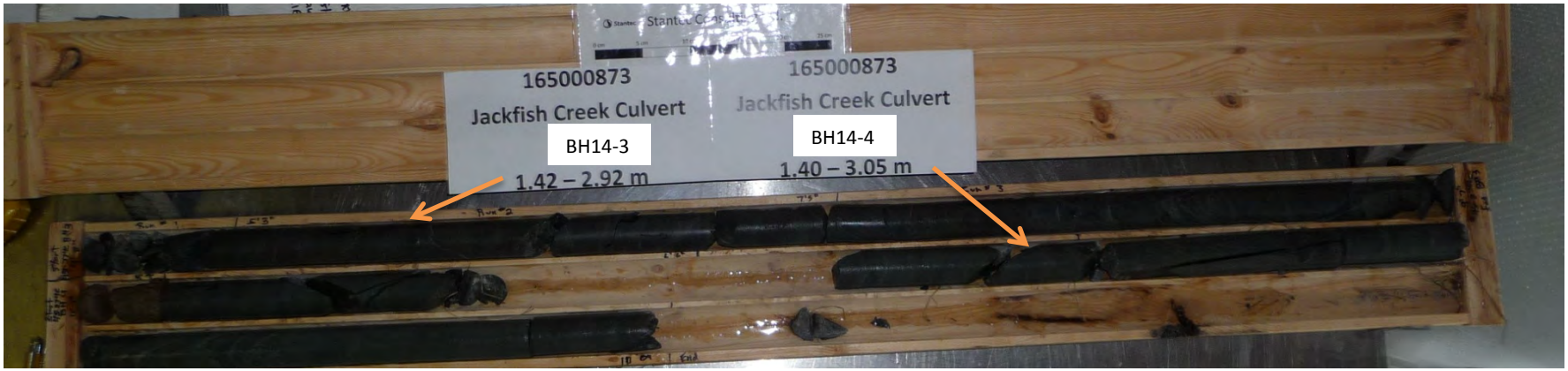
T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
S = Sandy, Clay Free
Si = Sandy, Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay

Stantec	Project No.: 165000958	GWP: 6212-14-00	Rockcore Photographs Date: May 15, 2014
	Project Name: Replacement of Jackfish Creek Culvert Northwest Region (Highway 11), Ontario		

Rock Core Photo No. 1	Borehole: BH14-1 (Site No. 45-274C, Jackfish Creek)	Depth: 5.21 to 8.23 m

Rock Core Photo No. 2	Borehole: BH14-2 (Site No. 45-274C, Jackfish Creek)	Depth: 5.74 to 7.67 m

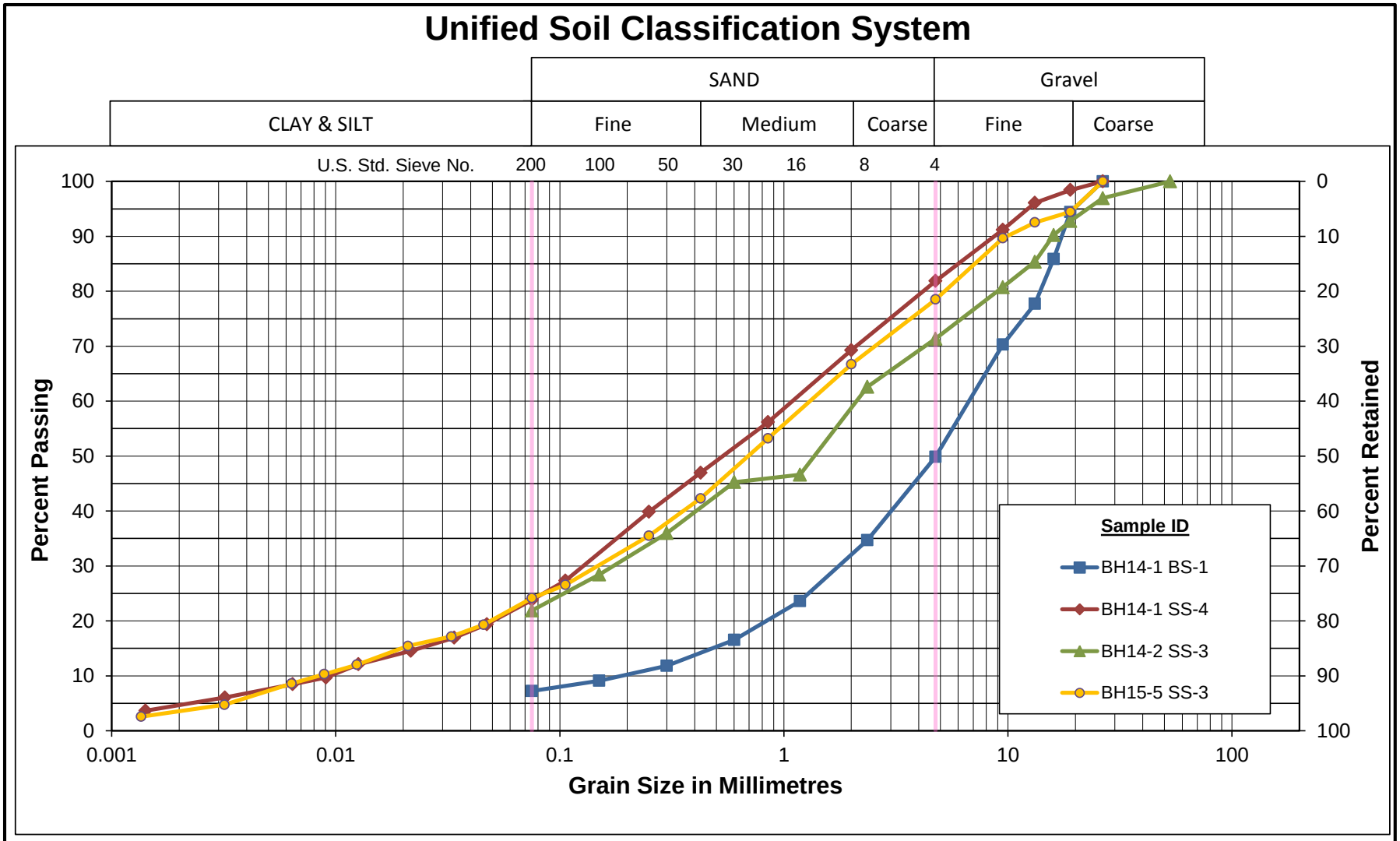
Stantec	Project No.: 165000958	GWP: 6212-14-00	Rockcore Photographs Date: May 28, 2014
	Project Name: Replacement of Jackfish Creek Culvert Northwest Region (Highway 11), Ontario		



Rock Core Photo No. 3	Borehole: BH14-3 & BH14-4 (Site No. 45-274C, Jackfish Creek)	Depth: 1.42 to 2.92; 1.40 to 3.05 m

APPENDIX C

Laboratory Test Results



Stantec

GRAIN SIZE DISTRIBUTION

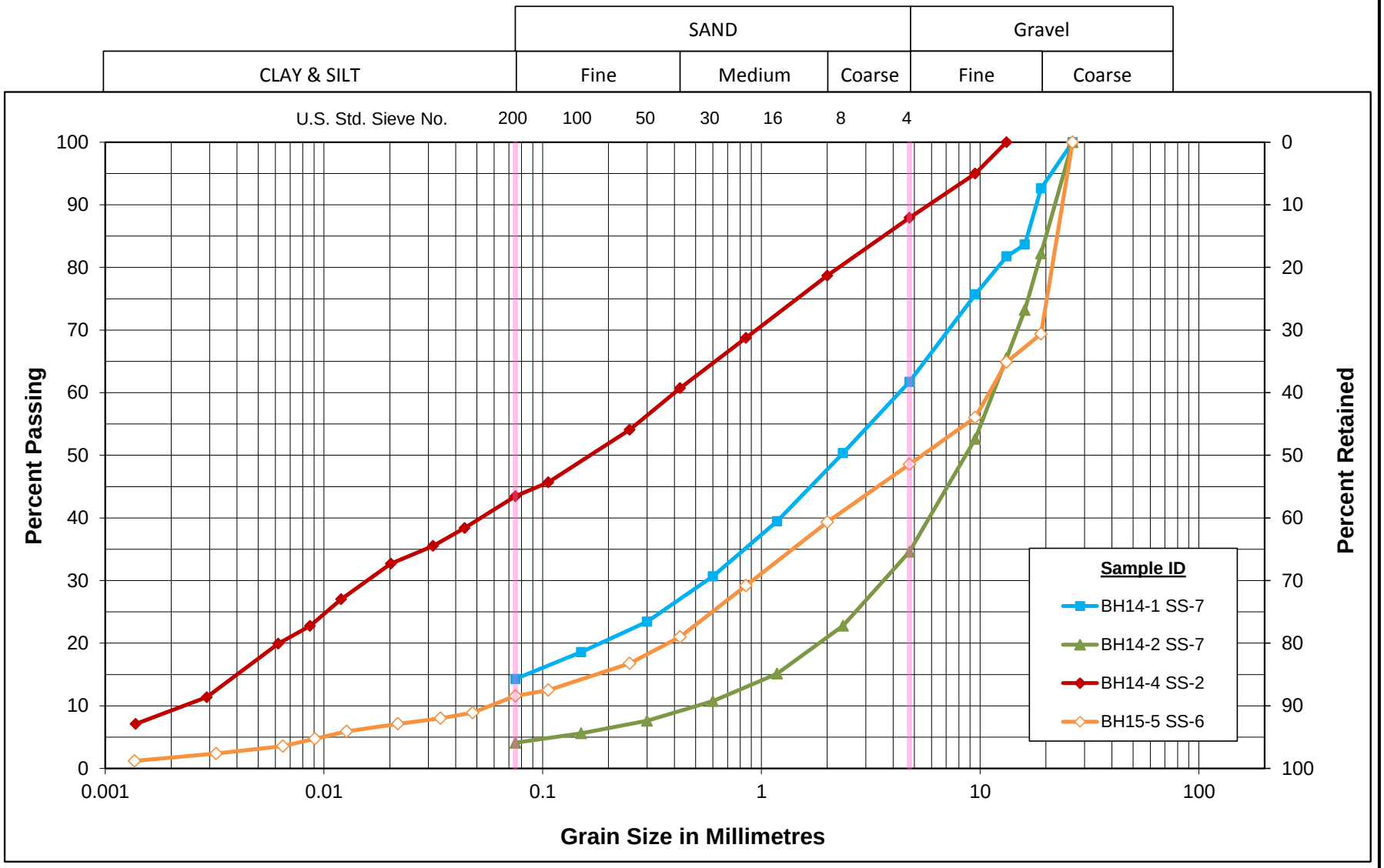
FILL: Silty sand with gravel (SM) to well-graded gravel with silt and sand (GW-GM)

Figure No. 1

Project No. 165000958

GWP 6212-14-00

Unified Soil Classification System



Stantec

GRAIN SIZE DISTRIBUTION

TILL: Silty sand with gravel (SM) to well-graded gravel with sand (GM)

Figure No. 2

Project No. 165000958

GWP 6212-14-00