Appendix C – Geotechnical Report

STANTEC CONSULTING LTD.

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FINAL REPORT

PRELIMINARY GEOTECHNICAL INVESTIGATION PROPOSED YELLOWHEAD NORTH ARTERIAL ROAD FUNCTIONAL DESIGN STUDY

Submitted to:
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REPORT

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Distribution:

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Table of Contents

TABLES

Figures

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by Stantec Consulting Ltd. (Stantec) to carry out a geotechnical investigation for the proposed Yellowhead North Arterial Road Functional Design Study between Highway 21 to the east and Range Road (RR) 232 to the west including grade line improvements on Range Road 231, two crossings over Oldman Creek and several railway crossings at RR 231 and 232.

The objective of this work was to assess soil conditions at the site for the functional design study of the proposed development. This report presents the results of the geotechnical investigation as well as our engineering comments and recommendations as outlined in our proposal dated October 29, 2007 to Stantec.

Authorization to proceed with the work was obtained from Mr. Manoj Medhekar, PhD., P.Eng. of Stantec, dated November 14, 2007.

Golder's original geotechnical proposal consisted of drilling ten (10) deep boreholes at 5 proposed crossings (4 railway crossings and 1 creek crossing) and up to 20 shallow boreholes along the proposed roadway section. A revised project scope submitted to us by Stantec showed only 7 boreholes along the roadway (no boreholes for the new alignment and all 7 boreholes for the realignment/widening of RR 231), a revised new alignment indicating a second crossing at Oldman Creek north of Township Road (TWP RD) 534 and deletion of the crossing at Canadian Pacific (CP) Rail line and RR 231. Also, due to lack of site access permission, one of the boreholes at each proposed Oldman Creek crossing (north and south of TWP RD 534) was later deleted by Stantec.

The professional services provided in this project include only the specific geotechnical aspects of the subsurface conditions at the site. The presence or implications of possible surface or subsurface contaminants from any source are outside the terms of reference for this geotechnical study and have not been investigated or addressed herein. Use of this report is subject to conditions outlined in the *Important Information and Limitations of this Report* section that follows the main text of this report and forms an integral part of the report.

2.0 PROPOSED DEVELOPMENT AND SITE LOCATION

This site is located at the northwest corner of Highway 21 (RR 230) and Highway 16 (Yellowhead Highway) in Strathcona County, Alberta as shown in Figure 1. The subject area is bounded by Highway 21 to the east, RR 232 to the west, TWP RD 534 to the north and Highway 16 to the south. The project consists of 4 railway crossings, 2 creek crossings (Oldman Creek), and approximately 6 km of arterial roadway.

It is understood that the proposed development will include highway overpass bridges at the railway crossings locations, a bridge or culvert at the creek crossings and arterial roadway pavement structures.

Preliminary design information provided by Stantec indicates that several options are being considered for overpass structures; (1) buried arch, (2) single-span bridge with MSE Wall abutments, (3) 2-span bridge with pier in railway right-of-way (R/W), and (4) 3-span bridge with piers outside railway R/W. The high pressure utility corridor is available with option (4). The ultimate road configuration at the overpass structures may consist of either 4 or 6 lanes.

The crossing at Oldman Creek south of TWP RD 534 (south creek crossing) will likely consist of either a one-span standard SCC composite girder bridge (32 m span) or a three-span standard SCC composite girder bridge (14-14-14 m spans) or a 100 m long and 4 × 6 m SPCSP culvert. The crossing north of TWP RD 534 at Oldman Creek (north creek crossing) will be a 18 m diameter SPCSP culvert or a three-span standard SCC composite girder bridge (24-24-24 m spans).

It is understood that RR 231 will be completely rebuild. It is also understood that the maximum approach/headslope fills will be about 10 m high at the rail overpass locations. At the south creek crossing, a total of 9 m high fill including 5 m above the crown of culvert structure is being considered. Detail of the proposed vertical grade profile at the overpasses and crossings were not known at the time of preparation of this report.

A site plan showing the proposed bridge/culvert crossings and new roadway alignment is provided in Figures 2 and 3.

The future interchange at Highway 21 and TWP RD 534 is not included in this scope of work.

3.0 SCOPE OF WORK AND METHODOLOGY

3.1 Desktop Review

A review of available surficial geological maps was carried out to obtain preliminary information on the soil and groundwater conditions within the project limits.

Available aerial photographs of the subject site for the year of 2006 were reviewed to obtain general geological and other surface features of the site before the site visit.

3.2 Site Reconnaissance

The site was first visited by Golder on November 26, 2007. Two recent site visits were carried out by Mr. John Chai, P.Eng. and Mr. Masud Karim, Ph.D, P.Eng. on July 15 and November 3, 2008. The November 3, 2008 site visit was required due to a change in the proposed alignment. The purpose of the site visits was to view the alignment and select test hole locations for both alignment and bridge/culvert crossings as well as to find areas near the site which have the potential to become a borrow source.

3.3 Field and Laboratory Investigations

3.3.1 Pre-Drilling Activities

Prior to the commencement of the site investigation, a Health and Safety Plan was developed to address potential on-site hazards. Alberta One-Call was notified, and the proposed borehole locations were determined to be clear of underground and overhead utilities prior to drilling. A Traffic Accommodation Strategy (TAS) was prepared by Golder and was approved by Strathcona County. The proper traffic signs were acquired from Alberta Traffic Supply and flagpersons from ProTemps were used to divert traffic on December 19, 22, and 23, 2008 in order to be able to drill on the pavement.

3.3.2 Drilling

As discussed in Section 1, the number of boreholes originally proposed had to be reduced due to site access restrictions.

The field investigation was carried out in various phases, as follows**:**

- 2 bore holes were drilled between December 2 and 4, 2008 at the Oldman Creek crossings (one per crossing);
- 5 bore holes were drilled on December 19, 2008 along the west (south bound) lane of the existing RR 231;

- Two more bore holes along the west lane of the existing RR 231 and two bore holes at RR 231 and Canadian National (CN) rail crossing were drilled on December 22, 2008; and
- 4 bore holes were drilled on December 23, 2008 at the CN and Canadian Pacific (CP) rail crossings along RR 232.

A summary of the drilling investigation is presented in Table 1.

Table 1: Summary Of Drilling Program

General Location	No. of Bore Holes	Bore Hole Number	Surface Elevation (m)	Depths (mbgs)*	Standpipe Piezometer Installed
Oldman Creek Crossing (South of TWP RD 534)	1	BH08-S10	654.24	12.7	Yes
Oldman Creek Crossing (North of TWP RD 534)	1	BH08-S8	640.68	22.7	Yes
RR 231	7	BH08-R1 through –R7	Not Available	4.5	No
RR 231 and CN Rail Crossing	2	BH08-S5 BH08-S6	Not Available	9.6	Yes
RR 232 and CN Rail Crossing	2	BH08-S1 BH08-S2	Not Available	8.1	Yes
RR 232 and CP Rail Crossing	2	BH08-S3 BH08-S4	Not Available	8.1 7.6	Yes

* meter below ground surface

Most of the boreholes were drilled either through the shoulder or pavement of the existing roadway except BH08-S8 and –S10 which were drilled close to the top of bank. Boreholes BH08-R1 to R5 were originally located by Stantec at approximately 20 m east from the existing RR 231 centreline. However, these boreholes were later moved within the existing right-of-way (R/W) based on instructions from Stantec due to site access constraints. Similarly, BH08-R6 and –R7 at the realignment portion of RR231 were also moved within the existing RR231 R/W. All other boreholes (S1 to S6) at crossings were shifted from the original planned position by Stantec due to utility clearance requirements.

At the proposed crossings, BH08-S1, -S2, -S5, and –S6 were drilled through the edge of the west lane (south bound) of the roadways and both sides of the crossings and BH08-S3 and –S4 were drilled through the edge of the east lane (north bound) of the roadway on both sides of the crossing. All the boreholes at the crossings were located approximately 30 m from each existing crossing except BH08-S3 which was located about 50 m south of the CP rail crossing due to the existence of a utility corridor right besides the crossing.

The borehole locations are shown in Figure 2**.** GPS coordinates at each borehole locations were recorded.

Boreholes were drilled using a truck-mounted drill rig equipped with solid and hollow-stem augers owned and operated by Beck Drilling & Environmental Services Inc. and Canadian Geological, both from Edmonton, Alberta. The field work was carried out under the supervision of a Golder staff member, who observed and logged in detail the subsurface and groundwater conditions encountered and took soil samples.

Representative disturbed soil samples were collected in conjunction with Standard Penetration Tests (SPTs) which were carried out at regular depth intervals in each borehole to assess the relative density and/or consistency of the in-situ soils. Disturbed soil samples were also obtained from the auger flights. In addition, undisturbed Shelby tube samples were collected at selected depths from boreholes at the proposed crossing locations. All soil samples collected were field inspected, stored in moisture-proof bags and brought to Golder's geotechnical laboratory for further soil classification and index testing.

All boreholes along RR 231 and at the proposed railway crossing locations were backfilled to the surface with drill cuttings, sand/gravel mixture, and topped off with 0.1 m of cold mix upon completion of drilling and sampling activities. Boreholes at the proposed creek crossing locations were backfilled with drill cuttings and bentonite. Standpipes were installed in bore holes at the proposed crossing locations. The water levels in the standpipes were read immediately after installation and again on February 4, 2009.

The results of the borehole drilling are provided on the Record of Borehole Sheets included in Appendix I. Classification and identification of soil have been based on Golder Associates Soil Classification System, attached in Appendix I.

3.4 Laboratory Testing

The geotechnical laboratory testing program included determination of water content, grain-size distribution, Atterberg limits and water soluble sulphate content. In addition, unconfined compression tests were carried out on selected Shelby tube samples from boreholes at the proposed crossing locations. All tests were conducted according to appropriate ASTM Standards.

In addition, resistivity and pH testing were performed on a selected sample from Borehole BH08-S10.

The results of the laboratory testing are attached in Appendix II and summarized on the Record of Borehole Sheets presented in Appendix I.

4.0 SITE AND SUBSURFACE CONDITIONS

4.1 Geology

Available geological evidence indicates that during the Pleistocene epoch a continental ice sheet originating on the Precambrian shield advanced from the northeast and covered the region at least twice. The last ice advance took place some 25,000 to 30,000 years ago in late Wisconsin time. The ice sheet advanced into western Alberta to coalesce with mountain ice sheets. During deglaciation which was essentially complete about 9,000 years ago the sea was covered by various surficial glacial materials including outwash, glacio-lacustrine sediments, and till deposits.

Available surficial geology mapping indicates locally the area is underlain by either silt or clay with local ice-rafted stones, reworked local till and typical till, with local water-sorted materials and bedrock.

4.2 Site Conditions

Based on site observations, underground and overhead utilities are generally located along both the east and west ditches of RR231 and RR232. High pressure utility corridors are located on the south of the CP rail crossing at RR231/232. In addition, a high pressure ATCO pipeline is located north of the CN crossing at RR231 and also parallel to RR232 on the east side of the road.

Telephone boxes and TELUS utilities flags were found along the ditches. Overhead power lines were observed on the east side of both RR231 and RR232 and are generally 5 to 10 m east of the east ditch (close to the fence line). One Guardrail is present on the east side of RR232 and CN rail crossing and spanned about 30 m. Both RR231 and RR232 are currently being used with no disruptions in traffic flow.

Typically, the surrounding land is flat on both sides of RR231 and RR232. The right-of-way area on both sides of the roads was clear of vegetation at the time of the field investigation. Outside of the right-of-way, the area is in general tree covered with occasional lower-lying wet areas vegetated with smaller bush or grasses RR232 is typically wider than RR231 and appeared to have been upgraded recently to serve local industrial businesses along the sides of the roadway.

In general, the existing roads have ditches on both sides and the road surface is typically about 1.5 to 2.0 metres above the adjacent ground surface. The side slopes of the existing embankment are typically about 2.5 to 3H:1V. The slopes are typically grass covered.

Due to site access constraints, the valley walls of the Oldman Creek at both south and north crossings of the proposed alignments could not be observed during Golder's site visits. However, an attempt was made to observe the nearest valley wall at the south creek crossing from the CP rail line. The creek flows northwesterly and appears to be relatively narrow meandering on the wide valley floor. Twin corrugated steel culverts were observed at the existing CP rail and creek crossings at an approximate depth of 10-15 m. Water was observed during Golder's site visit on July 2008.

Oldman Creek flows southeast-northwest at the proposed crossing locations. The valley walls were vegetated with smaller bush and/or grasses.

4.3 Subsurface Soil Conditions

Detailed descriptions of the subsurface conditions encountered in each of the boreholes drilled during this investigation are presented in the Record of Borehole Sheets provided in Appendix I.

The stratigraphic boundaries shown on the Record of Borehole Sheets represent transitions between soil types rather than distinct lithologic boundaries. It should be recognized that subsurface conditions often vary both with depth and laterally between individual borehole locations. The following is a summary of the subsurface conditions encountered at the site.

In general, the subsurface conditions encountered on site typically consisted of surficial fill or topsoil overlying clay till over dense sand and/or bedrock. Clay was encountered overlying the clay till in some of the boreholes.

Topsoil

Topsoil was encountered only in boreholes BH08-S8 and -S10 as all of the other boreholes were drilled on the road way and thus asphalt was present instead of topsoil. The topsoil layer was encountered from ground surface to a depth of approximately 0.15 m and 0.3 m below ground surface (mbgs) at BH08-S10 and –S8, respectively.

Fill

Fill was found in all of the boreholes except boreholes BH08-S8 and -S10. The fill material encountered included road structure and embankment fill. The road structure consisted of about 90 mm to 130 mm of asphalt pavement at RR231, 230 mm at RR232, and 90 mm to 240 mm in the boreholes at the RR231 and CN rail crossing.

The embankment fill consisted of clay and extended to depths of 1.0 m to 3.0 m at RR231 with greater thicknesses near the CN crossing. The thickness of fill encountered at RR232 varied between 1.0 and 2.5 m. The clay fill was generally silty, moist, and brown to grey with traces of sand, gravel, coal, and organics indicating a material similar to the local till material. The moisture content within the fill ranged from 10% to 37%. The result of one Atterberg limits test indicated the fill is silty clay. SPT ‘N’ numbers in clay fill ranged between 7 and 21 per 300 mm penetration suggesting a firm to very stiff consistency.

Clay

A silty clay to clay layer was encountered in some of the boreholes (BH08-R3, -R4; BH08-S2, and –S10) either at the ground surface (BH08-S10) or overlying the glacial till and extending to depths ranging between 2.8 m and 4.3 mbgs. The silty clay to clay was moist, brown to grayish brown in colour with traces of sand, gravel, and oxides. The moisture content of the clay deposit typically ranged from 19% to 28%. SPT N-values varied from 12 to 17 at RR231/232 and 5 to 6 at BH08-S10 indicating stiff to very stiff and firm consistency, respectively. The result of one Atterberg limit test indicated a clay deposit.

Till

RR 231(BH08-R1 through –R7 and BH08-S5/S6)

Glacial till was encountered in all of the boreholes either below the upper clay deposits or below the fill and extended to the end of the boreholes to a maximum depth of 9.6 m. The matrix of the till consists of clay, silt, and sand with traces of gravel and coal fragments. The till was generally moist and brown-grey/dark brown in colour. The moisture content of this deposit typically ranged from 15% to 20%. SPT N-values varied from 8 to 21 indicating stiff to very stiff consistency. The results of Atterberg limits indicated that the till has the plasticity of silty clay to clay.

Gradation analyses of one till sample indicated a matrix of sand, clay and silt with the following gradation limits:

- Sand: 38%;
- Silt: 36%;
- Clay: 25%; and
- Gravel: 1%

RR 232 (BH08-S1 through –S4)

Glacial till was encountered in all of these boreholes either below the clay deposits or below the fill and extended to the end of the borehole to a maximum depth of 8.1 m except for BH08-S1 where till was underlain by clay shale bedrock at a depth of 7.9 m.

The matrix of the till consists of clay, silt and sand with traces of gravel and coal fragments. The till was generally moist and typically brown in colour. The moisture content of this deposit typically ranged from 15% to 31%. SPT N-values typically varied from 8 to 22 indicating stiff to very stiff consistency. However, one N value of 4 was also measured. The results of Atterberg limits indicate till has the plasticity of silty clay to clay.

Oldman Creek Crossings (BH08-S8/S10)

Glacial till was encountered at both crossing locations below the upper clay deposits and extended to a depth of 13.7 mbgs at BH08-S8 and to the end of borehole BH08-S10, a maximum depth of 12.6 mbgs. The matrix of the till consists of clay, silt and sand with traces of gravel and coal fragments. The till was generally moist and light brown or brown to grey in colour. The moisture content of this deposit at the creek crossings typically ranged from 15% to 25%. SPT N-values varied from 10 to 28 indicating stiff to very stiff consistency. The results of Atterberg limits indicate till has the plasticity of silty clay.

Gradation analyses of two till samples indicated a matrix of sand, clay, and silt with the following gradation limits:

- Sand: 26-37%;
- Silt: 32-35%; and
- Clay: 31-39%

Table 2 below describes the results of the unconfined compressive strength for till at various depth intervals.

Table 2: Unconfined Compressive (UC) Strength Results for Till

Borehole	Sample No.	Sample Depth (mbgs)	Unconfined Compressive Strength (q_u) (kPa)	Undrained Shear Strength (S_u) (kPa)
BH08-S3	4	3.5	180	90
BH08-S6	11	8	257	128
BH08-S8	12	9	543	271
BH08-S10	8	6	288	144
Average	**--**	**--**	**317**	**136**

Silty Sand

Silty sand was encountered in boreholes BH08-S1, -S2, and –S5 at RR231/232 at a depths ranging between 5.2 mbgs and 6.9 mbgs and extended to depths ranging from 6.5 mbgs to 8 mbgs. Silty sand was also encountered at borehole BH08-S8 below the till at a depth of 13.7 mbgs and extended to a depth of about 20 mbgs. The silty sand was moist and brown in colour and contained trace amount of clay, gravel, and occasional coal laminations. The moisture content of silty sand deposit typically ranged from 5% to 22%. SPT N-values varied from 30 to 46 indicating dense material.

Bedrock

Bedrock was encountered in boreholes BH08-R5, BH08-S1, and -S4 underlying till at RR231/232 at depths ranging from 4.6 to 8 mbgs and at BH08-S8 at a depth of about 20 mbgs. The clay shales enountered at BH08-S4 is possibly rafted bedrock within the glacial till deposit; however, bedrock at other two borehole locations at RR231/232 could not be verified as borehole was terminated immediately. In general, the bedrock underlying the soils encountered in the boreholes consisted of clay shales. SPT N-values ranged between 26 and 41 per 300 mm penetration.

4.4 Ground Water Conditions

Standpipes were installed in all of the boreholes except for BH08-R1 through –R7a to allow for monitoring of groundwater levels. In addition, groundwater levels in the boreholes where seepage was noted were measured by Golder upon completion of borehole drilling and prior to backfilling of the boreholes. The levels are included on the Record of Borehole Sheets in Appendix I.

The groundwater level in each standpipe was measured once upon completion of drilling between December 19 and December 23, 2008 and again on February 4, 2009. Table 2 shows the summary of groundwater measurements at different locations on the site. Based on the measurements shown in Table 3, the ground water level varied between 4 mbgs and 7 mbgs at RR232 and about 5 mbgs at RR231 and CN rail crossing. At the Oldman Creek crossings, the groundwater level is higher at the south crossing indicating northerly direction of creek flow. Groundwater levels are expected to vary seasonally and with precipitation and run-off conditions.

It is recommended that the existing standpipes be left in place, if possible, in order that they may be read again during the detailed design phase. Water levels should also be read prior to the start of construction.

Table 3: Measured Groundwater Levels

Zone	Borehole No. (BH08-)	Borehole Depth (mbgs)	Tip Depth (mbgs)	Groundwater Level Depth (mbgs)	
				Dec 12 – 23/08	Feb 4/09
Oldman Creek Crossing (South of TWP RD 534)	S10	12.7	12.2	Dry	9.9
Oldman Creek Crossing (North of TWP RD 534)	S8	22.7	19.1	18	17.2
RR 231 and CN Rail Crossing	S5	9.6	9	Dry	5
	S6	9.6	9	Dry	5.2
RR 232 and CN Rail Crossing	S1	8.1	7.7	Dry	4.5
	S2	8.1	7.5	Dry	6.6
RR 232 and CP Rail Crossing	S3	8.1	7.5	Dry	6.9
	S4	7.6	7.6	6.1	3.8

5.0 DISCUSSION AND GEOTECHNICAL RECOMMENDATIONS

It is noted that the recommendations provided in this report are intended as a guideline for design and are made without the benefit of preliminary design details, grading requirements and topographic survey data. Where comments are made on the general site conditions and construction, they are provided to highlight aspects that could affect the design of the project. Parties requiring information on aspects of the site beyond the scope of this report must make their own interpretation of the subsurface information provided as it affects their proposed construction methods, costs, equipment selection, scheduling and the like.

5.1 Geotechnical Parameters

The soils encountered during the drilling investigation at this site are fairly uniform and can be divided into two main soil types for the purposes of providing recommended geotechnical parameters: the stiff to very stiff till and the lower dense silty sand. Some embedded silty sand deposits with varying thickness were encountered in the clay till.

Due to the size of the project and scatter of boreholes drilled, the project site is divided into a number of zones for discussion and recommendations purposes. Four different zones are identified based on the preliminary project information, namely (1) RR231; (2) RR232; (3) South Creek (Oldman) Crossing; and (4) North Creek Crossing.

Recommended unfactored soil parameters for geotechnical design purposes are presented in Table 4.

Table 4: Recommended (Unfactored) Geotechnical Strength Parameters

Zone	Soil Type	Unit Weight [(1)] (kN/m^3)	Undrained Shear Strength Su (kPa)[(2)]	Effective Friction Angle[(2)] (°)	Effective Cohesion[(2)] (kPa)
RR231 (BH08-S5/S6)	Till	19	90	n/a	n/a
RR232 (BH08-S1 through –S4)	Till	19	70	n/a	n/a
	Silty Sand	21	-	32	0
South Creek Crossing (BH08-S10)	Till	19	100	n/a	n/a
North Creek Crossing (BH08-S8)	Till	19	120	n/a	n/a
	Silty Sand	21	-	32	0

Notes:

(1) Based on visual observation of soil conditions encountered during investigation, laboratory test results, Golder's experience and previous testing on similar soils.

(2) Based on visual observation of the soil conditions, results of in-situ and laboratory testing, as well as previous experience with similar materials.

5.2 Foundations

Driven steel piles and drilled cast-in-place concrete caissons are possible suitable deep foundation elements for the proposed bridge abutment and piers, respectively.

Steel H-piles or pipe piles should be driven through the till and into the underlying dense sand and/or bedrock, if encountered, to practical refusal.

Either straight shaft or belled drilled cast-in-place concrete caissons may be founded within the till and the bedrock, if encountered, at this site. However, construction difficulties (i.e. controlling side wall slough and potential base heave, groundwater seepage, etc.) are expected from the sand encountered during drilling. Temporary steel casing may be required to facilitate proper placement of concrete and caisson installations. Cast-in-place belled piles should be extended into the till or bedrock if sand is encountered at pile tip.

It is suggested that steel piles (pipe or H-pile) be driven to practical refusal. Pile set criteria during driving should be developed by Golder prior to construction. It is noted that steel piles in the range of 300 mm to 400 mm width or diameter typically develop working loads of about 1,200 kN when driven to practical refusal.

Based on the results of the boreholes, it is anticipated that piles would likely encounter practical refusal to driving either within the silty sand or bedrock with an embedment depth of about 2 m to 3 m (if they penetrate the silty sand).

Piles would need to have an embedment depth of at least 7 m to adequately resist uplift (jacking) forces from frost action.

Where frost jacking and transient uplift loads (such as wind loading) occur simultaneously, these two loads need not be considered together; the larger of the two should be used.

5.2.1 Axial Compression Resistance of Pile Foundations

Based on the site investigation, laboratory testing and the proposed overall development, the axial compression resistance of pile foundation recommendations have been divided into four cases representing different geotechnical models and corresponding expected behaviour of pile foundation elements constructed within the currently proposed development areas:

- Case 1 represents the rail overpass at RR231 and CN rail crossing
- Case 2 represents the two rail overpasses at RR232
- Case 3 represents the South Creek Crossing Area
- Case 4 represents the North Creek Crossing Area

Further investigation will be required during detailed design phase to delineate the soil conditions. Furthermore, boreholes at other side of each creek crossing were not drilled at this time due to access issues and therefore, recommendations at creek crossing locations should be reviewed and confirmed during the detailed design.

Tables 5 and 6 present ultimate skin friction and end-bearing values, respectively, for the general cases presented above. These capacities must be factored for use during design, based on a geotechnical resistance factor (ϕ) of 0.4 at ultimate limit states (ULS) for axial compression loading. For uplift, the geotechnical resistance factor (ϕ) at ULS is 0.3.

Table 5: **Recommended Average Ultimate Skin Friction and End Bearing Design Parameters forCast-in-Place (Bored) Concrete Piles**

Case	Soil Type	Skin Friction (kPa)	End Bearing (kPa)
1	Till	50	800
2	Till	50	700
	Lower Silty Sand*	60	Not recommended
3	Till	50	800
4	Till	50	1000
	Lower Silty Sand**	60	Not recommended

* Assumed 6 mbgs, if encountered ** Assumed 12 mbgs

Table 6: **Recommended Average Ultimate Skin Friction and End Bearing Design Parameters for Driven Steel Pipe Piles**

Case	Soil Type	Skin Friction (kPa)	End Bearing (kPa)
1	Till	50	800
2	Till	50	700
	Lower Silty Sand*	60	1000
3	Till	50	800
4	Till	50	1000
	Lower Silty Sand**	60	1000

* Assumed 6 mbgs, if encountered ** Assumed 12 mbgs

The resistance along the top 2 m of the pile shaft should be ignored due to potential construction disturbance during pile installation (pile whip) for driven steel pipes. For normal driving conditions for open-ended pipe piles, it has been assumed that a soil plug will form at the end of the pile and resistance from the pile tip has been included in the design. This is also applicable if a driving shoe is used at the end of the pile. Similarly, for H-piles it is assumed that a soil plug will form so that the calculations for shaft area and end bearing area can be based on a rectangular (square) section.

For dynamic loading conditions, the values provided in Tables 5 and 6 above should be divided by a factor of two.

The above pile design parameters and values have been derived using conservative estimates of groundwater levels. They are intended to be average values for use in design. The pile parameters for the till and sand deposits are sensitive to assumptions made regarding the groundwater level and the extent of the soil deposits. It is recommended that detailed geotechnical investigation be carried out to confirm the assumptions made in deriving the above parameters and axial resistances.

For axial loading considerations, piles spaced at 2.5 pile diameters (center-to-center) can be assumed for design purposes to act as single piles, with no group interaction effects with regards to axial resistance (settlement of pile groups is dealt with in Section 5.2.2 below). For piles spaced at less than 2.5 diameters, the pile axial resistance should be reduced by a group reduction factor. For design, these group reduction factors may be approximated as:

1.0 for piles at spacing of 2.5 diameters

0.7 for piles at spacing of 1.5 diameters

0.55 for piles at spacing of 1.25 diameters

Reduction factors for other pile spacing may be interpolated from the values above.

For a large number of piles, consideration should be given to carrying out Pile Driving Analysis (PDA) testing of driven piles and potentially for smaller diameter concrete cast-in-place piles. Through pile load testing or PDA testing during driving, it may be justifiable to reduce the factor of safety due to reduced uncertainties related to pile design and estimation of pile design parameters. Golder would be pleased to provide additional assistance related to the costs/benefits of PDA testing.

5.2.2 Pile Settlements

5.2.2.1 Settlement of Single Piles

In addition to confirming the overall axial resistance of the pile, the pile should be designed such that the settlements under sustained working loads are tolerable. Settlement of piles will be due to a combination of short-term (or immediate) settlement of clayey and sandy soils and time dependent consolidation settlement of clayey soils. The clay and sand deposits are considered to be over-consolidated and are expected to have relatively good load-settlement characteristics.

For the envisaged foundation loadings, settlement problems are not expected for piles bearing on the competent till deposit However, detailed settlement analysis should be carried out once the layout of the structure, the foundation loading conditions and structural design are known in more detail.

It should also be noted that pile settlements depend upon construction technique, quality of construction, pile type and the final detailed design of the pile, as well as soil properties.

5.2.2.2 Settlement of Pile Groups

It is noted that the above does not consider the influence of adjacent piles (group effects), which undergo larger settlement compared to single pile. The design of pile groups may be governed by serviceability considerations and further analysis will be required. Group effects should be incorporated into the design as the foundation details and layout are developed.

Where closely spaced pile groups are used, the stresses beneath the piles tend to overlap within the soil. Settlements would be expected to increase due to the effects of overlapping stresses at depth.

5.2.3 Laterally Loaded Piles

The coefficient of horizontal subgrade reaction may be estimated using relationships referenced in the CFEM (3rd Edition, 1992) as follows:

Cohesive Soils:

$$k_s = \frac{67 \times s_u}{D}$$

Cohesionless Soils:

$$k_s = n_h \frac{z}{D}$$

Where s_u is the undrained shear strength of the soil (for design use appropriate values from Table 3 for till), z = depth below top of ground, D is the pile diameter and n_h is equal to approximately 6 MPa/m for compact granular fill.

Group interaction effects should be considered when the pile spacing in the direction of the applied loading is less than 8 pile diameters for all piles in the line of applied loading. For pile spacing of 3 times the pile diameter or less, a subgrade reduction factor of 0.25 should be applied to these subgrade modulus values. For pile spacing of 4 and 6 times the pile diameter, the reduction factors become 0.4 and 0.7, respectively. For pile spacing of 8 times the pile diameter and higher, no reduction factor is required (i.e. the factor is 1.0). These reduction factors should be applied to all piles within the group, with the exception of the lead (first) piles, where no reduction factor is required. Group interaction effects should be applied to both the subgrade modulus values and the serviceability lateral resistances aspects. For example, the group reduction factor for 3 piles in the direction of loading and spaced at 3 pile diameters is 0.5.

5.2.4 Pile Construction Considerations

5.2.4.1 Driven Steel Piles

Pre-drilling and Pile Tip Protection

Based on the subsurface conditions encountered during drilling, no pre-drilling for driven steel piles is required for this site.

5.2.4.2 Bored Cast-in-Place Concrete Piles

Due to the variation in the elevation and thickness of the silty sand layer, a temporary steel liner will be required for caisson installations extending beyond the bottom of the sand layer.

It should be noted that the recommended axial geotechnical resistances for caissons assume that the base of the caisson is free of loose or softened soil, and that the concrete can be placed in dry conditions. The piling contractor should be prepared to remove loose or wet material from the base prior to placing the concrete.

5.2.4.3 Pile Installation Monitoring and PDA Testing

The pile parameters and settlement estimates provided in the preceding sections assume quality pile construction practices. In addition, soil conditions can vary between boreholes both in terms of stratigraphy and material properties. It is recommended that the installation of pile foundations be inspected by a geotechnical engineer to confirm that the conditions encountered during construction are similar to those anticipated in developing the geotechnical recommendations and pile design. Consideration should be given to performing PDA and PIT testing as appropriate, as discussed previously.

5.2.4.4 General

The integrity of the pile installation should be field verified by a structured engineer and an experienced geotechnical engineer during installation to ensure that it can adequately support the loads.

The axial resistance from the top 2 m of the pile shaft is typically ignored due to potential construction induced ground disturbance during pile installation and subsequent effects of freeze/ thaw and wetting/drying cycles. Thus, excavation around an installed pile should be limited to 2 m below final ground surface. For lateral pile resistance, a significant portion of the lateral resistance is typically developed with in the upper 4 m to 6 m of the pile.

It is recommended that gaps that may be formed during construction be filled with lean or low strength concrete or dry sand. Excavating around an installed pile is not recommended without careful consideration of the potential reduction in lateral resistance.

5.3 Abutment Headslopes

Based on our site visits and subsurface conditions encountered during drilling, a headslope angle of 2.5H:1V is feasible at the creek crossings. However, a non-mechanically stabilized headslope should be no steeper than 2H:1V if constructed out of compacted till. Alternatively, the headslope can be mechanically stabilized at a slope angle of 2H:1V or steeper, such as reinforcement by geogrid or geotextile.

Detail slope stability analysis will be required to establish proper slope angle once the configuration of the headslope is known.

5.4 Approach Fill

5.4.1 Surface Preparation

All topsoil, organic soils (if encountered) and soft or disturbed soil should be removed from below the embankment fills prior to construction. Care should be taken not to disturb the subgrade during stripping and subgrade preparation. Disturbed subgrade should be scarified and recompacted to 95% Standard Proctor Maximum Dry Density (ASTM D – 698). If necessary, a woven geotextile may be paced over the excavated subgrade prior to subsequent fill placement.

5.4.2 Embankment Side Slopes

Based on our site visits and subsurface conditions encountered during drilling, a side slope angle of 3H:1V is feasible for approach embankment at this site constructed using low plastic clay or till placed and compacted at Strathcona County standards. Detailed slope stability analysis will be required to establish final embankment slope angles once the final configuration of the embankment is known.

5.4.3 Settlements

The near surface till should have good load-settlement characteristics and therefore, excessive long-term settlement should not be an issue at this site. However, it is recommended that settlement analysis be carried out for high fill locations with proper settlement parameters obtained from laboratory testing (consolidation) once the final configuration of the embankment is known.

5.4.4 Embankment Construction and Monitoring

Borrow sources for the embankment fills have not been identified at the time of preparing this report. However, the following general guidelines are provided for fill construction.

- Strathcona County guidelines for roadway construction requires fill to be placed in lifts of 150 mm compacted thickness and compacted to 95% of SPMDD with the exception of the top 300 mm of the subgrade which is to be compacted to 100% of SPMDD.
- The side slopes of the approach embankment should be promptly covered with salvaged topsoil and organic soil and seeded to promote quick grass cover to reduce the risk of surface erosion.
- Erosion protection for the head slopes should be assessed based on the potential for erosion requirements etc. Riprap protection armour may be required along the toe of headslopes below the groundwater level. Further assessment will be required.

All work should be carried out in accordance with the requirements outlined in the latest edition of Strathcona County's Standard Specifications.

Based on the preliminary design information and subsoil and groundwater conditions encountered during the preliminary investigation, the embankment for the overpasses could be built in one stage without difficulty; instrumentation and monitoring are recommended during construction to confirm the generation of construction induced pore water pressures that may affect the global stability of high fills.

5.5 Culverts

5.5.1 General

As mentioned previously, detailed design information is not available at this time regarding the possible culvert option at either of the creek crossings. However, it is understood that a 4 × 6 m diameter SPCSP culvert is being considered at south creek crossing as an alternative to a bridge overpass. An 8 m diameter SPCSP culvert is being considered at north creek crossing.

No boreholes were drilled on the south of either crossing due to access problems mentioned previously. The following recommendations are based on the information from the single borehole at each crossing location. The following recommendations may need to be revised if further borehole drilling is undertaken.

5.5.2 Corrosion Resistance

Resistivity and pH tests were performed on a soil sample from the south creek crossing location in order to estimate corrosion potential for galvanized steel culvert. The results are presented in Table 7.

Table 7: Resistivity and pH Testing Results (South Creek Crossing)

Bore Hole	Sample Location	Soil Type	Moisture Content (%)	Resistivity (Ohm-cm)	pH
BH08-S10	9.1 m to 9.9 m	Till	15	400	7.8

5.5.3 Erosion Control

Suitable size riprap should be placed at the culvert inlet and outlet to protect the embankment slopes from toe erosion by the creek and scour at the culvert ends. In addition, the side slopes should be covered with topsoil and seeded immediately after construction to reduce the potential for surface erosion by runoff. It is understood that detailed design of erosion protection will be undertaken by others.

5.6 Roadway

It is understood that the material required to construct the new road surface will be obtained from borrow locations located adjacent to the alignment. Based on the field drilling investigation along existing RR231, the subsurface soils typically consist of highly plastic clay and till soils. The clay and till are generally suitable for roadway construction. Organics, if encountered, should not be used for raising grade to support pavement structures.

All work should be carried out in accordance with the requirements outlined in the latest edition of Strathcona County’s Standard Specifications.

5.6.1 Cut and Fill Construction

If sand is used for embankment fill, it is recommended that the sand be used in the base of the roadway embankment up to about 0.6 m below subgrade. The sand, if silty, is expected to have a low resistance to erosion, will be moderately to highly frost susceptible and may be difficult to compact depending on its moisture content. A clay cap about 0.6 m thick should be placed in the upper portion of the embankment above the sand to reduce frost susceptibility and increase erosion resistance characteristics. Where clay is not available, well graded gravel may be used which will provide more erosion resistance than the sand.

Strathcona County's guidelines for roadway construction typically requires fill to be placed in lifts of 150 mm compacted thickness and compacted to 95% of SPMDD with the exception of the top 300 mm of the subgrade which is to be compacted to 100% of SPMDD.

The finished top of subgrade should be trimmed smooth and provided with a minimum cross fall of 2% to shed surface water towards the side ditches prior to placing surface gravel.

5.6.2 Frost Design

The clay and till encountered during the investigation are moderately to highly frost susceptible. However, groundwater levels are expected to be relatively deep. Consequently, frost heaving is not expected to occur in the new grade using the proposed materials as access to water may not be available.

5.6.3 Pavement Structure

For preliminary design purposes, it is assumed that the proposed section will be a 4 to 6 lane divided urban arterial roadway.

Corrected equivalent Beam deflection = 2.6 mm
AADT= 40,000 (Designed Daily by Stantec)
% TB= 10%
% TBDL= 45%
TF Arterial= 0.83
ITN= 1645
DTN= 1645
Total design ESALS (20 years) = 9.8x 10^6

For new roadways, a minimum of 365 mm asphalt concrete thickness (or 200 mm asphalt concrete, 350 mm gravel base) would be required for preliminary design purposes provided subgrade is prepared according to the recommendations included in this report. Asphalt concrete should be compacted to the City of Edmonton specifications (AC 98%, 75 below Marshall Density) or equivalent.

The pavement subgrade should be properly prepared and proof rolled in order to detect any soft spots prior to pavement construction. The top 300 mm of the clayfill maybe scarified and recompacted to 100% SPMDD. Due to similar soil conditions along RR 232, similar pavement structure may apply for preliminary purposes. It should be noted that RR 232 appears to have been upgraded to industrial standards. Little information was available for proposed new alignments. Further investigation is required.

5.7 Cement Type

Water-soluble sulphate tests were carried out on select samples taken during the field investigation. The results of testing are presented in Table 8.

Table 8: Water-Soluble Sulphate Test Results

Borehole	Sample #	Depth (m)	Sulphate (%)
BH08-S2	SS 4	3	0.025%
BH08-S4	SS 6	5	0.028%
BH08-S5	AS 6	4.5	0.54%
BH08-S6	AS 12	8.5	0.53%
BH08-S8	AS 17	13.2	0.28%
BH08-S10	AS 15	11.5	0.22%

Based on the results of these tests, the level of water-soluble sulphate within the native soil varies across the site and is greater than 0.5% at RR231, greater than 0.2% at creek crossing locations, and less than 0.1% at RR232. Based on these results, the level of sulphate exposure is considered to be severe at proposed overpass at RR231 and at creek crossing locations (CSA exposure class “S-2”); therefore, cement Type HS (high sulphate-resistant hydraulic cement) with maximum water: cementing materials ratio of 0.45 should be used for concrete structures that are in contact with the soil at these locations. However, water-soluble sulphate in soil samples at the proposed overpasses at RR232 is normal and thus, CSA Type GU (General Use hydraulic cement, old CSA Type 10) may be used in the subsurface concrete at this location. The results of the sulphate tests are presented on the individual test hole logs in Appendix I.

Any imported soils should be tested for compatibility with the proposed cement type.

6.0 CLOSURE

This report was prepared in accordance with generally accepted soil mechanics and foundation engineering practice. The recommendations presented herein are based on a preliminary geotechnical evaluation of the findings of this investigation. Further investigation is recommended for detailed design. If conditions other than those reported herein are noted during subsequent phases of the project, we require that we be notified to permit reassessment of our initial recommendations. It is also recommended that Golder be permitted to review the final foundation and site preparation design to assess whether it is in keeping with the intent of the geotechnical recommendations contained in this report, as well as the assumptions on which they have been based.

We trust that the information presented in this report meets your present requirements. If you have any questions, please contact the undersigned at your convenience.

Yours very truly,

GOLDER ASSOCIATES LTD.
APEGGA Permit to Practice P5122

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CE/JC/JHAC/jt

7.0 IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

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The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, and safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

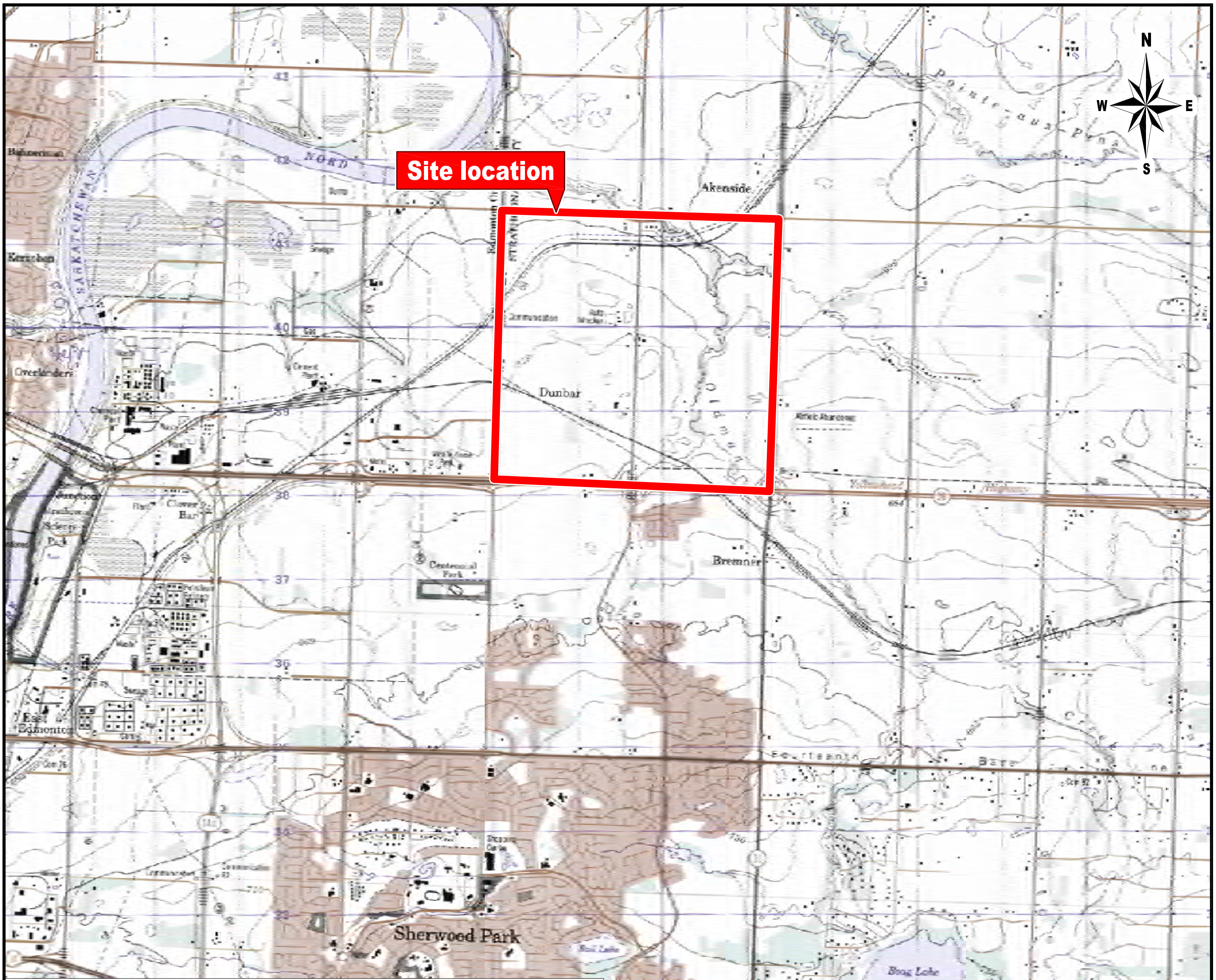
Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

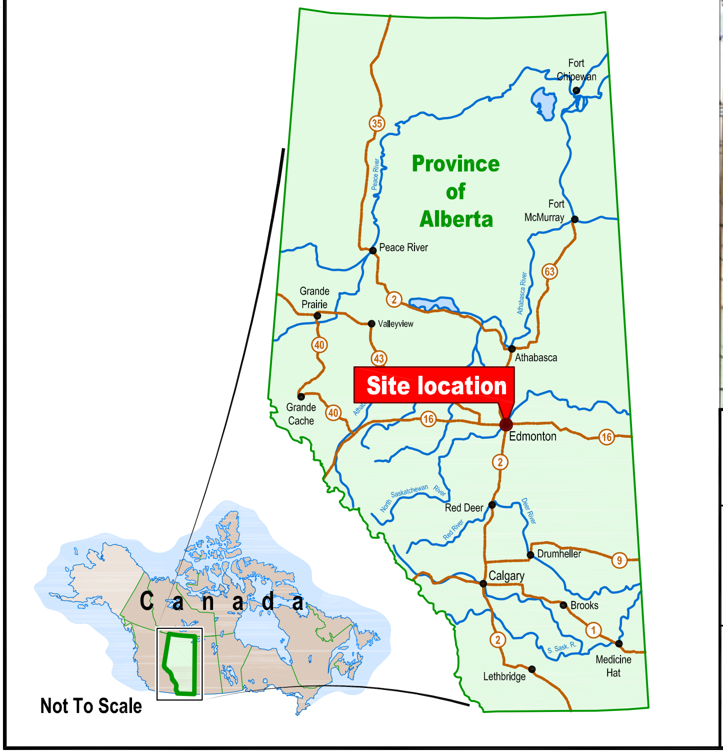
Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

FIGURES



Reference: **ETopo Maps - Leduc** (83H05), **Cooking Lake** (83H06),
Edmonton (83H11), **St. Albert** (83H12)



Not To Scale

Stantec

Yellowhead North Arterial Road
Functional Design Study

Title

Site Location Plan

Project No.		07.1377.0128	File No.	1733017	
Design	MK	23/12/2008	Scale	As shown	Rev. 0
Cadd	RW	23/12/2008			
Check	AHSW	09/02/2009			
Review	JC	10/02/2009			

Golder Associates
Edmonton, Alberta

Figure: **1**

Feb 17, 2009 (Tue 3:45 PM)

Images used: 83H05 (colour adjusted).png - 83H06 (colour adjusted).png - 83H11 (colour adjusted).png - 83H12 (colour adjusted).png -
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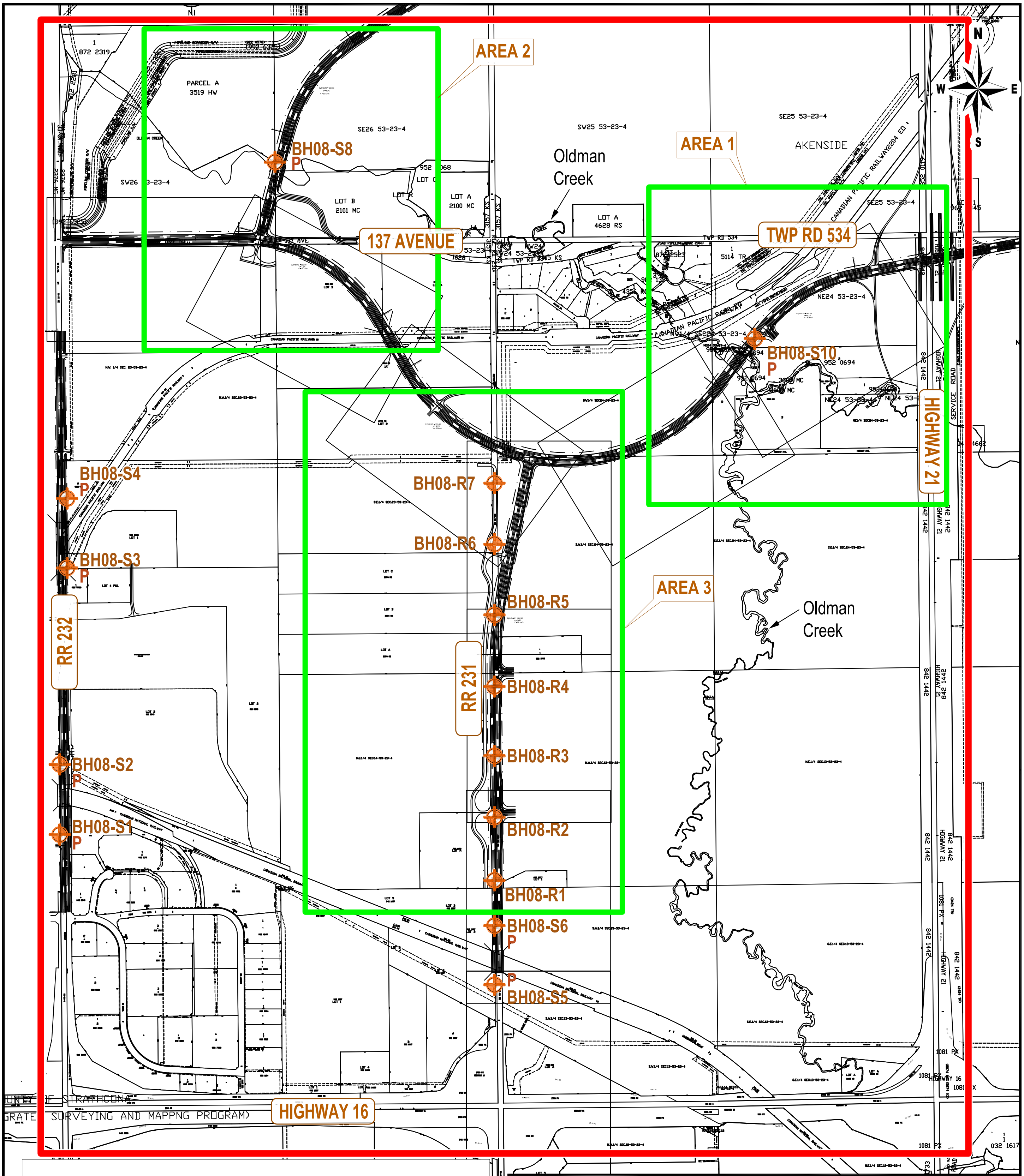

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Apr 23, 2009 (Thu 10:05 am) Yellowhead North Road Design, Edmonton\4000\02 - 1733100 boreholeLocations.dwg

Drawing path and name: N:\CAD\2007\1377\0128

Images used: edmonton_06.jpg -

LEGEND

🟥	Site boundary
🟩	Area boundary (see Figure 3 for details)
⊕	Approximate borehole location
P	Standpipe piezometer installed

500 0 500

Scale: Metres

Stantec

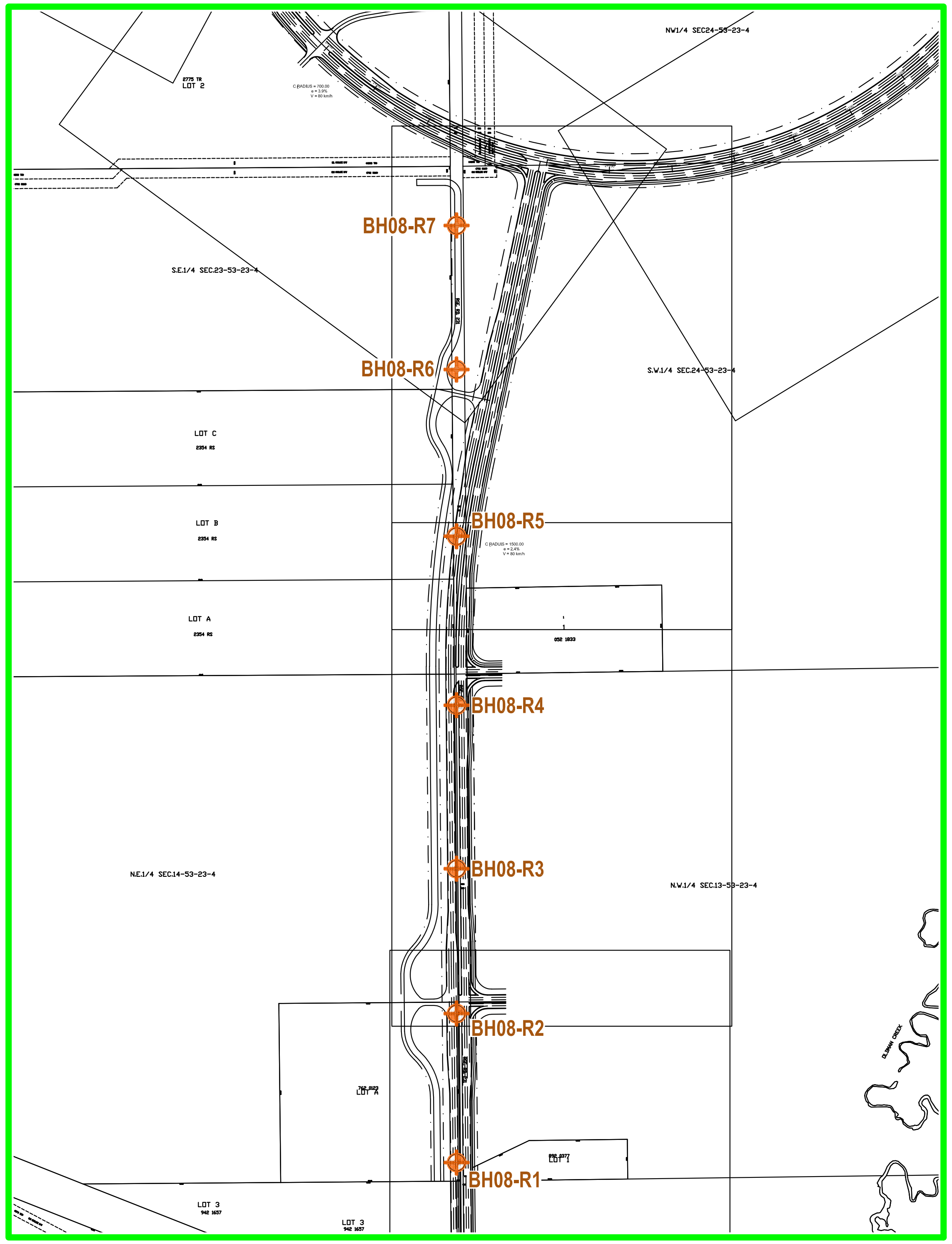
Yellowhead North Arterial Road
Functional Design Study

Title

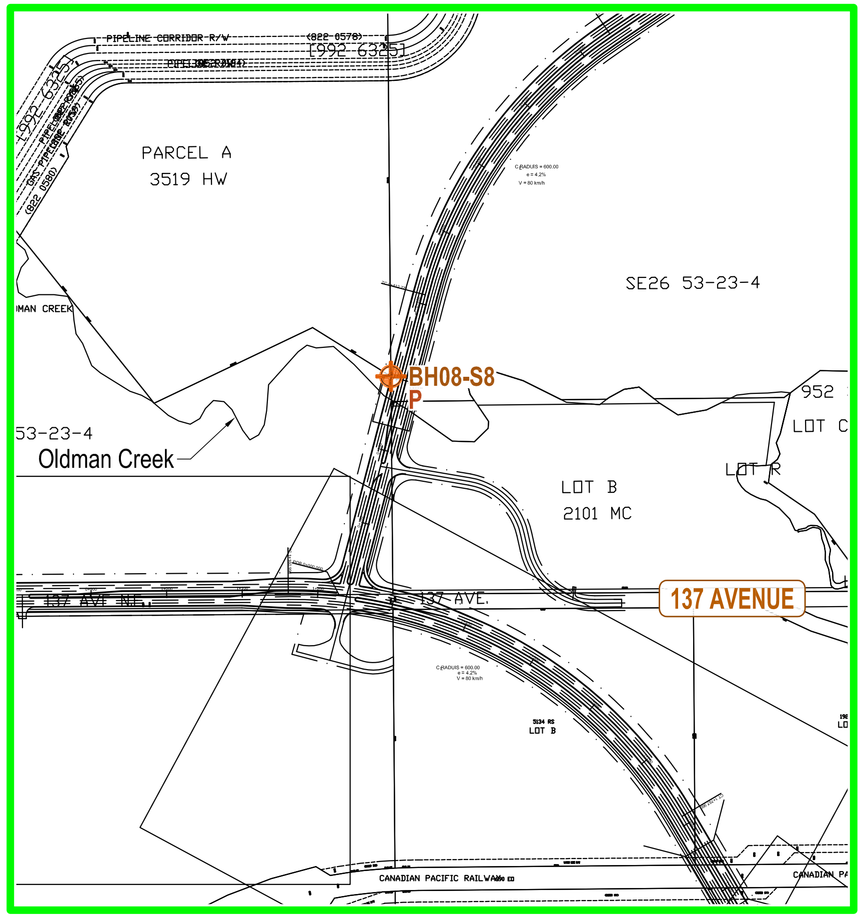
Borehole Location Plan

Golder Associates
Edmonton, Alberta

Project No.		07.1377.0128	File No.	1733100	
Design	MK	19/01/2009	Scale	As shown	Rev. 1
Cadd	DS	19/01/2009			
Check	AHSW	09/02/2009	Figure: 2		
Review	JC	10/02/2009			

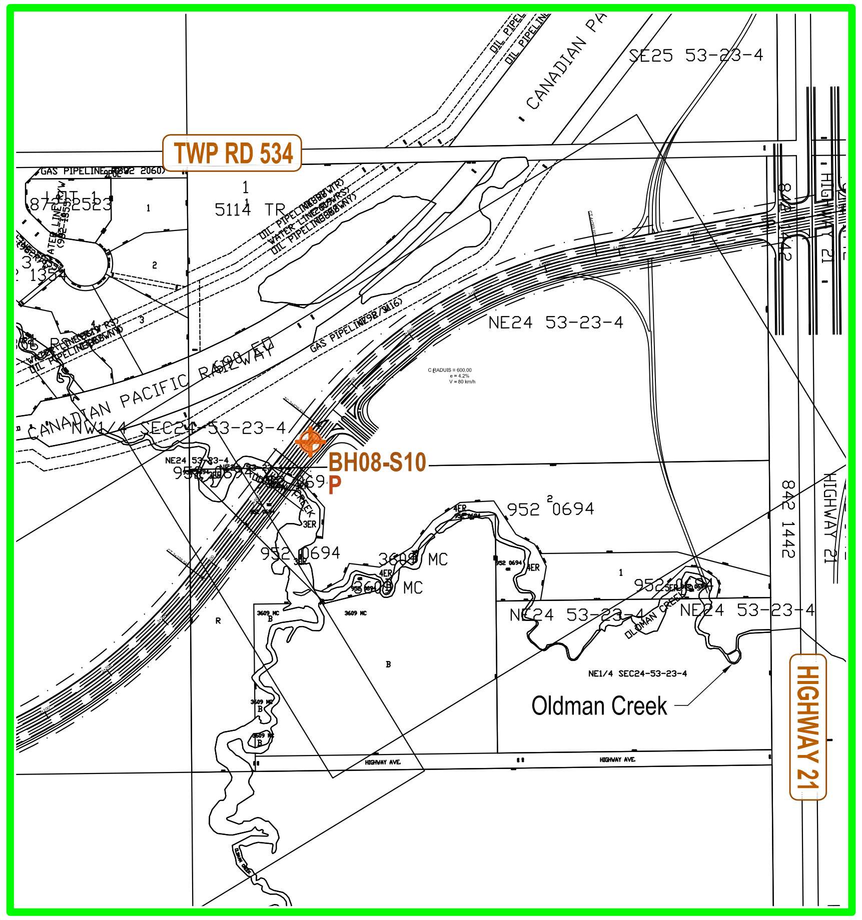


Area 3



Area 2

Oldman Creek Crossing (north of TWP RD 534 / 137 Avenue)



Area 1

Oldman Creek Crossing (south of TWP RD 534)

N
W E
S

LEGEND

🟩	Area boundary (see Figure 2)
⌖	Approximate borehole location
P	Standpipe piezometer installed

200 0 200

Scale: Metres

Stantec

Yellowhead North Arterial Road
Functional Design Study

Title

Proposed Widening/Re-alignment along RR 231 New Alignment at Oldman Creek Crossings

Golder Associates
Edmonton, Alberta

Project No.		07.1377.0128	File No.	1733118
Design	MK	30/01/2009	Scale As shown	Rev. 1
Cadd	DS	02/02/2009	Figure: 3	
Check	AHSW	09/02/2009		
Review	JC	10/02/2009		

Drawing path and name: N:\CAD\2007\1377\0128 Yellowhead North Road Design, Edmonton\4000\03 - 1733118.dwg Apr 23, 2009 (Thu 10:06 am) Copyright © 2009 Golder Associates Ltd.

APPENDIX I

GA List Abbreviations and Symbols
GA Soil Classification System
Record of Borehole Logs

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60º cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

Consistency	c_u,s_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

S:\FINALDAT\ABBREV\2000\LOFA-D00.DOC

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. General

π	3.1416
ln x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\ \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
v	poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma$-u)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1+\sigma_2+\sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_{w)}$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_1	liquid limit
w_p	plastic limit
I_p	plasticity index = $(w_1 - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p)/I_p$
I_C	consistency index = $(w_1 - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
OCR	over-consolidation ratio = σ'_p/σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c'	effective cohesion
c_u,s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 + \sigma_3)/2$ or $(\sigma'_1 + \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 + \sigma_3)$
S_t	sensitivity

Notes: 1 $\tau = c' + \sigma' \tan \phi'$

2 shear strength = (compressive strength)/2

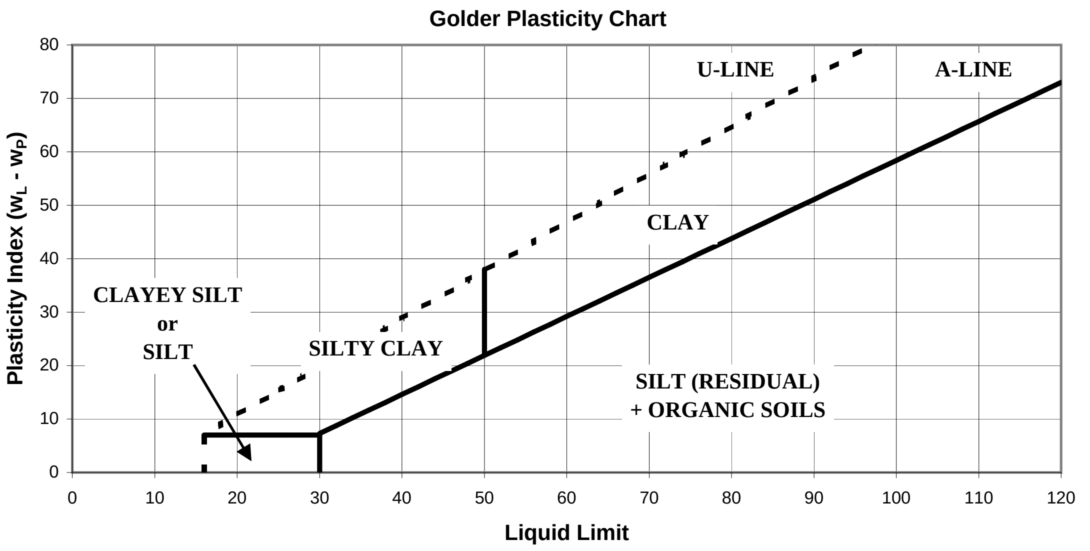
* density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

Golder Associates Soil Classification System

Step 1	**Step 2**	**Step 3**				**Step 4**	
		Define Primary Constituent				**Define Secondary / Minor Constituents**	
Organic/ Inorganic	**Determination of Behaviour**	**Criteria**			**Major Constituent**	**Percent by Mass**	**Modifiers**
			Particle Size Range **mm**	**USS Sieve**			
Inorganic <5% Organics	**Cobbles and Boulders**		> 300	> 12"	**BOULDER**	"contains"	
			300 - 75	12" - 3"	**COBBLE**		
	Cohesionless Soil (based on field assessment of plasticity, toughness and dry strength)	%Gravel > %Sand > %Silt	75 - 4.75 75 - 19 19 - 4.75	3" - #4 3" - 0.75" 0.75" - #4	**GRAVEL** Coarse Fine	> 30% 20% - 30% 12 - 20% 5 - 12% 0 - 5%	"and" (cohesionless) "with" (cohesive) (-ey) or (-y) Some Little Trace
		%Sand > %Gravel > %Silt	4.75 - 0.075 4.75 - 2.0 2.0 - 0.425 0.425 - 0.075	#4 - #200 #4 - #10 #10 - #40 #40 - #200	**SAND** Coarse Medium Fine		
		%Silt > %Gravel > %Sand	< 0.075	< #200	**SILT** Non-plastic		
	Cohesive Soil (based on field assessment of plasticity, toughness and dry strength)	**Plasticity (Atterberg Limits)**				> 30% 20% - 30% 12 - 20% 5 - 12% 0 - 5%	"with" *(cohesionless)* (-ey) or (-y) Some Little Trace
		Below A-Line LL < 30			**CLAYEY SILT**		
		Above A-Line LL < 50			**SILTY CLAY**		
		Above A-Line LL > 50			**CLAY**		
Organic > 5% Organics		**Organic Content**	**Appearance**				
	Organic Matter	75% to 100%	woody, mats, fibres, *etc.*		**FIBROUS PEAT**		
			amorphous		**FINE GRAINED PEAT**		
	Highly Organic Soils	30% to 75%	spongy		**SILTY PEAT**		
			visible sand		**SANDY PEAT**		
	Organic Soils	5% to 30%	tough thread		**ORGANIC CLAYEY SILT**		
			weak or no thread		**ORGANIC SAND OR SILT**		

Soil Description

relative density/consistency, structure, field moisture condition, colour, odour, shape/angularity, (minor)-*y* (PRIMARY CONSTITUENT), *and/with** (SECONDARY CONSTITUENT), *modifier* (minor constituents), *contains* (cobbles, boulders, debris, *etc*.)
(GEOLOGIC FORMATION) *eg.* (TILL)



PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-R1

SHEET 1 OF 1

LOCATION: See Location Plan

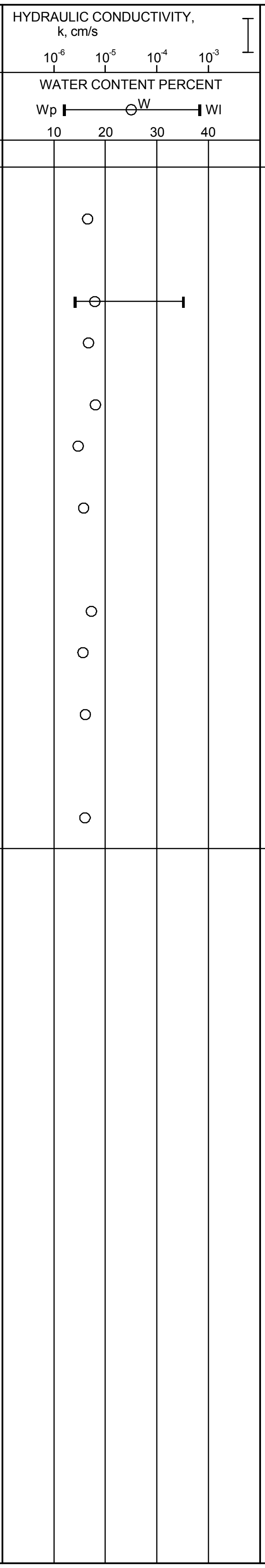
BORING DATE: December 22, 2008

DATUM: Local

BORING METHOD: Solid Stem Auger
Canadian Geological Drilling Ltd.

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
Ground Surface	
ASPHALT	
Stiff to very stiff, moist, brown to grey, SILTY CLAY,some sand (FILL)	0.09
... trace gravel, organics	
Stiff, dry, brown, SILTY CLAY, trace to little sand, trace gravel (TILL)	1.49
... sand pockets / lenses	
... coal, oxidation	
... sand pocket	
End of BOREHOLE. Dry upon completion. Frozen to 0.91m below ground. Backfilled with cuttings and asphalt patch.	5.03

SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
1a	AS		
1	SS	15	I_p = 21
1b	AS		
2	SS	13	
2a	AS		
3	SS	8	
4	SS	13	
4a	AS		
5	SS	12	
6	SS	10	



DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: EP

CHECKED: MK

DATA ENTRY: JPH

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-R2

SHEET 1 OF 1

LOCATION: See Location Plan

N: 5939207.0 E: 349665.0

BORING DATE: December 22, 2008

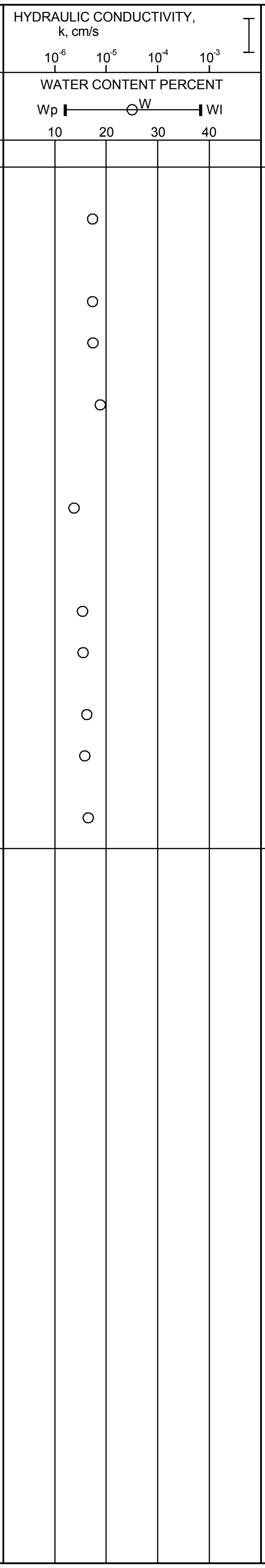
DATUM: Local

BORING METHOD: Solid Stem Auger, Canadian Geological Drilling Ltd.

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m
0	Ground Surface				
	ASPHALT				
	Moist, grey, SILTY CLAY (FILL)	0.09	1a	AS	
	Firm, moist, brown, SILTY CLAY, some sand , trace gravel (FILL)	0.61			
1			1	SS	8
			1b	AS	
	Firm, moist, brown with grey, SILTY CLAY, some sand, trace gravel, coal, oxidation (TILL)	1.52	2	SS	8
2	... becoming very stiff, trace roots		3	SS	18
3			4	SS	12
	... silt lenses, becoming with SAND		4a	AS	
4			5	SS	11
			5a	AS	
	... sand lenses		6	SS	13
5	End of BOREHOLE. Dry upon completion. Frost to 0.91m below ground. Backfilled with cuttings and asphalt patch.	5.03			
6					
7					
8					
9					
10					

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○: 20 40 60 80



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

BOREHOLE - EXPANDED ADD. LAB TESTING 07-1377-0128 YHN BH RECORDS.GPJ GLDR_CAN.GDT 4/28/09

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: EP

CHECKED: MK

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-R3

SHEET 1 OF 1

LOCATION: See Location Plan

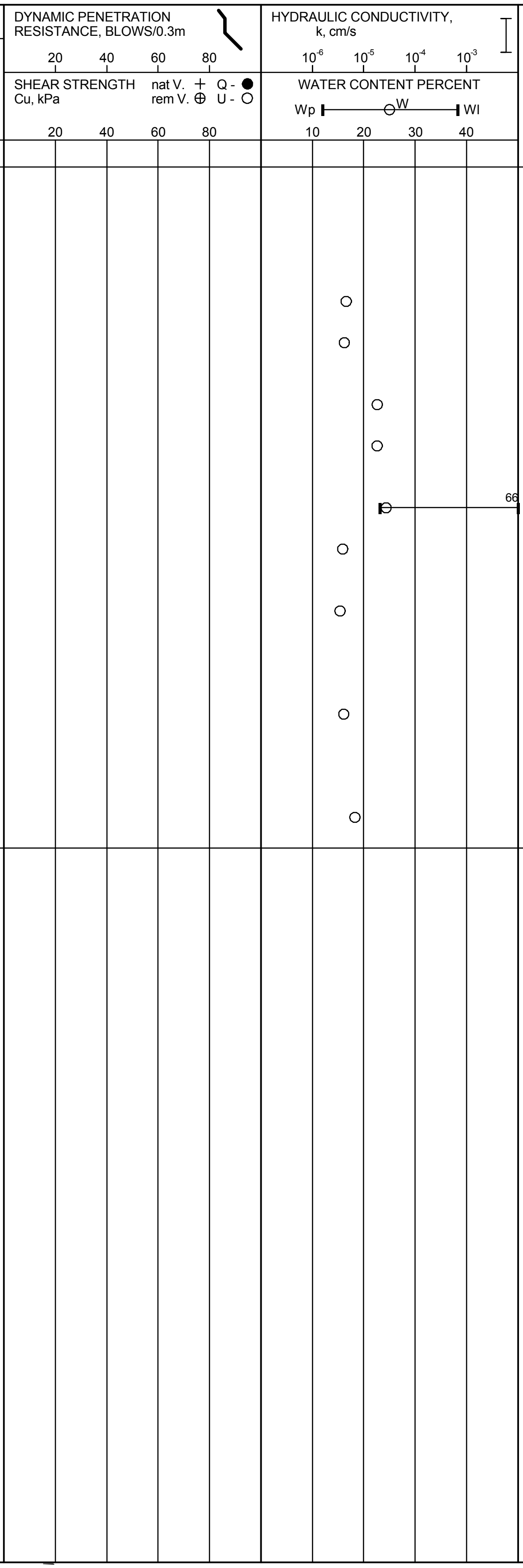
N: 5939547.0 E: 349675.0

BORING DATE: December 19, 2008

DATUM: Local

BORING METHOD: Solid Stem Auger, Canadian Geological Drilling Ltd.

SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
Ground Surface						
ASPHALT	■					
Firm, moist, brown, SILTY CLAY, some sand, trace gravel, oxidation, coal (FILL)	▩	0.09				
			1	SS	10	
			1a	AS		
Stiff, moist, brownish-grey mottled, CLAY, little to some silt	▨	1.49	2	SS	12	
... highly oxidized			2a	AS		
			3	SS	15	I_p = 43
Stiff, moist, brown, SILTY CLAY, trace gravel (TILL) ... sand pocket, oxidized, trace gravel, grey silt pockets		2.80	3a	AS		
... increased sand content			4	SS	14	
			5	SS	12	
... coal fragments			6	SS	15	
End of BOREHOLE. Dry upon completion. Frost to 0.91m below ground. Backfilled with cuttings and asphalt patch.		5.03				



PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: EP

CHECKED: MK

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-R4

SHEET 1 OF 1

LOCATION: See Location Plan

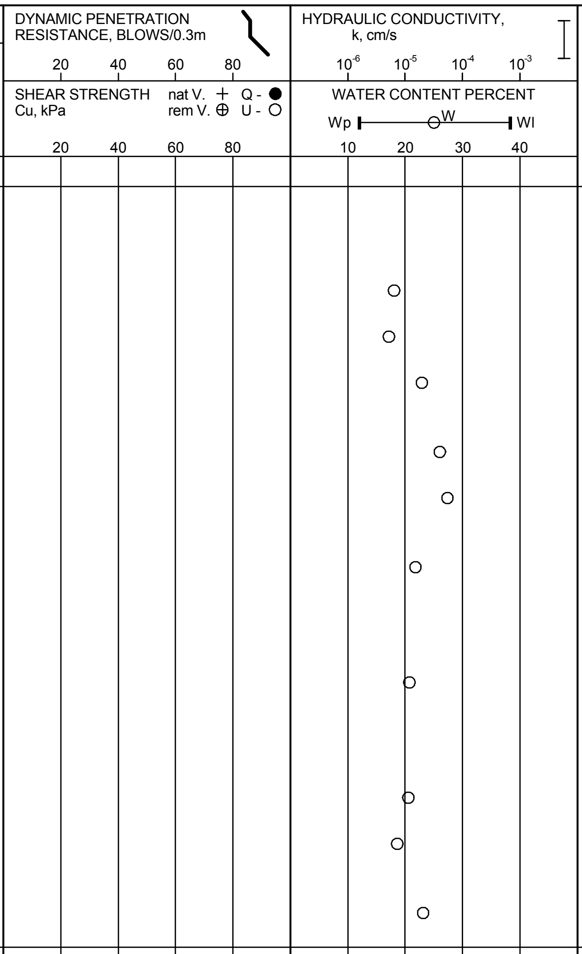
N: 5939684.0 E: 349679.0

BORING DATE: December 19, 2008

DATUM: Local

BORING METHOD: Solid Stem Auger, Canadian Geological Drilling Ltd.

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
0	Ground Surface				
	ASPHALT				
	Stiff, moist, grey, SILTY CLAY, little sand, trace gravel (FILL)	0.09			
			1a	AS	
1			1	SS	14
	Stiff, moist, brown, SILTY CLAY, little to some sand, trace gravel, coal, oxidation (Till-like)	1.07	1b	AS	
	... trace to no gravel				
			2	SS	12
2	... grey to grey-brown		2a	AS	
	... oxidation				
			3	SS	12
3	... sand pockets				
	Very stiff, moist, brown with rust, CLAYEY SILT with SAND, trace gravel, oxidation (TILL)	3.05	4	SS	20
4			5	SS	20
	... sand pocket (3 cm)		5a	AS	
	... highly oxidized		6	SS	21
5	End of BOREHOLE. Dry upon completion. Frost to 0.91m below ground. Backfilled with cuttings and asphalt patch.	5.03			
6					
7					
8					
9					
10					



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: EP
CHECKED: MK

DATA ENTRY: JPH

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-R5

SHEET 1 OF 1

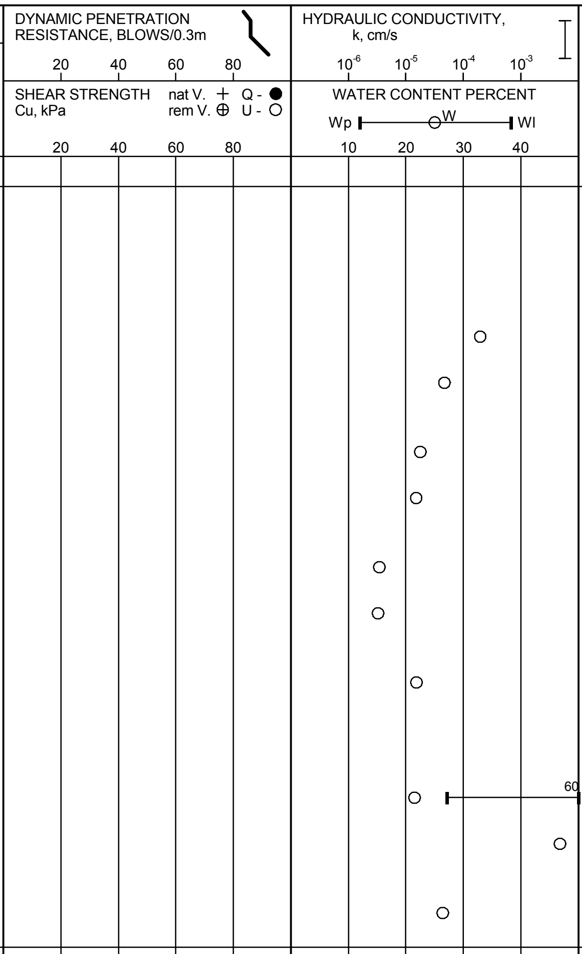
LOCATION: See Location Plan

N: 5940017.0 E: 349692.0

BORING DATE: December 19, 2008

DATUM: Local

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		Ground Surface							
0	Solid Stem Auger Canadian Geological Drilling Ltd.	ASPHALT		0.00					
		Stiff, moist, dark brown to grey-black, SILTY CLAY, some organics (FILL)		0.13					
1					1	SS	9		
		Stiff, moist, grey-brown, SILTY CLAY		1.22	1a	AS			
		... organic pockets, oxidation, coal fragments, trace gravel (becoming TILL)			2	SS	9		
2					2a	AS			
		Very stiff, moist, brown with grey, mottled, SILTY CLAY, little to some sand, trace gravel, oxidation, coal, grey silt lenses (TILL).		2.29	3	SS	19		
					3a	AS			
3		... silt and sand pockets / lenses							
					4	SS	11		
4		... coal lenses			5	SS	13	I_p = 33	
		... black coal pockets			5a	AS			
		... becoming hard							
		Hard, moist, dark brown, CLAY SHALE (Bedrock)		4.65	6	SS	39		
5		End of BOREHOLE. Dry upon completion. Frost to 0.46m below ground. Backfilled with cuttings and asphalt patch.		5.03					
6									
7									
8									
9									
10									



BOREHOLE - EXPANDED ADD. LAB TESTING 07-1377-0128 YHN BH RECORDS.GPJ GLDR_CAN.GDT 4/28/09

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: EP

CHECKED: MK

DATA ENTRY: JPH

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-R6

SHEET 1 OF 1

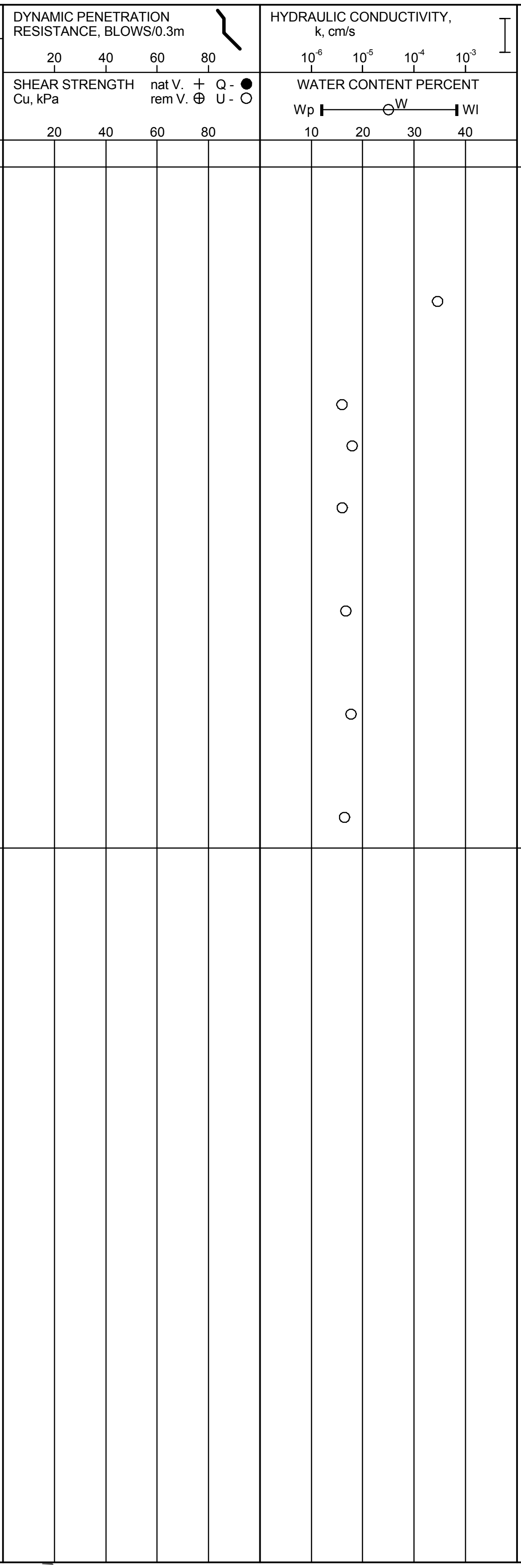
LOCATION: See Location Plan

N: 5940367.0 E: 349704.0

BORING DATE: December 19, 2008

DATUM: Local

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		Ground Surface							
0	Solid Stem Auger Canadian Geological Drilling Ltd.	ASPHALT	■	0.00					
		Firm, moist, black, SILTY CLAY, some organics, minor oxidation (FILL)	▨	0.12					
1		... becoming brown	▨		1	SS	9		
		Firm, moist, light brown, mottled, SILTY CLAY, trace gravel, little to some sand, coal fragments, (TILL)	▨	1.60	2	SS	10		
2					3	AS			
					4	SS	11		
3		... grey silt pockets			5	SS	11		
4		... fine sand lenses			6	SS	12		
					7	SS	12		
5		End of BOREHOLE. Dry upon completion. Backfilled with cuttings and asphalt patch. Frost to 0.46m below ground.		5.03					
6									
7									
8									
9									
10									



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: EP

CHECKED: MK

BOREHOLE - EXPANDED ADD. LAB TESTING 07-1377-0128 YHN BH RECORDS.GPJ GLDR_CAN.GDT 4/28/09

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-R7

SHEET 1 OF 1

LOCATION: See Location Plan

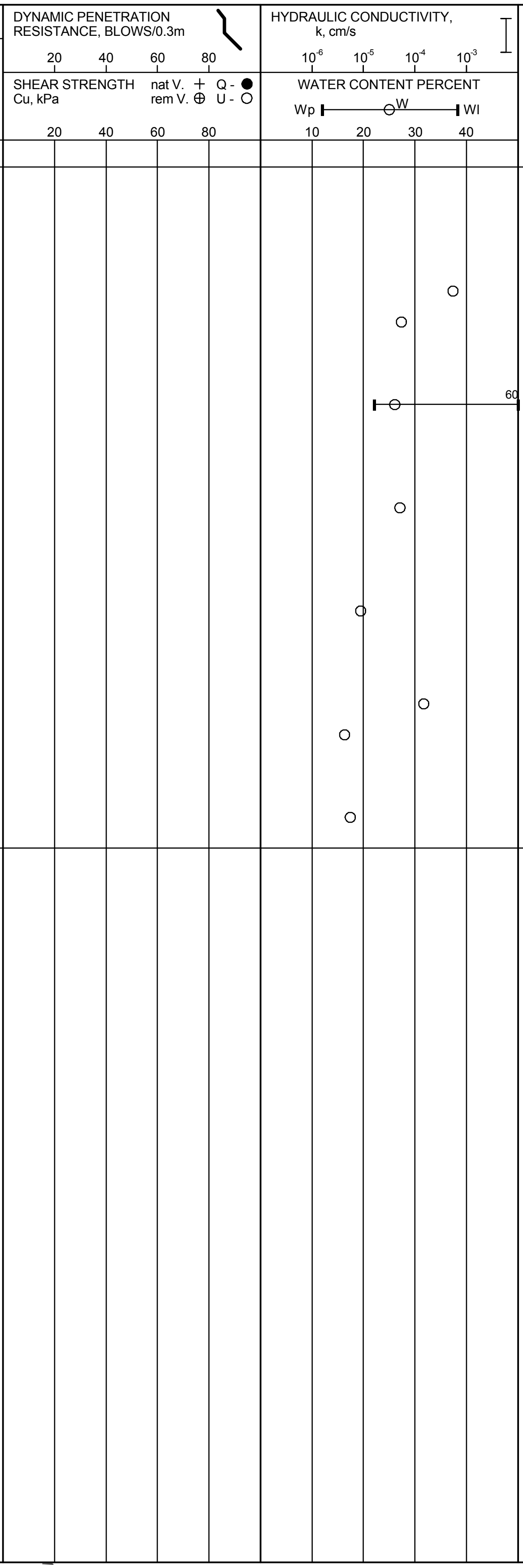
N: 5940432.0 E: 345656.0

BORING DATE: December 19, 2008

DATUM: Local

BORING METHOD: Solid Stem Auger
Canadian Geological Drilling Ltd.

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	Ground Surface						
0	ASPHALT	0.00					
	Firm, dark brown to black, SILTY CLAY, some organics (FILL)	0.13	1	SS	7		
1			1a	AS			
	Firm, moist, light brown, mottled, SILTY CLAY, trace gravel, little sand, oxidation, grey silt lenses, coal fragments (TILL)	1.14	2	SS	8	I_p = 38	
2	... grey lenses		3	SS	8		
3	... grey, silt and sand pockets		4	SS	9		
	Firm to stiff, brown with grey, CLAYEY SILT, little sand, trace gravel, coal, sand pockets (TILL)	3.51	5	SS	12		
4			5a	AS			
			6	SS	10		
5	End of BOREHOLE. Dry upon completion. Frozen to 0.46m below ground. Backfilled with cuttings and asphalt patch.	5.03					
6							
7							
8							
9							
10							



DEPTH SCALE

1 : 50

LOGGED: EP

CHECKED: MK

DATA ENTRY: JPH

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-S1

SHEET 1 OF 1

LOCATION: See Location Plan

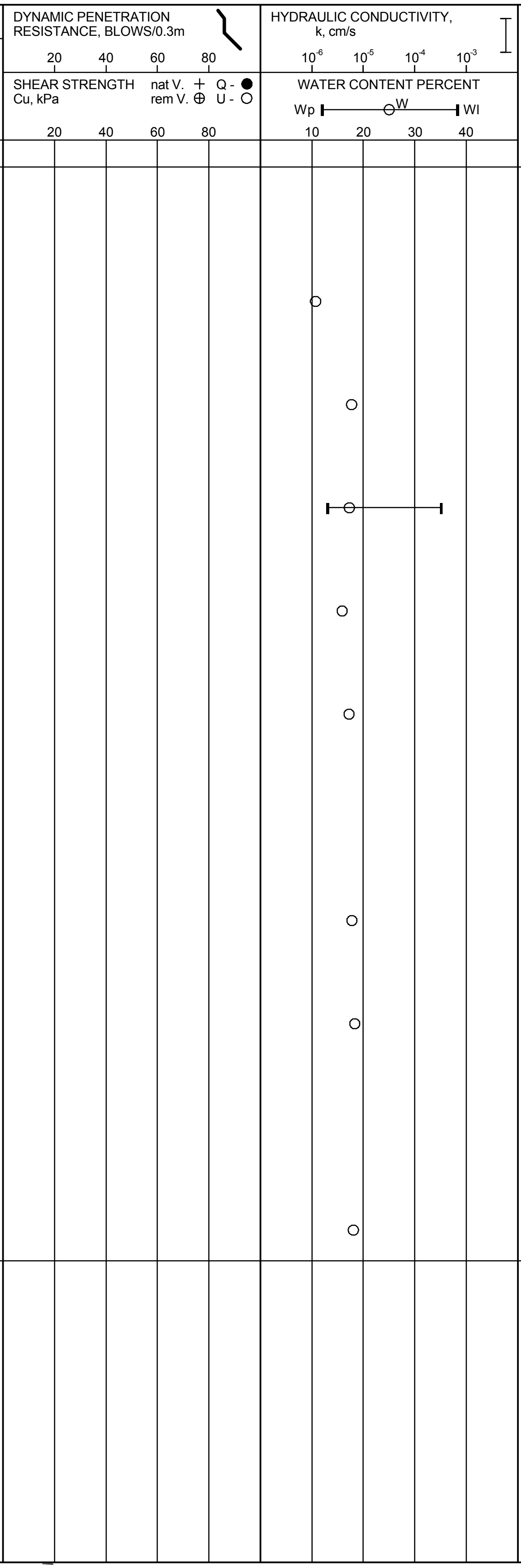
N: 5939266.0 E: 348038.0

BORING DATE: December 23, 2008

DATUM: Local

BORING METHOD: Solid Stem Auger, Beck Drilling and Environmental Services Ltd.

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	Ground Surface						
0	ASPHALT	0.00					Road Box
	Firm, moist, brown, SILTY CLAY, some sand, trace gravel (FILL)	0.23					Bentonite
1			1	AS			
	Firm, moist, brown, SILTY CLAY, some sand, trace gravel, coal, oxidation (TILL)	1.22					
			2	SS	8		
2							
			3	AS		I_p = 22	
3							
			4	SS	11		
4	... coarse gravel		5	AS			Cuttings
							04/02/2009 ▽
			6	TO			
5	Dense, moist, brown, SILTY SAND, some clay, trace gravel	5.18					
			7	AS			
6							
			8	SS	30		
7			9	TO			3.04m Slotted Section
	... coal, oxidation						
			10	SS	26		
8	Slightly weathered, extremely weak, grey, CLAY SHALE	7.92					
	End of BOREHOLE.	8.08					
	Dry upon completion. Standpipe installed.						
9							
10							



DEPTH SCALE

1 : 50

LOGGED: EP

CHECKED: MK

BOREHOLE - EXPANDED ADD. LAB TESTING 07-1377-0128 YHN BH RECORDS.GPJ GLDR_CAN.GDT 4/28/09

DATA ENTRY: JPH

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-S2

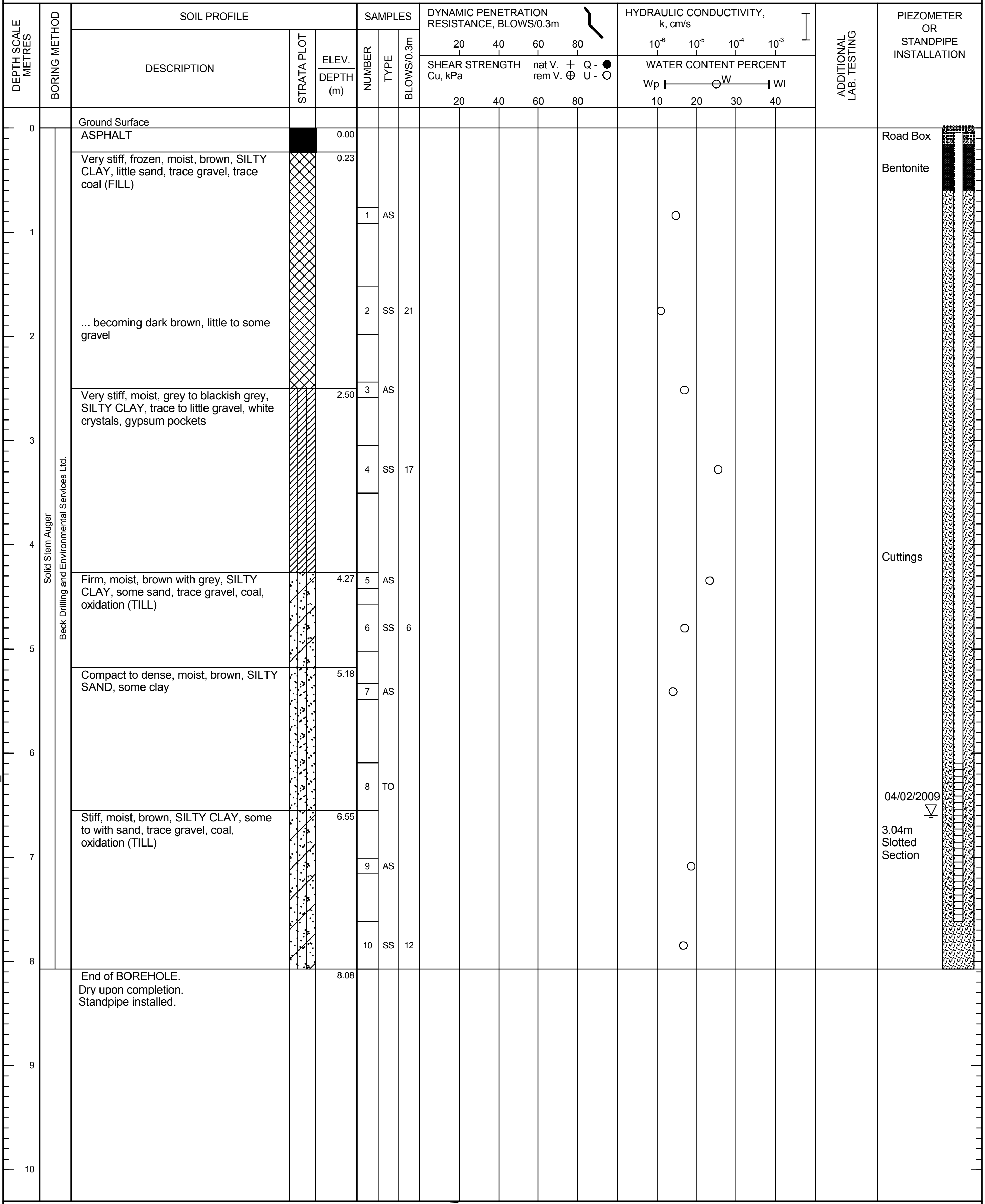
SHEET 1 OF 1

LOCATION: See Location Plan

N: 5939404.0 E: 348042.0

BORING DATE: December 23, 2008

DATUM: Local



DESCRIPTION	ELEV. DEPTH (m)
Ground Surface	
ASPHALT	0.00
Very stiff, frozen, moist, brown, SILTY CLAY, little sand, trace gravel, trace coal (FILL)	0.23
... becoming dark brown, little to some gravel	
Very stiff, moist, grey to blackish grey, SILTY CLAY, trace to little gravel, white crystals, gypsum pockets	2.50
Firm, moist, brown with grey, SILTY CLAY, some sand, trace gravel, coal, oxidation (TILL)	4.27
Compact to dense, moist, brown, SILTY SAND, some clay	5.18
Stiff, moist, brown, SILTY CLAY, some to with sand, trace gravel, coal, oxidation (TILL)	6.55
End of BOREHOLE. Dry upon completion. Standpipe installed.	8.08

NUMBER	TYPE	BLOWS/0.3m
1	AS	
2	SS	21
3	AS	
4	SS	17
5	AS	
6	SS	6
7	AS	
8	TO	
9	AS	
10	SS	12

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: EP

CHECKED: MK

BOREHOLE - EXPANDED ADD. LAB TESTING 07-1377-0128 YHN BH RECORDS.GPJ GLDR_CAN.GDT 4/28/09

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-S3

SHEET 1 OF 1

LOCATION: See Location Plan

N: 5940136.0 E: 348069.0

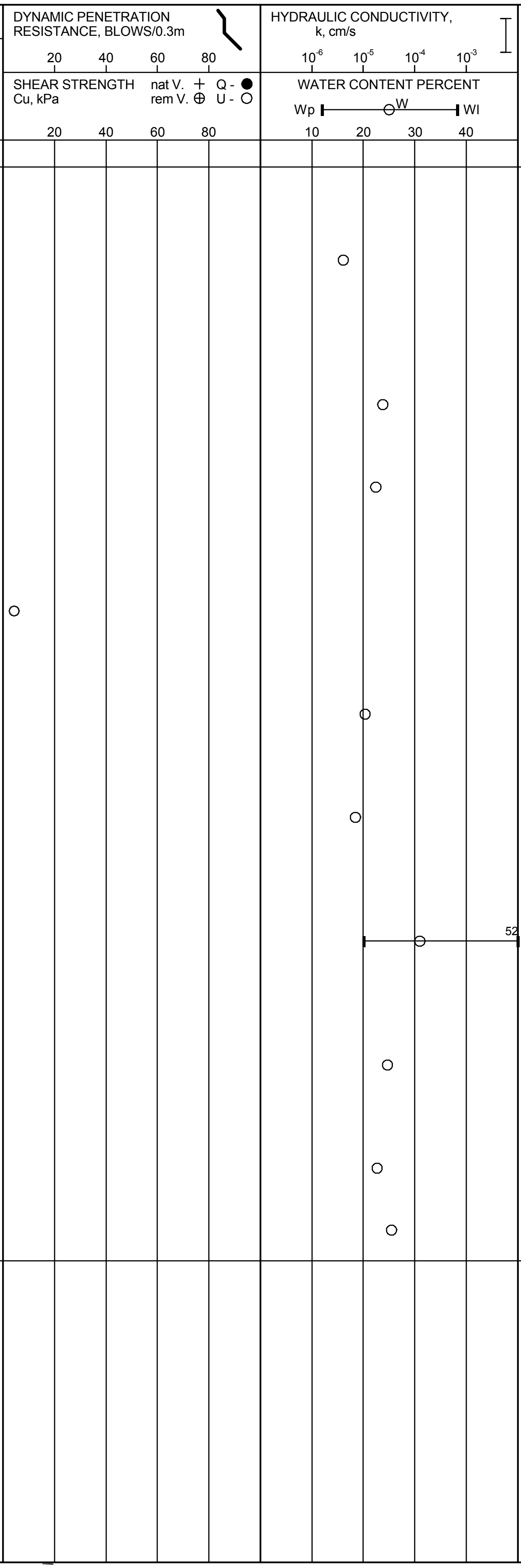
BORING DATE: December 23, 2008

DATUM: Local

BORING METHOD: Solid Stem Auger
Beck Drilling and Environmental Services Ltd.

DESCRIPTION	ELEV. DEPTH (m)
Ground Surface	
ASPHALT	0.00
Firm, moist, grey-brown, SILTY CLAY, little to some sand, trace gravel, organics, coal (FILL)	0.23
Soft to firm, brown, SILTY CLAY, little sand, trace gravel, coal (TILL)	2.59
Very stiff, moist dark brown, SILTY CLAY to CLAY some silt, some to little sand, trace gravel, oxidation (TILL)	6.55
... oxidation	
... coal lense	
End of BOREHOLE. Dry upon completion. Standpipe installed.	8.08

NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
1	AS		
2	SS	11	
3	AS		
4	TO		
5	AS		
6	SS	4	
7	AS		I_p = 32
8	TO		
9	AS		
10	AS		
11	SS	22	



PIEZOMETER OR STANDPIPE INSTALLATION

Road Box

Bentonite

Cuttings

04/02/2009

3.04m

Slotted Section

DEPTH SCALE

1 : 50

LOGGED: EP

CHECKED: MK

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-S4

SHEET 1 OF 1

LOCATION: See Location Plan

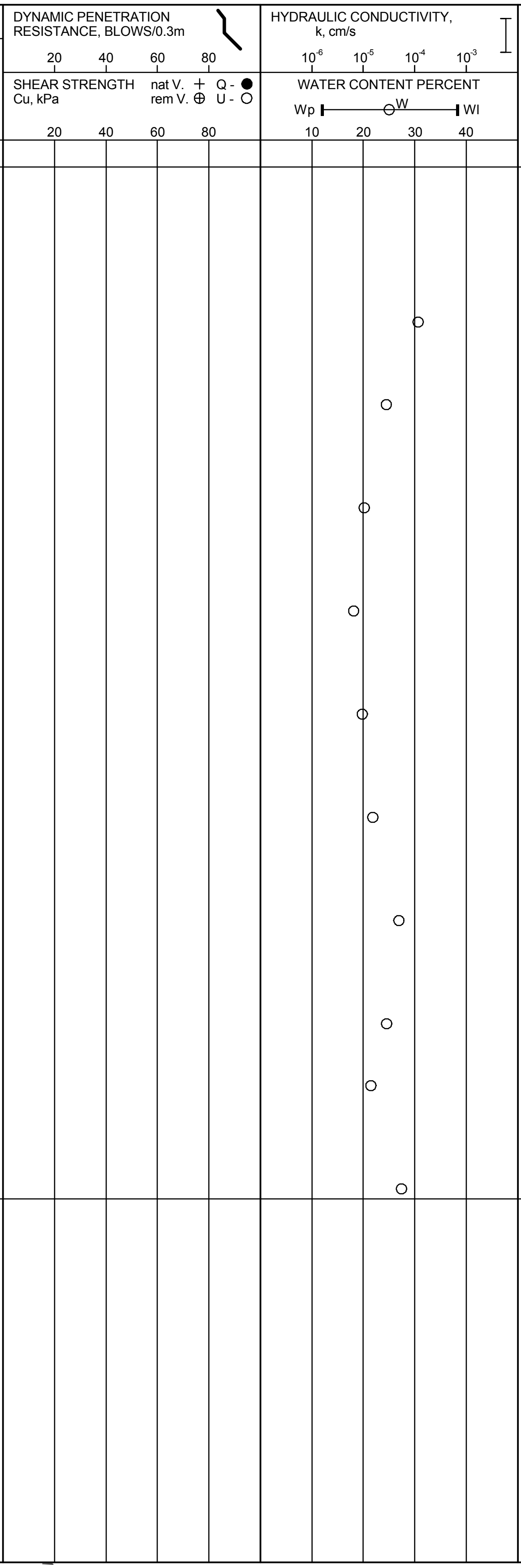
N: 5940390.0 E: 348078.0

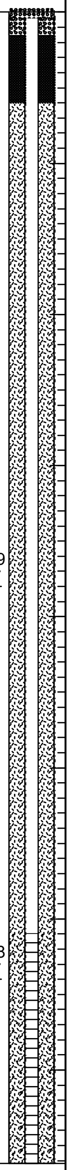
BORING DATE: December 23, 2008

DATUM: Local

BORING METHOD: Solid Stem Auger
Beck Drilling and Environmental Services Ltd.

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	Ground Surface						
0	ASPHALT	0.00					Road Box
	Frozen, moist, grey-brown, SILTY CLAY, some sand, trace gravel (FILL)	0.23					Bentonite
1	Firm, moist, brown with grey, SILTY CLAY, some sand, trace gravel, oxidation, coal (TILL)	1.07	1	AS			
			2	SS	8		
2			3	AS			
3	... coal, oxidation		4	SS	8		
							04/02/2009 ∇
4			5	AS			Cuttings
	... coal pockets / lenses						
			6	SS	10		
5	... sand pocket / lense (possibly wet)						
	Moderately weathered, dark brown, extremely weak, CLAY SHALE	5.18					
			7	AS			
6	... encountered water						23/12/2008 ∇
			8	SS	41		
	Stiff, varved, moist, brown, SILTY CLAY, trace coarse gravel, some sand (TILL)	6.55	9	AS			3.04m Slotted Section
7	... silty SAND pocket (15cm)						
			10	AS			
	End of BOREHOLE. Standpipe installed.	7.62					
8							
9							
10							





DEPTH SCALE

1 : 50

Golder Associates

LOGGED: EP

CHECKED: MK

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-S5

SHEET 1 OF 1

LOCATION: See Location Plan

BORING DATE: December 22, 2008

DATUM: Local

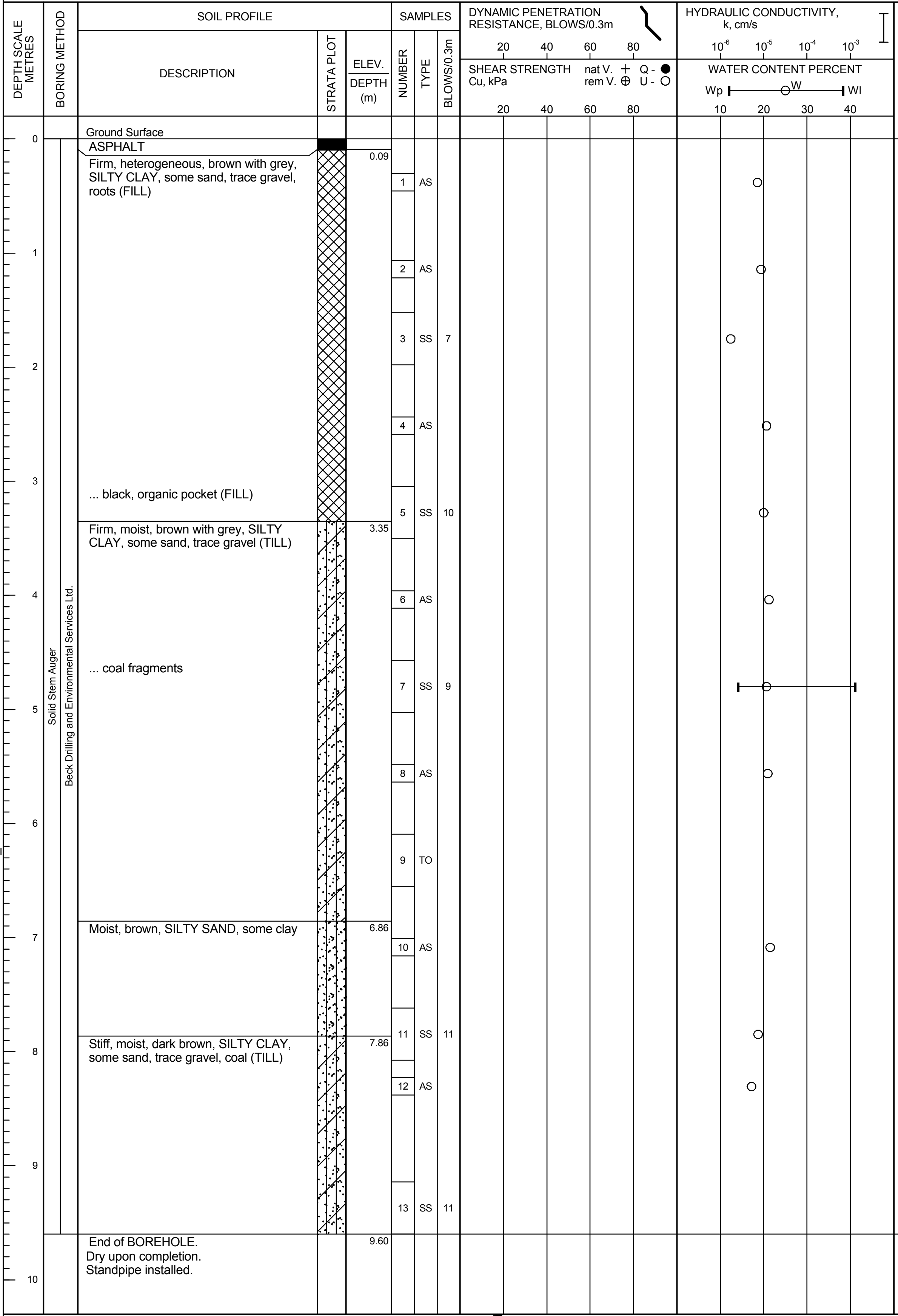
BORING METHOD: Solid Stem Auger
Beck Drilling and Environmental Services Ltd.

SOIL PROFILE

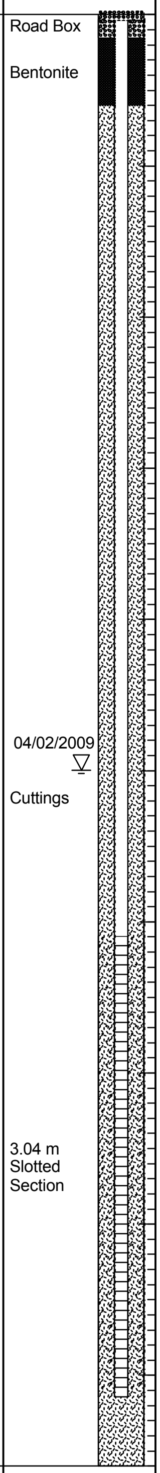
DESCRIPTION	ELEV. DEPTH (m)
Ground Surface	
ASPHALT	
Firm, heterogeneous, brown with grey, SILTY CLAY, some sand, trace gravel, roots (FILL)	0.09
... black, organic pocket (FILL)	
Firm, moist, brown with grey, SILTY CLAY, some sand, trace gravel (TILL)	3.35
... coal fragments	
Moist, brown, SILTY SAND, some clay	6.86
Stiff, moist, dark brown, SILTY CLAY, some sand, trace gravel, coal (TILL)	7.86
End of BOREHOLE. Dry upon completion. Standpipe installed.	9.60

SAMPLES

NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
1	AS		
2	AS		
3	SS	7	
4	AS		
5	SS	10	
6	AS		SO_4=0.538
7	SS	9	I_p = 27
8	AS		
9	TO		
10	AS		
11	SS	11	
12	AS		
13	SS	11	No Recovery



PIEZOMETER OR STANDPIPE INSTALLATION



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: EP
CHECKED: MK

DATA ENTRY: JPH

BOREHOLE - EXPANDED ADD. LAB TESTING 07-1377-0128 YHN BH RECORDS.GPJ GLDR_CAN.GDT 4/28/09

DATA ENTRY: JPH

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-S6

SHEET 1 OF 1

LOCATION: See Location Plan

N: 5938703.0 E: 349643.0

BORING DATE: December 22, 2008

DATUM: Local

BORING METHOD: Solid Stem Auger — Beck Drilling and Environmental Services Ltd.

DESCRIPTION	ELEV. DEPTH (m)
Ground Surface	
ASPHALT	0.00
Frozen, grey-brown, SILTY CLAY, some sand, trace gravel (FILL)	0.24
Firm, moist, black, SILTY CLAY, some organics (FILL)	1.52
Firm, moist, grey-brown, SILTY CLAY, trace gravel, little sand, some organics (FILL)	2.13
Firm, moist, brown, SILTY CLAY, trace to little gravel, gypsum pockets, coal pockets (TILL)	3.35
... sand pocket (3cm)	
Very stiff, moist, dark brown, SILTY CLAY, some to little sand, trace gravel, coal (TILL)	9.14
End of BOREHOLE. Dry upon completion. Standpipe installed.	9.60

SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
1a	AS		
1	SS	21	
2	AS		
3	AS		
4	SS	9	
5	AS		
6	TO		
7	AS		
8	SS	7	
9	AS		1% Gravel 38% Sand 36% Silt 25% Clay
9	SS	6	No Recovery
10	AS		
11	TO		
12	AS		SO_4=0.534
13	SS	19	

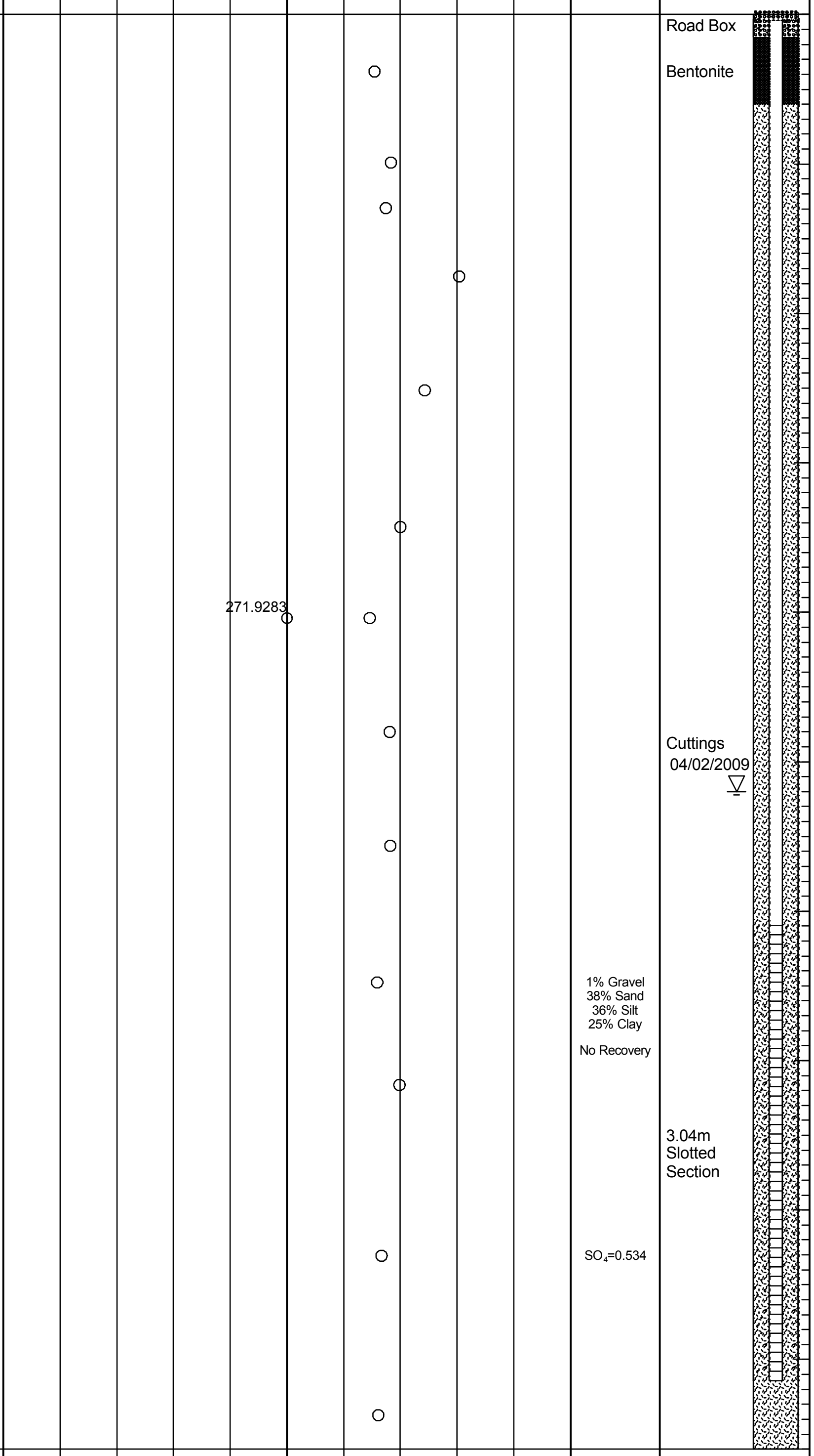
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 10 20 30 40

PIEZOMETER OR STANDPIPE INSTALLATION



DEPTH SCALE 1 : 50

LOGGED: EP

CHECKED: MK

DATA ENTRY: EP

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-S8

SHEET 1 OF 3

LOCATION: See Location Plan

BORING DATE: December 2, 2008

DATUM: Local

BORING METHOD: CME 55HD - Solid Stem Auger
Beck Drilling and Environmental Services Ltd.

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
Ground Surface					
Black, TOPSOIL	0.00				
Stiff, mottled, dry, tan brown, CLAYEY SILT, trace sand, oxidation	0.30				
		1	SS	11	
... becoming CLAY		2	SS	11	I_p = 44
Stiff, mottled, moist, brown, SILTY CLAY, trace sand, trace gravel, oxidation (TILL)	1.98	3	AS		
		4	TO		
Stiff, mottled, moist, greyish brown, SILTY CLAY, little to some sand, trace gravel, oxidation, coal fragments (TILL)	3.96	5	AS		
		6	SS	11	
		7	AS		
...becoming very stiff, sand pockets		8	SS	16	
...silt pockets/lenses (varved)		9	AS		
		10	SS	28	I_p = 27
...becoming grey		11	AS		26% Sand 35% Silt 39% Clay
		12	TO		
Very stiff, moist, grey, CLAY, trace silt, trace sand, trace gravel, coal (TILL)	9.60				

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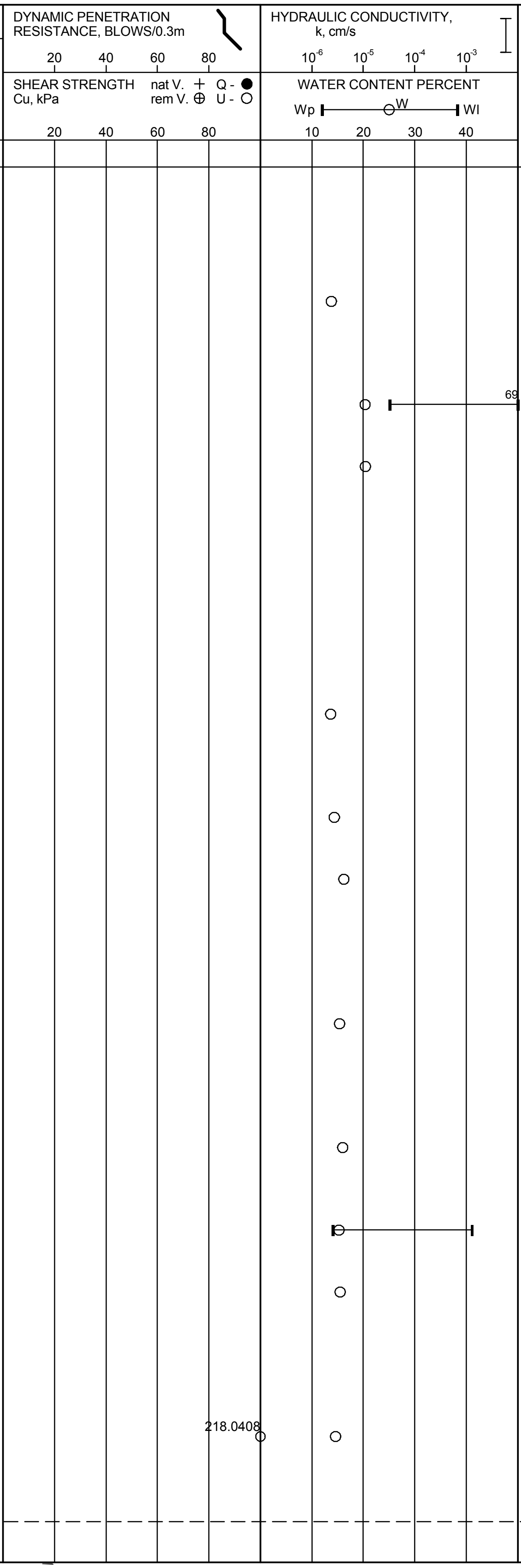

PIEZOMETER OR STANDPIPE INSTALLATION

0.86m Stickup

Bentonite

Cuttings

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: EP

CHECKED: MK

BOREHOLE - EXPANDED ADD. LAB TESTING 07-1377-0128 YHN BH RECORDS.GPJ GLDR_CAN.GDT 4/28/09

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-S8

SHEET 2 OF 3

LOCATION: See Location Plan

BORING DATE: December 2, 2008

DATUM: Local

BORING METHOD: CME 55HD - Solid Stem Auger
Beck Drilling and Environmental Services Ltd.

DEPTH SCALE METRES	SOIL PROFILE: DESCRIPTION	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
10	Very stiff, moist, grey, CLAY, trace silt, trace sand, trace gravel, coal (TILL) *(continued)*		13	AS			
			14	SS	26		
11	Very stiff, moist, grey with black, SILTY CLAY, trace sand, trace gravel, coal (TILL)	11.13	15	AS			
12			16	SS	19		
13	Hard, oxidized, moist, brown with orange (rusty), SILTY CLAY, some sand, trace gravel, oxidation, coal, silt and sand pockets (TILL).	12.80	17	AS		SO_4=0.226	
14	Dense, varved, dry to moist, grey with brown, SILTY SAND, trace gravel, trace clay, coal laminations	13.72	18	SS	39		Cuttings
	... SILTY CLAY pocket (~30cm).		19	AS			
15			20	SS	46		
16			21	AS			
	Dense, dry to moist, brown, SILTY SAND, trace gravel, trace clay, coal laminations.	16.46					
17			22	SS	46		02/04/2009 ⊻
			23	AS			
18							02/12/2008 ⊻ 3.1m Slotted Section
			24	SS	40		
19			25	AS			Slough
20	... encountered water.		26	SS	10		

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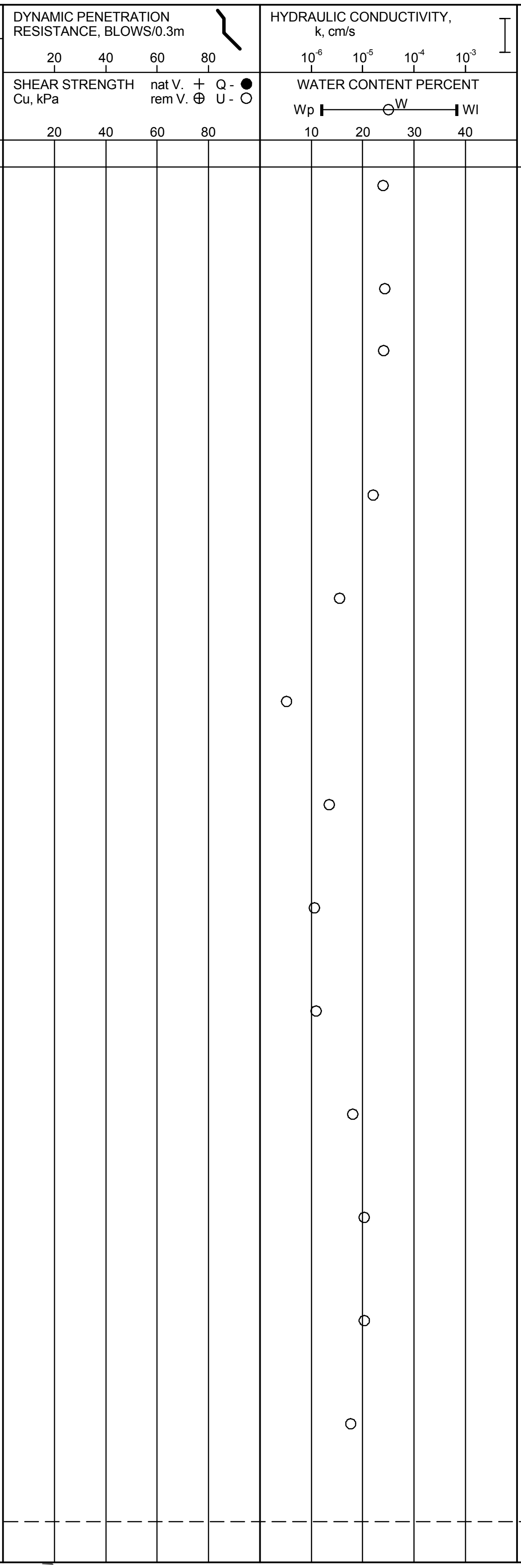
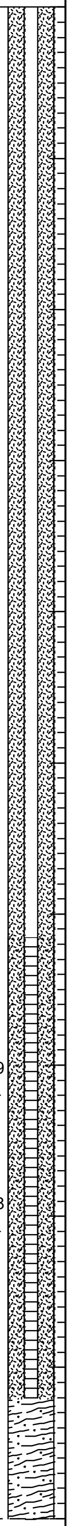




DEPTH SCALE

1 : 50

LOGGED: EP

CHECKED: MK

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-S8

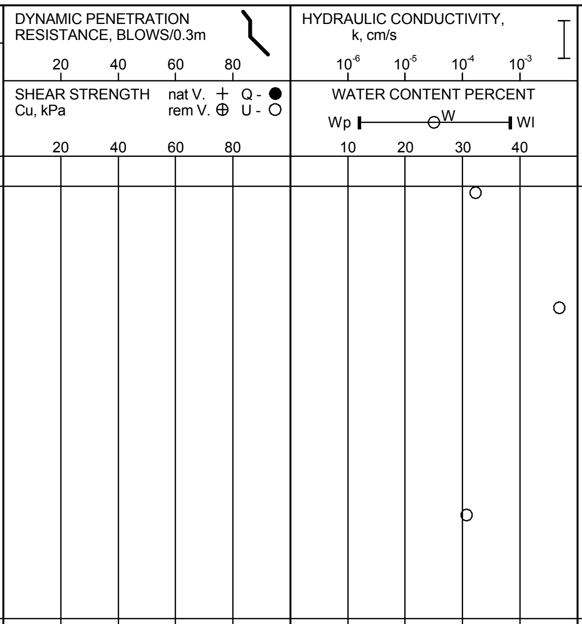
SHEET 3 OF 3

LOCATION: See Location Plan

BORING DATE: December 2, 2008

DATUM: Local

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
20	CME 55HD - Solid Stem Auger Beck Drilling and Environmental Services Ltd.	Slightly weathered, brown, extremely weak, CLAY SHALE (BEDROCK).		20.12	26	SS	10		
					27	AS			
21									Slough
22					28	AS			
23		End of BOREHOLE. Slough to 20.17m upon completion. Standpipe installed.		22.86					
24									
25									
26									
27									
28									
29									
30									



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: EP
CHECKED: MK

DATA ENTRY: EP

PROJECT No.: 07-1377-0128

RECORD OF BOREHOLE: BH08-S10

SHEET 1 OF 2

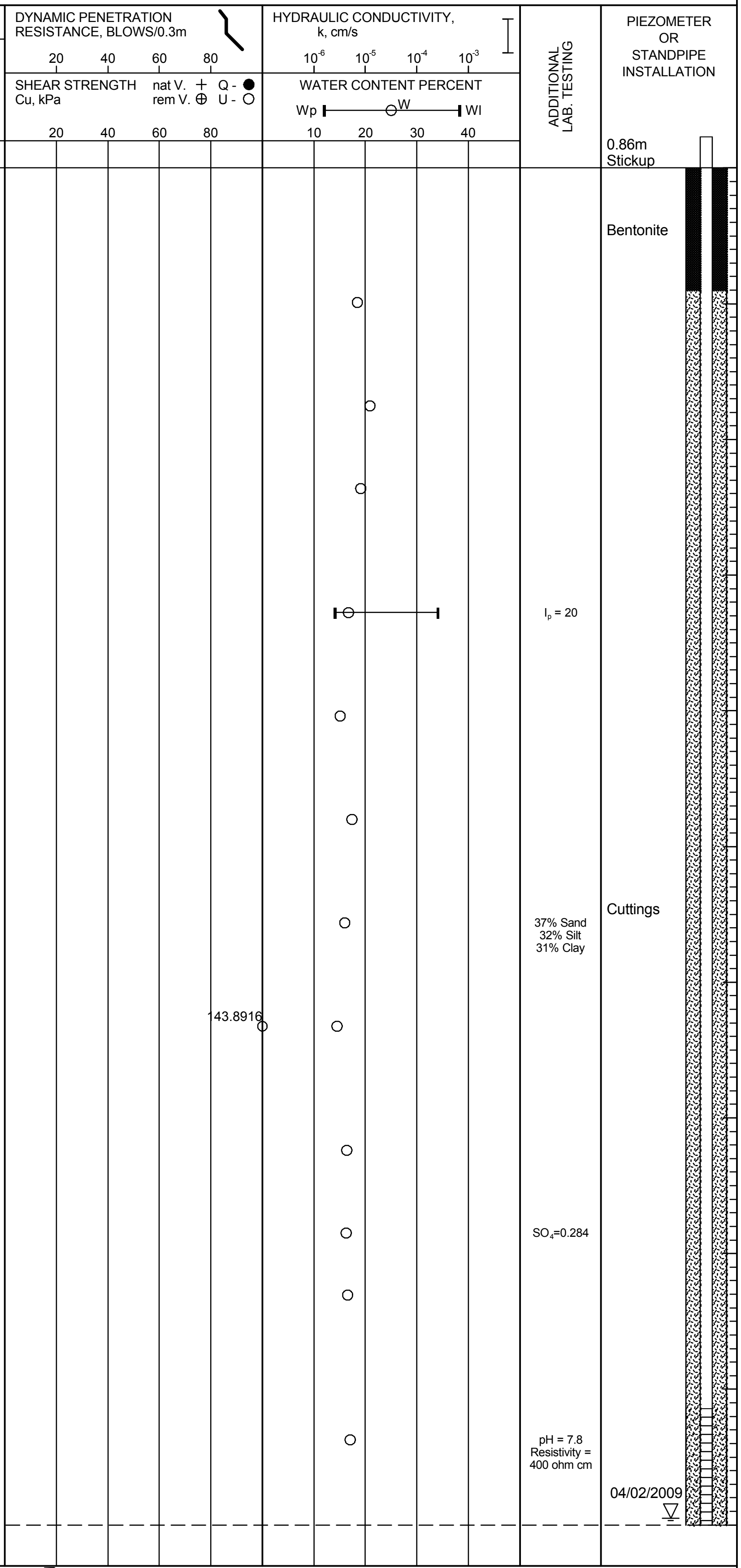
LOCATION: See Location Plan

BORING DATE: December 4, 2008

DATUM: Local

BORING METHOD: CME 55HD - Solid Stem Auger
Beck Drilling and Environmental Services Ltd.

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
0	Ground Surface						
	TOPSOIL		0.00				
	Firm, moist, brown, SILTY CLAY		0.15				
	... roots						
1				1	SS	6	
				2	SS	5	
2							
	... rust / oxidation, trace gravel (TILL-like)			3	AS		
3	Stiff, moist, mottled, light brown, SILTY CLAY, little sand, trace gravel, coal, oxidation (TILL)		3.05				
				4	SS	13	I_p = 20
4				5	AS		
	Very stiff, moist, brown, SILTY CLAY, some sand, trace gravel, oxidation (TILL)		4.57	6	SS	18	
5							
	... coal fragments			7	AS		37% Sand 32% Silt 31% Clay
6				8	TO		
	... becoming grey						
	Stiff, moist, grey, SILTY CLAY, some sand, trace gravel (TILL)		6.71				
7				9	AS		
				10	SS	12	SO_4=0.284
8				11	AS		
9				12	SS	13	pH = 7.8 Resistivity = 400 ohm cm
10	*CONTINUED NEXT PAGE*						



DEPTH SCALE

1 : 50

LOGGED: EP

CHECKED: MK

BOREHOLE - EXPANDED ADD. LAB TESTING 07-1377-0128 YHN BH RECORDS.GPJ GLDR_CAN.GDT 4/28/09

APPENDIX II

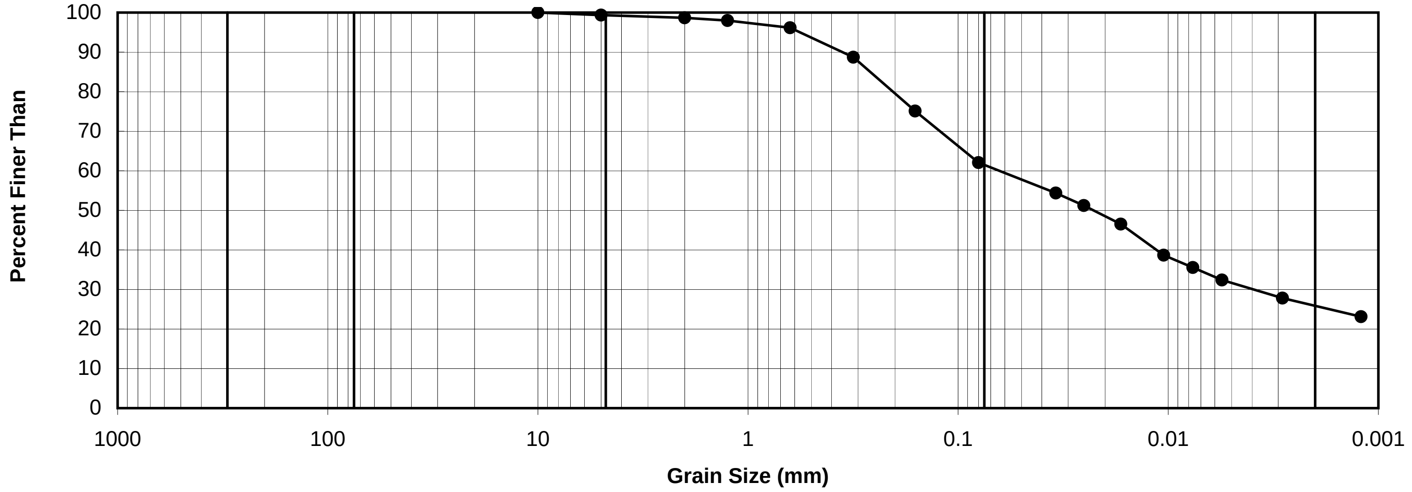
Laboratory Test Results

Particle Size Analysis of Soils
ASTM D422

Project #: 07-1377-0128 Phase: 3000 Report Number: A2057
Short Title: Yellowhead Geotech Investigation
Client: Stantec Consulting Ltd. Date Sampled: December 19, 2008

Sample Number	BH08-S6-AS9
Sample Location	Yellowhead North
Sampled By	Eric Paton
Source	In-situ
Sample Description	Stiff, Moist, Olive Brown, Clayey SAND and Silt, Trace Gravel
In situ Water Content	14.7
Date Tested	Monday, January 12, 2009
Tested By	DS
Remarks:	
Distribution	

Gradation Size (mm)	Percent Passing	
		Sieve
10	100.0	
5	99.4	
2.0	98.7	
1.25	98.0	
0.6	96.1	
0.32	88.7	
0.16	75.1	
0.080	62.1	
0.034	54.4	Hydrometer
0.025	51.2	
0.017	46.5	
0.010	38.7	
0.008	35.5	
0.006	32.4	
0.003	27.8	
0.001	23.1	



Boulders	Cobbles	Gravel		Sand			Silt	Clay
		Coarse	Fine	Coarse	Medium	Fine		

Gravel % 0.6 Sand % 38.3 Silt% 35.7 Clay% 25.4

Reviewed By: ____________________

Particle Size Analysis of Soils
ASTM D422

Project #:	07-1377-0128	Phase: 3000	Report Number: A2045
Short Title:	Yellowhead Geotech Investigation		
Client:	Stantec Consulting Ltd.	Date Sampled: 3-Dec-08	

Sample Number BH08-S8-AS11
Sample Location Yellowhead North

Sampled By Eric Paton

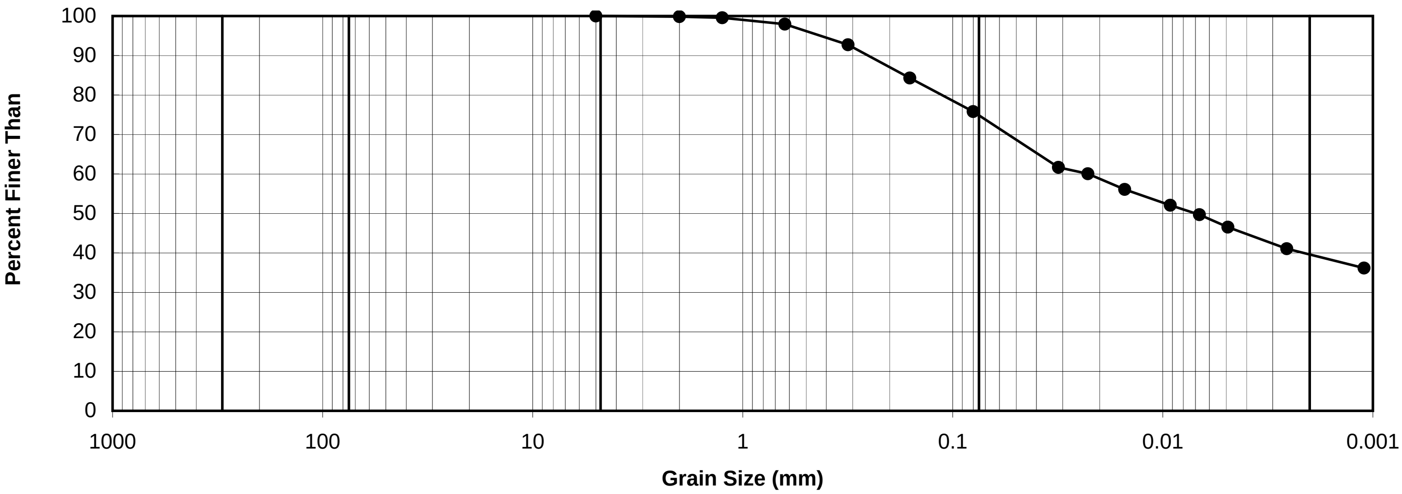
Source In-Situ
Sample Description Stiff, Moist, Dark Grey, CLAY with Silt, Sandy

In situ Water Content 15.1
Date Tested Tuesday, December 23, 2008
Tested By DS

Remarks:

Distribution

Gradation Size (mm)	Percent Passing	
		Sieve
5	100.0	
2.0	99.8	
1.25	99.5	
0.6	97.9	
0.32	92.7	
0.16	84.3	
0.080	75.8	
0.031	61.7	Hydrometer
0.023	60.1	
0.015	56.1	
0.009	52.1	
0.007	49.7	
0.005	46.5	
0.003	41.1	
0.001	36.1	



Boulders	Cobbles	Gravel		Sand			Silt	Clay
		Coarse	Fine	Coarse	Medium	Fine		

Gravel % 0.0 Sand % 26.0 Silt% 34.9 Clay% 39.1

Reviewed By: ____________________

Particle Size Analysis of Soils
ASTM D422

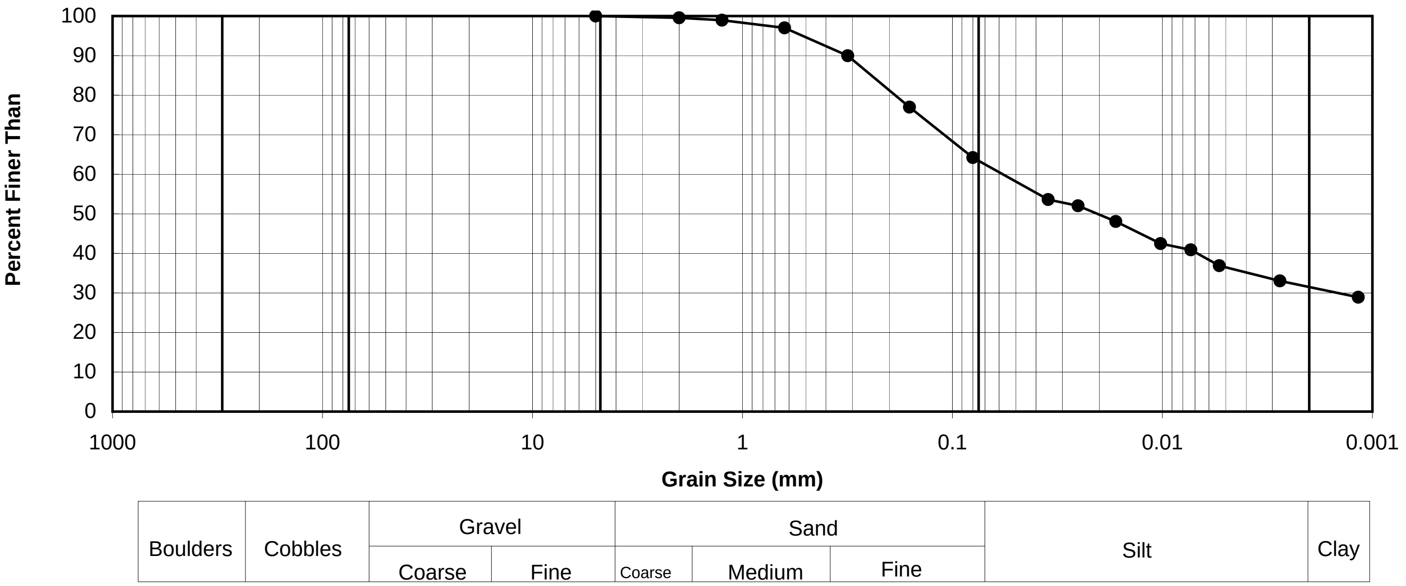
Project #: 07-1377-0128 Phase: 3000 Report Number: A2045
Short Title: Yellowhead Geotech Investigation
Client: Stantec Consulting Ltd. Date Sampled: 3-Dec-08

Sample Number	BH08-S10-AS7
Sample Location	Yellowhead North
Sampled By	Eric Paton
Source	In-Situ
Sample Description	Stiff, Moist, Medium Brown, SAND and Silt with Clay
In situ Water Content	15.1
Date Tested	Tuesday, December 23, 2008
Tested By	DS

Remarks:

Distribution

Gradation Size (mm)	Percent Passing	
		Sieve
5	100.0	
2.0	99.5	
1.25	99.0	
0.6	97.0	
0.32	90.0	
0.16	77.0	
0.080	64.2	
0.035	53.6	Hydrometer
0.025	52.0	
0.017	48.0	
0.010	42.5	
0.007	40.9	
0.005	36.9	
0.003	33.0	
0.001	28.9	



Gravel % 0.0 Sand % 37.2 Silt% 31.7 Clay% 31.1

Reviewed By: ____________________

Golder Associates

Unconfined Compressive Strength Test

Project #: 07-1377-0128 Phase: 3000
Short Title: Yellowhead North

Location: Edmonton
Site:
Tested By: DS Date: January 5, 2009

Borehole: 08-S8 Sample: 12

Time (min)	Strain Dial (mm)	Load Dial (1/1000 in)	Load (N)	Unit Strain	Corr Area (mm^2)	Stress (kPa)
0.0	0.000	25	0.0	0.0%	4060.20	0
0.5	2.212	25	304.0	1.5%	4123.41	73.7
1.0	2.523	25	542.0	1.7%	4132.46	131.2
1.5	2.680	25	756.0	1.9%	4137.04	182.7
2.0	3.196	25	933.0	2.2%	4152.17	224.7
2.5	3.546	25	1079.0	2.5%	4162.49	259.2
3.0	3.981	25	1207.0	2.8%	4175.39	289.1
3.5	4.238	25	1319.0	2.9%	4183.06	315.3
4.0	4.595	25	1421.0	3.2%	4193.75	338.8
4.5	4.956	25	1508.0	3.4%	4204.61	358.7
5.0	5.334	25	1593.0	3.7%	4216.05	377.8
5.5	5.684	25	1664.0	3.9%	4226.69	393.7
6.0	6.048	25	1732.0	4.2%	4237.82	408.7
6.5	6.401	25	1794.0	4.4%	4248.67	422.2
7.0	6.790	25	1847.0	4.7%	4260.69	433.5
7.5	7.125	25	1899.0	4.9%	4271.09	444.6
8.0	7.546	25	1946.0	5.2%	4284.24	454.2
8.5	7.860	25	1987.0	5.4%	4294.10	462.7
9.0	8.220	25	2029.0	5.7%	4305.46	471.3
9.5	8.576	25	2067.0	5.9%	4316.75	478.8
10.0	8.902	25	2105.0	6.2%	4327.15	486.5
10.5	9.251	25	2137.0	6.4%	4338.33	492.6
11.0	9.604	25	2179.0	6.7%	4349.70	501.0
11.5	9.953	25	2201.0	6.9%	4361.00	504.7
12.0	10.307	25	2229.0	7.1%	4372.52	509.8
12.5	10.657	25	2258.0	7.4%	4383.97	515.1
13.5	10.760	25	2310.0	7.5%	4387.35	526.5
14.5	11.397	25	2356.0	7.9%	4408.38	534.4
15.5	12.508	25	2394.0	8.7%	4445.54	538.5
16.5	13.242	25	2429.0	9.2%	4470.44	543.3
17.5	13.937	25	2453.0	9.7%	4494.28	545.8
18.5	14.656	25	2472.0	10.2%	4519.20	547.0
19.5	15.378	25	2485.0	10.7%	4544.51	546.8
20.5	16.134	25	2497.0	11.2%	4571.32	546.2
21.5	16.887	25	2495.0	11.7%	4598.33	542.6

Sample Description: Moist Olive Brown Silty CLAY some sand trace gravel (CLAY TILL)

Sample Dimensions

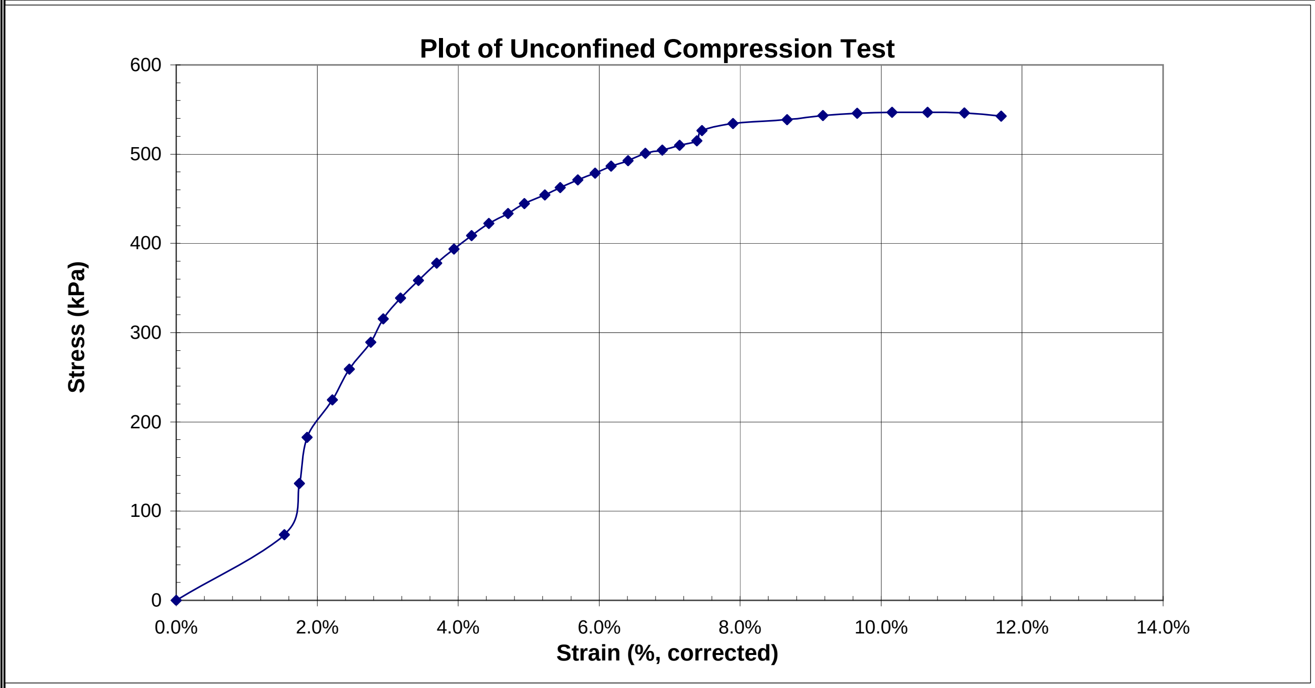
Diameter (mm)	71.9
Length (mm)	144.3

Water Content

Tare #	1F
Wet + tare (grams)	267.6
Dry + tare (grams)	258.4
Water (grams)	9.2
Tare (grams)	195.2
Dry Soil (grams)	63.2
Water Content	14.6%

Test Results

Compressive Stress at Failure (kPa)	543.3
Strain at Failure (%)	10.3
Undrained Shear Strength (kPa)	271.65
Water Content	14.6%



Checked By:____________________ Reviewed By:______________

Unconfined Compressive Strength Test

Golder Associates

Project #: 07-1377-0128
Phase: 3000
Short Title: Yellowhead North

Location: Edmonton
Site:
Tested By: DS
Date: January 5, 2009

Borehole: 08-S6
Sample: 11

Time (min)	Strain Dial (mm)	Load Dial (1/1000 in)	Load (N)	Unit Strain	Corr Area (mm^2)	Stress (kPa)
0.0	0.000		0.0	0.0%	4128.25	0
0.5	0.454		169.0	0.3%	4141.22	40.8
1.0	0.949		318.0	0.7%	4155.46	76.5
1.5	1.482		442.0	1.0%	4170.91	106.0
2.0	1.995		537.0	1.4%	4185.88	128.3
2.5	2.561		614.0	1.8%	4202.53	146.1
3.0	3.115		674.0	2.1%	4218.95	159.8
3.5	3.667		724.0	2.5%	4235.44	170.9
4.0	4.235		765.0	2.9%	4252.54	179.9
4.5	4.799		801.0	3.3%	4269.66	187.6
5.0	5.377		832.0	3.7%	4287.35	194.1
5.5	5.954		859.0	4.1%	4305.15	199.5
6.0	6.443		886.0	4.4%	4320.35	205.1
6.5	6.949		907.0	4.8%	4336.20	209.2
7.0	7.456		929.0	5.1%	4352.20	213.5
7.5	7.984		948.0	5.5%	4368.98	217.0
8.0	8.519		967.0	5.9%	4386.12	220.5
8.5	8.633		983.0	6.0%	4389.79	223.9
9.0	8.875		999.0	6.1%	4397.60	227.2
9.5	9.437		1015.0	6.5%	4415.84	229.9
10.0	9.988		1028.0	6.9%	4433.88	231.9
10.5	10.545		1043.0	7.3%	4452.26	234.3
11.0	11.077		1056.0	7.6%	4469.96	236.2
11.5	11.627		1069.0	8.0%	4488.41	238.2
12.0	12.146		1081.0	8.4%	4505.95	239.9
12.5	12.681		1094.0	8.8%	4524.19	241.8
13.5	13.421		1106.0	9.3%	4549.65	243.1
14.5	13.749		1116.0	9.5%	4561.03	244.7
15.5	14.229		1127.0	9.8%	4577.78	246.2
16.5	14.854		1138.0	10.3%	4599.78	247.4
17.5	15.415		1146.0	10.6%	4619.71	248.1
18.5	16.535		1166.0	11.4%	4660.02	250.2
19.5	17.636		1184.0	12.2%	4700.33	251.9
20.5	18.703		1201.0	12.9%	4740.08	253.4
21.5	18.932		1215.0	13.1%	4748.69	255.9
22.0	19.783		1228.0	13.7%	4780.99	256.9
22.5	20.913		1237.0	14.4%	4824.56	256.4
23.0	21.462		1239.0	14.8%	4846.02	255.7
23.5	22.023		1236.0	15.2%	4868.15	253.9

Sample Description: Moist Olive Brown Silty CLAY some sand trace gravel (CLAY TILL)

Sample Dimensions

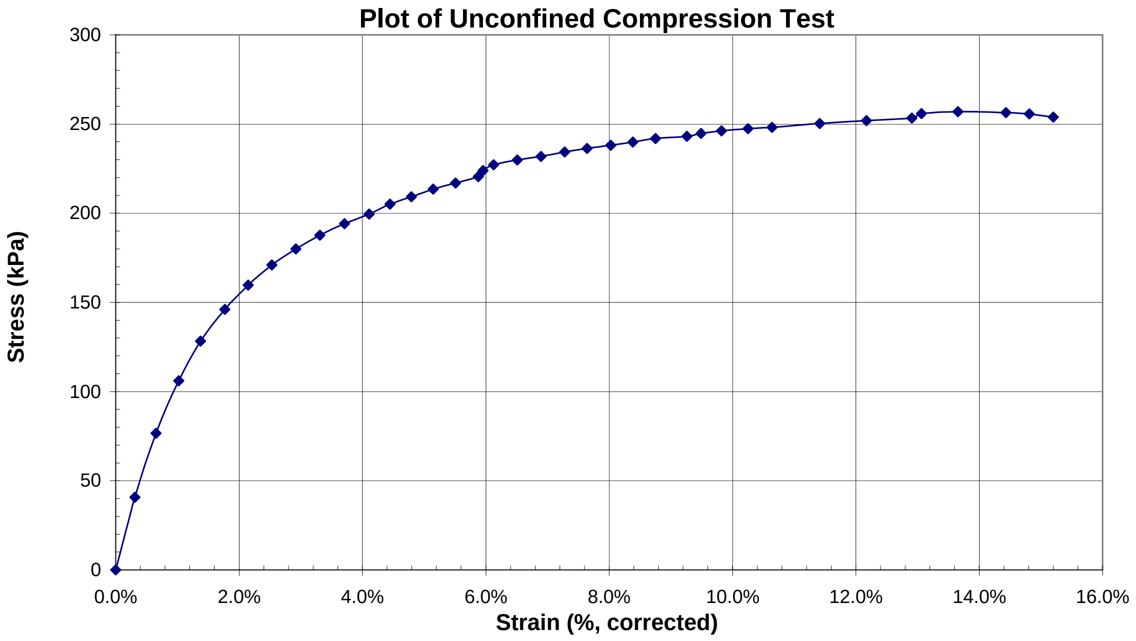
Diameter (mm)	72.5
Length (mm)	144.9

Water Content

Tare #	1C
Wet + tare (grams)	266.2
Dry + tare (grams)	255.1
Water (grams)	11.1
Tare (grams)	197.5
Dry Soil (grams)	57.6
Water Content	19.3%

Test Results

Compressive Stress at Failure (kPa)	256.9
Strain at Failure (%)	13.7
Undrained Shear Strength (kPa)	128.4252482
Water Content	19.3%



Checked By:__________________ Reviewed By:______________

Golder Associates

Unconfined Compressive Strength Test

Project #: 07-1377-0128 Phase: 3000
Short Title: Yellowhead North

Location: Edmonton
Site:
Tested By: DMc/DS Date: March 10, 2009

Borehole: 08-S3 Sample: 4

Time (min)	Strain Dial (mm)	Load Dial (1/1000 in)	Load (N)	Unit Strain	Corr Area (mm^2)	Stress (kPa)
0.0	0.000		0.0	0.0%	3848.45	0
0.5	0.535		127.0	0.5%	3867.75	32.8
1.0	1.070		243.0	1.0%	3887.25	62.5
1.5	1.605		326.0	1.5%	3906.95	83.4
2.0	2.140		392.0	2.0%	3926.84	99.8
2.5	2.675		443.0	2.5%	3946.94	112.2
3.0	3.210		487.0	3.0%	3967.25	122.8
3.5	3.745		523.0	3.5%	3987.76	131.2
4.0	4.280		556.0	4.0%	4008.49	138.7
4.5	4.815		581.0	4.5%	4029.44	144.2
5.0	5.350		607.0	5.0%	4050.60	149.9
5.5	5.885		629.0	5.5%	4071.99	154.5
6.0	6.420		647.0	6.0%	4093.61	158.1
6.5	6.955		666.0	6.5%	4115.46	161.8
7.0	7.490		681.0	7.0%	4137.54	164.6
7.5	8.025		695.0	7.5%	4159.86	167.1
8.0	8.560		708.0	8.0%	4182.42	169.3
8.5	9.095		720.0	8.5%	4205.23	171.2
9.0	9.630		730.0	9.0%	4228.29	172.6
9.5	10.165		740.0	9.5%	4251.60	174.1
10.0	10.700		747.0	10.0%	4275.17	174.7
10.5	11.235		756.0	10.5%	4299.00	175.9
11.0	11.770		763.0	11.0%	4323.11	176.5
11.5	12.305		776.0	11.5%	4347.48	178.5
12.0	12.840		785.0	12.0%	4372.13	179.5
12.5	13.375		791.0	12.5%	4397.06	179.9
13.0	13.910		793.0	13.0%	4422.27	179.3
13.5	14.445		794.0	13.5%	4447.78	178.5
14.0	14.980		797.0	14.0%	4473.58	178.2
14.5	15.515		795.0	14.5%	4499.69	176.7

Sample Description: Moist Olive Brown Sandy SILT with Clay, Trace Gravel (TILL)

Sample Dimensions

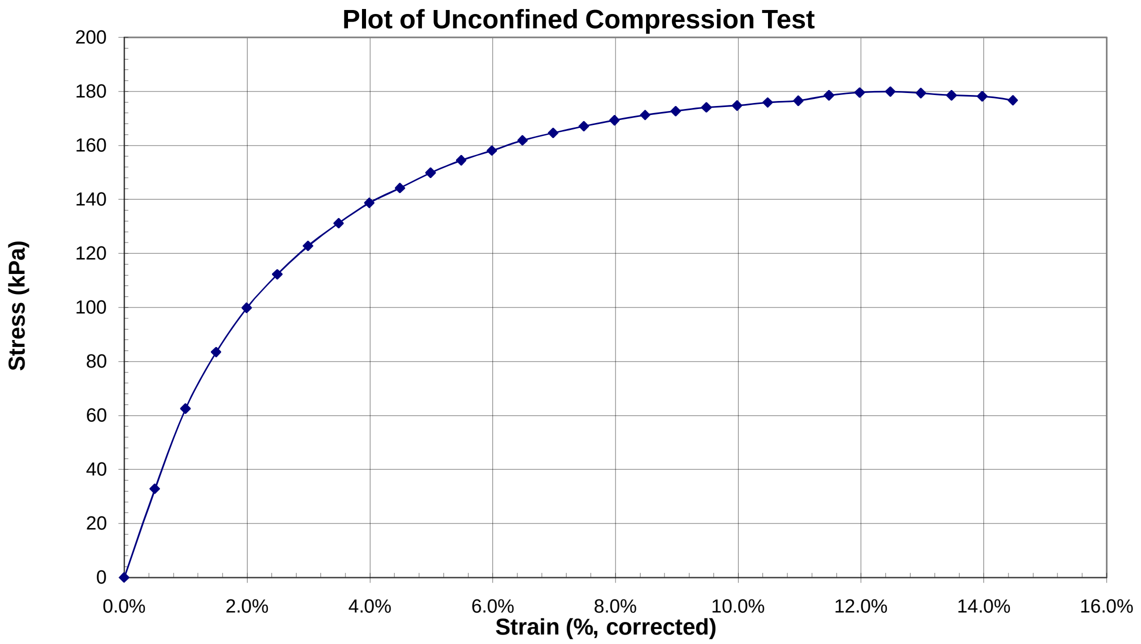
Diameter (mm)	70
Length (mm)	107.2

Water Content

Tare #	431
Wet + tare (grams)	150.31
Dry + tare (grams)	132.44
Water (grams)	17.87
Tare (grams)	34.06
Dry Soil (grams)	98.38
Water Content	18.2%

Test Results

Compressive Stress at Failure (kPa)	179.9
Strain at Failure (%)	12.5
Undrained Shear Strength (kPa)	89.95
Water Content	18.2%



Checked By:__________________ Reviewed By:________________

Unconfined Compressive Strength Test

Golder Associates

Project #: 07-1377-0128 Phase: 3000
Short Title: Yellowhead North

Location: Edmonton
Site:
Tested By: DS Date: January 5, 2009

Borehole: 08-S10 Sample: 8

Time (min)	**Strain Dial (mm)**	**Load Dial (1/1000 in)**	**Load (N)**	**Unit Strain**	**Corr Area (mm^2)**	**Stress (kPa)**
0.0	0.000	25	0.0	0.0%	4082.82	0
0.5	0.330	25	133.0	0.2%	4092.29	32.5
1.0	0.660	25	257.0	0.5%	4101.79	62.7
1.5	0.990	25	371.0	0.7%	4111.34	90.2
2.0	1.320	25	481.0	0.9%	4120.94	116.7
2.5	1.650	25	574.0	1.2%	4130.58	139.0
3.0	1.980	25	647.0	1.4%	4140.27	156.3
3.5	2.310	25	708.0	1.6%	4150.00	170.6
4.0	2.640	25	760.0	1.9%	4159.78	182.7
4.5	2.970	25	804.0	2.1%	4169.60	192.8
5.0	3.300	25	845.0	2.3%	4179.47	202.2
5.5	3.630	25	874.0	2.5%	4189.39	208.6
6.0	3.960	25	903.0	2.8%	4199.36	215.0
6.5	4.290	25	931.0	3.0%	4209.37	221.2
7.0	4.620	25	954.0	3.2%	4219.43	226.1
7.5	4.950	25	979.0	3.5%	4229.54	231.5
8.0	5.280	25	1000.0	3.7%	4239.69	235.9
8.5	5.610	25	1021.0	3.9%	4249.90	240.2
9.0	5.940	25	1041.0	4.2%	4260.15	244.4
9.5	6.270	25	1058.0	4.4%	4270.46	247.7
10.0	6.600	25	1076.0	4.6%	4280.81	251.4
10.5	6.930	25	1092.0	4.9%	4291.22	254.5
11.0	7.260	25	1107.0	5.1%	4301.67	257.3
11.5	7.590	25	1120.0	5.3%	4312.18	259.7
12.0	7.920	25	1136.0	5.6%	4322.74	262.8
12.5	8.250	25	1148.0	5.8%	4333.35	264.9
13.0	8.580	25	1161.0	6.0%	4344.01	267.3
13.5	8.910	25	1174.0	6.2%	4354.72	269.6
14.0	9.240	25	1186.0	6.5%	4365.49	271.7
15.0	9.550	25	1205.0	6.7%	4375.66	275.4
16.0	10.433	25	1225.0	7.3%	4404.87	278.1
17.0	11.155	25	1241.0	7.8%	4429.04	280.2
18.0	11.886	25	1259.0	8.3%	4453.79	282.7
19.0	12.557	25	1272.0	8.8%	4476.76	284.1
20.0	13.269	25	1289.0	9.3%	4501.38	286.4
21.0	14.015	25	1301.0	9.8%	4527.48	287.4
22.0	14.763	25	1311.0	10.3%	4553.95	287.9
23.0	15.468	25	1320.0	10.8%	4579.18	288.3
24.0	16.146	25	1324.0	11.3%	4603.72	287.6
25.0	16.858	25	1328.0	11.8%	4629.76	286.8
26.0	17.548	25	1326.0	12.3%	4655.29	284.8

Sample Description: Moist Olive Brown Silty CLAY some sand trace gravel (CLAY TILL)

Sample Dimensions

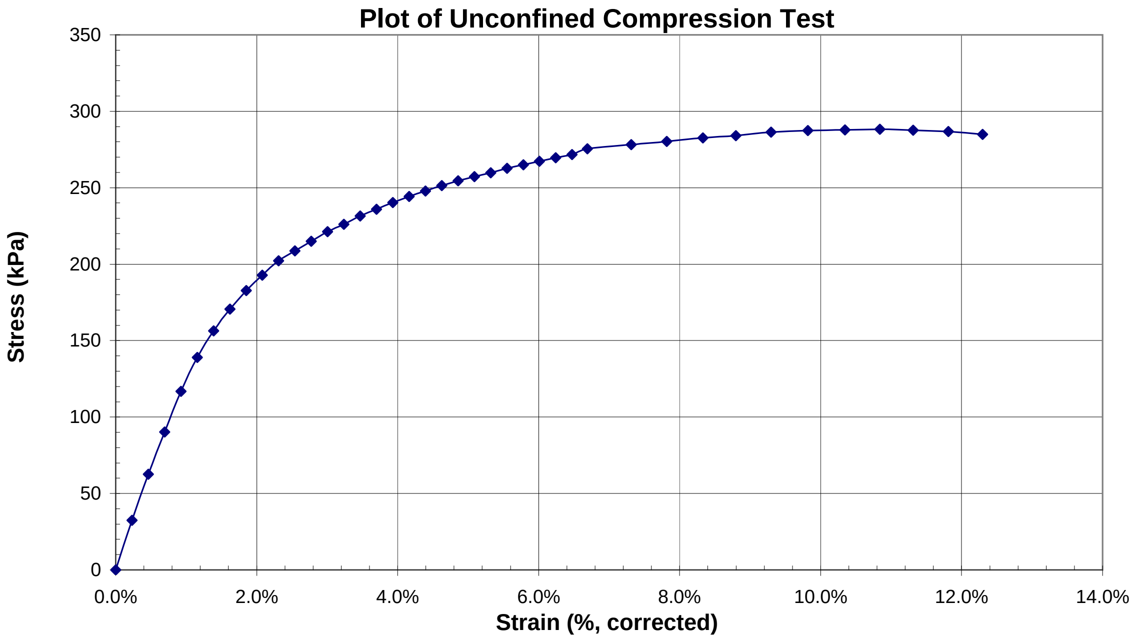
Diameter (mm)	72.1
Length (mm)	142.7

Water Content

Tare #	3D
Wet + tare (grams)	272.1
Dry + tare (grams)	262.2
Water (grams)	9.9
Tare (grams)	194
Dry Soil (grams)	68.2
Water Content	14.5%

Test Results

Compressive Stress at Failure (kPa)	288.3
Strain at Failure (%)	10.8
Undrained Shear Strength (kPa)	144.15
Water Content	14.5%



Checked By:__________________ Reviewed By:________________

Certificate of Analysis

GOLDER ASSOCIATES LTD
ATTN: MASUD KARIM
300, 10525 - 170 STREET

EDMONTON AB T5P 4W2

Reported On: 10-MAR-09 12:11 PM

Lab Work Order #: L739281 **Date Received:** 04-MAR-09

Project P.O. #:
Job Reference: 07-1377-0128
Legal Site Desc:
CofC Numbers:

Other Information:

Comments:

NHAN H NGUYEN
Senior Account Manager

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters		Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L739281-1	S10 SAMPLE#12 30-31.5 FT.								
Sampled By:	NOT PROVIDED								
Matrix:	SS								
	Resistivity	400		100	ohm cm		10-MAR-09	GCM	R797214
	pH	7.8		0.1	pH		06-MAR-09	CDU	R796216

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Methods Listed (if applicable):

ALS Test Code	Matrix	Test Description	Preparation Method Reference(Based On)	Analytical Method Reference(Based On)
PH-ED	Soil	pH		CSSS 16.3 - pH of 1:2 water extract
RESISTIVITY-1:2-CL	Soil	Resistivity - Inversion of Conductivity		MOEE E3137A

** Laboratory Methods employed follow in-house procedures, which are generally based on nationally or internationally accepted methodologies.

Chain of Custody numbers:

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location	Laboratory Definition Code	Laboratory Location
CL	ALS LABORATORY GROUP - CALGARY, ALBERTA, CANADA	ED	ALS LABORATORY GROUP - EDMONTON, ALBERTA, CANADA

GLOSSARY OF REPORT TERMS
Surr - A surrogate is an organic compound that is similar to the target analyte(s) in chemical composition and behavior but not normally detected in environmental samples. Prior to sample processing, samples are fortified with one or more surrogate compounds.
The reported surrogate recovery value provides a measure of method efficiency. The Laboratory control limits are determined under column heading D.L.
mg/kg (units) - unit of concentration based on mass, parts per million.
mg/L (units) - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
UNLESS OTHERWISE STATED, SAMPLES ARE NOT CORRECTED FOR CLIENT FIELD BLANKS.
Although test results are generated under strict QA/QC protocols, any unsigned test reports, faxes, or emails are considered preliminary.

ALS Laboratory Group has an extensive QA/QC program where all analytical data reported is analyzed using approved referenced procedures followed by checks and reviews by senior managers and quality assurance personnel. However, since the results are obtained from chemical measurements and thus cannot be guaranteed, ALS Laboratory Group assumes no liability for the use or interpretation of the results.

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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