GNWT Response to:
GoC NRCan IR#1 (ID15)

Topic
Explosive Storage

Comment
Additional information is required on explosive storage.

Recommendation
1) Is a factory (permanent or temporary) to make explosives required at or near the site? Please explain. 2) Is a magazine(s) to store explosives required at or near the site? Please describe location (quantity-distance), footprint, type of storage structure, site access, and other ancillary works. 3) There is mention of a need for an explosives permit under the Explosives Act. Will you be applying for a Factory Licence? Will you be applying for a Magazine Licence?

GNWT Response
At this time, it is not possible to provide the requested details as the procurement process for the project has not been completed. Project Co will be responsible for all details associated with potential explosives use for the project. Project Co will be responsible for obtaining all necessary permits in order to use, transport and store explosives where required. Project Co will also be responsible for determining where explosives are needed. Project Co will follow all applicable water licence/land use permit conditions in addition to any permits or licences issued by regulators for explosives use.

GNWT Response to:
GoC NRCan IR#2 (ID16)

Topic
Embankment Design

Comment
Information on road embankment design options that accommodate the range of anticipated soil, bedrock, permafrost and hydrological conditions along the road corridor is required to ensure that the impacts of the environment as well as the impact of the environment on the project are minimized. The proponent has provided one typical cross section (Fig. 4.6), which will vary along the stretch of highway as per terrain and thermal analyses, and noting that the final embankment thickness can only be specified at a future date. There are, however, no design options shown that indicate how the typical cross section could vary under a range of typical conditions within discontinuous permafrost terrain with soil and bedrock substrate. In particular, conditions where permafrost is not present or terrain is underlain by thaw stable soil or bedrock, in contrast to permafrost soils that may be thaw unstable. In addition, no options are shown in embankment design under dry, well drained conditions, in contrast to embankments adjacent to water bodies or wetland terrain. Such information is required to ensure that typical conditions within discontinuous permafrost terrain along the route potential impacts can be adequately accommodated for through engineering design of the embankment. It is not clear whether the Proponent has considered a range of design options suited to discontinuous permafrost terrain.

Recommendation
Please clarify whether design options accommodating the typical range of conditions encountered within discontinuous permafrost terrain have been developed. Please provide these if available.

GNWT Response
Different design options for the final embankment design of the roadway will only be available once Project Co has completed their design. This process can only be completed after procurement; however, Project Co's designs will consider and accommodate for the range of typical conditions encountered within discontinuous permafrost terrain. For example, the depth of the embankment layer is expected to be thinner on bedrock/gravel and thicker on clay/silty substrate; geotextile is expected to be avoided on bedrock substrate; and generally, coarser embankment material is expected to be used near swamps/wetland terrain in conjunction with proper drainage (e.g., culverts).

For permafrost soils or thaw unstable soils, some techniques have already been considered in the PDR (Section 4.4, PR#7); for example, there will be no cutting in these locations (so the natural insulative layer of organics is not disturbed), the embankment cross-section will be thicker, and may have a layer of geotextile between native ground and embankment material. On stable soils/bedrock, roadway embankment can be thinner. In addition to these considerations, the drainage system will be designed to standards that avoid ponding water and avoid permafrost thawing. Project Co may perform thermal analyses in select locations if they require additional information in order to complete their final road design.

Embankments adjacent to waterbodies or wetland terrain are typically designed to use coarser embankment material with proper drainage; whereas embankments within dry, well-drained terrain can typically be thinner. As stated in Section 4.4.2 of the PDR, the typical highway cross section (which includes geotextile between the existing ground and the embankment; Figure 4.6) will most likely be included along the entire alignment (PR#7). This method will increase the stability of the embankment.

GNWT Response to:
GoC NRCan IR#3 (ID17)

Topic
Design/Engineering

Comment
Details on embankment construction materials are required to ensure adequate design of the roadway to accommodate existing and future anticipated conditions. They are also required to evaluate the impacts of the project on the environment, and to ensure they are minimized. The proponent has indicated, in Figure 4.6, that the road embankment will be constructed of a 200 mm coarse granular base; with an embankment height minimum of 1.5 m, and a geotextile that will be placed between the existing ground and the embankment, which will most likely be included along the entire alignment. There is, however, no information given on the material specifications for the embankment fill, no information on the material specifications of the geotextile or the specific purpose that the geotextile is meant to serve. In particular, given that coarse embankment base material can have a high hydraulic conductivity, and that subsidence beneath the embankment is possible over the medium to long term, details on the material properties and purpose of the geotextile are warranted.

Recommendation
Please clarify the purpose of the non-woven geotextile between the existing ground and the embankment, and how this will be utilized in the context of engineering design of the roadway. Please provide the material specifications for the geotextile, if known, that will fulfill the requirements of the required purpose.

GNWT Response
The purpose of placing geotextile over the ground is to provide extra strength to the embankment and to stop penetration of the embankment material into the ground especially when the area is wet or marshy. The actual brand and material specifications for the geotextile that will be utilized depends on various properties, such as ultimate tensile strength, permeability, UV resistance, etc. Project Co will determine the required specifications of geotextile during the detailed design phase, which follows the procurement process. The material specifications for the embankment fill will also be finalized in the future by Project Co. Placing coarse material on the base is a way to avoid water rising due to the capillary action.

GNWT Response to:
GoC NRCan IR#4 (ID18)

Topic
Design/Engineering

Comment
Permafrost, active layer, and ground ice conditions vary naturally, and also vary with time following disturbance. The proposed TASR follows a former military winter road constructed in the 1950s and used until the 1980s, and subsequently used intermittently in summer and winter by a variety of vehicles (ATVs, snowmobiles and trucks) for access. Permafrost and terrain conditions along this right-of-way can be expected to be much different than within adjacent undisturbed terrain, where no previous impact has occurred. Similarly, the response to recent fires, and to temperature conditions caused by historically warming temperatures, are also likely to differ on and off this existing right of way due to differences in vegetation cover and soil disturbance. In other areas, the proposed TASR will cross undisturbed terrain. The contrasts between these disturbed and undisturbed areas will result in terrain conditions that need to be factored into design considerations.

Recommendation
Please clarify how terrain conditions on and off the existing disturbed terrain will be factored in the context of design criteria.

GNWT Response
Terrain conditions off the existing disturbed terrain will likely be accommodated by following the same procedure that will be utilized in areas suspected to contain permafrost (i.e., use of geotextile and no cutting); therefore, there is already a plan in place to address the contrast between the disturbed and undisturbed areas. Project Co will address these concerns in their final design of the roadway.

Based on the findings of the terrain analysis, most of the roadway alignment follows the existing cutline or winter/summer trail. In designing the embankment of the roadway, the aim is not to cut the existing ground, which means vegetation cover will not be disturbed and soil disturbance will be minimal. In addition, movement of heavy machines will be restricted to the roadway right of way area.

GNWT Response to:
GoC NRCan IR#5 (ID19)

Topic
Design/Engineering

Comment
Permafrost is ground that remains below 0°C for two or more consecutive years. Owing to the particular properties during phase change between ice and water, considerable heat is required to melt ice within permafrost. Thus, permafrost at temperatures near and below the melting point of ice can remain in that state for a considerable period of time. The proponent has indicated that, as a potential mitigation measure, isolated patches of permafrost can also be cleared and allowed to melt prior to construction. However, without adequate knowledge of the extent, temperature, and ground ice characteristics of the permafrost, such an approach may be unfeasible. In particular, given the time frame for construction of the TASR, the concern for disturbance of organic surfaces, and potential for construction during the winter season, it is unclear how isolated patches of permafrost can also be cleared and allowed to melt prior to construction.

Recommendation
Please clarify if clearing and melting of permafrost prior to construction is considered as a suitable option prior to construction.

GNWT Response
The GNWT would like to clarify that it does not intend to melt isolated patches of permafrost. Under certain circumstances where it is identified that it would be better for the long term success of the road to remove isolated patches of permafrost and/or significant ice lens (because these specific patches have been identified as expecting to melt within the next 20 years and this melting will cause the road to shift in the future), Project Co will remove all *insitu* material associated with the isolated patches of permafrost and will replace them with clean, compacted embankment material.

GNWT Response to:
GoC NRCan IR#6 (ID20)

Topic
Design/Engineering

Comment
Information on baseline terrain conditions and sensitivity, geotechnical and permafrost conditions, ground thermal conditions are required for adequate design of the highway and granular resources, impact assessment, effects of climate change on the project, and the implementation of mitigation techniques. Information on baseline terrain conditions and sensitivity along the proposed route is required to determine design parameters for the highway and for impact assessment, and to ensure impacts of the project on the environment as well as the impact of the environment on the project are minimized. Baseline information on geotechnical and permafrost conditions is required for adequate design of the highway and for characterizing potential borrow sites. This information is also required for assessment of potential impacts and implementation of mitigation techniques. Information on ground thermal conditions is required for adequate design of the highway, assessment of impacts associated with the highway and granular resource extraction and also for determining the effects of climate change on the project. The Proponent has indicated that results from geotechnical drilling will be incorporated into the final road design. At present, however, no information is available in regards to terrain sensitivity, overburden thickness, geotechnical and permafrost conditions, or ground thermal regimes.

Recommendation
Please provide any additional information on the geotechnical conditions presently known along the proposed roadway corridor, now that geotechnical drilling has been completed. If reports are incomplete, please provide borehole locations, depths drilled, and initial drilling results, if known.

GNWT Response
The draft geotechnical reports for major structures have been attached for your reference. These reports include the borehole locations, depths drilled and drilling results. The draft geotechnical report for the roadway alignment will only be available after July 3, 2017 and so will only be submitted to the public registry once it is available.

GNWT Response to:
GoC NRCan IR#7 (ID21)

Topic
Maintenance

Comment
An adequate supply of locally available granular and quarry bedrock materials is required for the construction and maintenance of the TASR embankment. The Proponent has indicated that total embankment volume is currently estimated at 3,100,000 m3 for a 1.5 m thick (average) embankment, and that estimated volumes are currently adequate. Ongoing maintenance, following initial construction will be an essential component of providing a safe driving surface, and for ensuring that no significant impacts on the environment occur during the life of the road. In addition, in evaluating the impacts on proposed granular and bedrock quarry sources, future requirements of materials for maintenance of the roadway should be considered.

Recommendation
Please clarify if estimated borrow materials from quarry and bedrock sources includes material sufficient for future maintenance of the proposed road. If material amounts include those for future maintenance, please indicate estimated amounts as part of the total resource requirements.

GNWT Response
There is enough gravel available within the preferred prospects for future maintenance to keep the roadway safe for drivers. The table located in Appendix J of the TASR PDR (PR#7) provides INF's initial estimate of available granular and bedrock prospects near the TASR. The estimated volume of these prospects exceeds INF's initial total embankment volume of 3,100,000 m^3, which INF estimated as being necessary to construct the TASR. These prospects will also contain a sufficient amount of material to support future road maintenance.

INF is currently conducting geotechnical investigations at 13 preferred prospects. Once the geotechnical investigations are complete and the final reports have been produced, actual quality and quantity of granular materials available at each source will be known in addition to whether the sources are suitable from a geochemical perspective.

EA1617-01: Tłı̨chǫ All-season Road

<u>Attachments for GNWT Information Request Response to NRCan IR6</u>

1. Geotechnical Data Report Proposed Culvert Crossing #5
2. Geotechnical Recommendation Report Proposed Culvert Crossing #5
3. Geotechnical Data Report Proposed Culvert Crossing #6
4. Geotechnical Recommendation Report Proposed Culvert Crossing #6
5. Geotechnical Data Report Proposed Bridge Crossing #8
6. Geotechnical Data Report Proposed Bridge Crossing #9
7. Geotechnical Data Report Proposed Arch Culvert Crossing #10a
8. Geotechnical Data Report Proposed Bridge Crossing #14
9. Geotechnical Data Report Proposed Bridge Crossing #15

Geotechnical Data Report
Proposed Culvert Crossing #5
Station 16+532

Geotechnical Investigation,
Proposed Tlicho All-Season Road,
Northwest Territories

Stantec

Prepared for:
Tlicho Engineering and
Environmental Services Ltd.

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Project No. 144902448

May 2017

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1.0 INTRODUCTION

Acting at the authorization of Tlicho Engineering and Environmental Services Ltd. (Tlicho), Stantec Consulting Ltd. (Stantec) carried out a geotechnical investigation in support of the culvert planned at 'Crossing #5' along the proposed Tlicho All Season Access Road (TASR). The purpose of the investigation was to characterize subsurface conditions and provide geotechnical comments and recommendations to assist with culvert design and site development.

The investigation was carried out in general accordance with Stantec's proposal dated January 12, 2017, as part of an overall geotechnical program by Tlicho for the Government of the Northwest Territories (GNWT) along the proposed 94 km TASR alignment extending from the Yellowknife Highway (Highway 3) to the Settlement of Whati on the south shore of Lac La Martre (RFP Event ID: EV000000001132). The scope of work outlined in the GNWT Request for Proposal includes the geotechnical investigation and design of the 94 km long TASR corridor, four bridges and three structural culverts. Tlicho was responsible for management and execution of the overall project and team as the Prime Contractor, with Stantec acting as sub-consultant providing geotechnical engineering and technical services to the project, including:

- Provision of geotechnical field personnel to log subsurface conditions during drilling operations at eighty-one (81) geotechnical boreholes in accordance with the RFP:
  - Thirteen (13) boreholes at the four (4) proposed major bridge crossings:
    - Crossing #8, Station 40+400 - Duport River Crossing
    - Crossing #9, Station 45+175 - (unnamed)
    - Crossing #14, Station 69+666 - James River Crossing
    - Crossing #15, Station 85+397 - La Martre River
  - Three (3) boreholes at the three (3) proposed major bridge culvert crossings:
    - Crossing #5, Station 16+532
    - Crossing #6, Station 19+427
    - Crossing #10a, Station 48+208
  - Sixty-five (65) boreholes to observe the subsurface conditions along the road alignment;
- Installation and reading of thermistors;
- Borehole layout and as-drilled survey;
- Completion of a laboratory testing program on the recovered borehole samples as specified in the RFP; and
- Geotechnical engineering assessment and reporting on the field and laboratory findings in two reports (Geotechnical Data Report and Geotechnical Recommendations Report) for each crossing location and for the overall roadway alignment.
  - These documents should be read in conjunction with the Statement of General Conditions, Appendix A

This Geotechnical Data Report contains the factual findings from the geotechnical investigation undertaken at the Crossing #5 site by Stantec including: a summary of the field and laboratory

procedures; Borehole Records; laboratory test results; and a discussion of the factual findings. The Geotechnical Recommendation Report for Crossing #5, presenting the results of our geotechnical analysis with discussion and recommendations for design purposes is provided under separate cover.

2.0 SITE DESCRIPTION AND GEOLOGY AND CLIMATE

2.1 SITE DESCRIPTION

The 'Crossing #5' culvert is proposed at an unnamed watercourse located at approximately the 16.5 km station mark along the TASR corridor as shown on Drawing No. 1 – Site Location Plan, provided in Appendix B. At this location the proposed road center line and culvert is aligned with the Old Lac La Martre roadway.

Based on a previous hydrologic study (Stantec, 2015), it is understood that the watercourse is an ephemeral tributary with poorly defined channel(s) within a relatively shallow and gentle northeast/southwest aligned trough measuring approximately 175 m wide and extending approximately 5 m below the surrounding topography. At the time of the investigation, the watercourse channel(s) were not visible from walk around inspection of the culvert location due to snow cover and/or dry, no-flow conditions. The apparent floodplain area immediately surrounding the roadway was vegetated with shrubs and trees with the upstream area more heavily vegetated than the downstream area. Several large boulders (up to 2.5 m diameter) were noted lying on ground surface or partially buried within the creek valley. Snow cover depths of approximately 50 to 55 cm were measured in surrounding areas. Photographs showing the general site conditions at the proposed culvert location are provided in Appendix B.

It is understood that the Old Lac La Martre overland winter road was established by the military in the 1950s, and utilized as a public winter road for the northern Tlicho communities up until the late 1980s. More recently it has been used by the local communities for travel using all-terrain vehicles including snowmobiles, dog sleds, ATVs, and trucks (GNWT DOT, 2016). Previous site development for the road at this location appears to be limited. The roadbed is approximately level with the surrounding undisturbed vegetated areas with no significant historic ground disturbance (regrading cut/fill) apparent.

2.2 PHYSIOLOGY AND GEOLOGY

The site is located within the Great Slave Plain High Boreal Ecoregion (ECG, 2009 and GNWT DOT, 2016). In this section of the TASR corridor (GNWT DOT, 2016), regional topography is generally subdued with plains and gently rolling hills. Drainage ranges from 'well' to 'moderately well' with occasional seasonal tributaries. Vegetation includes regenerating jack pine forest, ephemeral stream crossing/swampland, dwarf shrub and mixed stands. The general area was subjected to forest fires within the last decade.

Based on available surficial geology mapping conducted by the Geological Survey of Canada, and previous project terrain mapping (Kavik AXYS Inc, 2008 and GNWT DOT, 2016), natural overburden material in the area is thought to consist of till, coarse beach glacio-lacustrine and fine glacio-lacustrine material associated with glacial Lake McConnell, and occasional veneers of organic or fluvial materials overlying bedrock. Based on available geological mapping published by the Geological Survey of Canada (Okulitch, A.V, 2006), it is understood that the site is mapped within the Interior Platform geologic province, situated over Paleozoic aged sedimentary rocks of the Lonely Bay Formation consisting of brown limestone and minor dolostone.

2.3 CLIMATE & PERMAFROST

2.3.1 Climate

Based on a review of historic climate data completed previously by GNWT using the Yellowknife Airport (2204100), Whatì meteorological station (Lac la Martre, 2202678) and other sources (GNWT, 2016), it is understood that the TASR area has a subarctic climate (Köppen Dfc) characterized by generally relatively cold winters followed by short summers.

Average annual daily mean temperatures are on the order of -4.3 °C (Yellowknife Station) to -4.7 °C (Whati Station), with the lowest average daily winter temperatures generally occuring in January, while the warmest month (based on the average temperature) occurs in July. The average annual precipitation is estimated on the order of 288.6 mm, with an average annual rainfall of 170.7 mm generally occurring throughout June through September, and an average annual snowfall of 157.6 cm generally occurring from September through May (Yellowknife Station).

The average freezing and thawing indices between 1981 and 2010 have been 3343.1 C° days and 1813.3 C° days, respectively (Yellowknife Station). A study completed by Holubec, et. al. (2009), using data from 1978 to 2008 in their model was adapted by CSA (2010). The CSA study suggests a warming trend of 0.58 °C per decade within the Central Arctic region (including the TASR site). As per Table 5.2 in CSA (2010), seasonal mean temperature change under moderate (A1B) green-house gas scenarios, the mean annual temperatures for the Arctic Sector C1 are projected to be 1.3 °C (2011-2040), 2.7 °C (2041-2070), and 3.7 °C (2071 – 2100) respectively.

2.3.2 Permafrost

Permafrost mapping from the National Atlas of Canada (Heginbottom et al. 1995) shows the TASR site lies within the zone of extensive discontinuous permafrost (estimated 50% to 90% areal extent of the landscape), 'low' ice content in the upper 10 to 20 m, with possible 'sparse' ice wedges and massive ice bodies present.

It is understood that no public thermistor or intrusive investigation records exist for the immediate vicinity of the TASR. Previous reconnaissance trips by earlier AXYS terrain mapping and GNWT personnel did not identify permafrost landforms or thermokarst zones within the corridor at this location, however a large zone affected by thermokarst processes was noted between Whati, Behchoko and the area north of Slemon Lake Kavik (AXYS Inc, 2008 and GNWT DOT, 2016). Based on regional studies completed in surrounding areas (GNWT, 2016), permafrost is anticipated to be relatively warm and correlated with forest cover type areas underlain by finer-textured glacial and post-glacial sediments such as glaciolacustrine and lacustrine deposits, as well as peatlands where organic material contribute to the forming and preservation of permafrost. Ground ice is generally expected to be less common in areas of exposed bedrock and where the underlying sediments are coarse and vegetation cover is thin.

Permafrost near Yellowknife is reported to be generally warm (> -2°C), less than 50 m thick with active layer thickness <1 to up to 3 m (Wolfe, 1998). Permafrost conditions along the nearby Highway 3 have been reported as typically warmer than -1°C, with an active layer thickness varying from <0.7 m to 1.5 m. Extensive permafrost degradation has been noted along the Highway in recent years with settlements in soil-covered areas generally attributed to the degradation of the ice-rich permafrost subgrade particularly where it was constructed adjacent to a water body and where the road crossed over the old alignment (Stirling et al, 2015; BGC, 2011; Wolfe et al, 2015;). Permafrost, where present, will be susceptible to degradation due to ground disturbance, such as removal of trees and surface vegetation or earthworks.

Recent studies commissioned by GNWT have reported that climate change trends have negatively impacted and are projected to continue to negatively impact permafrost conditions in the region (Dillon 2007; BGC, 2011). Continued warming, changes in freeze-thaw patterns, and ultimately degradation of permafrost in the region are anticipated due to increasing temperatures and amounts of precipitation, and decreases in snow and ice cover.

3.0 INVESTIGATION PROCEDURES

3.1 FIELD INVESTIGATION

The geotechnical field investigation for the culvert, conducted as part of the overall TASR alignment geotechnical program between February 12, March 29, 2017, consisted of two geotechnical auger holes as shown on the General Layout and Borehole Location Plan, Drawing No. 2 in Appendix B. One hole was advanced at the proposed culvert center (BH14C) on February 24, 2017, and one additional hole was completed along the southern slope of the stream valley as part of the general road alignment investigation (BH13) on February 17, 2017. Borehole locations were selected by GNWT and were established in the field by Stantec using a Trimble Geo XH GPS unit.

Boreholes were completed using a track mounted Foremost auger drill rig provided and operated by Northtech Drilling Ltd. Boreholes were to be advanced to a target depth of 8 m below existing ground surface, or practical auger refusal using hallow and/or solid stem auguring techniques with regular sampling using conventional 50 mm split spoon samplers during the performance of the Standard Penetration Test (SPT). Auger refusal prior to the target depth was checked with three additional auger probe holes completed with the drill offset several meters to account for potential boulders.

The field work was conducted under the monitoring of a GNWT field representative and supervision of Stantec personnel who maintained detailed logs and obtained representative samples from the various strata encountered. Subsurface conditions were classified in general accordance with the procedures outlined in the attached explanatory key: Symbol and Terms Used on Borehole and Test Pit Records with soil descriptions prepared in accordance with ASTM D2487 and D2488. Temperatures of soils samples were measured by a handheld infrared thermometer on recovery at surface. Our observations of the temperature readings suggest the drilling process altered the temperature of the soil samples. For example, soil samples collected from the augers within the seasonal frost layer (denoted as AS) had temperature readings greater than 0° C. Frozen soils were classified in accordance with ASTM D4083 and D7099. Groundwater levels were estimated in the open boreholes at the time of drilling with water level tape and/or the moisture condition of the recovered samples.

Upon completion of drilling, holes were backfilled without instrumentation by cuttings and silica sand. At the direction of the field GNWT representative thermistor strings to permit ground temperature measurement were not installed due to the shallow depth of the holes.

3.2 LOCATION AND ELEVATION SURVEY

Final borehole locations and geodetic elevations were surveyed in the field by Stantec personnel using a Trimble Geo XH GPS with decimeter accuracy capability. The accuracy of the Trimble unit may be affected by satellite coverage at the time of the survey. Table 3.1 summarizes the borehole information.

Table 3.1: Borehole Summary

	Boreholes	
	BH17-13	**BH17-14C**
UTM Zone 11N Coordinates Northing Easting	 6933080.58 511712.10	 6933103.46 511691.98
Ground Surface Elevation, m	269.81	265.79
Total Depth Drilled, m	2.2	1.0
End of Borehole Elevation, m	267.61	264.79
Number of Soil Samples	3	2

3.3 LABORATORY TESTING

All samples were taken to the Stantec Edmonton or Calgary laboratories for detailed classification and testing. Sample preservation and handling of frozen samples was in general accordance with industry standard practices (ASTM WK24243, ASTM Special Technical Publication, no 599:88-112).

Selected soil samples underwent gradation analysis, Atterberg Limits, and moisture content testing. The laboratory testing summary is shown in Table 3.2 below.

Table 3.2: Laboratory Testing for Culvert Site

Laboratory Testing	Moisture Content	Gradation Analysis	Atterberg Limits
Number of Tests	5	3	2

To assess the potential for corrosion of buried steel elements and potential for sulphate attack on buried concrete elements, one sample of the native overburden material was tested at Maxxam Analytics for pH, water soluble sulphate and chloride concentrations, and resistivity.

Samples remaining after testing will be placed in storage for a period of one year after issuance of the final report. After the storage period, the samples will be discarded unless we are directed otherwise by Tlicho Engineering and Environmental Services Ltd.

4.0 SUBSURFACE CONDITIONS

4.1 SUBSURFACE PROFILE

The subsurface conditions observed in the boreholes are presented in detail on the Borehole Records provided in Appendix C with further discussion below on the individual soil units encountered. An explanation of the symbols and terms used to describe the Borehole Records is provided in Appendix C. The temperature of each soil sample was measured in the field and is provided on the Borehole Records.

The temperature of each soil sample was measured in the field using an infrared thermometer and is provided on the Borehole Records. Ground temperatures inferred from temperature measurements of soil samples should be considered with extreme caution. Soil sample temperatures may be either warmer than in-situ due to drilling disturbance or be colder than in-situ due to cold air temperature exposure of the soil samples prior to temperature measurement.

It should be noted that the blow counts and relative density/consistency descriptions of frozen soils in the Appendix C should be used with caution. It is highly likely, particularly for cohesive soils, that the strengths implied by the blow counts will be significantly reduced by thawing.

In general, the subsurface stratigraphy at the culvert location consisted of a thin veneer of frozen overburden materials overlying relatively shallow inferred bedrock. Soils conditions at BH17-14C differed and could not be directly correlated with those at BH17-13 located approximately 32 m away. Soils conditions at BH17-14C consisted of thin layers of topsoil/rootmat and silty sand with gravel overlying inferred bedrock, while soil conditions at BH17-13 consisted of thin layers of sandy silt, silty sand and sandy lean clay overlying bedrock.

4.1.1 Rootmat/Topsoil

A thin (75 mm) surficial layer of frozen rootmat/topsoil was encountered at BH17-14C completed just off recently cleared area on the east edge of existing roadway. Exposed soil was encountered at BH17-13, completed within the roadway.

4.1.2 Silty Sand with Gravel

At Borehole 17-14C a layer of frozen brown-grey silty sand (SM) to silty sand with gravel (SM) was encountered under the rootmat/topsoil and extending to the termination depth of the borehole (1.0 m). Temperatures of the soil samples ranged from 3.2 to -3.4 °C. The frozen soil description of the layer was N_f to N_{bn}.

Grain size distribution and moisture content tests carried out on a representative samples of the material yielded the following results:

Gravel:	16%
Sand:	60%
Silt:	17%
Clay:	7%
Moisture content:	3 to 4%

The grain size distribution curve is provided in Figure 1 and the corresponding plasticity chart is given in Figure 4 of Appendix D. The Unified Soil Classification System (USCS) group symbol for this layer is SM (silty sand with gravel).

4.1.3 Sandy Silt

At Borehole 17-13, a 1.1 m thick layer of frozen rusty brown to brown sandy silt to silty sand was encountered at surface. Temperatures of the soil samples ranged from 3.9 to 5.2 °C. The frozen soil description of the layer was N_{bn}

Grain size distribution and moisture content tests carried out on a representative sample of the material yielded the following results:

Gravel:	3%
Sand:	41%
Silt:	42%
Clay:	14%
Moisture content:	11%

The grain size distribution curve is provided in Figure 2 of Appendix D. The USCS group symbol for this layer is ML (sandy silt).

4.1.4 Silty Sand

At BH17-13, a thin (0.15 m) layer of frozen grey sandy material was encountered below the sandy silt layer. Based on visual examination, the material is classified as a silty sand (SM) and contained <5-10% visual ice content in thin horizontal lenses and individual inclusions. Temperatures of the soil samples ranged from -1.4 to -3.2 °C. The frozen soil description of the layer was V_x to V_c.

4.1.5 Sandy Clay

At BH17-13, an approximately 1.0 m thick layer of frozen grey-brown sandy lean clay (CL) was encountered below the sand layer and extending to the termination depth of the auger hole on practical refusal at 2.1 m. Temperatures of the soil samples range from -1.4 to -3.2 °C. The frozen soil description of the layer was N_f.

Grain size distribution, moisture content, and Atterberg limits tests carried out on a representative samples of the material yielded the following results:

Gravel:	6%
Sand:	36%
Silt:	35%
Clay:	23%
Moisture content:	12%
Liquid Limit	22
Plastic Limit	11
Plasticity Index	11

The grain size distribution curve is provided in Figure 3 and Atterberg Limits record are provided in Figure 5 Appendix D. The USCS group symbol for this layer is CL (sandy lean clay).

4.1.6 Inferred Bedrock

Practical auger refusal was encountered at both locations at maximum depths of 2.2 m and 1.0 m, corresponding to approximate elevations of 267.6 m and 264.8 m, respectively in BH17-13 and BH17-14C. Four additional auger probes completed further southwest along the approximate culvert centerline to the opposite side of the existing road from BH17-14C encountered refusals at progressively shallower depths at approximately 0.8 m, 0.6 m, and 0.5 m below ground surface. Additional auger probes at BH17-13 encountered refusals at similar approximate depths (2.2, 2.2 m).

It should be noted that practical auger and sampling equipment refusal can occur within dense/hard soil, cobbles and boulders, or well-bonded frozen soil and may not necessarily be representative of the bedrock surface. In order to confirm bedrock at the auger hole locations, diamond drilling with bedrock coring of 3 m or greater would be required.

4.2 PERMAFROST CONDITIONS

Based on the visual examination and infrared thermometer readings of the recovered auger and split spoon samples, frozen soil conditions were inferred to the termination depth of both boreholes (up to 2.1 m).

4.3 GROUNDWATER

Groundwater was not encountered in the open boreholes at the time of drilling, or inferred based on sample moisture contents.

It should be noted that water levels observations were recorded in winter conditions and will likely differ seasonally, and fluctuate in response to precipitation events and with alterations to the landscape. It is anticipated that drainage and groundwater flows in this area will be more developed at this location of in the warmer months (spring freshet to fall) as it is the location of an ephemeral watercourse. In permafrost terrain, groundwater will be confined to the seasonal active layer.

Table 4.1: Summary of Groundwater Levels

Borehole No.	Observation/Measurement Date	Groundwater Depth (m)	Ground Surface Elevation(m)	Groundwater Elevation (m)
BH17-13	February 17, 2017	Not observed	269.81	<267.6
BH17-14C	February 24, 2017	Not observed	265.79	<264.8

4.4 CHEMICAL TEST RESULTS

One sample of the native overburden material at Borehole 14C was tested for pH, water soluble sulphate and chloride concentrations, and resistivity at Maxxam Analytics. The analysis results are summarized in Table 4.2 and provided in Appendix D.

Table 4.2: Results of Chemical Analysis

Borehole No	Sample No.	Depth (m)	pH	Chloride (%)	Sulphate (%)	Resistivity (Ohm-m)
BH17-14C	AS1	0.0 to 8.1	7.7	0.0044	0.0017	13

5.0 CLOSURE

Use of this report is subject to the Statement of General Conditions provided in Appendix A. It is the responsibility of Tlicho Engineering and Environmental Services Ltd., who is identified as "the Client" within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec Consulting Ltd. should any of these not be satisfied. The Statement of General Conditions addresses the following:

- Use of the report
- Basis of the report
- Standard of care
- Interpretation of site conditions
- Varying or unexpected site conditions
- Planning, design or construction

This report was written by Justin Matthew, B.Eng. and reviewed by Christopher McGrath, P.Eng. and Jim Oswell, P.Eng. We trust that the information contained in this report is adequate for your present purposes. If you have any questions about the contents of the report or if we can be of any other assistance, please contact us at your convenience.

STANTEC CONSULTING LTD.

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6.0 REFERENCES

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2000. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

Canadian Standards Association (CSA). 2010. Technical Guide Infrastructure in permafrost: A guideline for climate change adaptation. Canadian Standards Association, Mississauga, ON, Canada.

Environment Canada. Warming Trends °C/Decade, Based on homogenized temperature data – the most recent 30 yr record (1981 – 2010); Environment Canada.

Environment Canada. (2016, September 1) Canadian Climate Normals 1981–2010. Yellowknife Station. Retrieved from http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProv&lstProvince=NT&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=1706&dispBack=0

GSC, 1965. Glacial Lake McConnell and the surficial geology of parts of Slave River and Redstone River map areas, District of Mackenzie; Craig, B G. Geological Survey of Canada, Bulletin 122, 1965, ; 44 pages, doi:10.4095/100639. Natural Resources Canada. 1995: Canada Permafrost; The National Atlas of Canada 5th Edition, scale 1:7 500 000.

Heginbottom, J.A., Dubreuil, M.A., and P.A. Harker. 1995. Canada-Permafrost; National Atlas of Canada, 5th edition, Plate 2.1. Geomatics Canada, National Atlas Information Service and Geological Survey of Canada (MCR 4177).

GSC, 1989. Glacial Features Around the Keewatin Ice Divide, Northwest Territories; Aylsworth, J M; Shilts, W W. Geological Survey of Canada, Preliminary Map 24-1987, 1989, ; 2 sheets, doi:10.4095/126992.

GNWT, 2008. Ecosystem Classification Group (ECG) 2008. Ecological Regions of the Northwest Territories: Taiga Shield. Department of Environment and Natural Resources, GNWT. Yellowknife, NT.

GNWT DOT, 2016. Proposed Tli?cho All-season Road, Project Description Report. March 2016

Kavik AXYS Inc. 2008a. Multi-Level Mapping and Route Analysis – Tlicho Transportation Corridor. Route Identification and Evaluation. Yellowknife, NT. January 2008.Project No. Project No. 144902005.

Kerr and Wilson, 2000. 2000-C3. Preliminary surficial geology studies and mineral exploration considerations in the Yellowknife area, Northwest Territories. D.E. Kerr and P. Wilson.

Stantec, 2015.Tli Cho Road Alignment, Hydrologic and Hydraulic Study. Project No. 144902005.

Wolfe, 1998. Living with frozen ground : a field guide to permafrost in Yellowknife, Northwest Territories, edited by Stephen A. Wolfe ; contributions by Stephen A. Wolfe

S.A. Wolfe, P.D. Morse, T.E. Hoeve, W.E Sladen, S.V. Kokelj, L.U. Arenson, 2015. Disequilibrium permafrost conditions on NWT Highway 3

APPENDIX A

Statement of General Conditions

STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec Consulting Ltd. and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec Consulting Ltd.'s present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec Consulting Ltd. is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec Consulting Ltd. at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec Consulting Ltd. must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec Consulting Ltd. will not be responsible to any party for damages incurred as a result of failing to notify Stantec Consulting Ltd. that differing site or sub-surface conditions are present upon becoming aware of such conditions.

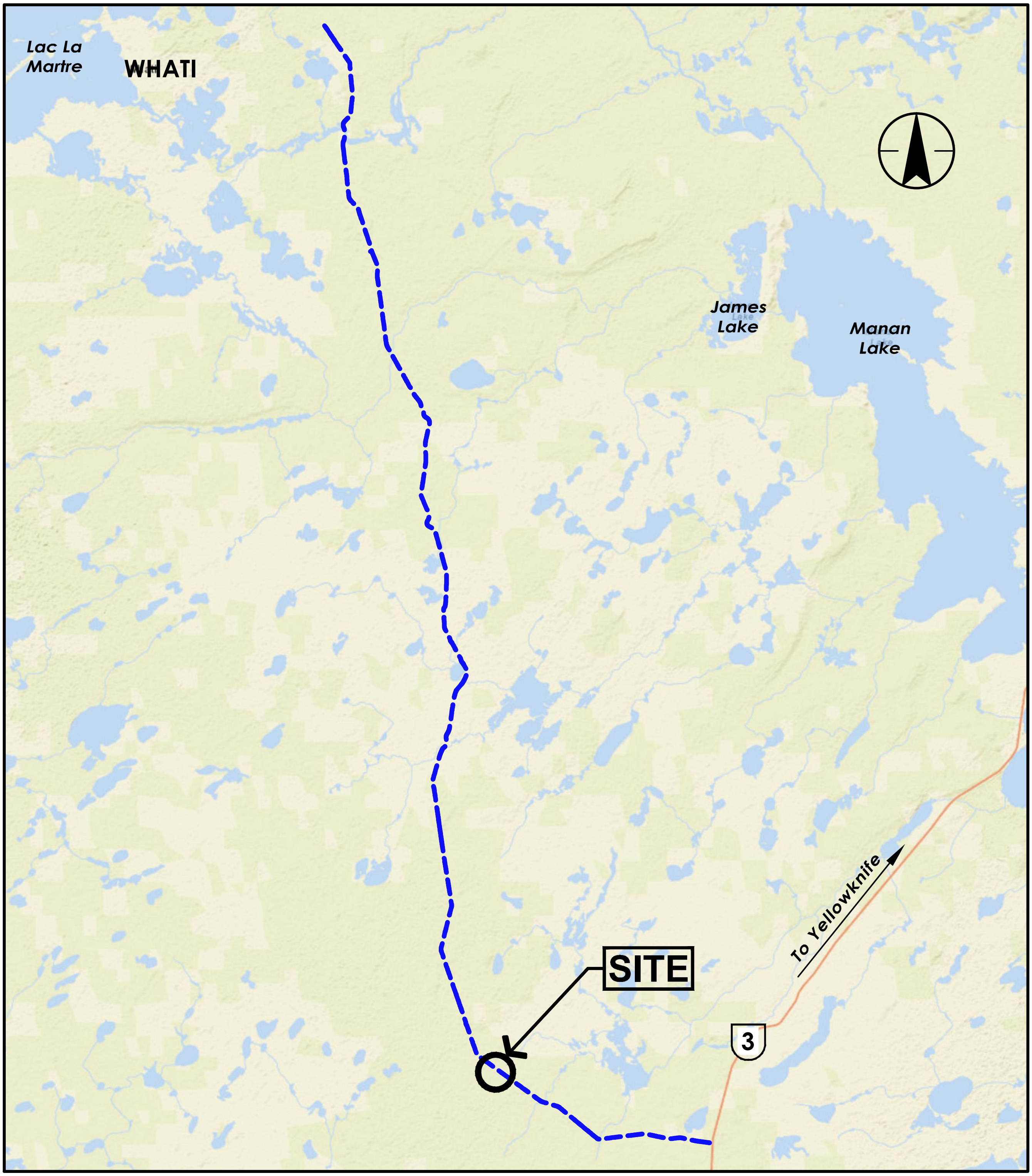
PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec Consulting Ltd., sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec Consulting Ltd. cannot be responsible for site work carried out without being present.

APPENDIX B

Drawing No. 1 – Site Location Plan

Drawing No. 2 - Borehole Location Plan and Soil Strata Plot

Site Photos



APRIL 2017
Project No. 144902448

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2017/04/28 3:06 PM By: Briones, Gliceria

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LEGEND

PROPOSED ALIGNMENT

NOTES

IMAGERY: ESRI ©2017.

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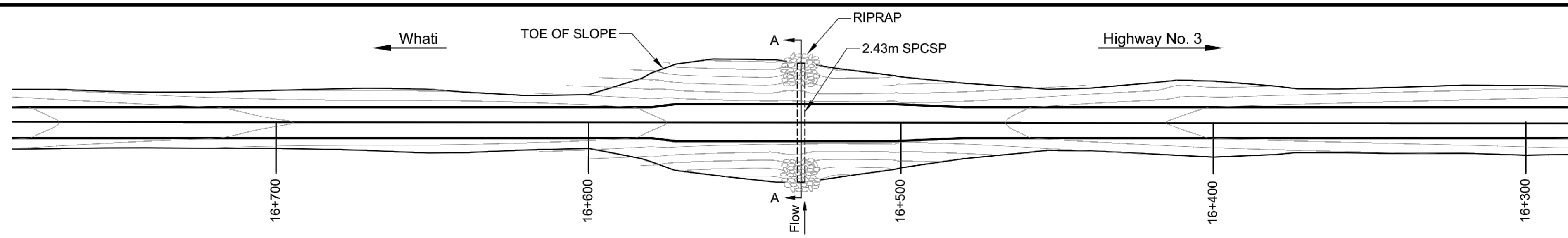
GEOTECHNICAL INVESTIGATION
CROSSING #5 CULVERT, NWT

Drawing No.

1

Title

KEY PLAN



SITE PLAN
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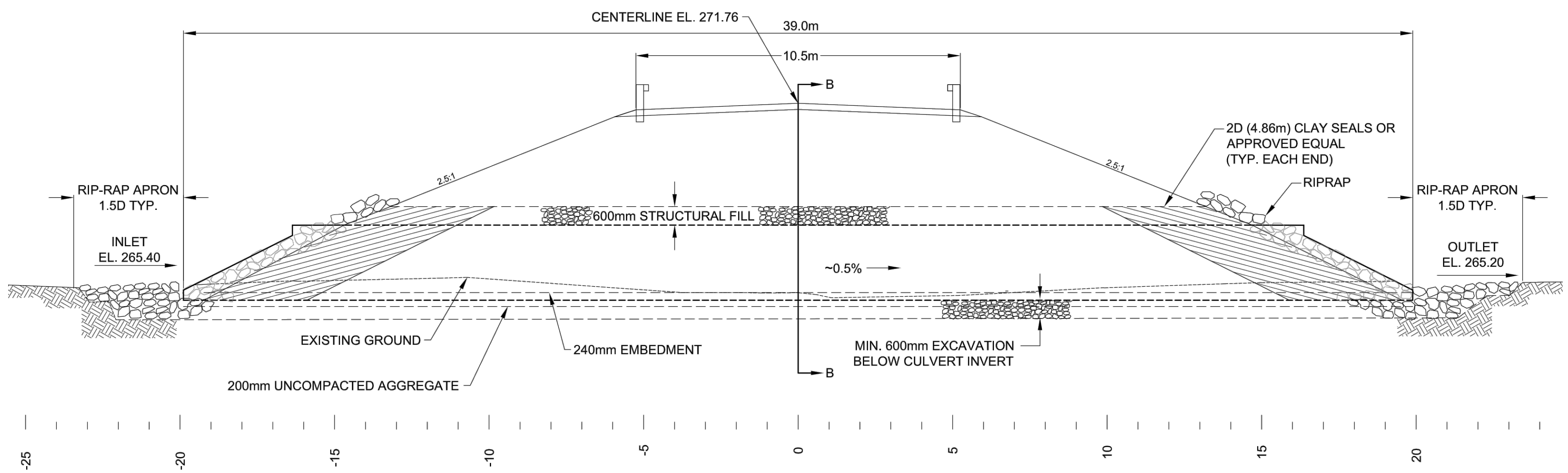

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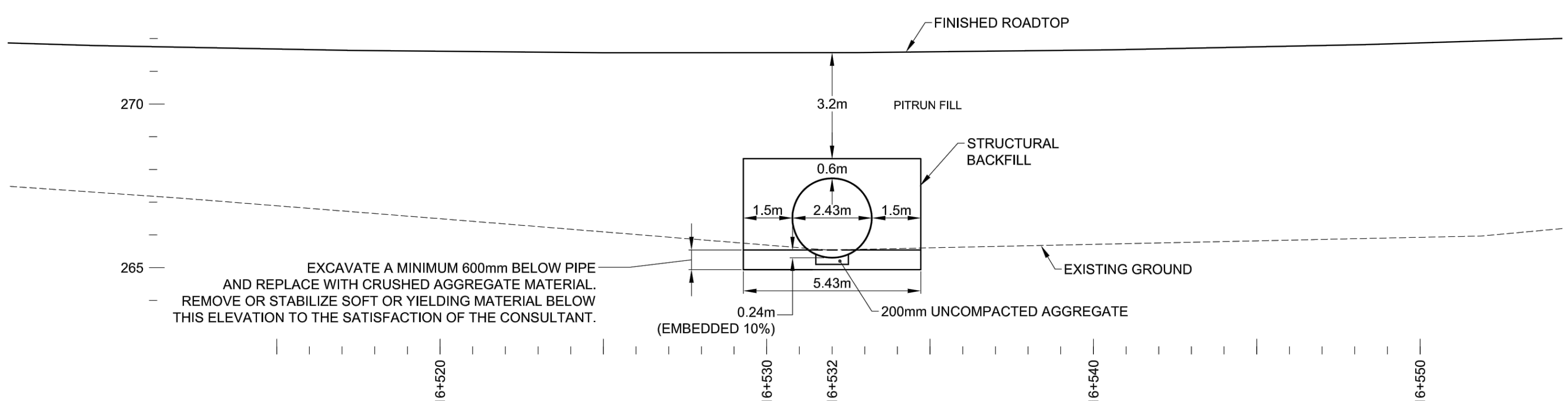

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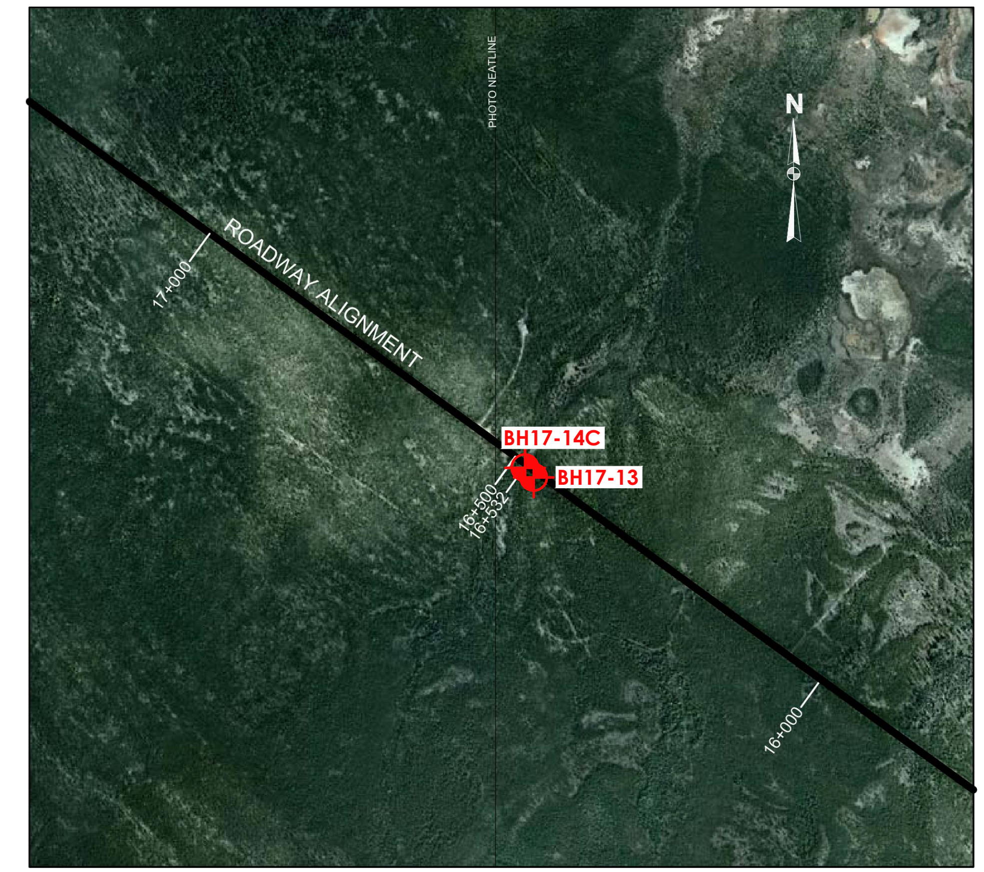

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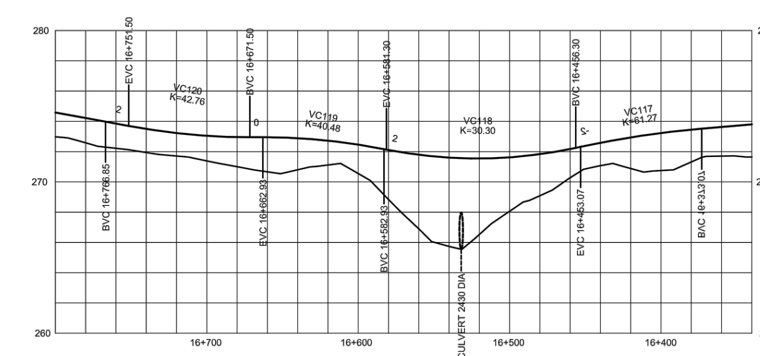

ROADWAY PROFILE
H 1:5,000 V 1:500

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2017/04/28 3:09 PM By: Briones, Gliceria

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APPROXIMATE BOREHOLE LOCATION

NOTES

1. DRAWING PROVIDED BY DOT TECHNICAL SERVICES (TASR-02-16 (CROSSING#5).

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GEOTECHNICAL INVESTIGATION
CROSSING #5 CULVERT, NWT

Drawing No.

2

Title

GENERAL LAYOUT AND BOREHOLE LOCATION PLAN

Photo No. 1: Borehole BH17-13 location (looking southeast).

Photo No. 2: Borehole BH17-13 location (looking northwest to BH17-14C)

Photo No. 3: Borehole BH17-14C (looking north)

Photo No. 4: Borehole BH17-14C location (looking northwest)

APPENDIX C

Symbols and Terms Used on Borehole Records

Stantec Borehole Records

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

Rootmat	- vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
Topsoil	- mixture of soil and humus capable of supporting vegetative growth
Peat	- mixture of visible and invisible fragments of decayed organic matter
Till	- unstratified glacial deposit which may range from clay to boulders
Fill	- material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

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

Terminology describing soil types:
The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4th Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):
Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

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

Terminology describing compactness of cohesionless soils:
The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. A relationship between compactness condition and N-Value is shown in the following table.

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

Terminology describing consistency of cohesive soils:
The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	Undrained Shear Strength		Approximate SPT N-Value
	kips/sq.ft.	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25 - 0.5	12.5 - 25	2-4
Firm	0.5 - 1.0	25 - 50	4-8
Stiff	1.0 - 2.0	50 – 100	8-15
Very Stiff	2.0 - 4.0	100 - 200	15-30
Hard	>4.0	>200	>30

ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Terminology describing rock quality:

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

Alternate (Colloquial) Rock Mass Quality	
Very Severely Fractured	*Crushed*
Severely Fractured	*Shattered or Very Blocky*
Fractured	*Blocky*
Moderately Jointed	*Sound*
Intact	*Very Sound*

RQD (Rock Quality Designation) denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 in.) long are summed and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

SCR (Solid Core Recovery) denotes the percentage of solid core (cylindrical) retrieved from a borehole of any orientation. All pieces of solid (cylindrical) core are summed and divided by the total length of the core run (It excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

Fracture Index (FI) is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

Terminology describing rock with respect to discontinuity and bedding spacing:

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

Terminology describing rock strength:

Strength Classification	Grade	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	<1
Very Weak	R1	1 – 5
Weak	R2	5 – 25
Medium Strong	R3	25 – 50
Strong	R4	50 – 100
Very Strong	R5	100 – 250
Extremely Strong	R6	>250

Terminology describing rock weathering:

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

STRATA PLOT

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

Boulders Cobbles Gravel	Sand	Silt	Clay	Organics	Asphalt	Concrete	Fill	Igneous Bedrock	Meta-morphic Bedrock	Sedi-mentary Bedrock

SAMPLE TYPE

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

WATER LEVEL MEASUREMENT

▼	measured in standpipe, piezometer, or well
▽	inferred

RECOVERY

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

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to 'A' size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

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

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

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BOREHOLE RECORD

N: 6 933 081 E: 511 712

BH17-13

CLIENT Tlicho Engineering and Environmental Services Ltd. | BOREHOLE No. BH17-13

LOCATION Northwest Territories, Canada | PROJECT No. 144902448

DATES: BORING July 17, 2017 WATER LEVEL N/A | DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	269,81	Very dense, rusty brown to brown, frozen, sandy SILT (ML), some clay, trace gravel and rootlets			AS	1	-	-
1	268,7	- Approx. sample temperature: AS1: +3.9 to +5.2 °C SS2: +3.9 to +5.2 °C			SS	2	381	54
	268,4	- Frozen soil description: Nf			AS	3	-	-
2	267,6	Very dense, rusty brown to brown, frozen, silty SAND (SM), trace gravel - Approx. sample temperature: SS2: -1.4 to -3.2°C - Frozen soil description: Vx to Vc						
3–4		Brown, frozen, sandy lean CLAY (CL) - Pulverized rock dust, trace gravel observed at termination depth - Frozen soil description: Nf						
5		End of Borehole - Auger refusal at 2.2 m depth - Auger refusal encountered at 2.2 m depth, 0.9 m east of borehole - Auger refusal also encountered at 2.2 m depth, 1.8 m east of borehole						
6								
7								
8								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Stantec

BOREHOLE RECORD

N: 6 933 103 E: 511 692

BH17-14C

CLIENT Tlicho Engineering and Environmental Services Ltd.

LOCATION Northwest Territories, Canada

DATES: BORING February 24, 2017 WATER LEVEL N/A

BOREHOLE No. BH17-14C

PROJECT No. 144902448

DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY (mm)	SAMPLES: N-VALUE OR RQD
0	**265,79**							
	265,7	76 mm FROZEN TOPSOIL/ROOTMAT						
		Very loose, brown-grey, frozen, silty SAND with gravel (SM)			AS	1	-	-
	264,8				SS	2	25%	50/0.03m
1		- Approx. sample temperature: AS1: +3.2 °C SS2: -2.8 to -3.4 °C - Frozen soil description: Nf to Nbn						
2		End of Borehole - Auger refusal on Inferred cobbles and boulders or bedrock - Auger refusal at 1.0 m depth - Auger refusal also encountered at 0.8 m depth, 0.8 m east of BH17-14C - Auger refusal also encountered at 0.6 m depth, 2.4 m south-east of BH17-14C - Auger refusal also encountered at 0.5 m depth, 2.1 m east of BH17-14C						
3								
4								
5								
6								
7								
8								

UNDRAINED SHEAR STRENGTH - kPa: 50 100 150 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd

Date

APPENDIX D

Laboratory Test Results

Stantec

Grain Size Analysis

Hydrometer Report
ASTM D422
CANFEM

Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho All Season Road
Project No: 144802448

OFFICE
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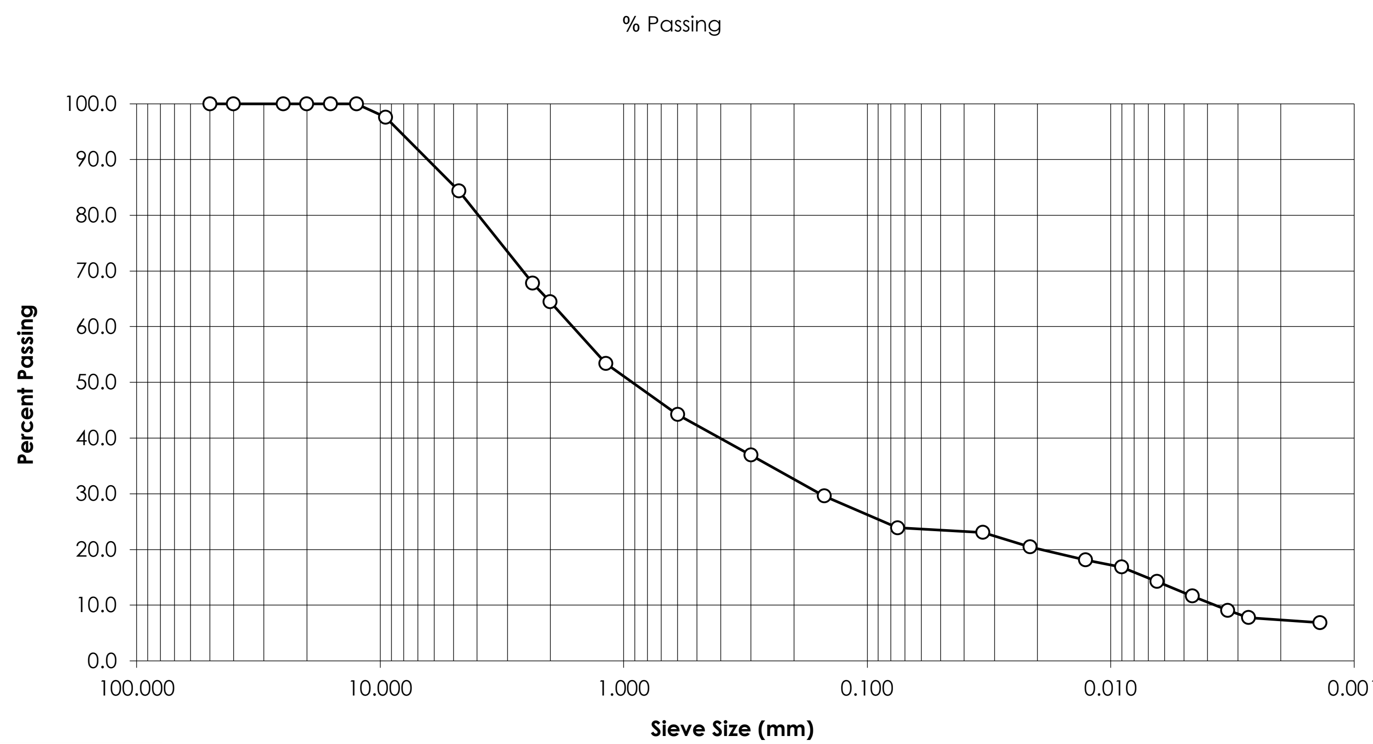
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: AS1
SOURCE: BH17-14C
TESTED BY: JA

DATE TESTED: April 8, 2017
DATE RECEIVED: March 27, 2017
SAMPLE DESCRIPTION: Silty sand with gravel



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0064	14.2
40.0	100.0	0.0046	11.7
25.0	100.0	0.0033	9.1
20.0	100.0	0.0027	7.8
16.0	100.0	0.0014	6.9
12.5	100.0		
9.5	97.6		
4.75	84.4		
2.36	67.8		
2.00	64.5		
1.18	53.3		
0.600	44.2		
0.300	37.0		
0.150	29.6		
0.075	23.9		
0.0335	23.0		
0.0214	20.5		
0.0127	18.1		
0.0090	16.8		

Gravel:	15.6%	D_{10}:	0.0038
Sand:	60.5%	D_{30}:	0.1588
Silt:	16.5%	D_{60}:	1.6893
Clay:	7.4%	C_u:	442.26
		C_c:	3.91

CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Comments:

Figure No. 1

Reviewed by:

Stantec

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

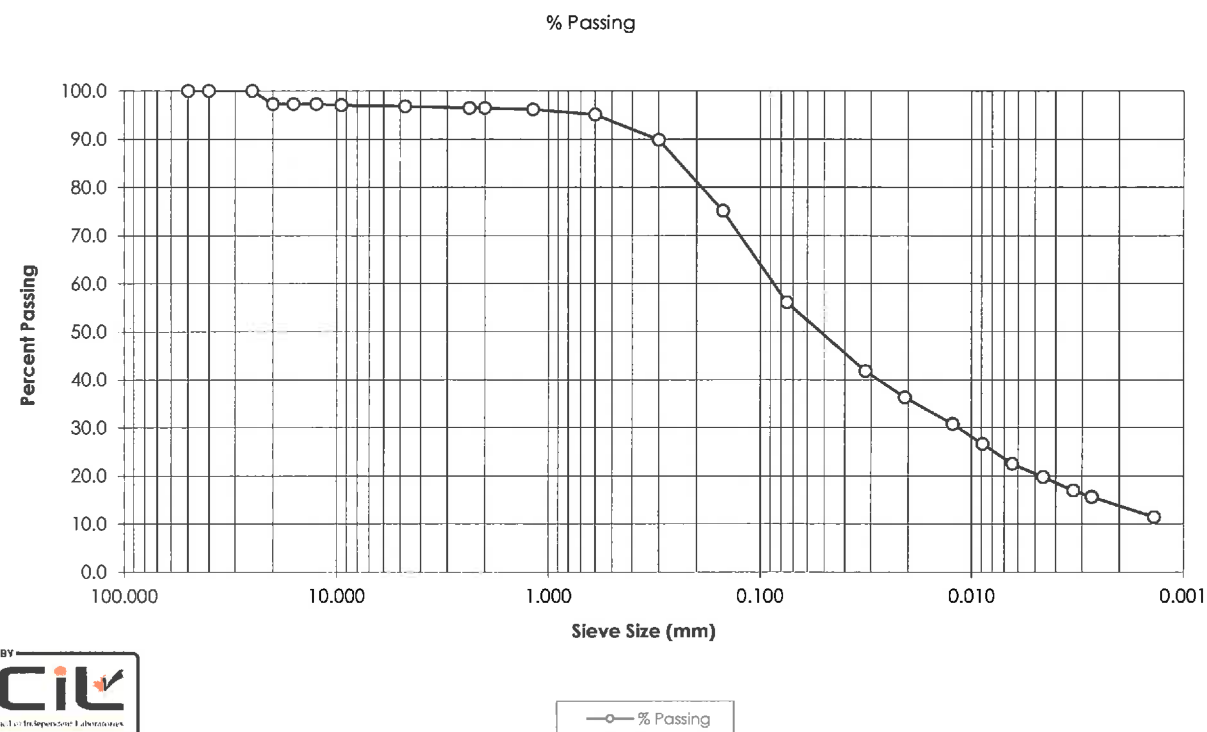
Client: Tli Cho Engineering&Environmental Services Ltd
Project Name: TliCho AllSeason Rd.Investig.
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: AS1
SOURCE: BH17-13
TESTED BY: JA

DATE TESTED: March 20, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy silt and/or clay



CERTIFIED BY CCIL
For specific tests as listed on www.ccil.com

Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0064	22.5
40.0	100.0	0.0046	19.7
25.0	100.0	0.0033	17.0
20.0	97.3	0.0027	15.6
16.0	97.3	0.0014	11.5
12.5	97.3		
9.5	97.0		
4.75	96.8		
2.36	96.4		
2.00	96.4		
1.18	96.1		
0.600	95.1		
0.300	89.9		
0.150	75.1		
0.075	56.1		
0.0319	41.8		
0.0208	36.3		
0.0123	30.8		
0.0089	26.6		

Gravel:	3.2%	D_{10}:	-
Sand:	40.6%	D_{30}:	0.0117
Silt:	42.4%	D_{60}:	0.0921
Clay:	13.8%	C_u:	-
		C_c:	-

Comments:

Figure No. 2

Reviewed by:

Stantec

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

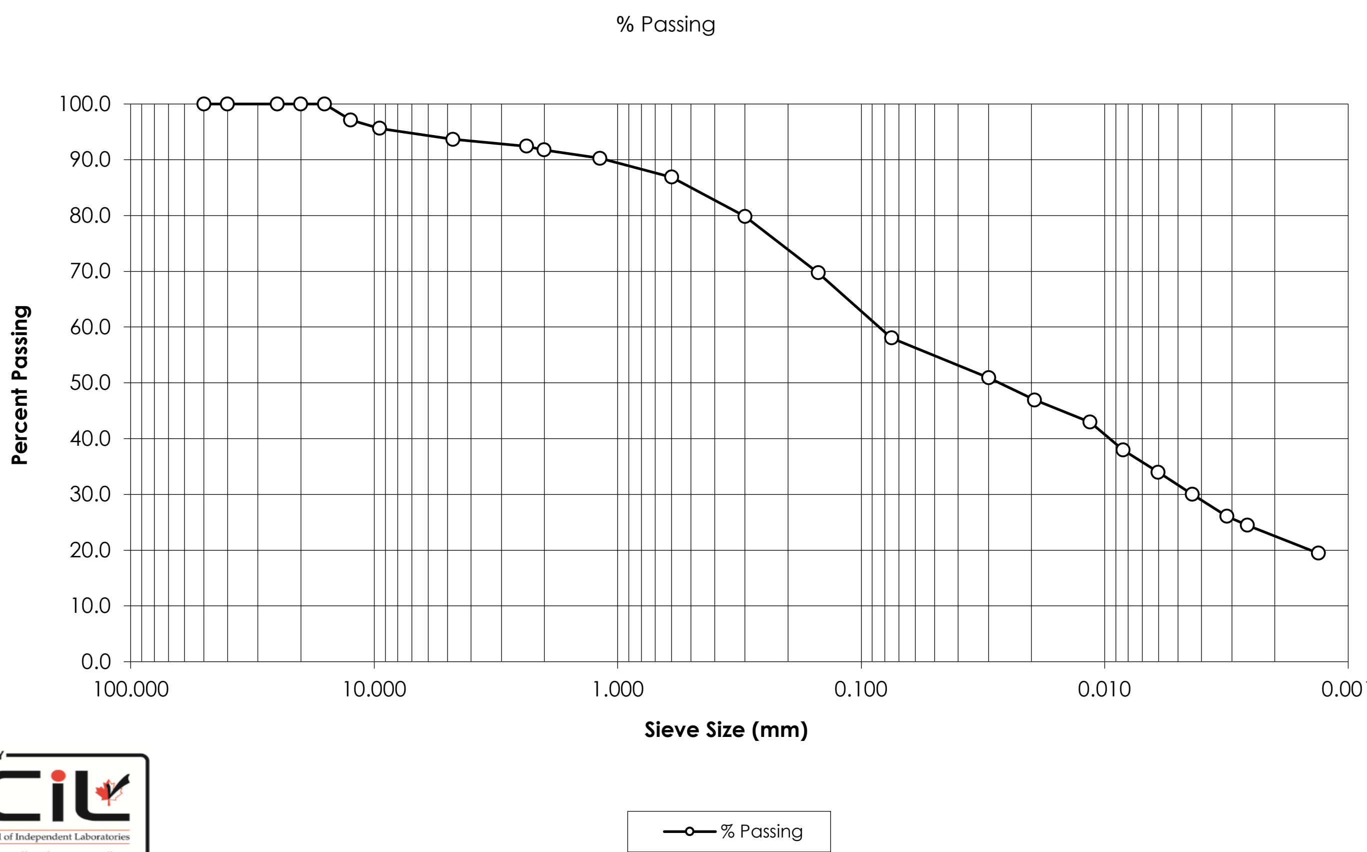
Client: Tlicho Engineering & Environmental Services
Project Name: TliCho All Season Road
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: AS3
SOURCE: BH17-13
TESTED BY: JA

DATE TESTED: March 22, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy lean clay



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	**100.0**	**0.0060**	**34.0**
40.0	**100.0**	**0.0044**	**30.0**
25.0	**100.0**	**0.0031**	**26.0**
20.0	**100.0**	**0.0026**	**24.5**
16.0	**100.0**	**0.0013**	**19.4**
12.5	**97.1**		
9.5	**95.6**		
4.75	**93.7**		
2.36	**92.4**		
2.00	**91.8**		
1.18	**90.3**		
0.600	**86.9**		
0.300	**79.8**		
0.150	**69.7**		
0.075	**58.1**		
0.0299	**50.9**		
0.0194	**46.9**		
0.0115	**43.0**		
0.0084	**37.9**		

Gravel:	6.3%	D_{10}:	-
Sand:	35.6%	D_{30}:	0.0044
Silt:	35.5%	D_{60}:	0.0885
Clay:	22.6%	C_u:	-
		C_c:	-

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Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Comments:

Figure No. 3

Reviewed by:

Reporting of these test results constitutes a testing service only. Engineering interpretation or evaluation of the test results is provided only on written request. The data presented above is for the sole use of the client stipulated above. Stantec is not responsible, nor can be held liable, for the use of this report by any other party, with or without the knowledge of Stantec.

Stantec

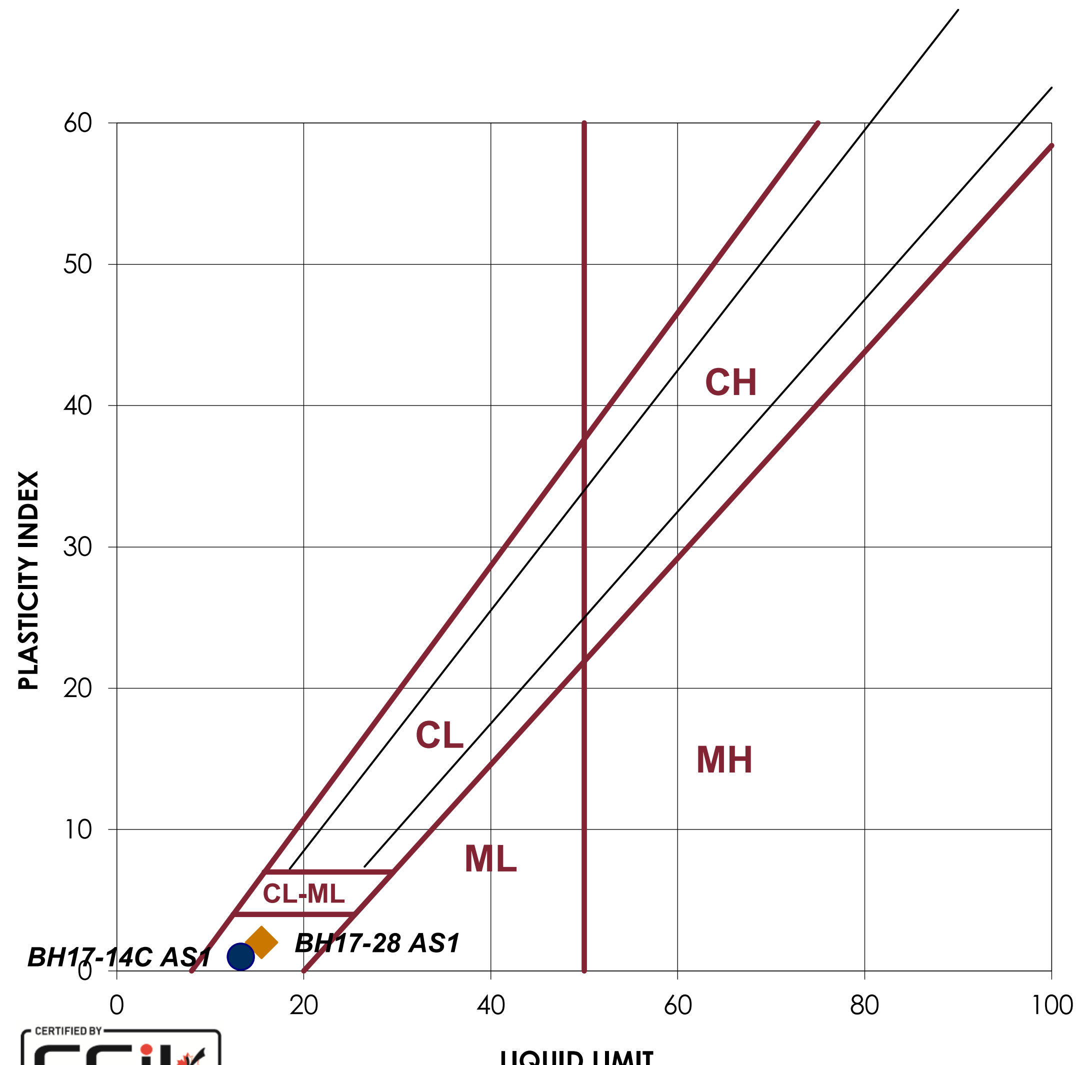
Atterberg Limits
ASTM D4318
Method B- One Point

Client:	Tlicho Engineering & Environtmental Servic
Project Name:	TliCho All Season Road
Project No:	144902448
Date Received:	March 27, 2017
Date Tested:	April 5, 2017
Tested By:	JA

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

Sample:			Sample:	
BH17-14C AS1			BH17-28 AS1	
LIQUID			LIQUID	
1	2	Trial No.	1	2
20	20	Number of Blows	20	20
30B	46	Container Number	43B	32B
47.87	45.08	Wt. Sample (wet+tare)(g)	53.09	59.04
43.97	41.49	Wt. Sample (dry+tare)(g)	47.88	53.03
15.29	15.33	Wt. Tare (g)	15.33	15.14
28.7	26.2	Wt. Dry Soil (g)	32.6	37.9
3.9	3.6	Wt. Water (g)	5.2	6.0
13.6%	13.7%	Water Content (%)	16.0%	15.9%
13.2%	13.4%	Corrected Water Content (%)	15.6%	15.4%
PLASTIC			PLASTIC	
1	2	Trial No.	1	2
AM	AN	Container Number	BC	BF
20.41	22.82	Wt. Sample (wet+tare)(g)	20.5	20.82
19.74	21.91	Wt. Sample (dry+tare)(g)	19.73	20.02
13.85	14.11	Wt. Tare (g)	14.18	14.13
5.9	7.8	Wt. Dry Soil (g)	5.6	5.9
0.7	0.9	Wt. Water (g)	0.8	0.8
11.4%	11.7%	Water Content (%)	13.9%	13.6%
AVERAGE VALUES			AVERAGE VALUES	
1	2		1	2
LL	13		LL	16
PL	12		PL	14
PI	1		PI	2
CLASSIFICATION			CLASSIFICATION	
ML			**ML**	



CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Reviewed By: ____________________

Figure No. 4

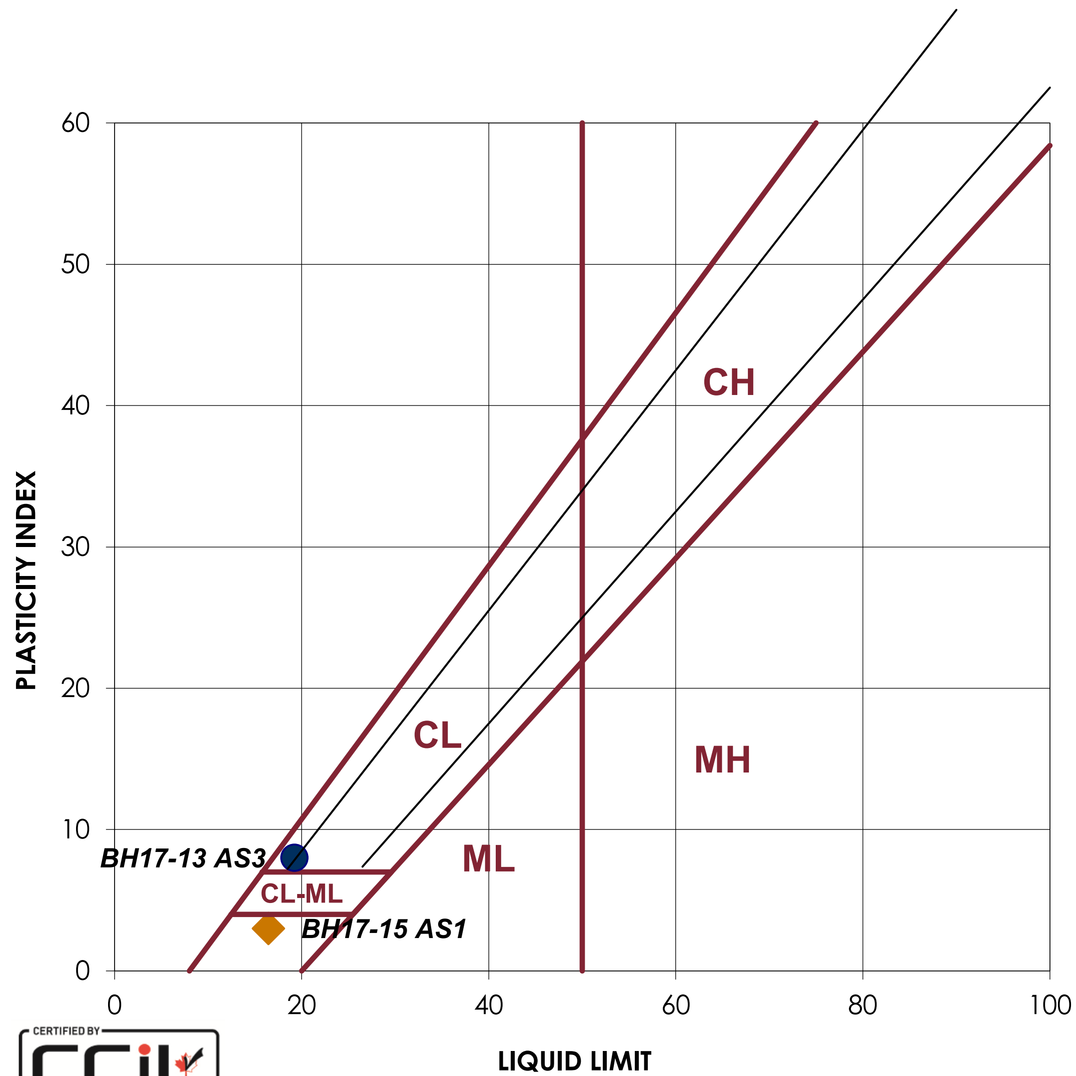
Atterberg Limits
ASTM D4318
Method B- One Point

Client:	Tlicho Engineering & Environtmental Servic
Project Name:	TliCho All Season Road
Project No:	144902448
Date Received:	February 27, 2017
Date Tested:	March 16, 2017
Tested By:	JA

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

Sample: BH17-13 AS3			Sample: BH17-15 AS1	
LIQUID			LIQUID	
1	2	Trial No.	1	2
21	21	Number of Blows	20	20
24B	47B	Container Number	9B	40B
38.57	40.85	Wt. Sample (wet+tare)(g)	42.98	45.31
34.71	36.72	Wt. Sample (dry+tare)(g)	39.02	40.98
15.19	15.61	Wt. Tare (g)	15.64	15.34
19.5	21.1	Wt. Dry Soil (g)	23.4	25.6
3.9	4.1	Wt. Water (g)	4.0	4.3
19.8%	19.6%	Water Content (%)	16.9%	16.9%
19.4%	19.2%	Corrected Water Content (%)	16.5%	16.4%
PLASTIC			PLASTIC	
1	2	Trial No.	1	2
BH	BO	Container Number	AY	AA
20.85	21.15	Wt. Sample (wet+tare)(g)	21.43	20.63
20.16	20.46	Wt. Sample (dry+tare)(g)	20.59	19.9
14.05	14.01	Wt. Tare (g)	13.83	14.17
6.1	6.5	Wt. Dry Soil (g)	6.8	5.7
0.7	0.7	Wt. Water (g)	0.8	0.7
11.3%	10.7%	Water Content (%)	12.4%	12.7%
AVERAGE VALUES			AVERAGE VALUES	
1	2		1	2
LL	19		LL	16
PL	11		PL	13
PI	8		PI	3
CLASSIFICATION			CLASSIFICATION	
CL			**ML**	



Reviewed By: ____________________

Figure No. 5

Confirmation of Sample Receipt

Maxxam Job Number: B724639
Job Received: 2017/04/04 13:16
Final Report Due: 2017/04/19 18:00

Invoice Information

Attn: ACCOUNTS PAYABLE
STANTEC CONSULTING LTD
10160-112 STREET
EDMONTON, AB, T5K 2L6
Email to:
accounts.payable.invoices@stantec.com

Report Information

Attn: RYLEY PROZNIK
STANTEC CONSULTING LTD
10160-112 STREET
EDMONTON, AB, T5K 2L6
Email to:
ryley.proznik@stantec.com

Project Information

Quote #: B50565
PO/AFE#:
Project #: 144902448
Site Location: TLICHO, NORTHWEST TERRITORIES
Sampled By: JM

Analytical Summary

A: Due On 2017/04/11 18:00
B: Due On 2017/04/19 18:00

Lab ID	Client Sample ID	Sampling Date/Time	Matrix	Chloride (Soluble)	Conductivity @25C (Soluble)	pH @25C (1:2 Calcium Chloride Extract)	pH @25C (Soluble)	Resistivity	Soluble Paste	Soluble Sulphate via CSA method [1]
COC# A174618										
QV2956	BH 17-14C AS1		SOIL	A	A	A	A	A	A	B

Include Criteria on CofA: No

[1] Subcontracted to ALS Edmonton (Soluble Sulphate via CSA method)

Sample Inspection Observations & Comments

# of Samples Received: 1

Details: No issues noted on this submission.

Average Temperature: Package 1: 18.0 °C

Additional Notes

- Unless special storage arrangements are made, all samples will be disposed 60 days after receipt. Additional fees may be applied for extended storage.
- Additional fees may be applied for the disposal of hazardous samples.

Confirmation of Sample Receipt

Parameter Summary

Package/Test	Parameter	RDL *	Unit	Samples
Chloride (Soluble)	Soluble Chloride (Cl)	5	mg/L	All
Conductivity @25C (Soluble)	Soluble Conductivity	0.02	dS/m	All
pH @25C (1:2 Calcium Chloride Extract)	Soluble (CaCl2) pH	N/A	pH	All
pH @25C (Soluble)	Soluble pH	N/A	pH	All
Resistivity	Resistivity @ 25 °C	0.05	ohm-m	All
Soluble Paste	Saturation %	N/A	%	All
Soluble Sulphate via CSA method	Subcontract Parameter	N/A	N/A	All

**RDLs are subject to change based on interferences present at the time of analysis.*

Maxxam

Calgary: 4000 19st St. NE, T2E 6P8. Ph: (403) 291-3077, Fax: (403) 735-2240, Toll free: (800) 386-7247
Edmonton: 9331 - 48 Street, T6B 2R4. Ph: (780) 577-7100, Fax: (780) 450-4187, Toll free: (877) 465-8889
www.maxxamanalytics.com

088

Chain of Custody A174018

Page: ____ of ____

	Invoice To:	C/O Report Address ☐	Report To:	Same as Invoice ☑	Report Distribution (E-Mail):	REGULATORY GUIDELINES:
Company:	STANTEC CONSULTING LTD.					☐ AT1
Contact:	RYLEY PROZNIK					☐ CCME
Address:	10160 112 ST NW, EDMONTON					☐ Regulated Drinking Water
	Prov: AB	PC: 1233	Prov:	PC:		☐ Other:
Contact #s:	Ph: 780-239-1498	Cell:	Ph:	Cell:		

All samples are held for 60 calendar days after sample receipt, unless specified otherwise.

PO #:	144902448
Project # / Name:	144902448
Site Location:	TLICHO, NORTHWEST TERRITORIES
Quote #:	
Sampled By:	J. MATTHEW

SERVICE REQUESTED: ☐ RUSH (Contact lab to reserve) Date Required: ☑ REGULAR (5 to 7 Days)

See reverse for package specifics

	Sample ID	Depth (unit)	Matrix GW / SW Soil	Date/Time Sampled YY/MM/DD 24:00	SOIL: BTEX F1-F4	SOIL: Sieve (75 micron)	SOIL: Regulated Metals (CCME / AT1)	SOIL: Salinity 4	SOIL: Assessment ICP Metals	SOIL: Basic Class II Landfill			WATER: ☐BTEX F1 ☐VOCs	WATER: ☐BTEX F1-F2 ☐BTEX F1-F4	WATER: ☐ Routine Water ☐ Turb ☐ F	WATER: ☐ TOC ☐ DOC	WATER: Regulated Metals (CCME / AT1) Total	WATER: Regulated Metals Dissolved	WATER: Mercury ☐ Total ☐ Dissolved	Other Analysis: RESISTIVITY	PH	SULPHATES & CHLORIDES									HOLD - Do not Analyze	# of Containers Submitted
1	BH 17-14C AS1	1'-2'8"																		✓	✓	✓										
2																																
3																																
4																																
5																																
6																																
7																																
8																																
9																																
10																																
11																																
12																																

Please indicate Filtered, Preserved or Both (F, P, F/P) → F/P

Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):
/ NICO NAVAL	17/04/04	13:15
Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):

Special Instructions: | # of Jars Used & Not Submitted

LAB USE ONLY

Received By:	Date:	Time:	Maxxam Job #:
Delaney McKerricher	2017/04/04	1316	B724639 D-T

Lab Comments:	Custody Seal	Temperature	Ice
	NO	Bag. 18, 18, 18	NO

AB FCD-00331 Rev3 2010/05

Maxxam Analytics International Corporation o/a Maxxam Analytics

Your Project #: 144902448
Your C.O.C. #: A174618

Attention:RYLEY PROZNIK

STANTEC CONSULTING LTD
10160-112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2017/04/10
Report #: R2367981
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B724639
Received: 2017/04/04, 13:16

Sample Matrix: Soil
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Chloride (Soluble)	1	2017/04/06	2017/04/07	AB SOP-00033 / AB SOP-00020	SM 22 4500-Cl G m
Resistivity	1	N/A	2017/04/07	AB WI-00065	Auto Calc
Conductivity @25C (Soluble)	1	2017/04/06	2017/04/07	AB SOP-00033 / AB SOP-00004	SM 22 2510 B m
pH @25C (1:2 Calcium Chloride Extract)	1	2017/04/06	2017/04/06	AB SOP-00033 / AB SOP-00006	SM 22 4500 H+B m
pH @25C (Soluble)	1	2017/04/06	2017/04/06	AB SOP-00033 / AB SOP-00006	SM 22 4500 H+B m
Soluble Ions	1	2017/04/06	2017/04/10	AB SOP-00033 / AB SOP-00042	EPA 200.7 CFR 2012 m
Soluble Paste	1	2017/04/06	2017/04/06	AB SOP-00033	Carter 2nd ed 15.2m
Soluble Ions Calculation	1	N/A	2017/04/10	AB WI-00065	Auto Calc

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Your Project #: 144902448
Your C.O.C. #: A174618

Attention:RYLEY PROZNIK

STANTEC CONSULTING LTD
10160-112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2017/04/10
Report #: R2367981
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B724639
Received: 2017/04/04, 13:16

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Wendy Sears, Project manager
Email: WSears@maxxam.ca
Phone# (403)735-2277
==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B724639
Report Date: 2017/04/10

STANTEC CONSULTING LTD
Client Project #: 144902448
Sampler Initials: JM

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		QV2956	QV2956		
Sampling Date					
COC Number		A174618	A174618		
	UNITS	**BH 17-14C AS1**	**BH 17-14C AS1 Lab-Dup**	**RDL**	**QC Batch**
Calculated Parameters					
Resistivity @ 25 °C	ohm-m	13	N/A	0.050	8595637
Calculated Chloride (Cl)	%	0.0044	N/A	0.00015	8599926
Calculated Sulphate (SO4)	%	0.0017	N/A	0.00015	8599926
Soluble Parameters					
Soluble Chloride (Cl)	mg/L	150	N/A	5.0	8598108
Soluble Conductivity	dS/m	0.80	N/A	0.020	8597408
Soluble pH	pH	7.79	7.87	N/A	8597453
Soluble (CaCl2) pH	pH	7.69	N/A	N/A	8596879
Saturation %	%	29	29	N/A	8596838
Soluble Sulphate (SO4)	mg/L	57	54	5.0	8600490

RDL = Reportable Detection Limit
Lab-Dup = Laboratory Initiated Duplicate
N/A = Not Applicable

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Maxxam Job #: B724639
Report Date: 2017/04/10

STANTEC CONSULTING LTD
Client Project #: 144902448
Sampler Initials: JM

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	18.0°C

Results relate only to the items tested.

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Maxxam Job #: B724639
Report Date: 2017/04/10

STANTEC CONSULTING LTD
Client Project #: 144902448
Sampler Initials: JM

QUALITY ASSURANCE REPORT

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
8596838	LX	QC Standard	Saturation %	2017/04/06		100	%	89 - 111
8596838	LX	RPD	Saturation %	2017/04/06	1.6		%	12
			Saturation %	2017/04/06	0.24		%	12
8596838	LX	RPD [QV2956-01]	Saturation %	2017/04/06	0.67		%	12
8596879	ACZ	QC Standard	Soluble (CaCl2) pH	2017/04/06		100	%	97 - 103
8596879	ACZ	Spiked Blank	Soluble (CaCl2) pH	2017/04/06		100	%	97 - 103
8596879	ACZ	RPD	Soluble (CaCl2) pH	2017/04/06	0.27		%	N/A
8597408	BJO	QC Standard	Soluble Conductivity	2017/04/07		103	%	75 - 125
8597408	BJO	Spiked Blank	Soluble Conductivity	2017/04/07		101	%	90 - 110
8597408	BJO	Method Blank	Soluble Conductivity	2017/04/07	<0.020		dS/m	
8597408	BJO	RPD	Soluble Conductivity	2017/04/07	1.3		%	20
8597453	ACZ	QC Standard	Soluble pH	2017/04/06		100	%	97 - 103
8597453	ACZ	Spiked Blank	Soluble pH	2017/04/06		100	%	97 - 103
8597453	ACZ	RPD [QV2956-01]	Soluble pH	2017/04/06	1.0		%	N/A
8598108	CH7	Matrix Spike	Soluble Chloride (Cl)	2017/04/07		113	%	75 - 125
8598108	CH7	QC Standard	Soluble Chloride (Cl)	2017/04/07		105	%	75 - 125
8598108	CH7	Spiked Blank	Soluble Chloride (Cl)	2017/04/07		106	%	80 - 120
8598108	CH7	Method Blank	Soluble Chloride (Cl)	2017/04/07	<5.0		mg/L	
8598108	CH7	RPD	Soluble Chloride (Cl)	2017/04/07	4.4		%	30
8600490	CJ5	QC Standard	Soluble Sulphate (SO4)	2017/04/10		101	%	75 - 125
8600490	CJ5	Method Blank	Soluble Sulphate (SO4)	2017/04/10	<5.0		mg/L	
8600490	CJ5	RPD [QV2956-01]	Soluble Sulphate (SO4)	2017/04/10	4.4		%	30

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

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Maxxam Job #: B724639
Report Date: 2017/04/10

STANTEC CONSULTING LTD
Client Project #: 144902448
Sampler Initials: JM

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

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Company:	STANTEC CONSULTING LTD.			☐ AT1
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All samples are held for 60 calendar days after sample receipt, unless specified otherwise.

PO #:	144902448
Project # / Name:	144902448
Site Location:	TLICHO, NORTHWEST TERRITORIES
Quote #:	
Sampled By:	J. MATTHEW

SERVICE REQUESTED: ☐ RUSH (Contact lab to reserve) Date Required: ☑ REGULAR (5 to 7 Days)

See reverse for package specifics

SOIL: BTEX F1-F4 | Sieve (75 micron) | Regulated Metals (CCME / AT1) | Salinity 4 | Assessment ICP Metals | Basic Class II Landfill

WATER: ☐BTEX F1 ☐VOCs | ☐BTEX F1-F2 ☐BTEX F1-F4 | ☐ Routine Water ☐ Turb ☐ F | ☐ TOC ☐ DOC | Regulated Metals (CCME / AT1): Total, Dissolved | Mercury ☐ Total ☐ Dissolved

Other Analysis: RESISTIVITY | PH | SULPHATES & CHLORIDES

#	Sample ID	Depth (unit)	Matrix GW / SW Soil	Date/Time Sampled YY/MM/DD 24:00	RESISTIVITY	PH	SULPHATES & CHLORIDES	HOLD - Do not Analyze	# of Containers Submitted
1	BH 17-14C AS1	1'-2'8"			✓	✓	✓		
2									
3									
4									
5									
6									
7									
8									
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11									
12									

Please indicate Filtered, Preserved or Both (F, P, F/P) → F/P

Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):
[signature] / NICO NAVAL	17/04/04	13:15
Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):

Special Instructions: | # of Jars Used & Not Submitted

LAB USE ONLY

Received By:	Date:	Time:	Maxxam Job #: B724639 D-T
[signature] Delaney McKerricher	2017/04/04	1316	

Lab Comments:

Custody Seal	Temperature	Ice
NO	Bag. 18, 18, 18	NO

AB FCD-00331 Rev3 2010/05

Maxxam Analytics International Corporation o/a Maxxam Analytics

Geotechnical Recommendation Report Proposed Culvert Crossing #5 Station 16+532

Geotechnical Investigation,
Proposed Tlicho All-Season Road,
Northwest Territories

Prepared for:
Tlicho Engineering and
Environmental Services Ltd.

Prepared by:
Stantec Consulting Ltd.
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Ottawa, ON K2C 3G4

Project No. 144902448

May 2017

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1.0 PROJECT DESCRIPTION AND BACKGROUND

Acting at the authorization of Tlicho Engineering and Environmental Services Ltd. (Tlicho), Stantec Consulting Ltd. (Stantec) carried out a geotechnical investigation in support of the culvert planned at 'Crossing #5' along the proposed Tlicho All Season Access Road (TASR). The purpose of the investigation was to characterize subsurface conditions and provide geotechnical comments and recommendations to assist with culvert design and site development.

The investigation was carried out in general accordance with Stantec's proposal dated January 12, 2017, as part of an overall geotechnical program by Tlicho for the Government of the Northwest Territories (GNWT) along the proposed 94 km TASR alignment extending from the Yellowknife Highway (Highway 3) to the Settlement of Whati on the south shore of Lac La Martre (RFP Event ID: EV000000001132). The scope of work outlined in the GNWT Request for Proposal includes the geotechnical investigation and design of the 94 km long TASR corridor, four bridges and three structural culverts. Tlicho was responsible for management and execution of the overall project and team as the Prime Contractor, with Stantec acting as sub-consultant providing geotechnical engineering and technical services to the project, including:

- Provision of geotechnical field personnel to log subsurface conditions during drilling operations at eighty-one (81) geotechnical boreholes in accordance with the RFP:
  - Thirteen (13) boreholes at the four (4) proposed major bridge crossings:
    - Crossing #8, Station 40+400 - Duport River Crossing
    - Crossing #9, Station 45+175 - (unnamed)
    - Crossing #14, Station 69+666 - James River Crossing
    - Crossing #15, Station 85+397 - La Martre River
  - Three (3) boreholes at the three (3) proposed major bridge culvert crossings:
    - Crossing #5, Station 16+532
    - Crossing #6, Station 19+427
    - Crossing #10a, Station 48+208
  - Sixty-five (65) boreholes to observe the subsurface conditions along the road alignment;
- Installation and reading of thermistors;
- Borehole layout and as-drilled survey;
- Completion of a laboratory testing program on the recovered borehole samples as specified in the RFP; and
- Geotechnical engineering assessment and reporting on the field and laboratory findings in two reports (Geotechnical Data Report and Geotechnical Recommendations Report) for each crossing location and for the overall roadway alignment.
  - These documents should be read in conjunction with the Statement of General Conditions, Appendix A

This geotechnical recommendation report has been prepared specifically for proposed culvert Crossing No. 5 on the Tlicho All Season Road at Station 16+532. This report should be read in conjunction with the Stantec Geotechnical Data Report titled "Geotechnical Data Report

Proposed Culvert Crossing #5 Station 16+532. The Geotechnical Data Report documents the results from the investigation completed for the culvert.

2.0 PROPOSED STRUCTURE AND EMBANKMENT

The 'Crossing #5' culvert is proposed at an unnamed, ephemeral watercourse located at approximately the 16.5 km station mark along the TASR corridor as shown on Drawing No. 1 – Site Location Plan provided in Appendix B. At this location the proposed TASR center line and crossing are aligned with the original Lac La Martre winter roadway, orientated approximately northwest, with the watercourse flowing perpendicular, approximately southwest to northeast on a shallow grade. It is understood that this minor watercourse only provides conveyance during significant rainfall events and spring freshet, and is generally otherwise dry or stagnant.

Based on the preliminary 'conceptual designs' provided by GNWT, which are presented on Drawing No. 2 (Appendix B), it is understood that a single 2430 mm diameter Structural Plate Corrugated Steel Pipe (SPCSP) culvert is proposed through the roadway embankment with 10% (0.24 m) embedment into the existing grade. In this area, the roadway is to be a fill only embankment design with approximately 2.5H:1V side slopes,10.5 m crest width, and a maximum rise of up to approximately 6.3 m higher than the existing grade at the proposed centerline of the culvert. The embankment is proposed to be constructed of pit run fill with a rip-rap apron and clay seals at the culvert location. A 600 mm sub-excavation, and a structural backfill envelope extending 5.43 m in width and 0.6 m in cover are planned.

Key approximate elevations associated with the proposed culvert are as follows:

Finished Roadtop Elevation:	271.76 m (at Centreline)
Proposed Invert Elevation:	265.40 m inlet
	265.20 m outlet
Proposed Obvert Elevation:	267.83 m inlet
	267.63 m outlet
Design Streambed Elevation:	Not Provided – Ephemeral, poorly defined channel(s)
Existing Ground Elevation	265.2 m
Design Water Level (obvert of pipe):	267.83 m

3.0 GEOTECHNICAL DESIGN RECOMMENDATIONS

In general, the subsurface stratigraphy at the culvert location consisted of a thin veneer of frozen overburden materials overlying relatively shallow inferred bedrock. Soil conditions at the approximate centerline of the proposed culvert at BH17-14C consisted of a thin layer of topsoil/rootmat and silty sand with gravel overlying inferred bedrock at 0.5 m to 1.0 m depth. Soil conditions at BH17-13 consisted of thin layers of sandy silt over, silty sand over, sandy lean clay overlying inferred bedrock at approximately 2.1 m depth.

Based on the elevations in the conceptual design details provided, the culvert will likely be founded near or at the level of inferred bedrock. It is recommended that the depth to bedrock be confirmed prior to construction by qualified geotechnical personnel. Should any conditions at the site be encountered that differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information.

The design and analysis approach for this report is based on the Canadian Standards Association (CSA), 2014 Canadian Highway Bridge Design Code (CHBDC) and assumes that the structure is classified as a Buried Structure (CSA S6-14 Section 7). The analysis approach assumes a force-based design (FBD) and elastic static analysis (ESA) methods for the structural design.

3.1 GEOTECHNICAL DESIGN PARAMETERS

For design purposes, the soil model provided in Table 3.1 will be used. The design methodology assumes that permafrost is not present at the culvert location. The parameters presented in Table 3.1 are unfrozen parameters. Design parameters for the proposed embankment fill are also provided.

The "degree of site and prediction model understanding for the native soils" has been assessed as "Typical Understanding" as per Section 6.5 of the Commentary on CSA S6-14, Canadian Highway Bridge Design Code (CHBDC), (S6, 1-14).

Table 3.1: Generalized Soil Profile at Crossing No. 5 Culvert

Approximate Depth (m)		Soil Type	Design Parameters				Design Temperature Profile
From	To		γ (kN/m³)	ϕ (°)	S_u (kPa)	E (MPa)	
-	-	Proposed Embankment Fill (Pit run fill) See Section 3.5	21.0	32	-	50	Seasonal Freeze Thaw
0	0.1	Organic soil (very loose)	18.0	28	-	5	
0.1	0.8	Silty sand with gravel	21.0	30	-	10	
Varies from 1.0 m to 0.5 m	-	Inferred Bedrock	26.5	N/A	N/A	N/A	

Notes: (1) γ = total unit weight, ϕ = soil friction angle, S_u = undrained shear strength, E = soil/rock modulus

(2) A design water level at elevation 267.83 m will be used (obvert of pipe). Submerged unit weights (γ') should be used below the groundwater level.

(3) The depths provided in the above table reflect a generalization of the borehole data to incorporate the most significant aspects of the geotechnical design and are not based on any specific location.

3.2 SEISMIC DESIGN CONSIDERATIONS

3.2.1 Site Class

It is recommended that Site Class B rock as defined in CHBDC (CHBDC, 2014) Section 4.4.3 be provisionally used in the seismic design of this site based on the apparent shallow bedrock conditions.

3.2.2 Peak Ground Acceleration (PGA)

Seismic hazard values for this site were obtained from Natural Resources Canada (2015 National Building Code). Table 3.2 summarizes the parameters based on a 2475-year return period as per CSA S6-14 Section 7.5.5.1 to be used in forced based design.

Table 3.2: Peak Ground Acceleration Data

PGA	$S_a(0.2)$	PGA_{ref}	Site Adjusted PGA	**Site Class**
0.030 g	0.052 g	0.024 g	0.0261 g	B

The 2015 NBC Seismic Hazard calculation sheet that corresponds to this site is provided in Appendix C.

3.2.3 Vertical Acceleration Ratio (A_v)

CSA S6-14 Section 7.5.5.1 indicates that for the design of buried structures the vertical component of an earthquake, expressed as the vertical acceleration ratio, A_v, effectively increases the unit weight of the soil from γ to γ $(1+A_v)$. The vertical acceleration ratio, A_v, is to be two-thirds of the Site Adjusted PGA value for the site. The recommended A_v value for this project is 0.0174 g.

3.2.4 Liquefaction Potential

The potential for soil liquefaction was evaluated by comparing the cyclic stress ratio (CSR) caused by the design earthquake with the soil resistance expressed in terms of the cyclic resistance ratio (CRR). The evaluation follows the analysis methodology suggested by Idriss and Boulanger (2008) and is based on the following:

- The blow count data from boreholes.
- A Site Adjusted PGA of 0.0261 g.
- An earthquake magnitude M_w of 5.84, which is based on a Seismic Hazard Deaggregation calculated by the Canadian Hazards Information Service. A copy of the deaggregation result is provided in Appendix C (Geological Survey of Canada, 2017).

The analysis indicates a factor of safety against liquefaction of over 2.0, and therefore earthquake induced liquefaction is not a concern at this site.

3.3 STRUCTURE FOUNDATIONS

3.3.1 General

It is understood that a culvert is proposed at Crossing No. 5 on the Tlicho All Season Road at Station 16+532. The preliminary structure design shows a 2430 mm diameter SPCSP culvert. The Preliminary General Arrangement drawing for the proposed culvert is presented on Drawing No. 2 in Appendix B.

The foundation soils at the site generally can provide adequate support for the proposed 2430 mm diameter SPCSP culvert, however the design of the culvert invert elevation and pipe bedding should consider the bedrock profile.

3.4 FOUNDATION RECOMMENDATIONS

3.4.1 Geotechnical Resistances

It is recommended that the culvert be founded on structural backfill placed on the native soil or bedrock. The Preliminary General Layout Plan notes a minimum 0.6 m thick pad of crushed aggregate to be placed below the pipe. The plan notes that soft or yielding material should be removed. The proposed backfill detail shown on the Preliminary General Layout is considered suitable for the observed subsurface conditions subject to the following:

- The excavations should be backfilled with compacted structural backfill – recommended grading specification for structural backfill is provided in Section 4.1.
- A 200 mm layer of uncompacted structural backfill material is placed directly beneath the culvert for bedding purposes.
- The edges of the granular pad should extend at least 1.5 m horizontally away from the culvert edge.
- A non-woven geotextile such as Terrafix 270R or approved equivalent is placed beneath the culvert bedding.

The geotechnical resistances provided in Table 3.3 may be used in the design provided the proposed culvert installation, bedding and backfill details have been carried out as outlined in this report.

The base of the working surface should be examined by a qualified geotechnical inspector to confirm that the soils/bedrock are consistent with those observed in the boreholes and to ensure that there is no soft/yielding or deleterious material present. If bedrock is encountered above the bedding level, then the bedrock should be removed to a depth of 0.6 m below the invert of the culvert in order to provide sufficient bedding and a uniform foundation across the entire culvert. Where deleterious materials are encountered, the material should be excavated, wasted and replaced with structural backfill compacted in lifts no greater than 150 mm. The lateral extent of such excavation should include all deleterious material within the influence zone of the culvert. Bedrock, if highly fractured or ice rich should be considered as deleterious material. Where construction is undertaken during winter conditions, the working surface subgrade should be protected from freezing.

Table 3.3: Recommended Factored Geotechnical Resistances

Founding Element	Founding Stratum	Culvert Size (m x m)		Factored Geotechnical Resistance at ULS (kPa) $\phi_{gu} = 0.5$	Factored Geotechnical Reaction at SLS (kPa) $\phi_{gs} = 0.8$
		Width (m)	Length (m)		
2430 mm Dia. SPCSP Culvert	Silty sand with gravel	2.4	39	150	80 (3,5)
	Inferred Bedrock			500	ULS Governs (6)

Notes:

1. The Geotechnical Resistances were estimated assuming a consequence classification of "Typical Consequence" with a consequence factor equal to 1.0. In accordance with Section 6.5 and Table 6.1 of CHBDC, 2014.
2. In accordance with Section 6.9 and Table 6.2 of the CHBDC, 2014, a resistance factor of 0.5 has been applied to calculate the factored geotechnical resistance at Ultimate Limit States (ULS).
3. The geotechnical reaction at Serviceability Limit States (SLS) typically corresponds to a maximum settlement of 25 mm. In accordance with Section 6.9 and Table 6.2 of CHBDC, 2014, a geotechnical resistance factor of 0.8 has been applied to calculate the factored geotechnical resistance at SLS. If the subgrade is frozen at the time of construction, additional settlement due to thaw consolidation is anticipated.
4. The use of structural backfill beneath the culvert foundation is not for the purpose of achieving high bearing resistances or reactions but rather to ensure that the foundations are supported on a consistent engineered structural backfill once the existing subgrade has been removed from beneath the culvert.
5. The low SLS reaction reflects the potentially loose nature of the silty sand with gravel encountered at the site in an unfrozen, saturated state in spring/summer.
6. Bedrock was not directly examined from bedrock core sample or outcrops at this site. A preliminary design bearing pressure has been assumed based on the assumption of relatively sound sedimentary rock from the mapped lithology in the area and the augering difficulty encountered. Provided the bedrock surface is ice-free, sound and properly cleaned of soil and weathered materials, settlements should be negligible and SLS need not be considered.

3.5 EMBANKMENT DESIGN

The roadway profile at the culvert location will be raised above the existing profile by approximately 6.3 m. The proposed embankment will be constructed at a 2.5H:1V slope according to the Preliminary General Layout Plan. According to the Plan, the embankment will be constructed with pit run fill and will have a rip-rap apron and clay seals at the culvert location.

The following sections provide recommendations for the design and construction of the embankment at the culvert.

3.5.1 Embankment Construction

To mitigate degradation of permafrost (although permafrost was not observed, scattered patches may be present), the topsoil/rootmat layers should be maintained beneath the footprint of the embankment (except beneath the culverts), and construction activity should be staged to avoid disturbance of these layers. A non-woven geotextile such as Terrafix 270R or approved equivalent should be placed directly on the subgrade and should extend 6 m laterally into the embankment footprint from the toe of embankment.

The embankment should be constructed with pit run fill placed in lifts no thicker than 150 mm and compacted to at least 95% Standard Proctor Maximum Dry Density (SPMDD). Pit run fill should consist of well graded sand and gravel with less than 10% fines (clay and silt size particles). Soil gradation testing of the fill should be carried out and reviewed by a geotechnical engineer prior to delivery to site. All fill should be placed and compacted when air temperatures are consistently above freezing. No fill should be placed and compacted that is frozen or at freezing temperatures.

3.5.2 Embankment Settlement

The settlement of the embankment has been assessed based on the following mechanisms; self-weight settlement of embankment fill, thaw consolidation of underlying permafrost (if present) and the seasonal freeze / thaw layer, and the consolidation of underlying unfrozen soil layers.

Table 3.4 summarizes the embankment settlement estimated at borehole BH17-14C. The analysis predicts about 105 mm of settlement.

To mitigate embankment deformation related to self-weight settlement and related processes we recommend the following:

- Placing embankment fills during summer.
- Over building the embankment by approximately 0.3 m to 0.5 m.
- Monitoring the embankment for a period of 2 years. Monitoring should include mapping of cracks, measurement of crack apertures (if present), observations on the condition of the embankment slope and toe of slope.
- Installing multibead thermistor cables in the subgrade to monitor changes in the geothermal regime.
- The monitoring observations should be reviewed by a geotechnical engineer. After completion of monitoring the embankment could be re-graded to final grades.

Table 3.4: Estimated Embankment Settlement

Settlement Consolidation Mechanism	Culvert Location
	BH17-14C
Self-weight Settlement of Embankment Fills[1] (mm)	65
Thaw Consolidation of Underlying Soil[2] (mm)	0
Consolidation of Underlying Unfrozen Soil[3] (mm)	50
Total Settlement	105

Notes:

1) Estimate assumes fill placement during temperatures above 0°C. Estimate assumes self-weight settlement equal to 1% of embankment fill height.
2) Estimate assumes permafrost is not present at the culvert location.
3) Consolidation of unfrozen soil was calculated using Settle3D program by Rocscience (Rocscience, 2009) using soil design parameters noted in Table 3.1.

3.5.3 Stability of Slopes

A global stability analysis of a 2.5H:1V embankment slope as shown on the Preliminary General Layout drawing was carried out. Both static and conventional pseudo-static limit equilibrium slope stability analysis methods were applied using the program Slope/W (Geo-Slope, 2012) and the design parameters noted in Table 3.1.

The analysis assumes the embankment will be constructed with pit run fill.

The pseudo-static stability analysis of the embankment slope considered seismic loading of 0.0131, which is one-half of the Site Adjusted Peak Ground Acceleration (PGA).

The slope stability evaluation results indicate that the estimated factor of safety against critical failure is greater than 1.5 for static conditions using a design high water level at elevation 267.8 m. The factor of safety against critical failure meets the required target value of 1.1 (seismic) for highway embankments.

3.6 EROSION AND SCOUR PROTECTION

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. All slopes within 3 m of the culvert inlet and outlet should be surfaced with rip-rap at least 300 mm thick placed on a non-woven filter fabric such as Terrafix 270R or approved equivalent; the rip-rap should extend up the slope to 0.3 m above the design high water level. Rip-rap aprons are shown on the Preliminary General Layout Plan at the culvert inlet and outlet. Where embankment construction includes earth fill, normal slope vegetation should be established as soon as possible after completion of the embankment fills in order to control surficial erosion.

Two 4.86 m thick (two times the culvert diameter) clay seals or approved equivalent are shown on Section A-A of the Preliminary General Layout Plan. Clay seals should be provided near the culvert inlet and outlet to prevent seepage through the backfill material. Clay seals should be constructed as follows:

- Clay seals should extend 5 m into the embankment.
- Extend from at least 0.3 m above the high water level to the full depth of excavation.
- Clay seals should not be located beneath the travelled portion of the lanes.

Material for the clay seal should meet the following specifications (Ontario Provincial Standard Specification, 2009):

- The coefficient of permeability as determined in the flexible wall permeameter according to ASTM D5084 should not exceed 1 x 10^{-6} cm/s.
- Liquid limit should be > 40%.
- Plasticity index should be > 0.73 x (Liquid Limit - 20%).

Alternatively, a geosynthetic clay liner may be used (sodium bentonite clay sandwiched between two protective geotextiles). Material specifications containing the physical, mechanical, and hydraulic properties of the geosynthetic clay liner should be obtained from the manufacturer. The material specification should include a manufacturer's certification and warranty.

The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediment from running off the site.

3.7 CLIMATE CHANGE SENSITIVITY AND PERMAFROST DEGRADATION RISK

Permafrost is not likely present at the culvert location, therefore permafrost degradation due to climate change is not a design consideration for the culvert. A multibead thermistor should be installed in the roadway embankment extending to bedrock to allow long term ground temperature monitoring. Long term monitoring of the thermistor should be carried out as part of the evaluation of the long term performance of the culvert and embankment.

3.8 CEMENT TYPE AND CORROSION PROTECTION

One sample of the native soil was submitted to Maxxam Analytics for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in foundations and buried infrastructure. The analysis results are summarized in Table 4.2 in the Geotechnical Data Report.

The soluble sulphate concentration for the sample was 0.0017 %. Soluble sulphate concentrations less than 0.1 % generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater (CSA, 2014). Type GU (General Use) Portland Cement should therefore be suitable for use in concrete at this site, if applicable.

The soil pH value was 7.7, which is within what is considered the normal range for soil pH of 5.5 to 9.0, and does not indicate a highly corrosive environment. The resistivity result was 13 Ohm-m, which suggests a moderate degree of corrosiveness for steel according to the National Corrugated Steel Pipe Association. The test results provided in Table 4.2 in the Geotechnical Data Report may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

4.0 CONSTRUCTION CONSIDERATIONS

4.1 EXCAVATION AND BACKFILLING

Side slopes for open cut excavations should have a gradient of one horizontal to one vertical, or shallower, sloped from the bottom of the excavation.

Excavation and backfill for the culvert structures should be carried out in accordance with Section 7, Buried Structures of the 2014 CHBDC, which specifies, but not limited to, the following:

- Structural backfill shall be placed between multi-conduit structure.
- A minimum transverse distance of backfill equal to ½ the horizontal diameter of culvert (measured at mid-height) for structure constructed in trench in which the natural soil is poorer than the engineered soil.
- The material for structural backfill shall be boulder free and shall be selected from the Group I or II soils specified in Table 7.4 of the CHDBC, with compaction corresponding to the modulus of soil stiffness used in the design. The backfill shall be placed and compacted in layers not exceeding 200 mm of compacted thickness, with each layer compacted to the required density prior to the addition of the next layer. The difference in levels of structural backfill on the two sides of a conduit at any transverse section shall not exceed 200 mm. The structural backfill within 300 mm of the conduit walls shall be free of stones exceeding 75 mm in any dimension. Heavy equipment shall not be allowed within 1 m of the conduit walls. The structural backfill adjacent to the conduit wall and to within the frost penetration depth shall be free of frost-susceptible soils.

All vegetation, organic soils and other deleterious materials must be removed from beneath the proposed culverts. Where deleterious materials are encountered, the material should be excavated, wasted and replaced with structural backfill. The lateral extent of such excavation should include all deleterious material within the influence zone of the culverts.

The Preliminary General Layout Plan notes a minimum of 0.6 m depth below the pipe should be excavated and replaced with crushed aggregate material. Section B-B of the plan shows a 5.4 m wide box of structural backfill surrounding the culvert that consists of 1.5 m of structural backfill at the sides of the culvert and 0.6 m of structural backfill directly above the culvert.

Section B-B shows pit run fill above the structural backfill up to finished roadtop. The structural backfill details meet or exceed the CHBDC specifications noted above.

Bedding, leveling and cover material for the culverts should consist of structural backfill meeting the grading specifications outlined in Table 4.1.

Table 4.1: Aggregate Specifications for Structural Backfill

<table>
<tr><th colspan="2">DESIGNATION</th><th>Percent Passing</th></tr>
<tr><th colspan="2">Class (mm)</th><th>25</th></tr>
<tr><td rowspan="12">Percent Passing Metric Sieve (CGSB 8-GP-2M) • m</td><td>25.000</td><td>100</td></tr>
<tr><td>20.000</td><td>82-97</td></tr>
<tr><td>16.000</td><td>70-94</td></tr>
<tr><td>12.500</td><td></td></tr>
<tr><td>10.000</td><td>52-79</td></tr>
<tr><td>8.000</td><td></td></tr>
<tr><td>5.000</td><td>35-64</td></tr>
<tr><td>1.250</td><td>18-43</td></tr>
<tr><td>0.630</td><td>12-34</td></tr>
<tr><td>0.315</td><td>8-26</td></tr>
<tr><td>0.160</td><td>5-18</td></tr>
<tr><td>0.080</td><td>2-8</td></tr>
<tr><td>% FRACTURE BY WEIGHT (2 FACES)</td><td>ALL
+5.000</td><td>60+</td></tr>
<tr><td colspan="2">PLASTICITY INDEX (PI)</td><td>Non-plastic</td></tr>
<tr><td colspan="2">L.A. ABRASION LOSS PERCENT MAX.</td><td>50</td></tr>
</table>

Note: Aggregate specifications for structural backfill adapted from the Alberta Transportation Standard Specification for Highway Construction, Table 3.2.3.1 Specification for Aggregate (Alberta Transportation, 2013).

4.2 REUSE OF EXCAVATED MATERIAL

The native material in the vicinity of the project site consists of material with high fines content (>10% fines). This material will not be suitable as backfill for the proposed culverts. The silty sand may be used for embankments if properly processed and compacted so long as it is not in a location where seasonal frost heaving could negatively impact the performance of the road embankment or culvert.

4.3 TEMPORARY CONSTRUCTION DEWATERING

Groundwater was not encountered in the open boreholes at the time of drilling, or inferred based on sample moisture contents. It should be noted that water levels observations were recorded in winter conditions. Fluctuations in the groundwater due to seasonal changes or in response to a particular precipitation event should be anticipated.

Depending on the time of year of construction, installation of the culvert may require excavation below the groundwater level. Control of groundwater during construction may be required.

The groundwater level should be lowered to at least 0.5 m below the subgrade level of the culvert and the subcut for the granular bedding material to provide a stable base during placement of culvert bedding material.

The native soils within the anticipated depth of excavation have a low to moderate hydraulic conductivity, in the order of 10^{-3} to 10^{-5} cm/s. Significant groundwater flow should be anticipated within unfrozen soils. Dewatering of the culvert excavation using conventional sump and pump techniques should be adequate. If high groundwater levels are present during construction, cofferdams enclosing the work area may be required.

For reference, the results of the grain size distribution tests (and Unified Soil Classifications) completed on the predominant soil strata encountered in the boreholes have been compared to the grain size curves and soil types referenced in Supplementary Standard SB-6 of the 2012 Ontario Building Code (OBC). The OBC has been used as a guideline to estimate the likely range in the coefficient of permeability of the soils encountered in the investigation. It is noted that the industry typically refers to "hydraulic conductivity" rather than "coefficient of permeability" in this respect. The terms are often considered interchangeable, but for purposes of this report the values provided are in the form of "length/time" (cm/sec) and are therefore considered strictly applicable to "hydraulic conductivity", and hence "hydraulic conductivity" is used herein.

Based on the comparison conducted, the following values are provided:

Unfrozen Soil Type	Estimated Hydraulic Conductivity	Comment
Silty Sand (SM)	10^{-3} to 10^{-5} cm/sec	Medium to Low Permeability

The OBC states, in part, that "it must be emphasized that, particularly for fine grained soils, there is no consistent relationship (between coefficient of permeability and soils of various types) due to the many factors involved". Such factors as structure, mineralogy, density (compactness or consistency), plasticity, and organic contents of the soil can have a large influence on the hydraulic conductivity; variations in excess of an "order of magnitude" are common place in this respect.

It is recommended that the contract documents for this site include a special provision to address issues related to groundwater control during construction. A Notice to Contractor is provided in Appendix D that alerts the contractor to the presence of high permeability soils at the site.

5.0 DESIGN UNCERTAINTIES

A primary uncertainty for the design of this culvert structure is the variability of foundation conditions. This includes the potential presence of buried massive ice under the culvert location. The geotechnical drilling program was not able to penetrate to significant depths due to auger refusal. Such refusal may be caused by many factors including encountering bedrock, or well-bonded permafrost soils. Experience on the reconstruction of Highway 3 between Behchoko and Yellowknife found that many culvert crossings were underlain by massive ice, which negatively impacted the performance of the road embankment and culvert. To address the potential for the presence of massive ice and shallow bedrock at this culvert site several recommendations are provided to the Client for their consideration:

- Conducting an additional geotechnical program at the time of construction consisting of test pits or additional drilling using a more powerful drill than what was used for the initial geotechnical program.
- Conducting a geophysical survey along the road alignment to provide additional information on the subsurface conditions at depth.
- Developing a construction contingency plan for the presence of massive ice or shallow bedrock, prior to construction, so that the plan is in place and can be readily implemented should the need arise.

This design report has not considered the hydraulic characteristics of the culvert placement. In northern and permafrost terrain the seasonal freezing of culverts is a persistent issue, in that the culverts fill with ice and snow in the fall and early winter, and remain plugged well into the spring and summer after snow melt and runoff has begun. Thus the road embankment and ice-filled culverts act as a dam, restricting the passage of runoff. To address this issue, one strategy is to install two culverts with one culvert vertically higher than the other so that it will remain ice-free over the winter. If the Client and Owners have concerns regarding potential for ice plugs in the culverts, the above strategy or other strategies should be considered.

6.0 DESIGN REVIEW AND CONSTRUCTION MONITORING

Stantec Consulting Ltd. should review the design details, specifications and drawings prior to construction. Quality assurance and construction monitoring should be provided during construction in order to confirm that the contractor is following the recommendations in this Report. Long term monitoring should be completed to monitor for settlement and performance of the culvert and embankments.

7.0 CLOSURE

A soil investigation is a limited sampling of a site. The recommendations given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information and its effects on the above recommendations. Use of this report is subject to the Statement of General Conditions provided in Appendix A. It is the responsibility of Tlicho Engineering & Environmental Services Ltd., who is identified as "the Client" within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec Consulting Ltd. should any of these not be satisfied. The Statement of General Conditions addresses the following:

- Use of the report
- Basis of the report
- Standard of care
- Interpretation of site conditions
- Varying or unexpected site conditions
- Planning, design or construction

This report has been prepared by Zachary Popper and reviewed by Christopher McGrath and Jim Oswell. Mr. McGrath and Dr. Oswell are registered members of the Northwest Territories and Nunavut Association of Professional Engineers and Geoscientists. We trust that the information contained in this report is adequate for your present purposes. If you have any questions about the contents of the report or if we can be of any other assistance, please contact us at your convenience.

Respectfully submitted,

STANTEC CONSULTING LTD.

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Senior Geotechnical Advisor
jim.oswell@stantec.com

8.0 REFERENCES

Alberta Transportation, 2013. Alberta Transportation Standard Specification for Highway Construction, Table 3.2.3.1 Specification for Aggregate, Edmonton, Alberta.

Andersland, O.B., and Ladanyi, B. 1994. An Introduction to Frozen Ground Engineering. Chapman & Hall Inc., New York, NY, USA.

ASTM. 2000. Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter D5084. ASTM International, West Conshohocken, PA.

Canadian Standards Association (CSA). 2010. Technical Guide Infrastructure in permafrost: A guideline for climate change adaptation. Canadian Standards Association, Mississauga, ON, Canada.

Canadian Standards Association (CSA). 2014. Concrete materials and methods of concrete construction / Test methods and standard practices for concrete. Canadian Standards Association.

CHBDC. 2014. Canadian Highway Bridge Design Code. Canadian Standards Association, Mississauga, Ontario.

Geo-Slope International, Ltd. 2012. GeoStudio 2012 (Slope/W 2012), Calgary, Alberta.

Geological Survey of Canada, Seismic Hazard Deaggregation calculated by the Canadian Hazards Information Service, April 21, 2017, Canada.

GNWT DOT, 2016. Proposed Tlicho All-season Road, Project Description Report. March 2016

Natural Resources Canada, 2015 National Building Code Seismic Hazard Calculation (2017, April 20). Retrieved from http://www.earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/index_2015-en.php

Ontario Building Code. 2012. Ministry of Municipal Affairs and Housing, Building and Development Branch.

Ontario Provincial Standard Specification, 2009. Material Specification For Clay Seal OPSS 1205, November 2009.

Rocscience, 2009. Settle3D Settlement and Consolidation Analysis, v 3.009: Theory Manual, Rocscience, Inc.

9.0 BIBLIOGRAPHY

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2009. Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) (ASTM D2488). ASTM International, West Conshohocken, PA.

ASTM. 2010. Standard Terminology Relating to Frozen Soil and Rock (ASTM D7099). ASTM International, West Conshohocken, PA.

ASTM. 2011. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

ASTM. 2016. Standard Practice for Description of Frozen Soils (Visual-Manual Procedure) (ASTM D4083). ASTM International, West Conshohocken, PA.

BGC Engineering Inc. 2011. Highway 3 – Climate Change Vulnerability Assessment – Final Report.

Canadian Foundation Engineering Manual (CFEM). 2006. Fourth Edition. Canadian Geotechnical Society, 488 p.

Dillon Consulting Ltd. 2007. Climate Change and Transportation in the NWT. March 2007.

Ecosystem Classification Group. 2009. Ecological Regions of the Northwest Territories - Taiga Plains. Department of Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT, Canada.

Environment Canada. Warming Trends °C/Decade, Based on homogenized temperature data – the most recent 30 yr record (1981 – 2010); Environment Canada.

Environment Canada. (2016, September 1) Canadian Climate Normals 1981–2010. Yellowknife Station. Retrieved from http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProv&lstProvince=NT&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=1706&dispBack=0

GNWT, 2009. Ecosystem Classification Group (ECG) 2009. Ecological Regions of the Northwest Territories: Taiga Shield. Department of Environment and Natural Resources, GNWT. Yellowknife, NT.

Heginbottom, J.A., Dubreuil, M.A., and P.A. Harker. 1995. Canada-Permafrost; National Atlas of Canada, 5th edition, Plate 2.1. Geomatics Canada, National Atlas Information Service and Geological Survey of Canada (MCR 4177).

Kavik AXYS Inc. 2008a. Multi-Level Mapping and Route Analysis – Tlicho Transportation Corridor. Route Identification and Evaluation. Yellowknife, NT. January 2008.Project No. Project No. 144902005.

Kerr and Wilson, 2000. 2000-C3. Preliminary surficial geology studies and mineral exploration considerations in the Yellowknife area, Northwest Territories. D.E. Kerr and P. Wilson.

Natural Resources Canada. 1995: Canada Permafrost; The National Atlas of Canada 5th Edition, scale 1:7 500 000.

Okulitch, A.V. 2004. Geological compilation of Phanerozic Bedrock Geology (Map NP-11/12-G), Slave River District of MacKenzie, Northwest Territories. Geological Survey of Canada, Open File 5281.

Stantec, 2015.Tli Cho Road Alignment, Hydrologic and Hydraulic Study. Project No. 144902005.

Wolfe, 1998. Living with frozen ground : a field guide to permafrost in Yellowknife, Northwest Territories, edited by Stephen A. Wolfe ; contributions by Stephen A. Wolfe

S.A. Wolfe, P.D. Morse, T.E. Hoeve, W.E Sladen, S.V. Kokelj, L.U. Arenson, 2015. Disequilibrium permafrost conditions on NWT Highway 3

APPENDIX A

Statement of General Conditions

STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec Consulting Ltd. and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec Consulting Ltd.'s present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec Consulting Ltd. is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec Consulting Ltd. at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec Consulting Ltd. must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec Consulting Ltd. will not be responsible to any party for damages incurred as a result of failing to notify Stantec Consulting Ltd. that differing site or sub-surface conditions are present upon becoming aware of such conditions.

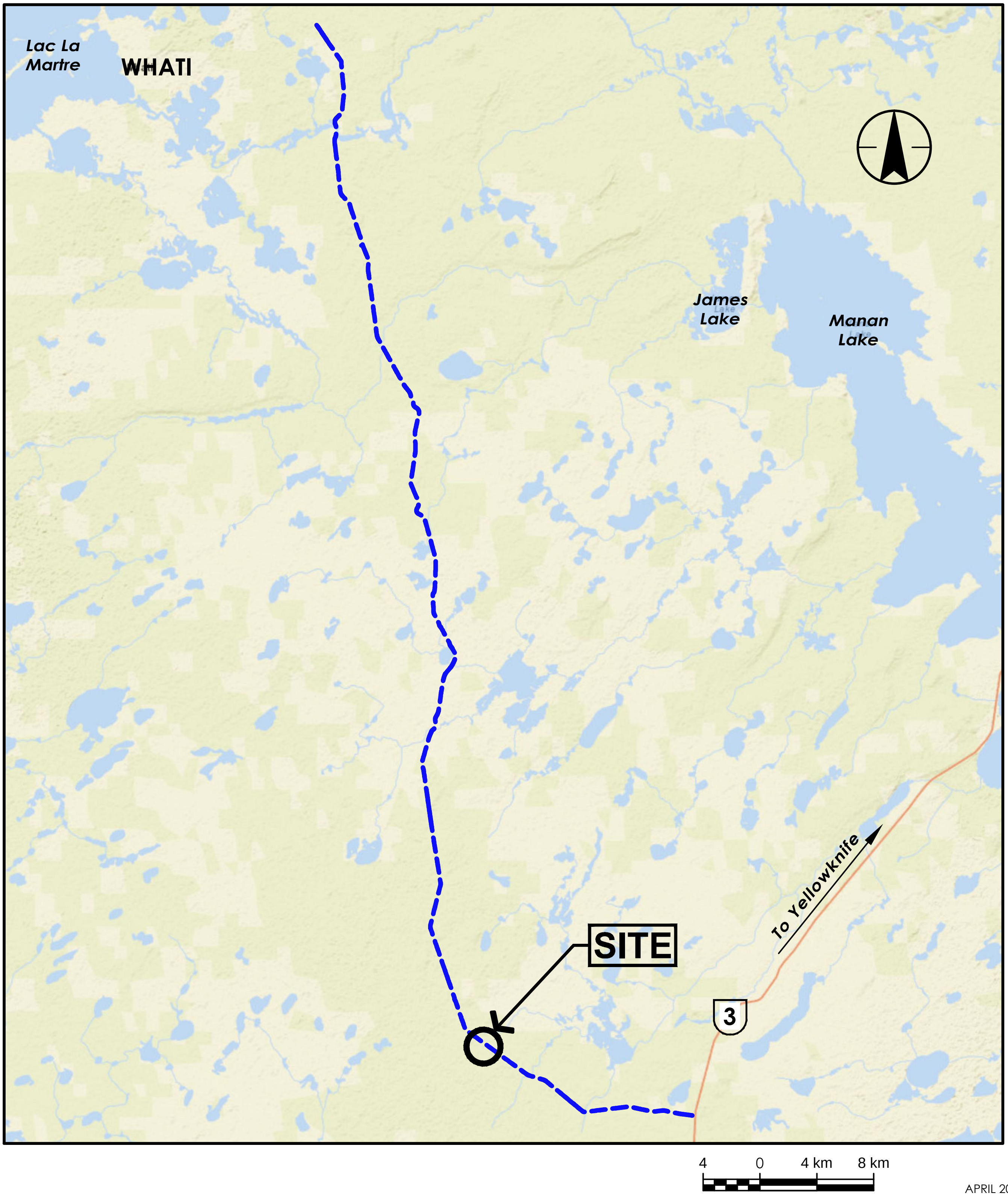
PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec Consulting Ltd., sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec Consulting Ltd. cannot be responsible for site work carried out without being present.

APPENDIX B

Drawing No. 1 – Key Plan

Drawing No. 2 – General Layout and Borehole Location Plan

Site Photos



APRIL 2017
Project No. 144902448

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2017/04/28 3:06 PM By: Briones, Gliceria

Stantec

400 - 1331 Clyde Avenue
Ottawa, ON, Canada K2C 3G4
www.stantec.com

LEGEND

PROPOSED ALIGNMENT

NOTES

IMAGERY: ESRI ©2017.

Client/Project

TLICHO ENGINEERING & ENVIRONMENTAL SERVICES LTD.

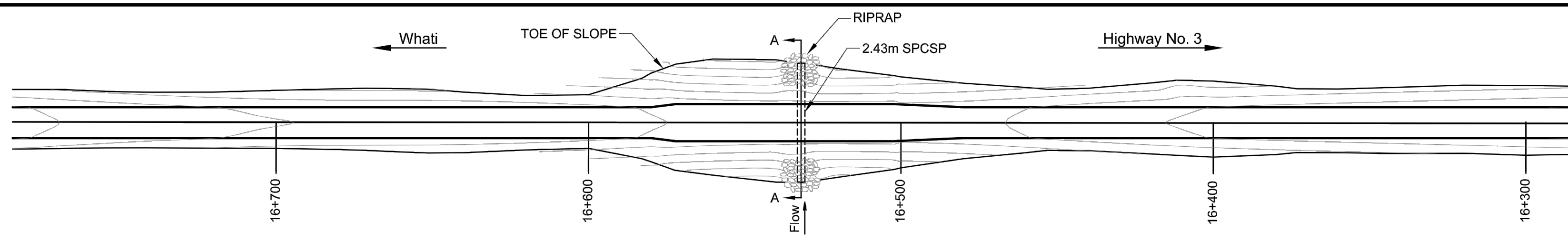
GEOTECHNICAL INVESTIGATION
CROSSING #5 CULVERT, NWT

Drawing No.

1

Title

KEY PLAN



SITE PLAN
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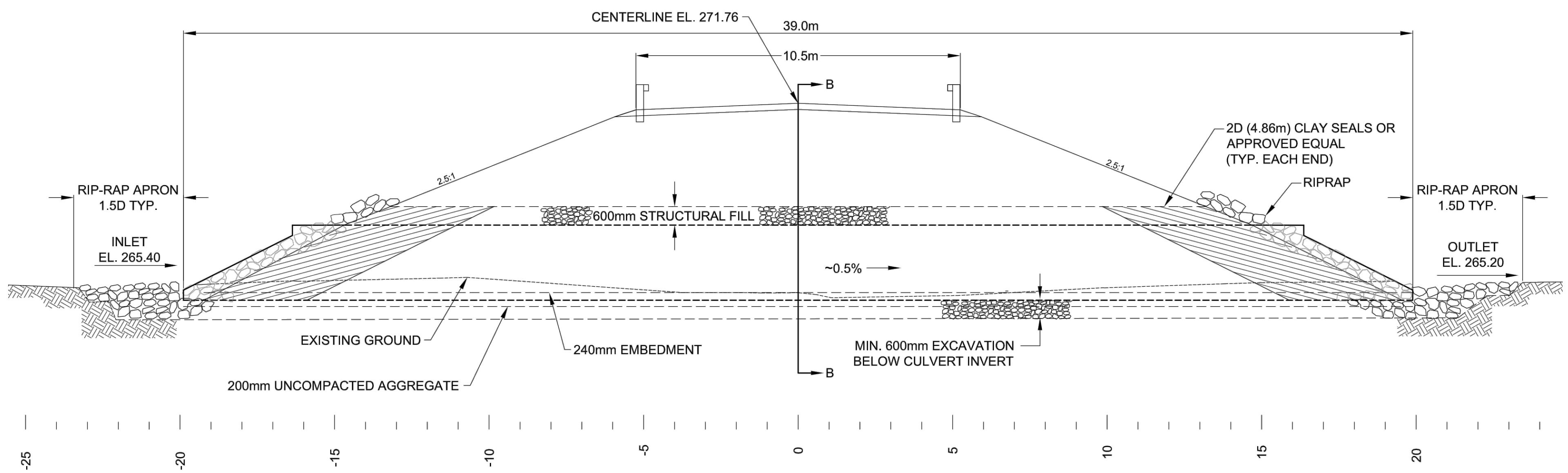
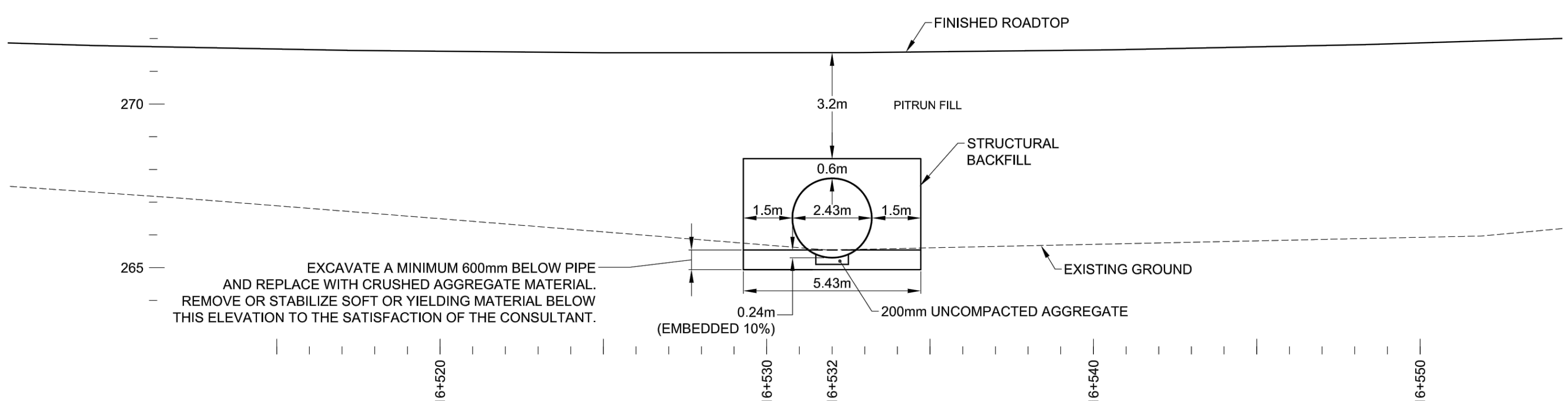


CULVERT PROFILE A-A @ 16+532
1:200



SECTION B-B
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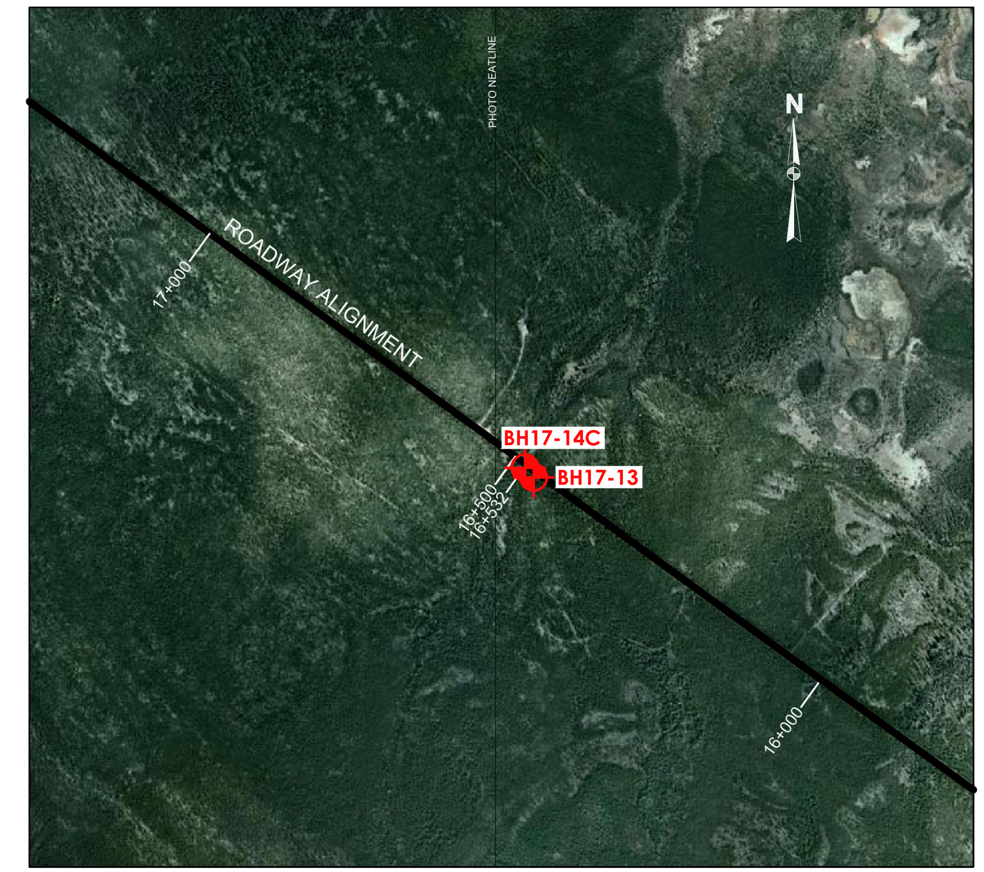

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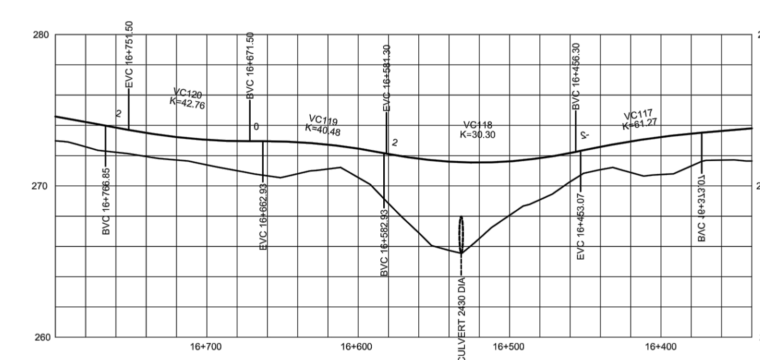

ROADWAY PROFILE
H 1:5,000 V 1:500

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2017/04/28 3:09 PM By: Briones, Gliceria

APRIL 2017
PROJECT No. 144902448

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LEGEND

APPROXIMATE BOREHOLE LOCATION

NOTES

1. DRAWING PROVIDED BY DOT TECHNICAL SERVICES (TASR-02-16 (CROSSING#5).

Client/Project

TLICHO ENGINEERING & ENVIRONMENTAL SERVICES LTD.
GEOTECHNICAL INVESTIGATION
CROSSING #5 CULVERT, NWT

Drawing No.

2

Title

GENERAL LAYOUT AND BOREHOLE LOCATION PLAN

Photo No. 1: Borehole BH17-13 location (looking southeast).

Photo No. 2: Borehole BH17-13 location (looking northwest to BH17-14C)

Photo No. 3: Borehole BH17-14C (looking north)

Photo No. 4: Borehole BH17-14C location (looking northwest)

APPENDIX C

NBC Seismic Hazard Calculation Sheet

Seismic Hazard Deaggregation

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

April 19, 2017

Site: 62.5286 N, 116.7728 W   User File Reference: Geotechnical Investigation, Proposed T¯Ð˜flch˙« All-S

Requested by: ,

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.05)	Sa(0.1)	**Sa(0.2)**	Sa(0.3)	**Sa(0.5)**	**Sa(1.0)**	**Sa(2.0)**	**Sa(5.0)**	**Sa(10.0)**	**PGA (g)**	**PGV (m/s)**
0.040	0.056	**0.052**	0.044	**0.040**	**0.033**	**0.021**	**0.0072**	**0.0034**	**0.030**	**0.034**

Notes. Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. ***These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.***

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.0025	0.011	0.020
Sa(0.1)	0.0040	0.016	0.029
Sa(0.2)	0.0057	0.018	0.029
Sa(0.3)	0.0070	0.018	0.027
Sa(0.5)	0.0075	0.019	0.026
Sa(1.0)	0.0065	0.016	0.023
Sa(2.0)	0.0040	0.010	0.015
Sa(5.0)	0.0014	0.0035	0.0049
Sa(10.0)	0.0008	0.0016	0.0023
PGA	0.0023	0.0089	0.016
PGV	0.0058	0.015	0.022

References

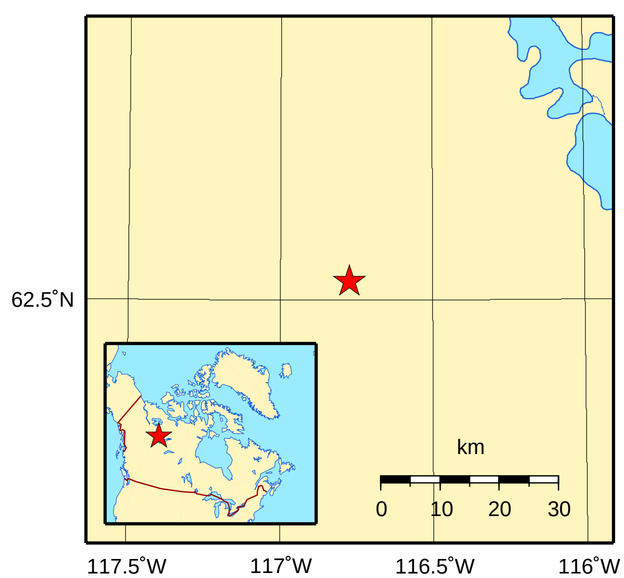
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français



Seismic Hazard Deaggregation

calculated by the Canadian Hazards Information Service

INFORMATION: *EarthquakesCanada.nrcan.gc.ca*

Eastern Canada (613) 995-5548 Western Canada (250) 363-6500

Requested by: Zach Popper, Stantec

2017/04/21

For site Tlicho All Season Road, NT at 62.548 N 116.806 W

For ground motion parameter peak ground acceleration (PGA)

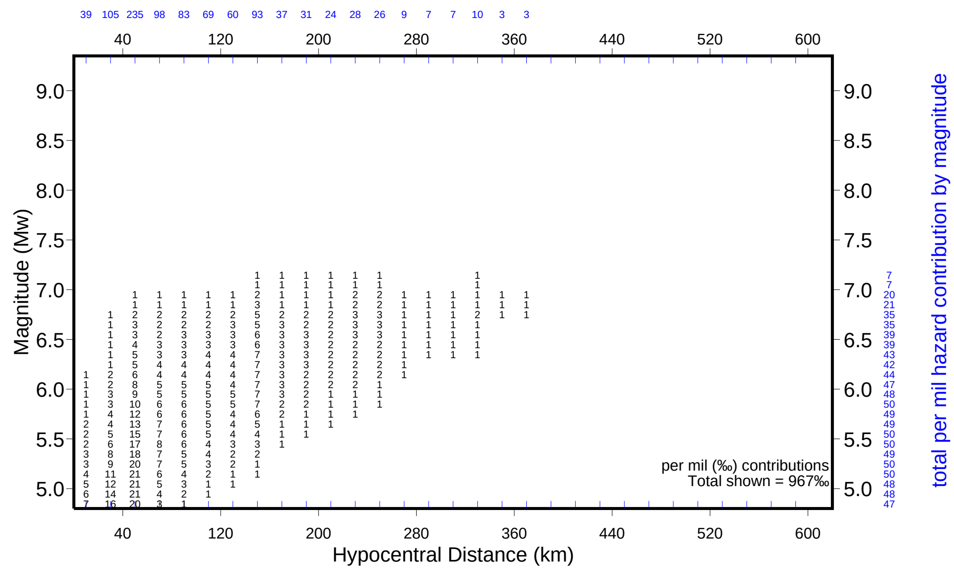
at a probability of 0.000404 per annum, seismic hazard = 0.030 g

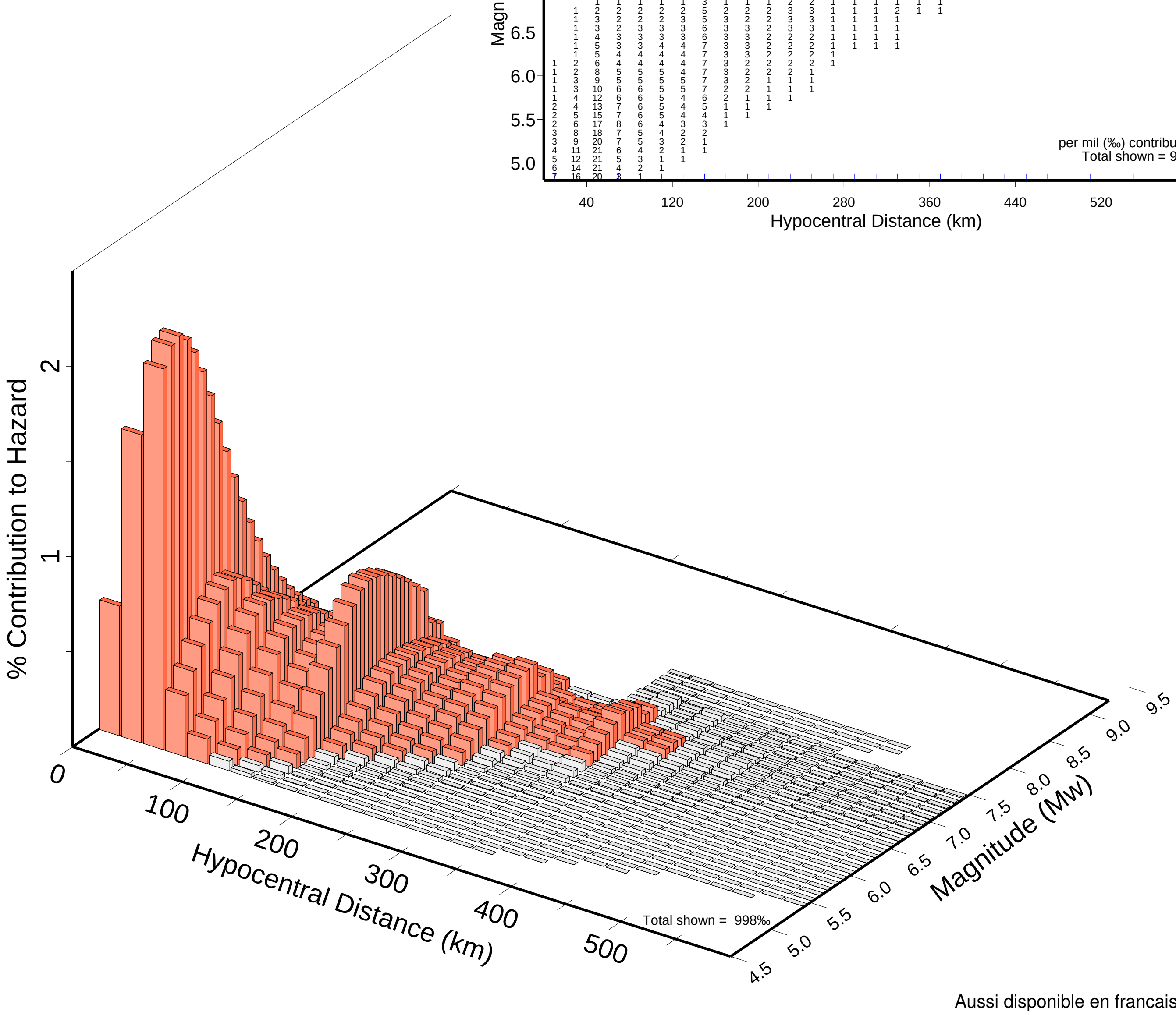
Mean magnitude (Mw) 5.84   Mean distance 112 km

Mode magnitude (Mw) 5.050   Mode distance 50 km

Deaggregation of mean hazard

Model: WArctic_g2015clC.model





APPENDIX D

Notice to Contractor – Groundwater Control

NOTICE TO CONTRACTOR – GROUNDWATER CONTROL

Special Provision

PRESENCE OF HIGH PERMEABILITY SOILS

The work required for the above tender item shall include consideration of dewatering to provide a stable working platform during construction of the culvert.

The contractor is advised of the following:

- Excavation is required for the construction of new culverts.
- The contractor shall consider that seasonal groundwater fluctuations may result in high groundwater levels and that higher groundwater levels may result in an unstable working earth platform.
- The estimated hydraulic conductivity for the native soil at the site is expected to range from $1x10^{-3}$ cm/s to $1x10^{-5}$ cm/s.
- The anticipated excavation level may be below the groundwater level at the time of construction.
- The presence of cohesionless sand can render the soils susceptible to unbalanced hydrostatic head, soil sloughing and cave-in.
- The contractor shall consider the site conditions, sequence of work and schedule when assessing requirements for dewatering.

Geotechnical Data Report
Proposed Culvert Crossing #6
Stations 19+427 and 19+432

Geotechnical Investigation,
Proposed Tlicho All-Season Road,
Northwest Territories

Prepared for:
Tlicho Engineering and
Environmental Services Ltd.

Prepared by:
Stantec Consulting Ltd.
400 – 1331 Clyde Avenue
Ottawa, ON K2C 3G4

Project No. 144902448

May 2017

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APPENDIX E Thermistor Resistance versus Temperature Relationship
Thermistor Readings

1.0 INTRODUCTION

Acting under the authorization of Tlicho Engineering and Environmental Services Ltd. (Tlicho), Stantec Consulting Ltd. (Stantec) carried out a geotechnical investigation in support of the culverts planned at 'Crossing #6' along the proposed Tlicho All Season Access Road (TASR). The purpose of the investigation was to characterize subsurface conditions and provide geotechnical comments and recommendations to assist with culvert design and site development.

The investigation was carried out in general accordance with Stantec's proposal dated January 12, 2017, as part of an overall geotechnical program by Tlicho for the Government of the Northwest Territories (GNWT) along the proposed 94 km TASR alignment extending from the Yellowknife Highway (Highway 3) to the Settlement of Whatì on the south shore of Lac La Martre (RFP Event ID: EV000000001132). The scope of work outlined in the GNWT Request for Proposal includes the geotechnical investigation and design of the 94 km long TASR corridor, four bridges and three structural culverts. Tlicho was responsible for management and execution of the overall project and team as the Prime Contractor, with Stantec acting as sub-consultant providing geotechnical engineering and technical services to the project, including:

- Provision of geotechnical field personnel to log subsurface conditions during drilling operations at eighty-one (81) geotechnical boreholes in accordance with the RFP:
  - Thirteen (13) boreholes at the four (4) proposed major bridge crossings:
    - Crossing #8, Station 40+400 - Duport River Crossing
    - Crossing #9, Station 45+175 - (unnamed)
    - Crossing #14, Station 69+666 - James River Crossing
    - Crossing #15, Station 85+397 - La Martre River
  - Three (3) boreholes at the three (3) proposed major bridge culvert crossings:
    - Crossing #5, Station 16+532
    - Crossing #6, Station 19+427
    - Crossing #10a, Station 48+208
  - Sixty-five (65) boreholes to observe the subsurface conditions along the road alignment;
- Installation and reading of thermistors;
- Borehole layout and as-drilled survey;
- Completion of a laboratory testing program on the recovered borehole samples as specified in the RFP; and
- Geotechnical engineering assessment and reporting on the field and laboratory findings in two reports (Geotechnical Data Report and Geotechnical Recommendations Report) for each crossing location and for the overall roadway alignment.
  - These documents should be read in conjunction with the Statement of General Conditions, Appendix A.

This Report has been prepared specifically and solely for the culvert crossing at Crossing #6 of the Tlicho All Season Road in the Northwest Territories, Canada.

2.0 SITE DESCRIPTION AND GEOLOGY AND CLIMATE

2.1 SITE DESCRIPTION

The site location is shown on the Key Plan, Drawing No. 1 provided in Appendix B. The site for the proposed culvert crossing is along the alignment of the Tlicho All Season Road and existing winter road from Highway 3 to Whatì. The site location is approximately 20 km northwest of Highway 3 and approximately 68 km southeast of the Community of Whatì in the Northwest Territories, Canada. Photographs showing the general site conditions of the proposed culvert location are provided in Appendix B.

The existing road has been cleared of trees and runs approximately north-south at the project location; chainage increases in the northern direction towards Whatì. The proposed culvert locations are at Stations 19+427 and 19+432. The location of the proposed culvert crossing is at a low point on the existing road profile with an approximate existing elevation of 271.8 m. The area on both the east and west sides of the existing road is covered with brush and trees. On February 24, 2017, the watercourse channel(s) were not visible from walk around inspection of the culvert location due to snow cover and/or dry, no-flow conditions. Satellite imagery demonstrates that a seasonal watercourse crosses the existing road at the proposed culvert location. Snow cover depths of approximately 50 to 55 cm were measured in surrounding undisturbed areas. Site photographs are shown in Appendix B.

It is understood that the Old Lac La Martre overland winter road was established by the military in the 1950s, and utilized as a public winter road for the northern Tlicho communities up until the late 1980s. More recently it has been used by the local communities for travel using all-terrain vehicles including snowmobiles, dog sleds, ATVs, and trucks (GNWT DOT, 2016). Previous site development for the road at this location appears to be limited. The roadbed is approximately level with the surrounding undisturbed vegetated areas with no significant historic ground disturbance (regrading cut/fill) apparent.

2.2 PHYSIOGRAPHY AND GEOLOGY

The site is located within the Great Slave Plain High Boreal Ecoregion (GNWT, 2009 and GNWT DOT, 2016). In this section of the TASR corridor (GNWT DOT, 2016), regional topography is generally subdued with plains and gently rolling hills. Drainage ranges from 'well' to 'moderately well' with occasional seasonal tributaries. Vegetation includes regenerating jack pine forest, ephemeral stream crossing/swampland, dwarf shrub and mixed stands. The general area was subjected to forest fires within the last decade.

Based on available surficial geology mapping conducted by the Geological Survey of Canada, and previous project terrain mapping (Kavik AXYS Inc, 2008 and GNWT DOT, 2016), natural overburden material in the area has been mapped as till, coarse beach glacio-lacustrine, and fine glacio-lacustrine material associated with glacial Lake McConnell, and occasional veneers of organic or fluvial materials overlying bedrock. Based on geological mapping published by the Geological Survey of Canada (Okulitch, 2004), the site is mapped within the Interior Platform geologic province, situated over Paleozoic aged sedimentary rocks of the Lonely Bay Formation consisting of brown limestone and minor dolostone.

2.3 CLIMATE

2.3.1 Climate

Based on a review of historic climate data completed using the Yellowknife Airport (Climate Reference ID: 2204100), Whatì meteorological station (Lac la Martre, Climate Reference ID: 2202678) and other sources (GNWT, 2016), it is understood that the TASR area has a subarctic climate (Dfc, according to the Köppen climate classification system) characterized by generally relatively cold winters followed by short summers. It is noted that the Whatì station is located approximately 13 km west of the northern limit of the TASR and the Yellowknife station is located approximately 100 km east of the southern limit of the TASR.

Average annual daily mean temperatures are on the order of -4.3 °C (Yellowknife Station) to - 4.7°C (Whatì Station), with the lowest average daily winter temperatures generally occurring in January, while the warmest month (based on the average temperature) occurs in July. The average annual precipitation is estimated on the order of 288.6 mm, with an average annual rainfall of 170.7 mm generally occurring throughout June through September, and an average annual snowfall of 157.6 cm generally occurring from September through May (Yellowknife Station).

The average freezing and thawing indices between 1981 and 2010 have been 3343.1 C° days and 1813.3 C° days, respectively (Yellowknife Station). A study completed by Holubec, et. al., using data from 1978 to 2008 in their model was adapted by CSA (2010). The CSA study suggests a warming trend of 0.58 °C per decade within the Central Arctic region (including the TASR site). As per Table 5.2 in CSA (2010), seasonal mean temperature change under moderate (A1B) green-house gas scenarios, the mean annual temperatures for the Arctic Sector C1 are projected to be 1.3 °C (2011-2040), 2.7 °C (2041-2070), and 3.7 °C (2071 – 2100) respectively.

2.3.2 Permafrost

Canada Permafrost mapping from the National Atlas of Canada (Heginbottom et al. 1995) shows the TASR site lies within the zone of extensive discontinuous permafrost, with an estimated 50% and 90% of the landscape covered. It is understood that no public thermistor or intrusive investigation records exist for the immediate vicinity of the TASR. Previous reconnaissance trips by earlier AXYS terrain mapping crews and GNWT personnel did not identify any apparent permafrost landforms or thermokarst zones within the corridor, however a zone affected by thermokarst processes was noted between Whatì, Behchoko and the area north of Slemon Lake Kavik (AXYS Inc, 2008 and GNWT DOT, 2016).

Based on regional studies completed in surrounding areas (GNWT, 2016 and Stantec, 2015), permafrost is anticipated to be relatively warm and correlated with forest cover type areas underlain by finer-textured glacial and post-glacial sediments such as glaciolacustrine and lacustrine deposits, as well as peatlands where organic material contributes to the forming and preservation of permafrost. Ground ice content, if present in these finer grained deposits in the upper 10 to 20 m is anticipated to be <10% to 20% ice by volume (Heginbottom et al. 1995). Ground ice is generally expected to be less common in areas of exposed bedrock and where the underlying sediments are coarse and vegetation cover is thin.

Permafrost near Yellowknife is reported to be generally warm (>-2°C), less than 50 m thick with active layer thickness <1 to up to 3 m (Wolfe, 1998). Permafrost conditions along the nearby Highway 3 have been reported as typically warmer than -1°C, with an active layer thickness varying from <0.7 m to 1.5 m. Extensive permafrost degradation has been noted along the Highway in recent years with settlements in soil-covered areas generally attributed to the degradation of the ice-rich permafrost subgrade, particularly where it was constructed adjacent to a water body and where the road crossed over the old alignment (BGC, 2011; and Wolfe et al, 2015;). Permafrost, where present, will be susceptible to degradation due to ground disturbance, such as removal of trees and surface vegetation or earthworks.

Recent studies commissioned by GNWT have reported that climate change trends have negatively impacted and are projected to continue to negatively impact permafrost conditions in the region (Dillon 2007; BGC, 2011). Continued warming, changes in freeze-thaw patterns, and ultimately degradation of permafrost in the region are anticipated due to increasing temperatures and amounts of precipitation, and decreases in snow and ice cover.

3.0 INVESTIGATION PROCEDURES

3.1 FIELD INVESTIGATION

A geotechnical field investigation for the proposed culverts consisting of two boreholes was carried out for this assignment as part of the overall TASR alignment geotechnical field program between February 12 and March 29, 2017. The boreholes were designated BH17-16C and BH17-17 and their locations are shown on the General Layout and Borehole Location Plan, Drawing No. 2 in Appendix B. The General Layout drawing is based on the Tlicho All Season Road Predesign Report and was designed by DOT Structures and drawn/drafted by DOT Technical Services. It is to be noted that the layout is conceptual and the final design details will be determined at a later date.

The field drilling program at this crossing location was carried out on February 17 and 24, 2017. Boreholes BH17-16C and BH17-17 were advanced with solid 150 mm augers and NW casing using a track mounted Foremost CME drill rig equipped for soil sampling and operated by Northtech Drilling Ltd. Auger refusal prior to the target depth was checked with at least two additional auger probe holes completed with the drill offset several meters to account for potential boulders.

The field work was conducted under the monitoring of a GNWT field representative and supervision of Justin Matthew, P.Eng. and Kyle Polito (Stantec) who maintained detailed logs and obtained representative samples from the various strata encountered. Subsurface conditions were classified in general accordance with the procedures outlined in the attached explanatory key: Symbol and Terms Used on Borehole and Test Pit Records with soil descriptions prepared in accordance with ASTM D2487 and D2488. Temperatures of soil samples were measured by a handheld infrared thermometer on recovery at surface. Our observations of the temperature readings suggest the drilling process altered the temperature of the soil samples and that these measurements should not be considered representative of in situ conditions. For example, soil samples collected from the augers within the seasonal frost layer (denoted as AS) had temperature readings greater than 0° C. Frozen soils were classified in accordance with ASTM D4083 and D7099. Groundwater levels were estimated in the open boreholes at the time of drilling with water level tape and/or the moisture condition of the recovered samples.

Three single-bead thermistor cables with 3000 Ohm thermistors manufactured by RST Instruments Ltd. were installed in borehole BH17-16C at depths of 0.9 m, 2.1 m, and 3.2 m below ground surface. Initial thermistor resistance readings were taken upon installation with a digital multimeter. Two readings at 6 days and 21 days after installation were also completed. The borehole was backfilled to the original ground surface level with auger cuttings and with silica sand 0.3 m above and below the thermistor beads. A PVC protective casing with approximately 1 m stickup was installed at the thermistor location.

Groundwater levels were estimated in the open boreholes if groundwater was encountered. Boreholes were backfilled with auger cuttings or with silica sand and auger cuttings for thermistor installations.

3.2 LOCATION AND ELEVATION SURVEY

The borehole locations and geodetic elevations were surveyed in the field by Stantec personnel using a Trimble Geo XH GPS with decimeter accuracy capability. The accuracy of the Trimble unit may be affected by satellite coverage at the time of survey. Table 3.1 summarizes the borehole information.

Table 3.1: Borehole Summary

	Boreholes	
	BH17-16C	**BH17-17**
NAD83 / UTM Zone 11 V Coordinates Northing Easting	 6935278 509983	 6935340 509951
Ground Surface Elevation, m	271.9	273.8
Total Depth Drilled, m	3.4	7.6
End of Borehole Elevation, m	268.5	266.1
Depth of Casing, m	0	0
Number of Soil Samples	5	9

3.3 LABORATORY TESTING

All samples were taken to the Stantec Edmonton and Calgary laboratories for detailed classification and testing. Selected soil samples underwent gradation analysis, Atterberg Limits, and moisture content testing. The laboratory testing summary is shown in Table 3.2 below.

Table 3.2: Laboratory Testing for Culvert Site

Laboratory Testing	**Moisture Content**	**Gradation Analysis**	**Atterberg Limits**
Number of Tests	13	8	3

One soil sample was tested for pH, soluble sulphate content, chloride content, and resistivity. One sample was tested for organic carbon content. Samples remaining after testing will be placed in storage for a period of one year after issuance of the final report. After the storage period, the samples will be discarded unless we are directed otherwise by Tlicho Engineering and Environmental Services Ltd.

4.0 SUBSURFACE CONDITIONS

4.1 SUBSURFACE PROFILE

The subsurface conditions observed in the Stantec boreholes are presented in detail on the Borehole Records provided in Appendix C. An explanation of the symbols and terms used to describe the Borehole Records is provided in Appendix C.

The temperature of each soil sample was measured in the field using an infrared thermometer and is provided on the Borehole Records. Temperatures inferred from temperature measurements of soil samples should be considered with extreme caution. Soil sample temperatures may be either warmer than in-situ due to drilling disturbance or be colder than in-situ due to cold air temperature exposure of the soil samples prior to temperature measurement.

It should be noted that the blow counts and relative density/consistency descriptions of frozen soils in the following section and in Appendix C should be used with caution. It is highly likely, particularly for cohesive soils, that the strengths implied by the blow counts will be significantly reduced by thawing.

In general, the subsurface stratigraphy at the site consisted of organic material at the surface, over sand with varying amounts of silt, over lean clay with varying amounts of sand, silt and gravel. Cobbles and boulders were inferred in the sand and in the clay.

4.1.1 Organic Soil

Peat was encountered in borehole BH17-16C from surface to 0.5 m below ground surface. Organic soil was also noted in the underlying sand layer in borehole BH17-16C. Organic content testing carried out on one representative sample from the organic soil yielded an organic carbon content of 13%. Temperatures of the peat samples obtained from the infrared thermometer at the time of drilling ranged from -2.4 to -3.1 °C. The frozen soil description of the layer was V_C.

One moisture content test carried out on a representative sample of the organic soil yielded a moisture content of 44%.

4.1.2 Sand

A frozen sand layer with varying amounts of gravel and silt (fines) was encountered in boreholes BH17-16C and BH17-17. The SPT N-values for the sand deposit ranged from 7 to 36 blows per 0.3 m.

<u>BH17-17</u>

Sand with a lesser fines content was encountered in borehole BH17-17. The sand deposit extended from ground surface to 3.7 m. The sand is described as poorly graded sand (SP) and poorly graded sand with silt (SP-SM) based on the Unified Soil Classification System (USCS). Cobbles were noted within the sand layer. Temperatures of the poorly graded sand obtained from the infrared thermometer at the time of drilling ranged from -3.5 to -4.8 °C. The frozen soil description of the layer was N_F.

Grain size distribution and moisture content tests carried out on representative samples of the poorly graded sand yielded the following results:

Gravel:	0%
Sand:	94 and 96%
Fines (silt and clay):	4 and 6%
Silt size:	3%
Clay size:	3%
Moisture Content:	4 to 19%

The grain size distribution curves for the poorly graded sand material are provided in Figures 1 to 3 of Appendix D.

BH17-16C

Sand with a higher fines content was encountered from 0.5 m to 2.0 m below ground surface in borehole BH17-16C. The sand is described as silty sand (SM) based on the USCS. The sand deposit contained pockets of organic soil. Temperatures of the silty sand samples obtained from the infrared thermometer at the time of drilling ranged from 0.2 to –2.1 °C.

Grain size distribution and moisture content tests carried out on representative samples of the silty sand yielded the following results:

Gravel:	0 %
Sand:	81 and 85%
Fines (silt and clay):	15 and 18%
Silt size:	13%
Clay size:	6%
Moisture Content:	14 to 19%

The grain size distribution curve for the silty sand material is provided in Figures 4 and 5 of Appendix D.

4.1.3 Clay

A frozen clay layer consisting of lean clay with varying amounts of sand, silt and gravel was encountered below the sand in boreholes BH17-16C and BH17-17. Drilling refusal occurred within the clay layer at a depth of 3.4 m in borehole BH17-16C. Cobbles and boulders or bedrock were inferred below the clay in borehole BH17-16C. Borehole BH17-17 was terminated within the clay layer. Temperatures of the clay samples obtained from the infrared thermometer at the time of drilling ranged from 3.7 to -4.5 °C. The frozen soil description of the layer was N_f.

The SPT N-values for this deposit ranged from 6 to 22 blows per 0.3 m. Pocket penetrometer tests of the frozen clay yielded shear strength values of over 200 kPa.

Grain size distribution and moisture content tests carried out on representative samples of the clay yielded the following results:

Gravel:	2 to 3%
Sand:	38 to 39%
Fines (silt and clay):	59 to 60%
Silt size:	34 to 37%
Clay size:	23 to 26%
Moisture Content:	9 to 18%

Atterberg limits tests carried out on three representative samples from this layer indicated a plasticity index range of 9 to 14. The USCS group symbol for this layer is CL (sandy lean clay). Representative grain size distribution plots for this layer are given in Figures 6 to 8 and the corresponding plasticity charts are given in Figure 9 of Appendix D.

4.1.4 Bedrock

Bedrock was not proven by coring in the boreholes, however multiple augers were advanced offset several meters from the original borehole location. Auger refusal occurred at depths of 2.3 and 3.4 m in borehole BH17-16C where cobbles and boulders or bedrock are inferred (grinding of augers was noted during drilling).

4.2 PERMAFROST CONDITIONS

Based on field observations of frozen soil recoveries during advancement of the boreholes, frozen soil was encountered within boreholes BH17-16C and BH17-17. The frozen soil was encountered in borehole BH17-16C from ground surface to 1.2 m below the existing ground surface. The organic soil in borehole BH17-16C was described as having ice coatings on particles, V_c in accordance with ASTM D4083. The underlying soils in BH17-16C and the soil in borehole BH17-17 were described as having no visible ice, N_f in accordance with ASTM D4083. Infrared temperatures of soil samples recorded in the field ranged from 0.2 to -3.1 °C within the frozen zone of borehole BH17-16C. Warmer soil sample temperatures of 0.6 to 3.7 °C were measured below a depth of 1.2 m. Temperatures of soil samples in borehole BH17-17 were generally colder and ranged from -1.8 to -4.8 °C, with the exception of sample AS7 measured as 2.6 °C.

Three single-bead thermistor cables with 3000 Ohm thermistors manufactured by RST Instruments Ltd. were installed in borehole BH17-16C at depths of 0.9 m, 2.1 m, and 3.2 m. Initial thermistor resistance readings were taken upon installation with a digital multimeter. Two resistance readings at 6 days and 21 days after installation were also completed. The resistance versus temperature relationship for the thermistors is included in Appendix E. Figure 10 in Appendix E presents the Temperature versus Depth as determined by the thermistor readings for borehole BH17-16C. The figure presents above 0 °C temperature readings that are increasing with depth.

The thermistor readings are considered to be a more reliable indication of the temperature of the soils compared to the infrared thermometer readings. The infrared thermometer was used during sampling when the soils have been heated by friction generated by the action of the drill. It was also observed during the field work that when outside temperatures ranged between -20 °C and -30 °C that readings indicated that the sample was colder than the actual air temperature which was not likely. Therefore, the reported infrared temperature readings should be used with caution.

The temperature of the soil samples obtained using the infrared thermometer in BH17-16C suggest the absence of permafrost at the culvert location and at Borehole BH17-17 permafrost extending below the termination depth of 7.6 m. The thermistor readings in BH17-16C also suggest permafrost is not present at the culvert location. It should be noted that borings BH17-16C and BH17-17 are 68 m apart, therefore it is possible that permafrost conditions vary between borings as the site is located in a discontinuous permafrost zone (Section 2.3.2).

4.3 GROUNDWATER

Groundwater was not encountered in the open boreholes during the investigation. Fluctuations in the groundwater due to seasonal changes or in response to a particular precipitation event should be anticipated. It is noted that satellite imagery shows a seasonal watercourse crossing at the site location.

4.4 CHEMICAL TEST RESULTS

One sample of the native soil material was tested for pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis results are provided in Table 4.1. The results and certificates of analysis from Maxxam Analytics are provided in Appendix D.

Table 4.1: Results of Chemical Analysis

Borehole No	Sample No.	Depth (m)	pH	Chloride (%)	Sulphate (%)	Resistivity (Ohm-m)
BH17-16C	AS3	1.55 to 2.31	7.93	<0.00023	0.0028	28

5.0 CLOSURE

A subsurface investigation is a limited sampling of a site. The subsurface conditions given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information. Use of this report is subject to the Statement of General Conditions provided in Appendix A. It is the responsibility of Tlicho Engineering and Environmental Services Ltd., who is identified as "the Client" within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec Consulting Ltd. should any of these not be satisfied. The Statement of General Conditions addresses the following:

- Use of the report
- Basis of the report
- Standard of care
- Interpretation of site conditions
- Varying or unexpected site conditions
- Planning, design or construction

This report was written by Zachary Popper, B.Eng. and reviewed by Christopher McGrath, P.Eng. and Jim Oswell, P.Eng. Mr. McGrath and Dr. Oswell are registered members of the Northwest Territories and Nunavut Association of Professional Engineers and Geoscientists. We trust that the information contained in this report is adequate for your present purposes. If you have any questions about the contents of the report or if we can be of further assistance, please contact us at your convenience.

Respectfully Submitted;

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6.0 REFERENCES

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2009. Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) (ASTM D2488). ASTM International, West Conshohocken, PA.

ASTM. 2010. Standard Terminology Relating to Frozen Soil and Rock (ASTM D7099). ASTM International, West Conshohocken, PA.

ASTM. 2011. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

ASTM. 2016. Standard Practice for Description of Frozen Soils (Visual-Manual Procedure) (ASTM D4083). ASTM International, West Conshohocken, PA.

BGC Engineering Inc. 2011. Highway 3 – Climate Change Vulnerability Assessment – Final Report.

Canadian Standards Association (CSA). 2010. Technical Guide Infrastructure in permafrost: A guideline for climate change adaptation. Canadian Standards Association, Mississauga, ON, Canada.

Dillon Consulting Ltd. 2007. Climate Change and Transportation in the NWT. March 2007.

Environment Canada. Warming Trends °C/Decade, Based on homogenized temperature data – the most recent 30 yr record (1981 – 2010); Environment Canada.

Environment Canada. (2016, September 1) Canadian Climate Normals 1981–2010. Yellowknife Station. Retrieved from http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProv&lstProvince=NT&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=1706&dispBack=0

GNWT, 2009. Ecosystem Classification Group (ECG) 2009. Ecological Regions of the Northwest Territories: Taiga Shield. Department of Environment and Natural Resources, GNWT. Yellowknife, NT.

GNWT DOT, 2016. Proposed Tlicho All-season Road, Project Description Report. March 2016

Heginbottom, J.A., Dubreuil, M.A., and P.A. Harker. 1995. Canada-Permafrost; National Atlas of Canada, 5th edition, Plate 2.1. Geomatics Canada, National Atlas Information Service and Geological Survey of Canada (MCR 4177).

Kavik AXYS Inc. 2008a. Multi-Level Mapping and Route Analysis – Tlicho Transportation Corridor. Route Identification and Evaluation. Yellowknife, NT. January 2008.Project No. Project No. 144902005.

Okulitch, A.V. 2004. Geological compilation of Phanerozic Bedrock Geology (Map NP-11/12-G), Slave River District of MacKenzie, Northwest Territories. Geological Survey of Canada, Open File 5281.

Stantec, 2015.Tli Cho Road Alignment, Hydrologic and Hydraulic Study. Project No. 144902005.

Wolfe, 1998. Living with frozen ground : a field guide to permafrost in Yellowknife, Northwest Territories, edited by Stephen A. Wolfe ; contributions by Stephen A. Wolfe

S.A. Wolfe, P.D. Morse, T.E. Hoeve, W.E Sladen, S.V. Kokelj, L.U. Arenson, 2015. Disequilibrium permafrost conditions on NWT Highway 3

7.0 BIBLIOGRAPHY

Andersland, O.B., and Ladanyi, B. 1994. An Introduction to Frozen Ground Engineering. Chapman & Hall Inc., New York, NY, USA.

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2000. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

ASTM. 2000. Standard Practice for Description of Frozen Soils (Visual-Manual Procedure) (ASTM D4083). ASTM International, West Conshohocken, PA.

Canadian Foundation Engineering Manual (CFEM). 2006. Fourth Edition. Canadian Geotechnical Society, 488 p.

CHBDC. 2014. Canadian Highway Bridge Design Code. Canadian Standards Association, Mississauga, Ontario.

GSC, 1965. Glacial Lake McConnell and the surficial geology of parts of Slave River and Redstone River map areas, District of Mackenzie; Craig, B G. Geological Survey of Canada, Bulletin 122, 1965,; 44 pages, doi:10.4095/100639. Natural Resources Canada. 1995: Canada Permafrost; The National Atlas of Canada 5th Edition, scale 1:7 500 000.

GSC, 1989. Glacial Features Around the Keewatin Ice Divide, Northwest Territories; Aylsworth, J M; Shilts, W W. Geological Survey of Canada, Preliminary Map 24-1987, 1989, ; 2 sheets, doi:10.4095/126992.

Kerr and Wilson, 2000. 2000-C3. Preliminary surficial geology studies and mineral exploration considerations in the Yellowknife area, Northwest Territories. D.E. Kerr and P. Wilson.

APPENDIX A

Statement of General Conditions

STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec Consulting Ltd. and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec Consulting Ltd.'s present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec Consulting Ltd. is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec Consulting Ltd. at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec Consulting Ltd. must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec Consulting Ltd. will not be responsible to any party for damages incurred as a result of failing to notify Stantec Consulting Ltd. that differing site or sub-surface conditions are present upon becoming aware of such conditions.

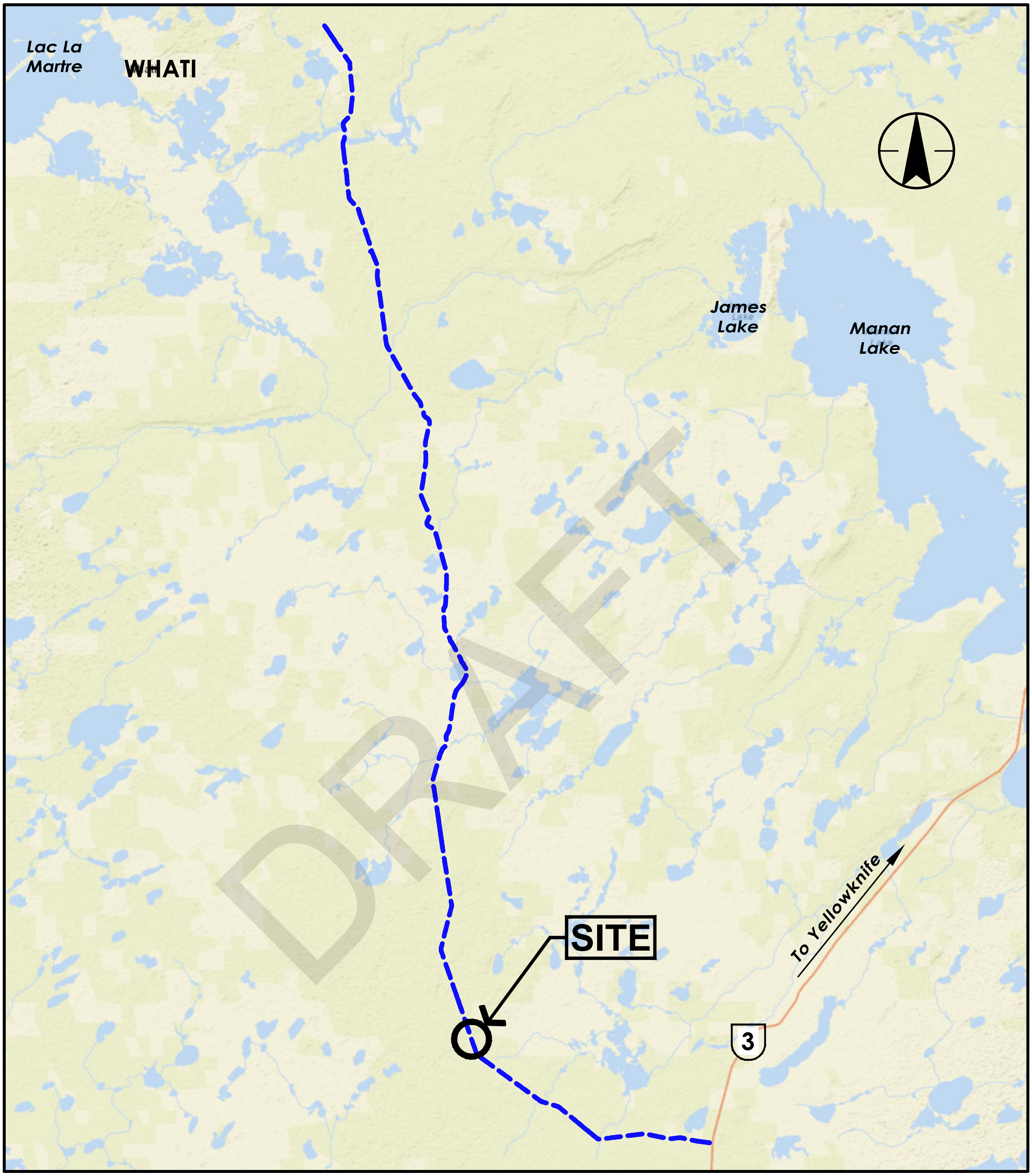
PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec Consulting Ltd., sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec Consulting Ltd. cannot be responsible for site work carried out without being present.

APPENDIX B

Drawing No. 1 – Key Plan

Drawing No. 2 – General Layout and Borehole Location Plan

Site Photos



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LEGEND

PROPOSED ALIGNMENT

NOTES

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Client/Project

TLICHO ENGINEERING & ENVIRONMENTAL SERVICES LTD.

GEOTECHNICAL INVESTIGATION
CROSSING #6 CULVERT, NWT

Drawing No.

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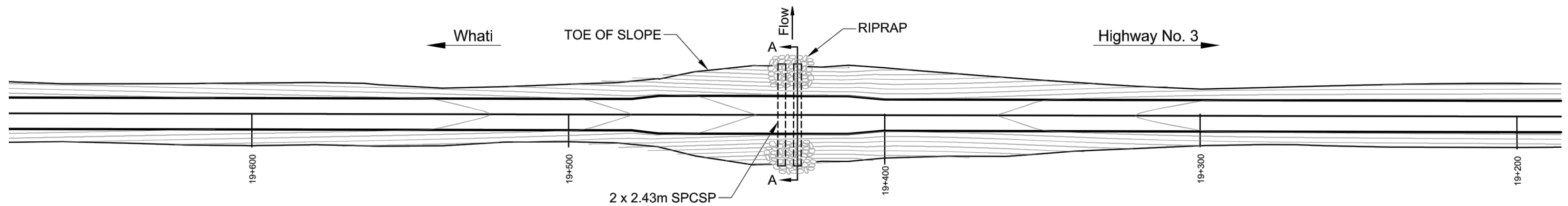
Title

KEY PLAN



SITE PLAN
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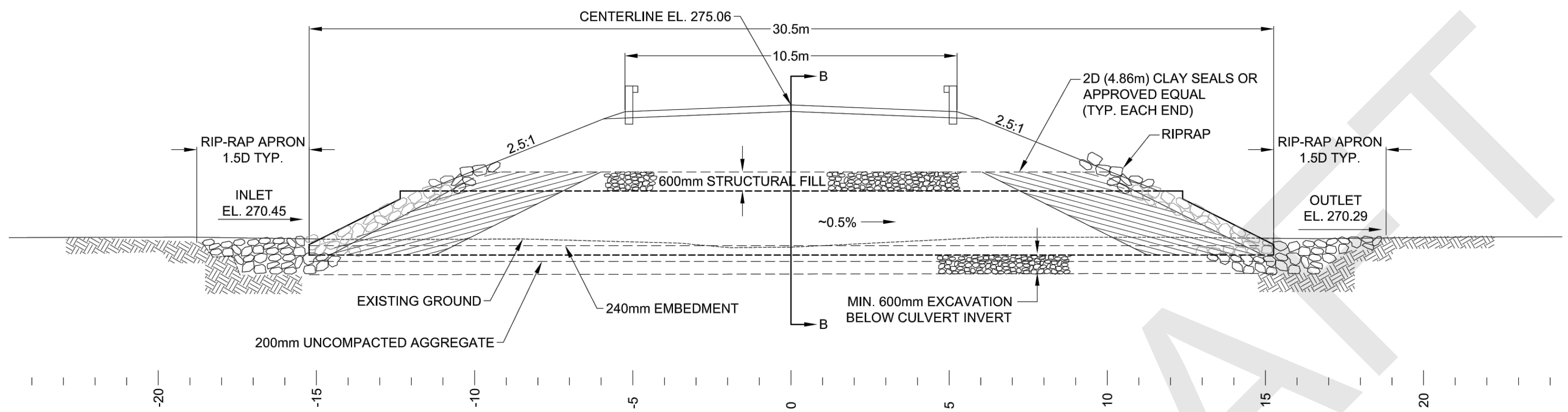
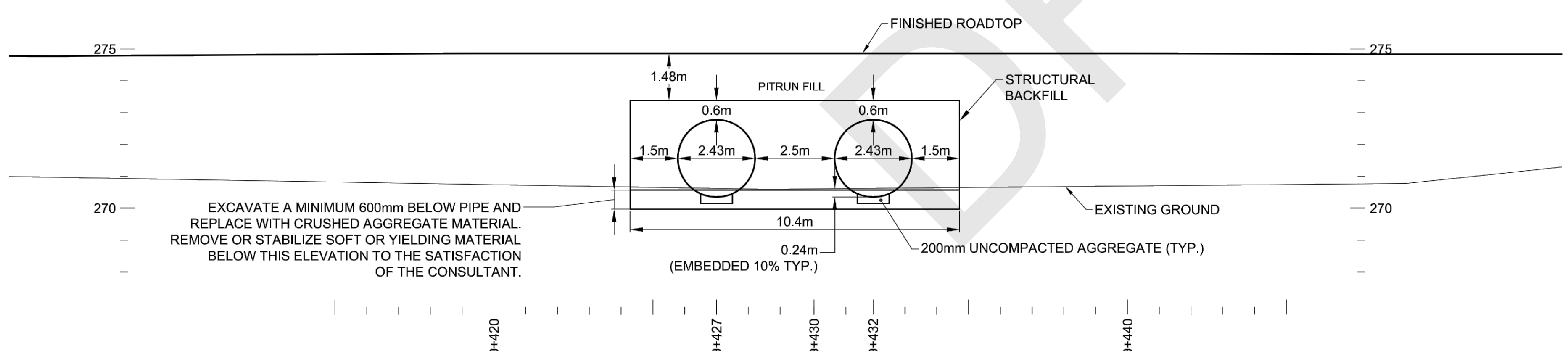
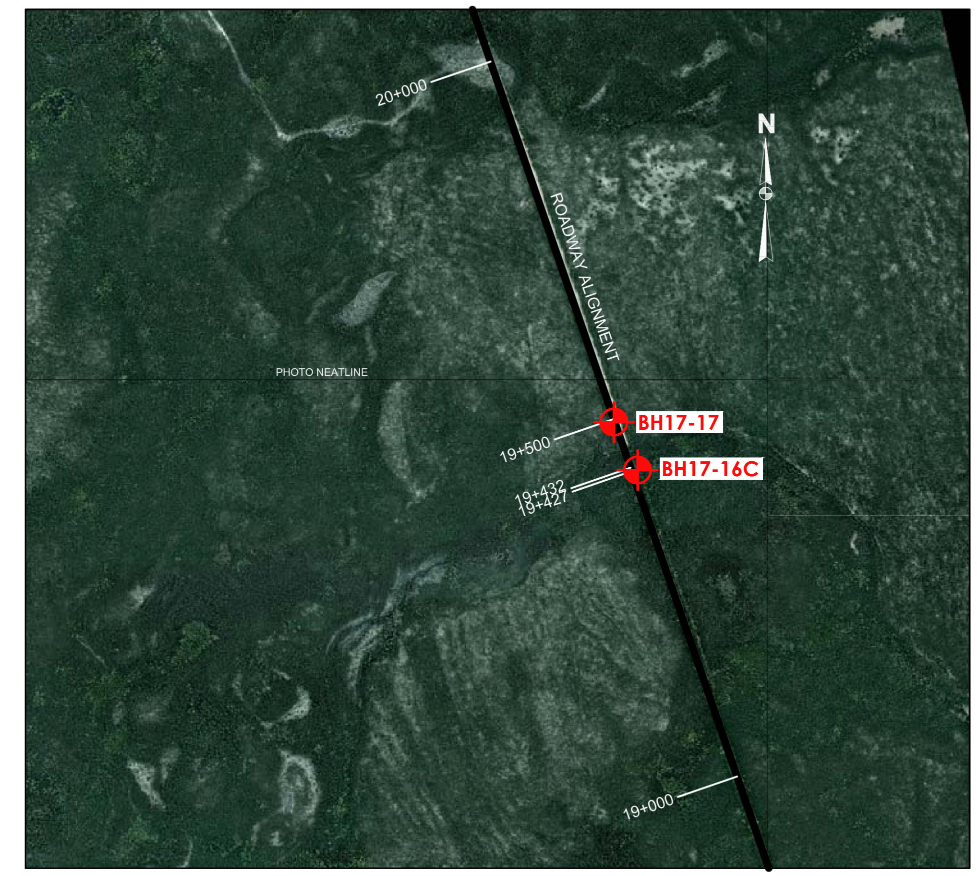


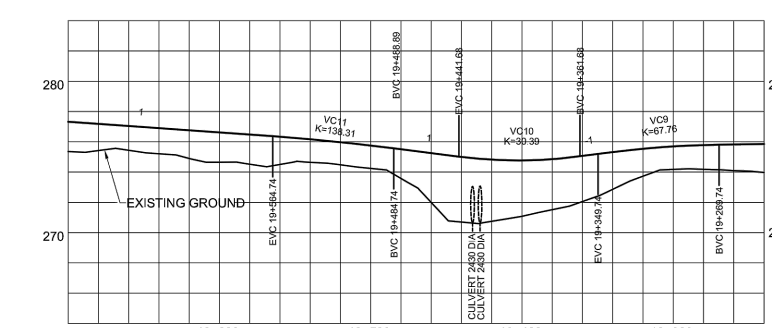
CULVERT PROFILE A-A @ 19+427
1:200



SECTION B-B
1:200



PLAN
1:10,000



ROADWAY PROFILE
H 1:5,000 V 1:500

DRAFT

T:\Autocad\Drawings\Project Drawings\2017\144902448\Crossing 6\144902448_C6_General Layout.dwg
2017/04/28 3:09 PM By: Briones, Gliceria

APRIL 2017
PROJECT No. 144902448

Stantec

400 - 1331 CLYDE AVENUE
OTTAWA, ON, CANADA K2C 3G4
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LEGEND

APPROXIMATE BOREHOLE LOCATION

NOTES

1. DRAWING PROVIDED BY DOT TECHNICAL SERVICES (TASR-03-16 (CROSSING#6).

Client/Project

TLICHO ENGINEERING & ENVIRONMENTAL SERVICES LTD.

GEOTECHNICAL INVESTIGATION
CROSSING #6 CULVERT, NWT

Drawing No.
2

Title

GENERAL LAYOUT AND BOREHOLE LOCATION PLAN

Photo No. 1: Borehole BH17-16C location.

Photo No. 2: Borehole BH17-16C location.

Photo No. 3: Borehole BH17-16C with thermistor cables and PVC pipe.

Photo No. 4: Borehole BH17-17 location looking northwest.

Photo No. 5: Borehole BH17-17 location looking southeast towards culvert Crossing No. 6.

Photo No. 6: Borehole BH17-17 location.

APPENDIX C

Symbols and Terms Used on Borehole Records

Stantec Borehole Records

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

Rootmat	- vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
Topsoil	- mixture of soil and humus capable of supporting vegetative growth
Peat	- mixture of visible and invisible fragments of decayed organic matter
Till	- unstratified glacial deposit which may range from clay to boulders
Fill	- material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

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

Terminology describing soil types:
The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4th Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):
Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

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

Terminology describing compactness of cohesionless soils:
The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. A relationship between compactness condition and N-Value is shown in the following table.

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

Terminology describing consistency of cohesive soils:
The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	Undrained Shear Strength		Approximate SPT N-Value
	kips/sq.ft.	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25 - 0.5	12.5 - 25	2-4
Firm	0.5 - 1.0	25 - 50	4-8
Stiff	1.0 - 2.0	50 – 100	8-15
Very Stiff	2.0 - 4.0	100 - 200	15-30
Hard	>4.0	>200	>30

ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Terminology describing rock quality:

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

Alternate (Colloquial) Rock Mass Quality	
Very Severely Fractured	*Crushed*
Severely Fractured	*Shattered or Very Blocky*
Fractured	*Blocky*
Moderately Jointed	*Sound*
Intact	*Very Sound*

RQD (Rock Quality Designation) denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 in.) long are summed and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

SCR (Solid Core Recovery) denotes the percentage of solid core (cylindrical) retrieved from a borehole of any orientation. All pieces of solid (cylindrical) core are summed and divided by the total length of the core run (It excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

Fracture Index (FI) is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

Terminology describing rock with respect to discontinuity and bedding spacing:

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

Terminology describing rock strength:

Strength Classification	Grade	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	<1
Very Weak	R1	1 – 5
Weak	R2	5 – 25
Medium Strong	R3	25 – 50
Strong	R4	50 – 100
Very Strong	R5	100 – 250
Extremely Strong	R6	>250

Terminology describing rock weathering:

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

STRATA PLOT

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

Boulders Cobbles Gravel	Sand	Silt	Clay	Organics	Asphalt	Concrete	Fill	Igneous Bedrock	Meta-morphic Bedrock	Sedi-mentary Bedrock

SAMPLE TYPE

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

WATER LEVEL MEASUREMENT

▼ measured in standpipe, piezometer, or well

▽ inferred

RECOVERY

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

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to 'A' size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

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

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

Stantec

BOREHOLE RECORD

N: 6 935 278 E: 509 983

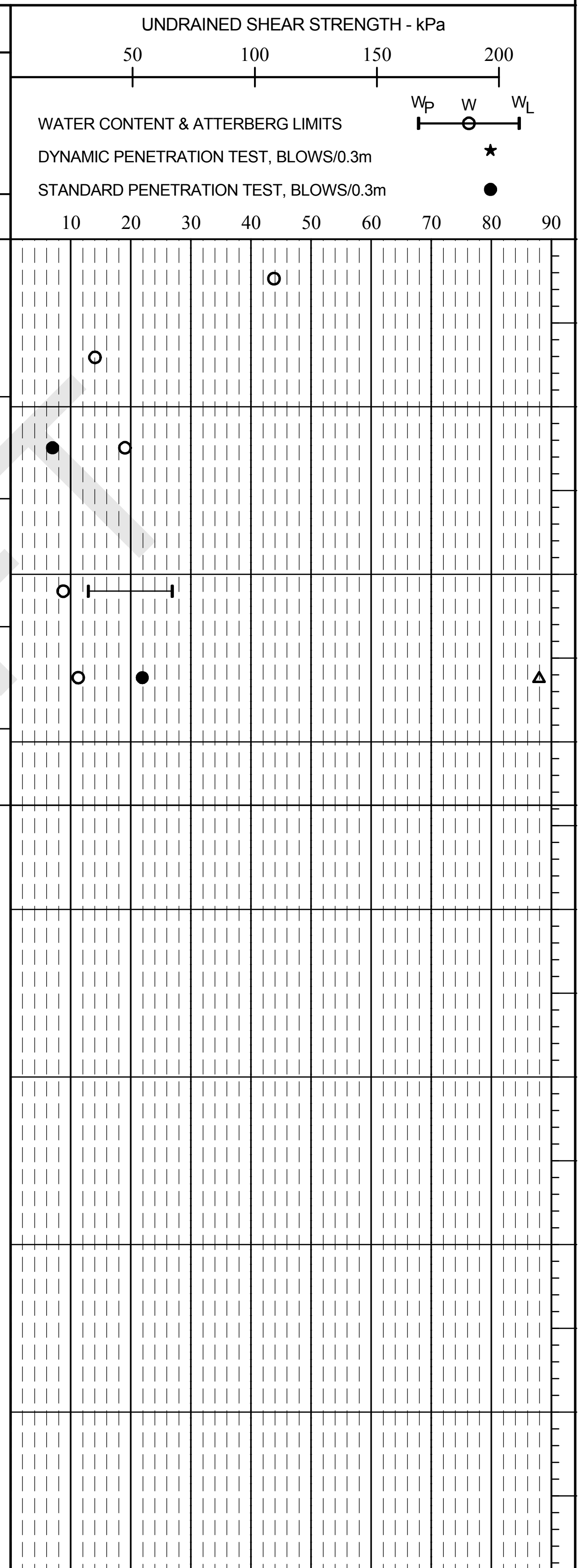
BH17-16C

CLIENT: Tlicho Engineering and Environmental Services Ltd. — BOREHOLE No.: BH17-16C

LOCATION: Northwest Territories, Canada — PROJECT No.: 144902448

DATES: BORING February 24, 2017 — WATER LEVEL N/A — DATUM: Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
0	271.91	460 mm frozen PEAT						
	271.5	- Approx. sample temperature: AS1: -3.1 to -2.4 °C - Frozen soil description: Vc			AS	1	-	-
1		Dark grey to grey, frozen, silty SAND (SM), with pockets of organic material			SS	2	33%	7
2	269.9	- Approx. sample temperature: AS1: -1.9 to -1.2 °C at 0.5 m SS2: -2.1 to 0.2 °C - Unfrozen below 1.2 m depth			AS	3	-	-
		Hard, grey, sandy lean CLAY (CL)			SS	4	20%	22
3	268.5	- Laminations of silty sand - Moist - Inferred cobbles and boulders - Approx. sample temperature: AS3: 0.6 to 1.3°C SS4: 3.7 to 2.8°C			AS	5	-	-
		End of Borehole - Auger refusal at 3.4 m depth - Auger refusal encountered at 2.3 m depth, 3.0 m northwest of borehole - Auger refusal encountered at 3.4 m depth, 1.2 m m west of borehole -Thermistor Installed						
4								
5								
6								
7								
8								



DRAFT

Inferred Groundwater Level

Groundwater Level Measured in Standpipe

Field Vane Test, kPa

Remoulded Vane Test, kPa

Pocket Penetrometer Test, kPa

App'd ________

Date ________

STN13-STAN-GEO 144902448 TLICHO ALL SEASON ROAD INVESTIGATION.GPJ SMART.GDT 5/17/17

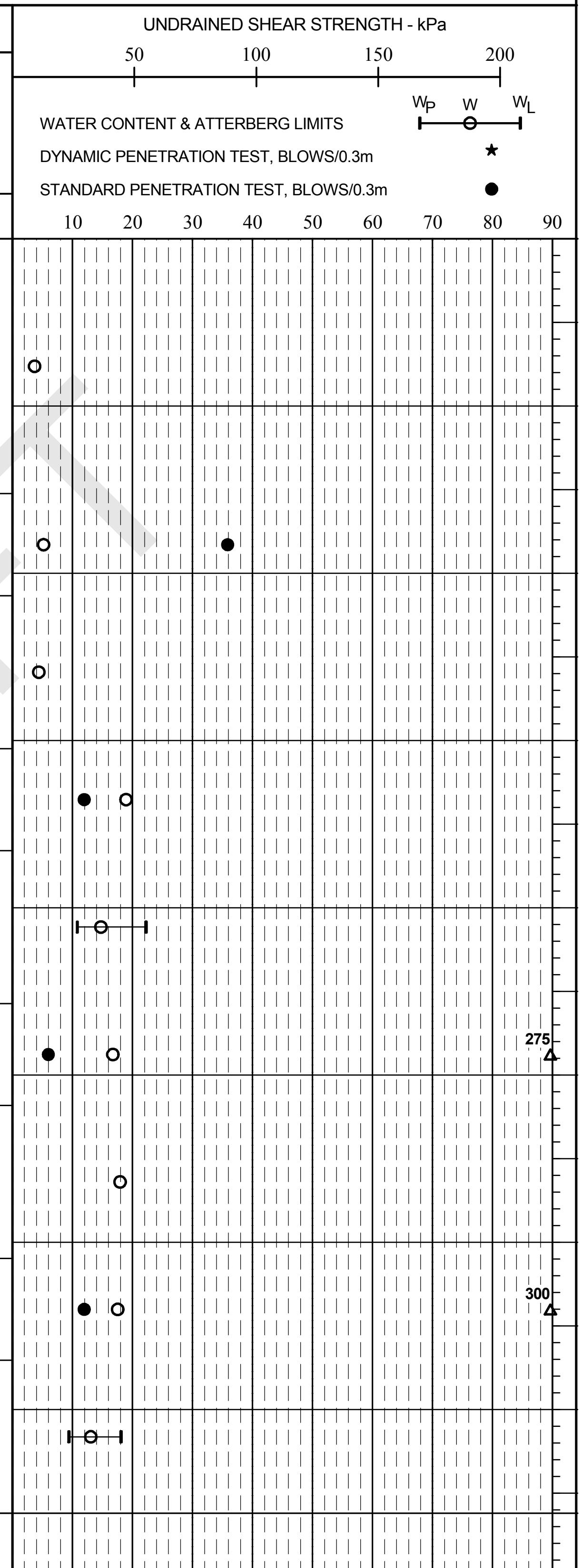
BOREHOLE RECORD

N: 6 935 340 E: 509 951

BH17-17

CLIENT: Tlicho Engineering and Environmental Services Ltd.	BOREHOLE No.: BH17-17
LOCATION: Northwest Territories, Canada	PROJECT No.: 144902448
DATES: BORING February 17, 2017 WATER LEVEL N/A	DATUM: Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	273.76	Brown, frozen, poorly graded SAND (SP) to poorly graded SAND with silt (SP-SM) -Some cobbles - Approx. sample temp: AS1: -3.5 to -4.0 °C SS2: -3.5 to -3.8 °C AS3: -4 to -4.8 °C SS4: -3.9 °C - Frozen soil description: Nf				
			AS	1	-	-
			SS	2	500	36
			AS	3	-	-
			SS	4	490	12
	270.1	Brown to grey, frozen, sandy lean CLAY (CL), trace gravel - Approx. sample temperature: AS5: -4.3 to -4.8 °C AS7: 2.6°C SS8: -1.8°C AS9: -4.5°C - Frozen soil description: Nf				
			AS	5	-	-
			SS	6	560	6
			AS	7	-	-
			SS	8	350	12
			AS	9		-
	266.1	End of Borehole				



DRAFT

∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ________
Date ________

APPENDIX D

Laboratory Test Results

Stantec

Grain Size Analysis
ASTM C136, ASTM C117

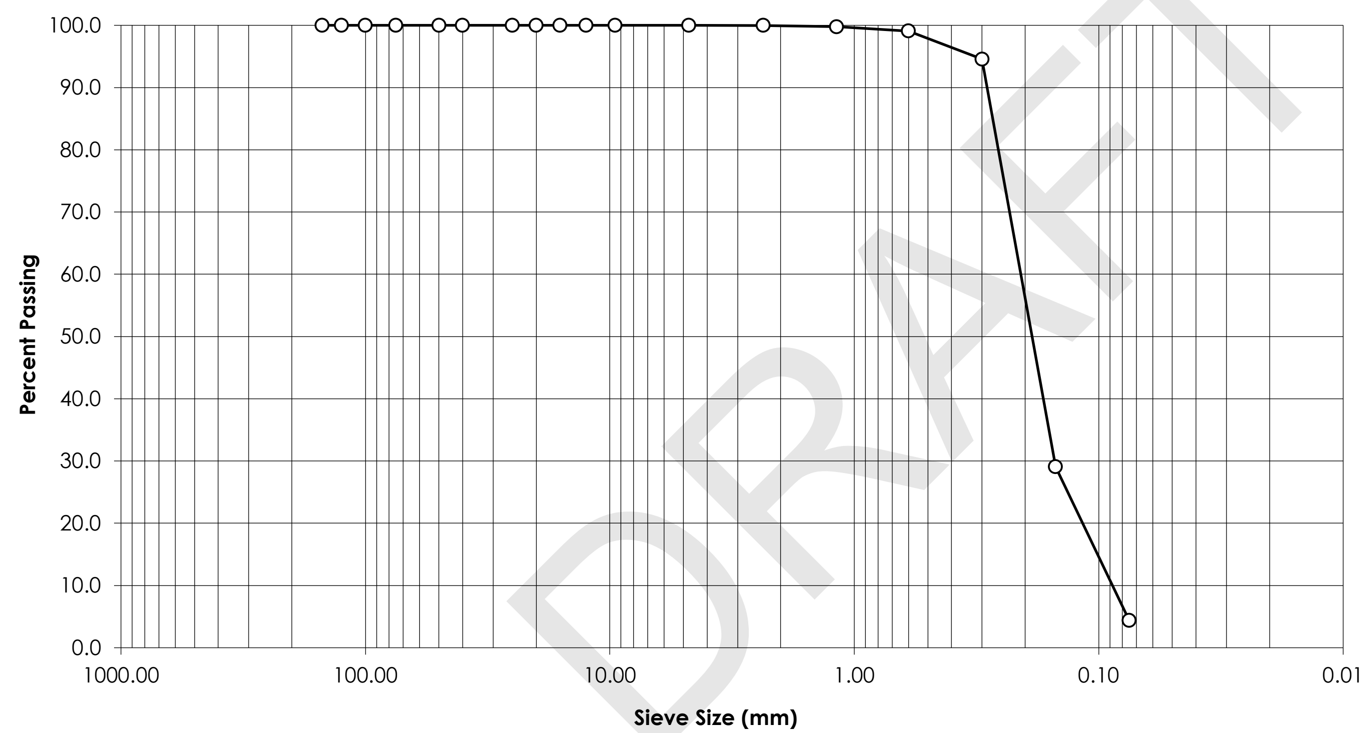
Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho All Season Road
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: AS1
SOURCE: BH17-17
TESTED BY: JA

DATE RECEIVED: February 27, 2017
DATE TESTED: March 15, 2017
SAMPLE DESCRIPTION: Poorly graded sand



Sieve (mm)	Sample % Passing	Specifications Lower	Specifications Upper
150.0	100.0	-	-
125.0	100.0	-	-
100.0	100.0	-	-
75.0	100.0	-	-
50.0	100.0	-	-
40.0	100.0	-	-
25.0	100.0	-	-
20.0	100.0	-	-
16.0	100.0	-	-
12.5	100.0	-	-
9.5	100.0	-	-
4.75	100.0	-	-
2.36	100.0	-	-
1.18	99.8	-	-
0.600	99.1	-	-
0.300	94.6	-	-
0.150	29.1	-	-
0.075	4.4	-	-

Cobble:	0.0%	D_{10}:	0.1078
Gravel:	0.0%	D_{30}:	0.1541
Sand:	95.6%	D_{60}:	0.2422
Fines:	4.4%	C_u:	2.25
		C_c:	0.91

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Comments:

Figure No. 1

Reviewed by:

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LABORATORY
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Edmonton, Alberta
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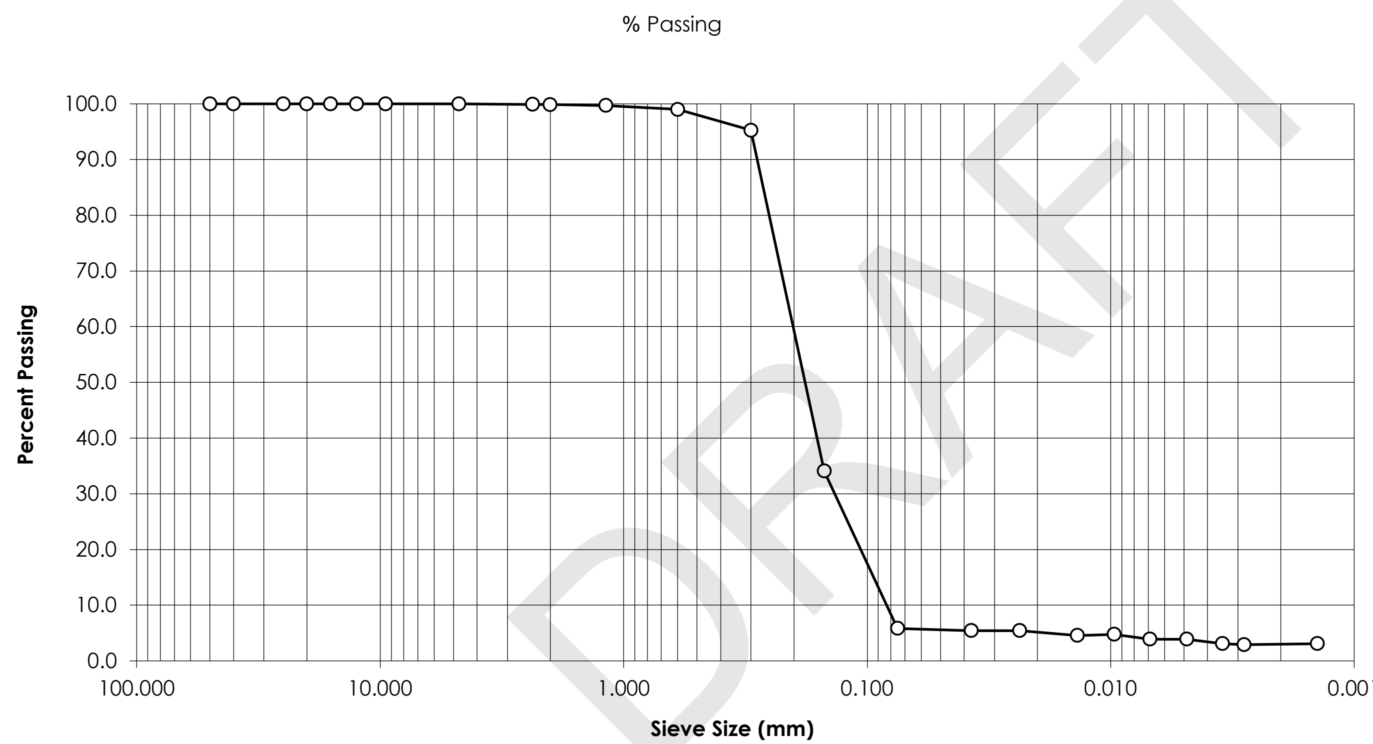
Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho All Season Road
Project No: 144902448

SAMPLE No.: AS1
SOURCE: BH17-17
TESTED BY: JA

DATE TESTED: March 22, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Poorly graded sand with silt



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0069	3.9
40.0	100.0	0.0049	3.9
25.0	100.0	0.0035	3.1
20.0	100.0	0.0028	2.9
16.0	100.0	0.0014	3.1
12.5	100.0		
9.5	100.0		
4.75	100.0		
2.36	99.9		
2.00	99.9		
1.18	99.7		
0.600	99.0		
0.300	95.3		
0.150	34.1		
0.075	5.8		
0.0374	5.4		
0.0236	5.4		
0.0137	4.6		
0.0097	4.7		

Gravel:	0.0%	D_{10}:	0.0980
Sand:	94.2%	D_{30}:	0.1446
Silt:	2.8%	D_{60}:	0.2326
Clay:	3.0%	C_u:	2.37
		C_c:	0.92

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Comments:

Figure No. 2

Reviewed by:

Reporting of these test results constitutes a testing service only. Engineering interpretation or evaluation of the test results is provided only on written request. The data presented above is for the sole use of the client stipulated above. Stantec is not responsible, nor can be held liable, for the use of this report by any other party, with or without the knowledge of Stantec.

Grain Size Analysis

ASTM C136, ASTM C117

Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho All Season Road
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
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LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: SS2
SOURCE: BH17-17
TESTED BY: JA

DATE RECEIVED: February 27, 2017
DATE TESTED: March 15, 2017
SAMPLE DESCRIPTION: Poorly graded sand with silt

Sieve (mm)	Sample % Passing	Specifications Lower	Specifications Upper
150.0	100.0	-	-
125.0	100.0	-	-
100.0	100.0	-	-
75.0	100.0	-	-
50.0	100.0	-	-
40.0	100.0	-	-
25.0	100.0	-	-
20.0	100.0	-	-
16.0	100.0	-	-
12.5	100.0	-	-
9.5	100.0	-	-
4.75	100.0	-	-
2.36	99.9	-	-
1.18	99.8	-	-
0.600	99.4	-	-
0.300	98.3	-	-
0.150	46.7	-	-
0.075	6.1	-	-

Cobble:	0.0%	D_{10}:	0.0930
Gravel:	0.0%	D_{30}:	0.1336
Sand:	93.8%	D_{60}:	0.2005
Fines:	6.2%	C_u:	2.15
		C_c:	0.96

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Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Comments:

Figure No. 3

Reviewed by:

Stantec

Grain Size Analysis

ASTM C136, ASTM C117

Client: Tlicho Engineering & Environmental Services Lt
Project Name: Tlicho All Season Road
Project No: 144902448

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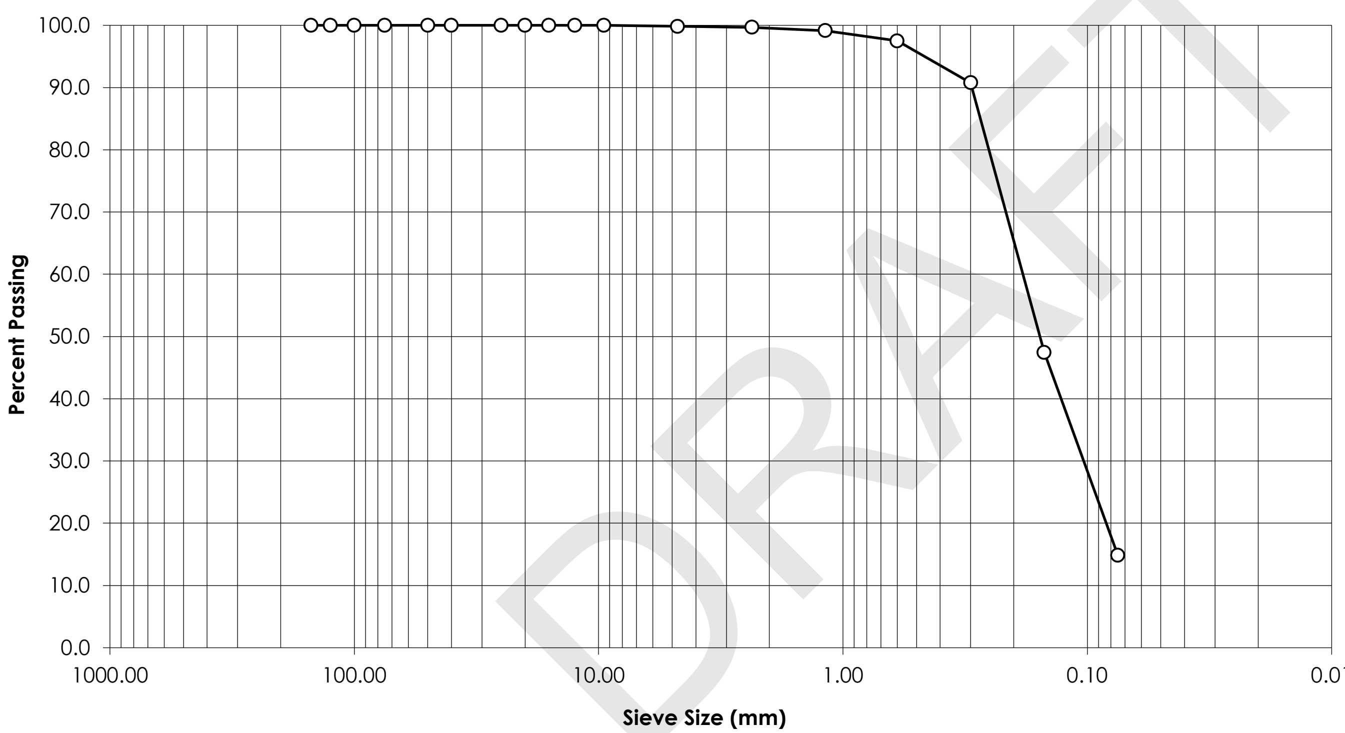
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: AS1B
SOURCE: BH 17-16C
TESTED BY: NN

DATE RECEIVED: March 27, 2017
DATE TESTED: April 14, 2017
SAMPLE DESCRIPTION: Silty sand



Sieve (mm)	Sample % Passing	Specifications Lower	Specifications Upper
150.0	100.0	-	-
125.0	100.0	-	-
100.0	100.0	-	-
75.0	100.0	-	-
50.0	100.0	-	-
40.0	100.0	-	-
25.0	100.0	-	-
20.0	100.0	-	-
16.0	100.0	-	-
12.5	100.0	-	-
9.5	100.0	-	-
4.75	99.8	-	-
2.36	99.7	-	-
1.18	99.1	-	-
0.600	97.5	-	-
0.300	90.8	-	-
0.150	47.4	-	-
0.075	14.9	-	-

Cobble:	0.0%	D_{10}:	-
Gravel:	0.2%	D_{30}:	0.1204
Sand:	85.0%	D_{60}:	0.2043
Fines:	14.8%	C_u:	-
		C_c:	-

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Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Comments:

Figure No. 4

Reviewed by:

Stantec

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho All Season Road
Project No: 144902448

OFFICE
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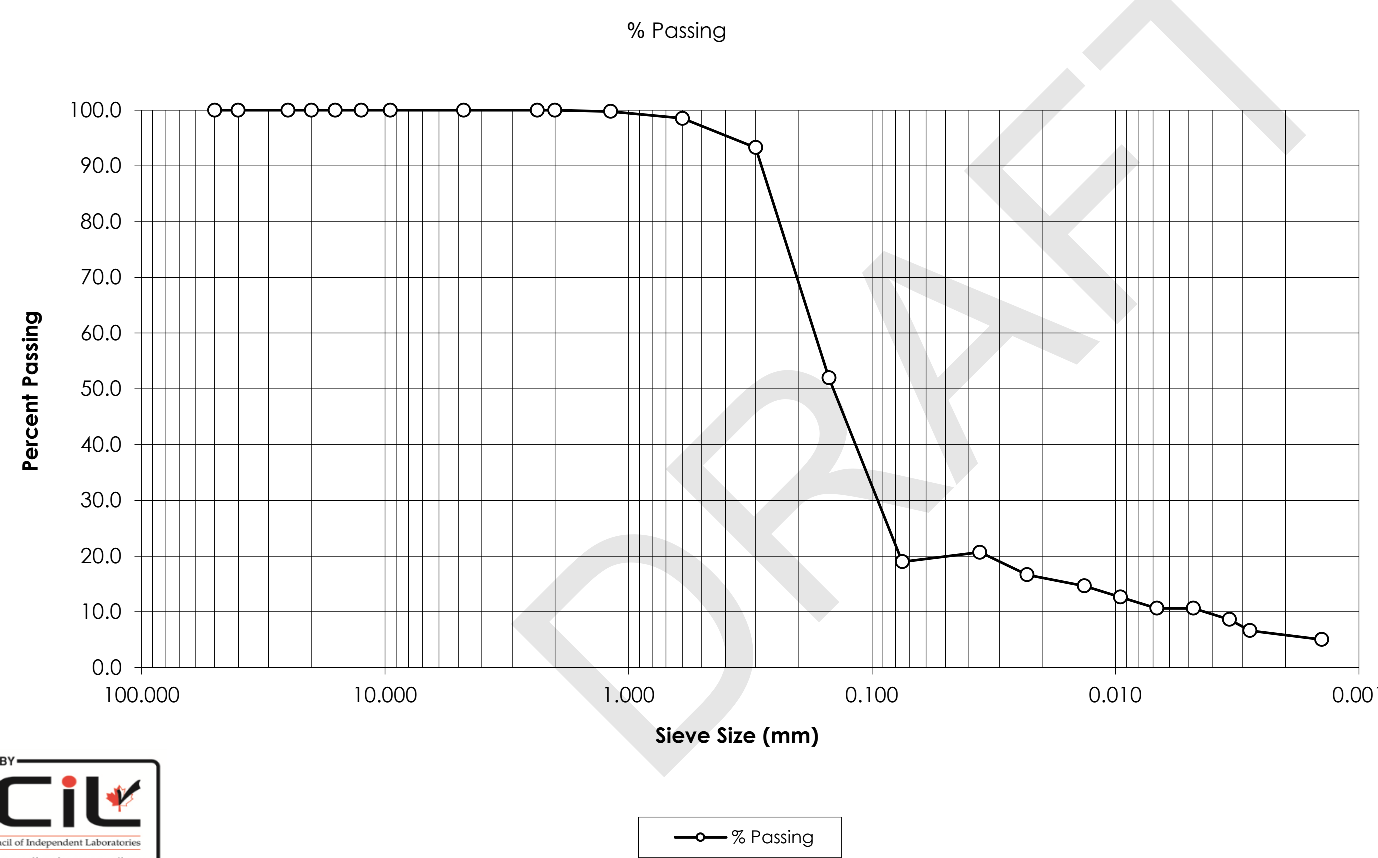
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: AS1B
SOURCE: BH17-16C
TESTED BY: JA

DATE TESTED: April 17, 2017
DATE RECEIVED: March 27, 2017
SAMPLE DESCRIPTION: Silty sand



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	**100.0**	**0.0068**	**10.6**
40.0	**100.0**	**0.0048**	**10.6**
25.0	**100.0**	**0.0034**	**8.6**
20.0	**100.0**	**0.0028**	**6.6**
16.0	**100.0**	**0.0014**	**5.0**
12.5	**100.0**		
9.5	**100.0**		
4.75	**100.0**		
2.36	**100.0**		
2.00	**100.0**		
1.18	**99.8**		
0.600	**98.5**		
0.300	**93.3**		
0.150	**52.0**		
0.075	**19.0**		
0.0360	**20.7**		
0.0230	**16.7**		
0.0134	**14.7**		
0.0095	**12.6**		
Gravel:	0.0%	D_{10}:	0.0044
Sand:	81.0%	D_{30}:	0.1091
Silt:	13.1%	D_{60}:	0.1869
Clay:	5.9%	C_u:	42.74
		C_c:	14.57

Comments:

Figure No. 5

Reviewed by:

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Stantec

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

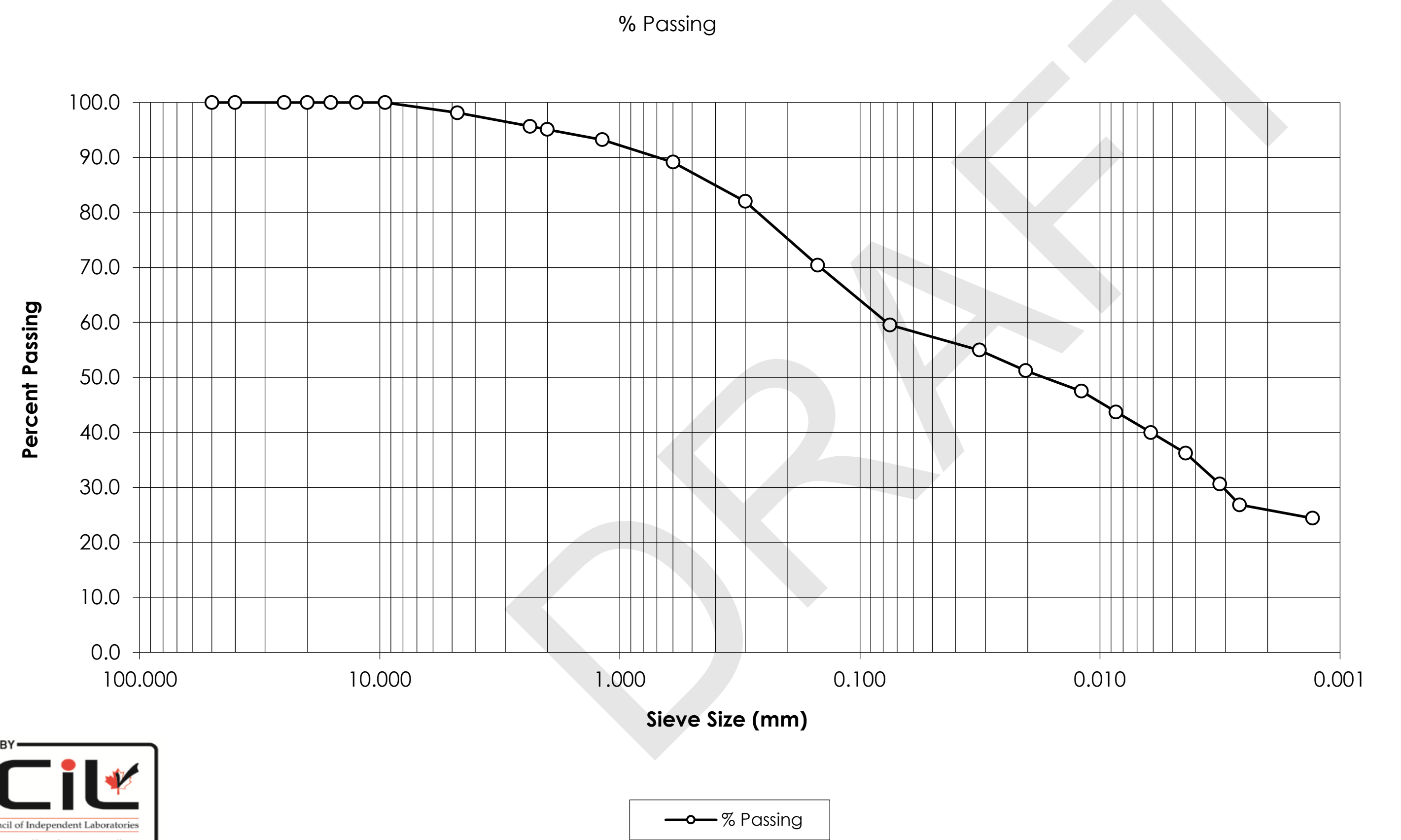
Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho All Season Road
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: AS3
SOURCE: BH17-16C
TESTED BY: JA

DATE TESTED: April 20, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy lean clay



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0061	40.0
40.0	100.0	0.0044	36.2
25.0	100.0	0.0032	30.6
20.0	100.0	0.0026	26.8
16.0	100.0	0.0013	24.4
12.5	100.0		
9.5	100.0		
4.75	98.1		
2.36	95.7		
2.00	95.1		
1.18	93.2		
0.600	89.1		
0.300	82.0		
0.150	70.4		
0.075	59.5		
0.0318	55.0		
0.0204	51.2		
0.0119	47.5		
0.0086	43.7		

Gravel:	1.9%	D_{10}:	-
Sand:	38.6%	D_{30}:	0.0031
Silt:	33.6%	D_{60}:	0.0785
Clay:	25.9%	C_u:	-
		C_c:	-

Comments:

Figure No. 6

Reviewed by:

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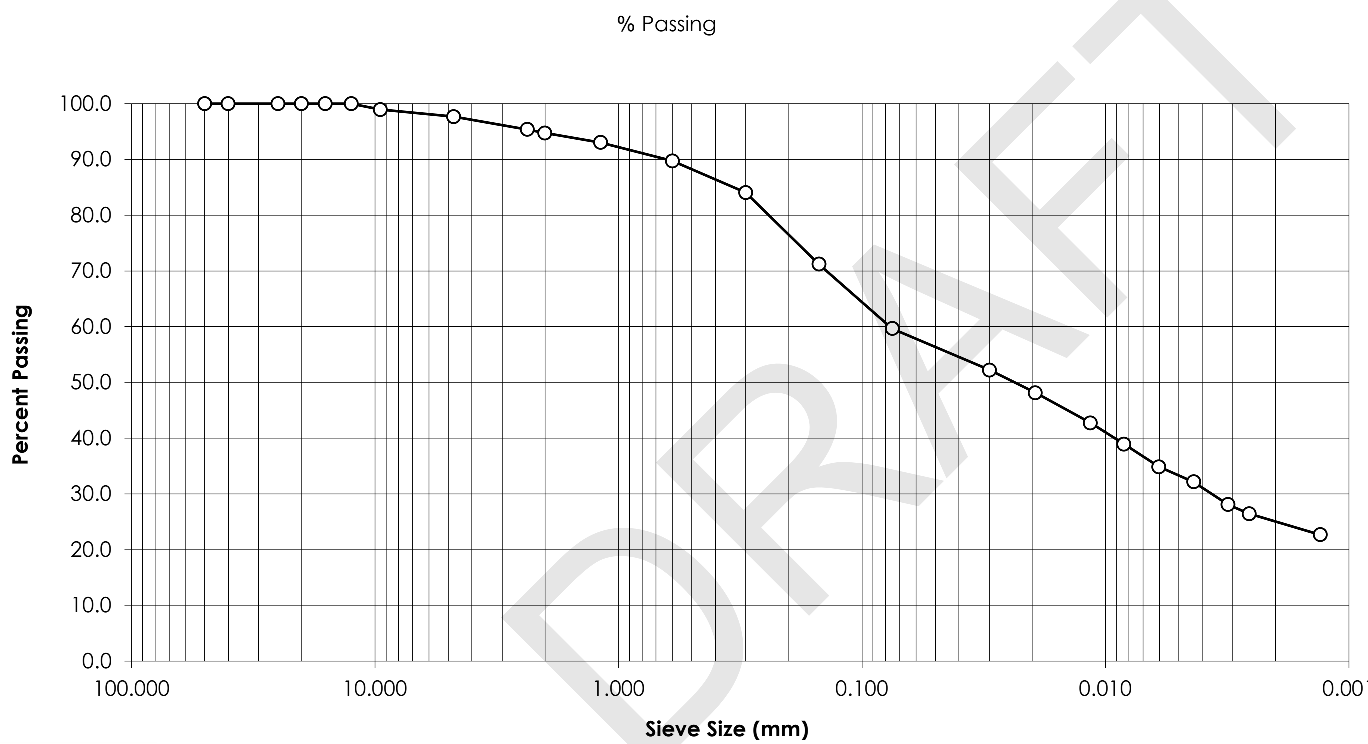
Stantec

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho All Season Road
Project No: 144902448

SAMPLE No.: AS5
SOURCE: BH17-17
TESTED BY: JA

DATE TESTED: March 22, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy lean clay



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	**100.0**	**0.0060**	**34.8**
40.0	**100.0**	**0.0043**	**32.1**
25.0	**100.0**	**0.0031**	**28.1**
20.0	**100.0**	**0.0026**	**26.4**
16.0	**100.0**	**0.0013**	**22.6**
12.5	**100.0**		
9.5	**98.9**		
4.75	**97.7**		
2.36	**95.3**		
2.00	**94.7**		
1.18	**93.0**		
0.600	**89.7**		
0.300	**84.0**		
0.150	**71.2**		
0.075	**59.6**		
0.0299	**52.2**		
0.0194	**48.1**		
0.0115	**42.7**		
0.0084	**38.9**		

Gravel:	2.3%	D_{10}:	-
Sand:	38.0%	D_{30}:	0.0037
Silt:	34.6%	D_{60}:	0.0776
Clay:	25.1%	C_u:	-
		C_c:	-

CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Comments:

Figure No. 7

Reviewed by:

Stantec

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho All Season Road
Project No: 144902448

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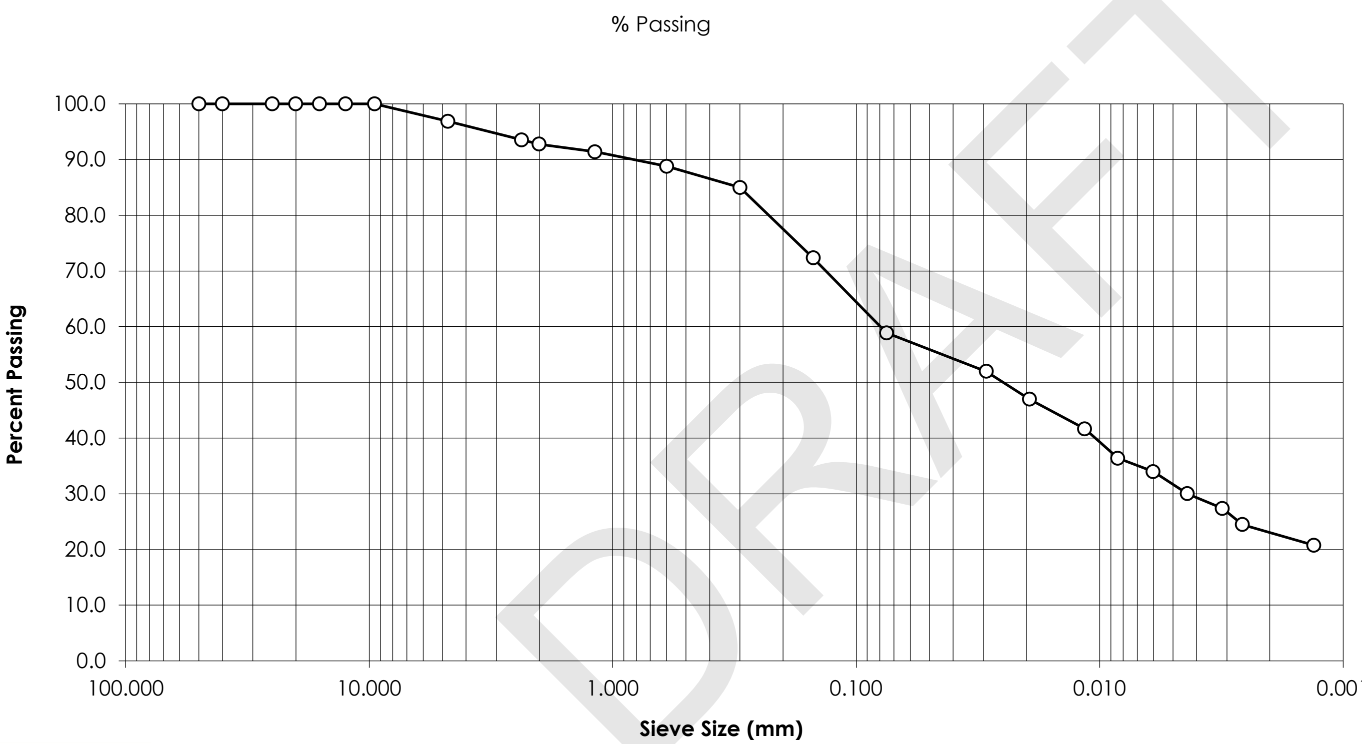
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: AS9
SOURCE: BH17-17
TESTED BY: JA

DATE TESTED: March 22, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy lean clay



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0060	34.0
40.0	100.0	0.0044	30.0
25.0	100.0	0.0031	27.4
20.0	100.0	0.0026	24.5
16.0	100.0	0.0013	20.8
12.5	100.0		
9.5	100.0		
4.75	96.9		
2.36	93.5		
2.00	92.7		
1.18	91.4		
0.600	88.8		
0.300	85.0		
0.150	72.3		
0.075	58.9		
0.0292	52.0		
0.0194	46.9		
0.0115	41.7		
0.0084	36.4		

Gravel:	3.1%	D_{10}:	-
Sand:	38.0%	D_{30}:	0.0044
Silt:	35.8%	D_{60}:	0.0819
Clay:	23.1%	C_u:	-
		C_c:	-

CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Comments:

Figure No. 8

Reviewed by:

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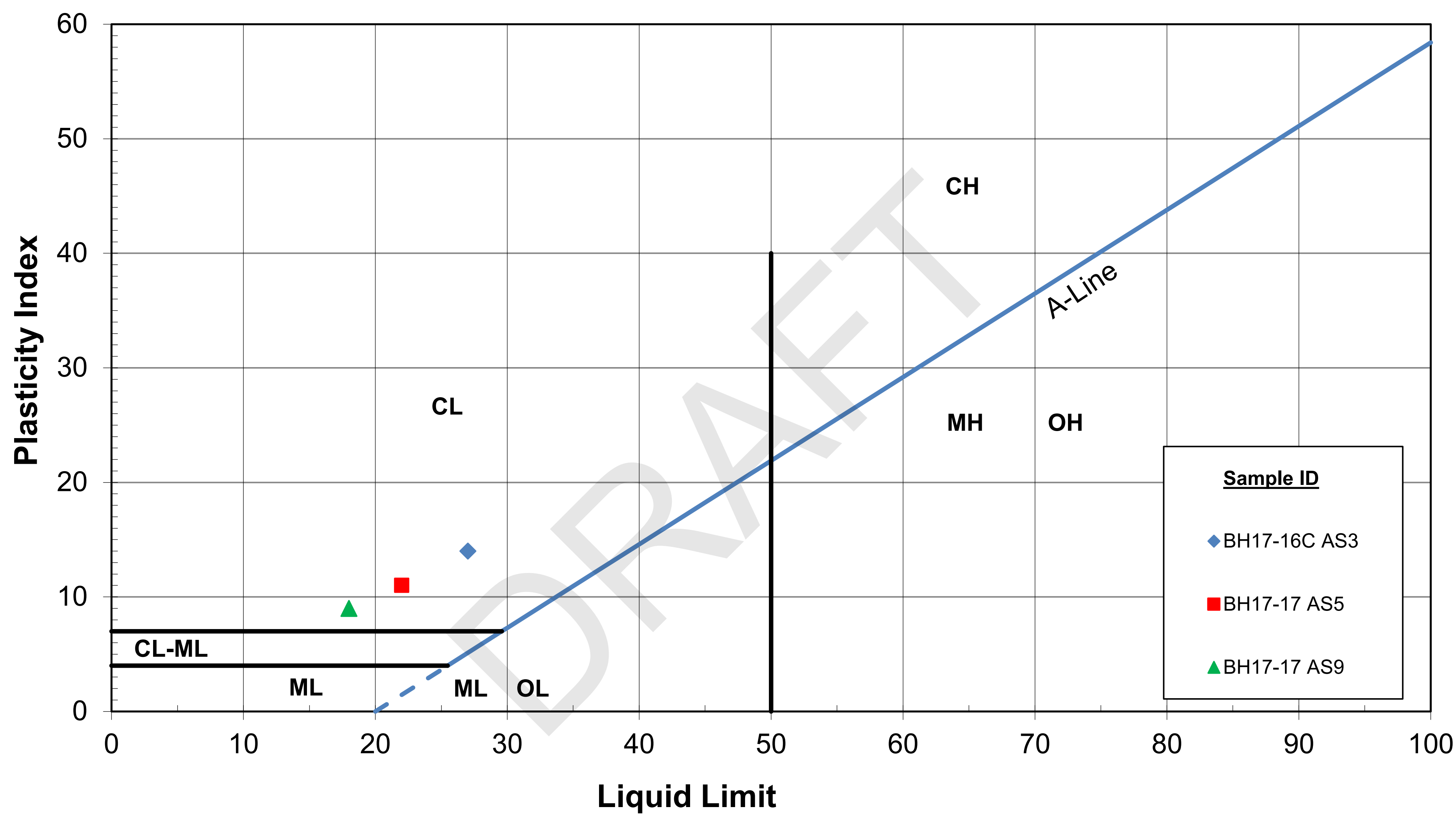

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Tlicho Engineering & Environmental Services

Tlicho All Season Road

PLASTICITY CHART

Figure No. 9

Project No. 144902448

Maxxam
A Bureau Veritas Group Company

Success Through Science®

Your Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Your C.O.C. #: A174619

Attention:RYLEY PROZNIK

STANTEC CONSULTING LTD
10160-112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2017/04/20
Report #: R2371968
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B728026
Received: 2017/04/17, 14:30

Sample Matrix: Soil
Samples Received: 12

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Chloride (Soluble)	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00020	SM 22 4500-Cl G m
Resistivity	9	N/A	2017/04/18	AB WI-00065	Auto Calc
Conductivity @25C (Soluble)	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00004	SM 22 2510 B m
Total Organic Carbon by Combustion-Sub (1)	3	2017/04/20	2017/04/20		
pH @25C (Soluble)	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00006	SM 22 4500 H+B m
Soluble Ions	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00042	EPA 200.7 CFR 2012 m
Soluble Paste	9	2017/04/18	2017/04/18	AB SOP-00033	Carter 2nd ed 15.2m
Soluble Ions Calculation	9	N/A	2017/04/18	AB WI-00065	Auto Calc

DRAFT

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
(1) This test was performed by Maxxam Ontario (From Edmonton)

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Success Through Science®

Your Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Your C.O.C. #: A174619

Attention:RYLEY PROZNIK

STANTEC CONSULTING LTD
10160-112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2017/04/20
Report #: R2371968
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B728026
Received: 2017/04/17, 14:30

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Wendy Sears, Project manager
Email: WSears@maxxam.ca
Phone# (403)735-2277
==
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Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		QW8655	QW8656		QW8657		QW8658		
Sampling Date		2017/02/24	2017/03/12		2017/03/24		2017/03/22		
COC Number		A174619	A174619		A174619		A174619		
	UNITS	**BH17-16C AS1-A**	**BH17-33B 10'-11.5'**	**RDL**	**BH17-74B AS1**	**RDL**	**BH17-60B AS4**	**RDL**	**QC Batch**
CONVENTIONALS									
Total Organic Carbon (C)	mg/kg	ATTACHED	N/A	500	N/A	500	N/A	500	8608469
Calculated Parameters									
Resistivity @ 25 °C	ohm-m	N/A	3.9	0.050	24	0.050	7.9	0.050	8605241
Calculated Chloride (Cl)	%	N/A	0.018	0.00044	0.0027	0.0010	0.0030	0.00026	8604932
Calculated Sulphate (SO4)	%	N/A	0.16	0.00044	0.0049	0.0010	0.036	0.00026	8604932
Soluble Parameters									
Soluble Chloride (Cl)	mg/L	N/A	210	5.0	13	5.0	57	5.0	8605786
Soluble Conductivity	dS/m	N/A	2.5	0.020	0.41	0.020	1.3	0.020	8605626
Soluble pH	pH	N/A	7.57	N/A	7.28	N/A	7.47	N/A	8605629
Saturation %	%	N/A	88	N/A	210	N/A	52	N/A	8605356
Soluble Sulphate (SO4)	mg/L	N/A	1900	5.0	24	5.0	700	5.0	8605816

RDL = Reportable Detection Limit
N/A = Not Applicable

Maxxam ID		QW8659		QW8660		QW8661	QW8661		
Sampling Date		2017/03/20		2017/03/09		2017/03/21	2017/03/21		
COC Number		A174619		A174619		A174619	A174619		
	UNITS	**BH17-57B 40'-42'**	**RDL**	**BH17-31B 5'-6.5'**	**RDL**	**BH17-59B AS2**	**BH17-59B AS2 Lab-Dup**	**RDL**	**QC Batch**
Calculated Parameters									
Resistivity @ 25 °C	ohm-m	3.5	0.050	4.4	0.050	12	N/A	0.050	8605241
Calculated Chloride (Cl)	%	0.0011	0.00033	0.0015	0.00045	0.0031	N/A	0.00027	8604932
Calculated Sulphate (SO4)	%	0.13	0.00033	0.13	0.00045	0.023	N/A	0.00027	8604932
Soluble Parameters									
Soluble Chloride (Cl)	mg/L	17	5.0	17	5.0	57	52	5.0	8605786
Soluble Conductivity	dS/m	2.9	0.020	2.3	0.020	0.83	0.91	0.020	8605626
Soluble pH	pH	7.95	N/A	7.56	N/A	7.51	7.52	N/A	8605629
Saturation %	%	65	N/A	91	N/A	55	54	N/A	8605356
Soluble Sulphate (SO4)	mg/L	2000	5.0	1400	5.0	430	N/A	5.0	8605816

RDL = Reportable Detection Limit
Lab-Dup = Laboratory Initiated Duplicate
N/A = Not Applicable

Maxxam

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Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		QW8662		QW8663		QW8664	QW8665		
Sampling Date		2017/03/05		2017/03/17		2017/02/24	2017/02/27		
COC Number		A174619		A174619		A174619	A174619		
	UNITS	**BH17-32B AS3**	**RDL**	**BH17-38B AS1**	**RDL**	**BH17-16C AS3**	**BH17-25 GS1**	**RDL**	**QC Batch**
CONVENTIONALS									
Total Organic Carbon (C)	mg/kg	N/A	500	N/A	500	N/A	ATTACHED	500	8608469
Calculated Parameters									
Resistivity @ 25 °C	ohm-m	3.9	0.050	16	0.050	28	N/A	0.050	8605241
Calculated Chloride (Cl)	%	0.012	0.00032	0.00080	0.00034	<0.00023	N/A	0.00023	8604932
Calculated Sulphate (SO4)	%	0.11	0.00032	0.0027	0.00034	0.0028	N/A	0.00023	8604932
Soluble Parameters									
Soluble Chloride (Cl)	mg/L	190	5.0	12	5.0	<5.0	N/A	5.0	8605786
Soluble Conductivity	dS/m	2.5	0.020	0.62	0.020	0.35	N/A	0.020	8605626
Soluble pH	pH	7.81	N/A	7.70	N/A	7.93	N/A	N/A	8605629
Saturation %	%	65	N/A	68	N/A	46	N/A	N/A	8605356
Soluble Sulphate (SO4)	mg/L	1800	5.0	39	5.0	61	N/A	5.0	8605816

RDL = Reportable Detection Limit
N/A = Not Applicable

Maxxam ID		QW8666		
Sampling Date		2017/02/17		
COC Number		A174619		
	UNITS	**BH17-12 AS1**	**RDL**	**QC Batch**
CONVENTIONALS				
Total Organic Carbon (C)	mg/kg	ATTACHED	500	8608469

RDL = Reportable Detection Limit

Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	18.3°C

TOC by Combustion results are attached to this report file. The reference number from Maxxam Campobello for these results is B777170

Results relate only to the items tested.

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Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

QUALITY ASSURANCE REPORT

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
8605356	LX	QC Standard	Saturation %	2017/04/18		101	%	89 - 111
8605356	LX	RPD	Saturation %	2017/04/18	0.93		%	12
8605356	LX	RPD [QW8661-01]	Saturation %	2017/04/18	0.65		%	12
8605626	ACZ	QC Standard	Soluble Conductivity	2017/04/18		93	%	75 - 125
8605626	ACZ	Spiked Blank	Soluble Conductivity	2017/04/18		99	%	90 - 110
8605626	ACZ	Method Blank	Soluble Conductivity	2017/04/18	<0.020		dS/m	
8605626	ACZ	RPD [QW8661-01]	Soluble Conductivity	2017/04/18	9.0		%	20
8605629	BJO	QC Standard	Soluble pH	2017/04/18		99	%	97 - 103
8605629	BJO	Spiked Blank	Soluble pH	2017/04/18		100	%	97 - 103
8605629	BJO	RPD [QW8661-01]	Soluble pH	2017/04/18	0.13		%	N/A
8605786	CH7	Matrix Spike [QW8661-01]	Soluble Chloride (Cl)	2017/04/18		107	%	75 - 125
8605786	CH7	QC Standard	Soluble Chloride (Cl)	2017/04/18		100	%	75 - 125
8605786	CH7	Spiked Blank	Soluble Chloride (Cl)	2017/04/18		106	%	80 - 120
8605786	CH7	Method Blank	Soluble Chloride (Cl)	2017/04/18	<5.0		mg/L	
8605786	CH7	RPD [QW8661-01]	Soluble Chloride (Cl)	2017/04/18	7.9		%	30
8605816	CJ5	QC Standard	Soluble Sulphate (SO4)	2017/04/18		89	%	75 - 125
8605816	CJ5	Method Blank	Soluble Sulphate (SO4)	2017/04/18	<5.0		mg/L	

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

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Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Micheline Piche, Project Manager

Suwan Fock, B.Sc., QP, Inorganics Senior Analyst

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Chain of Custody A174619

Page: ____ of ____

475

	Invoice To: C/O Report Address ☐	Report To: Same as Invoice ☑	Report Distribution (E-Mail):
Company:	STANTEC CONSULTING LTD.		RYLEY.PROZNIK@STANTEC.COM
Contact:	RYLEY PROZNIK		
Address:	Prov: AB PC: 1233	Prov: PC:	
Contact #s:	Ph: 780-239-1498 Cell:	Ph: Cell:	

REGULATORY GUIDELINES:
- ☐ AT1
- ☐ CCME
- ☐ Regulated Drinking Water
- ☐ Other:

All samples are held for 60 calendar days after sample receipt, unless specified otherwise.

PO #:	1449 02448
Project # / Name:	144902448 / TLICHO ALL SEASON ROAD
Site Location:	NORTHWEST TERRITORIES
Quote #:	
Sampled By:	JM / KP

SERVICE REQUESTED: ☐ RUSH (Contact lab to reserve) Date Required: ☐ REGULAR (5 to 7 Days)

See reverse for package specifics

#	Sample ID	Depth (unit)	Matrix GW / SW Soil	Date/Time Sampled YY/MM/DD 24:00	SOIL: BTEX F1-F4	Sieve (75 micron)	Regulated Metals (CCME / AT1)	Salinity 4	Assessment ICP Metals	Basic Class II Landfill	Resistivity	pH	Sulphates & Chlorides	WATER: ☐VOCs / ☐BTEX F1	☐BTEX F1-F4 / ☐BTEX F1-F2	Routine Water ☐ Turb ☐ F	☐ TOC / ☐ DOC	Regulated Metals (CCME / AT1) Total	Dissolved	Mercury ☐ Total ☐ Dissolved	Other Analysis: ORGANIC CONTENT	HOLD - Do not Analyze	# of Containers Submitted
1	BH17-16C AS1-A										~~✓~~	~~✓~~	~~✓~~								✓		
2	BH17-33B 10'-11.5'										✓	✓	✓										
3	BH17-74B AS1										✓	✓	✓										
4	BH17-60B AS4										✓	✓	✓										
5	BH17-57B 40'-42'										✓	✓	✓										
6	BH17-31B 5'-6.5'										✓	✓	✓										
7	BH17-59B AS2										✓	✓	✓										
8	BH17-32B AS3										✓	✓	✓										
9	BH17-38B AS1										✓	✓	✓										
10	BH17-16C AS3										✓	✓	✓										
11	BH17-25 GS1																				✓		
12	BH17-12 AS1																				✓		

Please indicate Filtered, Preserved or Both (F, P, F/P) F/P

DRAFT

Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):
/Niko Naval	17/04/07	
Relinquished By (Signature/Print): /Ryley Proznik	17/04/17	14:30

Special Instructions:

# of Jars Used & Not Submitted

LAB USE ONLY

Received By:	Date:	Time:	Maxxam Job #:
David Tidman	20170417	1430	B728026 D-T

Lab Comments:

Custody Seal	Temperature	Ice
No	Bags 18, 19, 18	No

APPENDIX E

Thermistor Resistance versus Temperature Table

Thermistor Readings

Resistance versus Temperature Relationship 3000 Ohm NTC Thermistors

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	30	525.4	70	153.2	110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.99K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-35	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	282.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	56.92	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965	53	250.9	93	83.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	3000	25	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

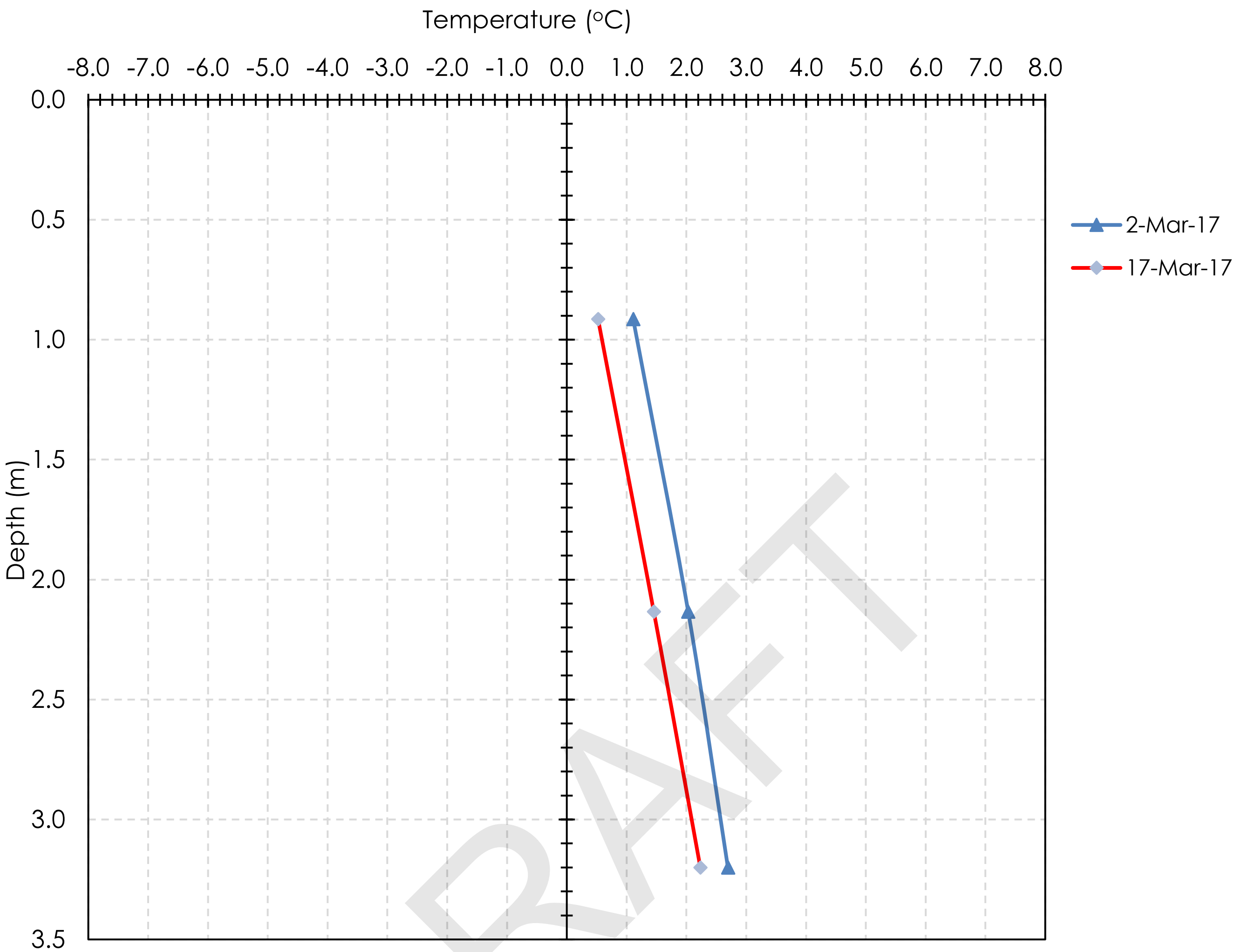
Temperature calculated using:

Steinhart-Hart Linearization

$$T_C = \frac{1}{C_0 + C_1(\ln R) + C_3(\ln R)^3} - 273.15$$

3000 Ohm @ 25C NTC Thermistor

C_0= 0.0014051
C_1= 0.0002369
C_3= 0.0000001019
lnR= Natural Log of Resistance
T_C= Temperature in °C



Borehole	**BH-16C**					
Drilled:	24-Feb-17		Drilled Depth:		3.4	m
Installed:	24-Feb-17					
Reading			**Bead**	TS4339	TS4334	TS4337
Date		**Days**	**Depth (m)**	0.91	2.13	3.20
Post-Install	24-Feb-17	0	R (ohms)	9.78	8.36	5.74
			T (°C)	0.0	3.1	10.8
2	2-Mar-17	6	R (ohms)	9.25	8.83	8.54
			T (°C)	1.1	2.0	2.7
3	17-Mar-17	21	R (ohms)	9.53	9.09	8.74
			T (°C)	0.5	1.5	2.2

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Thermistor Readings
BH17-16C

Figure No. 10

Project No. 144902448

Geotechnical Recommendation Report Proposed Culvert Crossing #6 Stations 19+427 and 19+432

Geotechnical Investigation,
Proposed Tlicho All-Season Road,
Northwest Territories

Prepared for:
Tlicho Engineering &
Environmental Services Ltd.

Prepared by:
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Ottawa, ON K2C 3G4

Project No. 144902448

May 2017

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1.0 PROJECT DESCRIPTION AND BACKGROUND

Project Description

Acting under the authorization of Tlicho Engineering and Environmental Services Ltd. (Tlicho), Stantec Consulting Ltd. (Stantec) carried out a geotechnical investigation in support of the culverts planned at 'Crossing #6' along the proposed Tlicho All Season Access Road (TASR). The purpose of the investigation was to characterize subsurface conditions and provide geotechnical comments and recommendations to assist with culvert design and site development.

The investigation was carried out in general accordance with Stantec's proposal dated January 12, 2017, as part of an overall geotechnical program by Tlicho for the Government of the Northwest Territories (GNWT) along the proposed 94 km TASR alignment extending from the Yellowknife Highway (Highway 3) to the Settlement of Whati on the south shore of Lac La Martre (RFP Event ID: EV000000001132). The scope of work outlined in the GNWT Request for Proposal includes the geotechnical investigation and design of the 94 km long TASR corridor, four bridges and three structural culverts. Tlicho was responsible for management and execution of the overall project and team as the Prime Contractor, with Stantec acting as sub-consultant providing geotechnical engineering and technical services to the project, including:

- Provision of geotechnical field personnel to log subsurface conditions during drilling operations at eighty-one (81) geotechnical boreholes in accordance with the RFP:
  - Thirteen (13) boreholes at the four (4) proposed major bridge crossings:
    - Crossing #8, Station 40+400 - Duport River Crossing
    - Crossing #9, Station 45+175 - (unnamed)
    - Crossing #14, Station 69+666 - James River Crossing
    - Crossing #15, Station 85+397 - La Martre River
  - Three (3) boreholes at the three (3) proposed major bridge culvert crossings:
    - Crossing #5, Station 16+532
    - Crossing #6, Station 19+427
    - Crossing #10a, Station 48+208
  - Sixty-five (65) boreholes to observe the subsurface conditions along the road alignment;
- Installation and reading of thermistors;
- Borehole layout and as-drilled survey;
- Completion of a laboratory testing program on the recovered borehole samples as specified in the RFP; and
- Geotechnical engineering assessment and reporting on the field and laboratory findings in two reports (Geotechnical Data Report and Geotechnical Recommendations Report) for each crossing location and for the overall roadway alignment.
  - These documents should be read in conjunction with the Statement of General Conditions, Appendix A.

This geotechnical recommendation report has been prepared specifically for the proposed culvert Crossing No. 6 on the Tlicho All Season Road at Stations 19+427 and 19+432. This report should be read in conjunction with the Stantec Geotechnical Data Report titled "Geotechnical Data Report Proposed Culvert Crossing #6 Stations 19+427 and 19+432". The Geotechnical Data Report documents the results from the investigation completed for the culvert.

Background - Proposed Structure

Two culverts are proposed at Crossing No. 6 on the Tlicho All Season Road alignment at Stations 19+427 and 19+432. The preliminary structure design consists of two 2430 mm diameter steel plate corrugated steel pipe (SPCSP) culverts.

The Preliminary General Layout drawing for the proposed culverts is presented on Drawing No. 2 in Appendix B. The General Layout drawing is based on the Tlicho All Season Road Predesign Report and was designed by DOT Structures and drawn/drafted by DOT Technical Services. GNWT DOT was responsible for the precise station location and culvert diameter. The proposed culverts will facilitate water flow beneath the Tlicho All Season Road from west to east. The road embankment has proposed side slopes of approximately 2.5H: 1V. The finished road top surface of the highway is approximately 4.5 m to 4.8 m higher than the ground surface on both sides of the road. It is to be noted that the layout is conceptual and the final design details will be determined at a later date.

Key approximate elevations associated with the proposed culvert are as follows:

Finished Road top Elevation:	275.06 m (at Centreline)
Proposed Invert Elevation:	270.45 m inlet
	270.29 m outlet
Proposed Obvert Elevation:	272.88 m inlet
	272.72 m outlet
Design Streambed Elevation:	272.8 m inlet
	272.7 m outlet
Existing Ground Elevation	270.8 m
Design Water Level (obvert of pipe):	272.9 m

2.0 GEOTECHNICAL DESIGN RECOMMENDATIONS

The design and analysis approach for this report is based on the Canadian Standards Association (CSA), 2014 Canadian Highway Bridge Design Code (CHBDC) and assumes that the structures are classified as a Buried Structure (CSA S6-14 Section 7). The analysis approach assumes a force-based design (FBD) and elastic static analysis (ESA) methods for the structural design.

2.1 GEOTECHNICAL DESIGN PARAMETERS

In general, the subsurface stratigraphy at the site consisted of organic material or sand at the surface, over sand with varying amounts of silt, over lean clay with varying amounts of sand, silt and gravel. Cobbles and boulders were inferred within the clay.

For design purposes, the soil models provided in Table 2.1 will be used. The soil model is based on the soil properties encountered in the boreholes from the field investigation. The design methodology assumes that permafrost is not present at the culvert location and the parameters in Table 2.1 are unfrozen parameters. Design parameters for the proposed embankment fill are also provided.

The "degree of site and prediction model understanding for the native soils" has been assessed as "Typical Understanding" as per Section 6.5 of the Commentary on CSA S6-14, Canadian Highway Bridge Design Code (CHBDC), (S6, 1-14).

Table 2.1: Generalized Soil Profile at Crossing No. 6 Culvert

Approximate Depth (m)		Soil Type	Design Parameters				Design Temperature Profile
From	To		γ (kN/m^3)	ϕ (°)	S_u (kPa)	E (MPa)	
-	-	Proposed Embankment Fill (Pit run fill) See Section 2.5	21.0	32	-	50	Seasonal Freeze Thaw
0	0.5	Peat (very loose)	16.0	28	-	5	Seasonal Freeze Thaw
0.5	2.0	Sand to silty sand (loose to dense)	21.0	28	-	10	Seasonal Freeze Thaw
2.0	3.4	Sandy lean clay (hard)	21.0	-	200	15 to 20	1 to 3 °C
3.4	-	Inferred Bedrock	26.5	N/A	N/A	N/A	N/A

Notes: (1) γ = total unit weight, ϕ = soil friction angle, S_u = undrained shear strength, E = soil/rock modulus

(2) A design water level at elevation 272.9 m will be used (obvert of pipe). Submerged unit weights (γ') should be used below the groundwater level.

(3) The depths provided in the above table reflect a generalization of the borehole data to incorporate the most significant aspects of the geotechnical design and are not based on any specific location.

2.2 SEISMIC DESIGN CONSIDERATIONS

2.2.1 Site Class

It is recommended that Site Class C very dense soil and soft rock as defined in CHBDC (CHBDC, 2014) Section 4.4.3 be used in the seismic design for this site. The energy-corrected weighted harmonic mean penetration resistance, $\overline{N}_{60}$ was assessed as 54, values used to assess the seismic site classification for this site are as follows.

Depth Below Culvert	Soil	$\overline{N}_{60}$
0 to 4 m	Silty Sand / Sandy Lean Clay	14
4 to 30 m	Glacial Till or Bedrock	100

Notes:

(1) An energy-corrected penetration resistance $\overline{N}_{60}$ of 100 was used below 4 m depth due to auger refusal at a depth of 3.4 m below ground surface on inferred bedrock or very dense till.

2.2.2 Peak Ground Acceleration (PGA)

Seismic hazard values for this site were obtained from Natural Resources Canada (2015 National Building Code). Table 2.2 summarizes the parameters based on a 2475-year return period to be used in forced based design.

Table 2.2: Peak Ground Acceleration Data

PGA	$S_a(0.2)$	PGA_{ref}	Site Adjusted PGA	Site Class
0.030 g	0.052 g	0.0240 g	0.0300 g	C

The 2015 NBC Seismic Hazard calculation sheet that corresponds to this site is provided in Appendix C.

2.2.3 Vertical Acceleration Ratio (A_v)

CSA S6-14 Section 7.5.5.1 indicates that for the design of buried structures the vertical component of an earthquake, expressed as the vertical acceleration ratio, A_v, effectively increases the unit weight of the soil from γ to γ $(1+A_v)$. The vertical acceleration ratio, A_v, is to be two-thirds of the Site Adjusted PGA value for the site. The recommended A_v value for this project is 0.02 g.

2.2.4 Liquefaction Potential

The potential for soil liquefaction was evaluated by comparing the cyclic stress ratio (CSR) caused by the design earthquake with the soil resistance expressed in terms of the cyclic resistance ratio (CRR). The evaluation follows the analysis methodology suggested by Idriss and Boulanger (2008) and is based on the following:

- The blow count data from boreholes.
- A Site Adjusted PGA of 0.03 g.
- An earthquake magnitude M_w of 5.84, which is based on a Seismic Hazard Deaggregation calculated by the Canadian Hazards Information Service. A copy of the deaggregation result is provided in Appendix C (Geological Survey of Canada, 2017).

The analysis indicates a factor of safety against liquefaction of over 2.0, and therefore earthquake induced liquefaction is not a concern at this site.

2.3 STRUCTURE FOUNDATIONS

2.3.1 General

It is understood that two culverts are proposed at Crossing No. 6 on the Tlicho All Season Road at Stations 19+427 and 19+432. The preliminary structure design is two 2430 mm diameter SPCSP culverts.

The Preliminary General Arrangement drawing for the proposed culverts is presented on Drawing No. 2 in Appendix B.

The foundation soils at the site generally can provide adequate support for the two 2430 mm diameter SPCSP culverts.

2.4 FOUNDATION RECOMMENDATIONS

2.4.1 Geotechnical Resistances

It is recommended that the culverts be founded on structural backfill placed on the native soil. The Preliminary General Layout Plan notes a minimum 0.6 m thick pad of crushed aggregate to be placed below the pipe. The plan notes that soft or yielding material should be removed. The proposed backfill detail shown on the Preliminary General Layout is considered suitable for the observed subsurface conditions subject to the following:

- The excavations should be backfilled with compacted structural backfill – recommended grading specification for structural backfill is provided in Section 3.1.
- A 200 mm layer of uncompacted structural backfill material is placed directly beneath the culvert for bedding purposes.
- The edges of the granular pad should extend at least 1.5 m horizontally away from the culvert edge.

- A non-woven geotextile such as Terrafix 270R or approved equivalent is placed beneath the culvert bedding.

The geotechnical resistances provided in Table 2.3 may be used in the design provided the culverts are placed on structural backfill bedding over undisturbed native material as described above.

An approximately 0.5 m thick peat layer is present at ground surface in the vicinity of the culvert invert elevation. Organic soil was also noted in the underlying sand layer. Peat and other deleterious materials must be removed from beneath the proposed culverts. Where deleterious materials are encountered, the material should be excavated, wasted and replaced with structural backfill. The lateral extent of such excavation should include all deleterious material within the influence zone of the culverts. The base of the working surface should be examined by a qualified geotechnical inspector to confirm that the soils are consistent with those observed in the boreholes and to ensure that there is no loose or deleterious material present. Any loose, disturbed, or organic material identified during the inspection will require removal to the satisfaction of the geotechnical inspector. Where construction is undertaken during winter conditions, the working surface subgrade should be protected from freezing.

Table 2.3: Recommended Factored Geotechnical Resistances

Founding Element	Approximate Founding Elev. (m)	Culvert Size (m x m)		Factored Geotechnical Resistance at ULS (kPa) $\phi_{gu} = 0.5$	Factored Geotechnical Reaction at SLS (kPa) $\phi_{gs} = 0.8$
		Width (m)	Length (m)		
2430 mm Dia. SPCSP Culverts	270.3	2.4	30.5	330	80(5)

Notes:

(1) The Geotechnical Resistances were estimated assuming a consequence classification of "Typical Consequence" with a consequence factor equal to 1.0. In accordance with Section 6.5 and Table 6.1 of CHBDC, 2014.

(2) In accordance with Section 6.9 and Table 6.2 of the CHBDC, 2014, a resistance factor of 0.5 has been applied to calculate the factored geotechnical resistance at Ultimate Limit States (ULS).

(3) The geotechnical reaction at Serviceability Limit States (SLS) typically corresponds to a maximum settlement of 25 mm. In accordance with Section 6.9 and Table 6.2 of CHBDC, 2014, a geotechnical resistance factor of 0.8 has been applied to calculate the factored geotechnical resistance at SLS. If the subgrade is frozen at the time of construction, additional settlement due to the thaw consolidation is anticipated.

(4) The use of structural backfill beneath the culvert foundation is not for the purpose of achieving high bearing resistances or reactions but rather to ensure that the foundations are supported on a consistent engineered structural backfill once the existing soils have been removed from beneath the influence zone of the culverts.

(5) The low SLS reaction reflects the relatively loose nature of the silty sand encountered at the site.

2.5 EMBANKMENT DESIGN

The roadway profile at the culvert location will be raised above the existing profile by approximately 4.5 m. The proposed embankment will be constructed at a 2.5H:1V slope according to the Preliminary General Layout Plan. According to the Plan, the embankment will be constructed with Pit run fill and will have a rip-rap apron and clay seals at the culvert location.

Based on the thermistor and temperature data recorded for borehole BH17-16C, permafrost is not likely present at the culvert location. However, scattered patches of permafrost could be present within the footprint of the approach embankments. Soil sample temperature measurements from borehole BH17-17 that was drilled about 68 m to the north of the culvert suggest temperatures of -2 to -4 °C to about 7.5m below ground surface.

The potential presence of fine-grained thaw sensitive soils including the organic soil, the high silt content of the silty sand (>10% fines) and the clay at the site increase the potential for thaw related settlement and subsidence (CSA, 2010) if permafrost is present. Thaw sensitive soils consolidate and discharge excess water as they thaw (CSA, 2010). If unfrozen, the soils are also susceptible to expansion during freezing leading to frost heave. The fine-grained soils may be susceptible to frost heave in the presence of a high water table. Both vertical and horizontal movements could develop within the subgrade. The movements could impact the performance of the road embankment. Seasonal maintenance of the impacted infrastructure and ground surface should be carried out.

The following sections provide recommendations for the design and construction of the embankment at the culvert.

2.5.1 Embankment Construction

The peat layer should be removed from beneath the footprint of the embankment and replaced with pit run fill. A non-woven geotextile such as Terrafix 270R or approved equivalent should be placed directly on the subgrade and should extend 6 m laterally into the embankment footprint from the toe of embankment.

The embankment should be constructed with pit run fill placed in lifts no thicker than 150 mm and compacted to at least 95% Standard Proctor Maximum Dry Density (SPMDD). Pit run fill should consist of well graded sand and gravel with less than 10% fines (clay and silt size particles). Soil gradation testing of the fill should be carried out and reviewed by a geotechnical engineer prior to delivery to site. All fill should be placed and compacted when air temperatures are consistently above freezing. No fill should be placed and compacted that is frozen or at freezing temperatures.

2.5.2 Embankment Settlement

The settlement of the embankment has been assessed based on the following mechanisms; self-weight settlement of embankment fill, thaw consolidation of underlying permafrost (if present) and the seasonal freeze / thaw layer, and the consolidation of underlying unfrozen soil layers.

Table 2.4 summarizes the embankment settlement estimated at borehole locations BH17-17 and BH17-16C, the analysis predicts about 70 mm to 90 mm of settlement. Andersland and Ladanyi (1994) note that where variations of subsurface conditions (soil type and moisture content and ice content) and variable thaw progression beneath the embankment occur, significant differential settlements can be anticipated. These conditions are present at the culvert location near borehole BH17-17, significant differential settlements could occur.

To mitigate embankment deformation related to self-weight settlement and related processes we recommend the following:

- Placing embankment fills during summer.
- Over building the embankment by approximately 0.3 m to 0.5 m.
- Monitoring the embankment for a period of 2 years. Monitoring should include mapping of cracks, measurement of crack apertures (if present), observations on the condition of the embankment slope and toe of slope.
- Installing multibead thermistor cables in the subgrade to monitor changes in the geothermal regime.
- The monitoring observations should be reviewed by a geotechnical engineer. After completion of monitoring the embankment could be re-graded to final grades.

Table 2.4: Estimated Embankment Settlement

Settlement Consolidation Mechanism	Borehole Location	
	BH17-17	BH17-16C
Self-weight Settlement of Embankment Fills[1] (mm)	50	50
Thaw Consolidation of Soil[2] (mm)	Negligible	Negligible
Consolidation of Unfrozen Soil[3] (mm)	40	20
Total Settlement	90	70

Notes:

1) Estimate assumes fill placement during temperatures above 0°C. Estimate assumes self-weight settlement equal to 1% of the embankment fill height.
2) Estimate assumes the active layer / seasonal freeze thaw layer are frozen during fill placement and a maximum depth of 5 m. Ice may be present at the bottom of the active layer where water accumulates on the top of the permafrost (where present). Unit thaw settlement assessed based on statistical method proposed by Nixon Ladanyi (1978) Modified (as referenced in Andersland and Ladanyi, 1994).
3) Consolidation of unfrozen soil settlement estimate calculated using Settle3D program by Rocscience (Rocscience, 2009) using soil design parameters noted in Table 2.1. The estimate assumes that the peat has been removed and replaced with pit run fill.

2.5.3 Stability of Slopes

A global stability analysis of a 2.5H:1V embankment slope as shown on the Preliminary General Layout drawing was carried out. Both static and conventional pseudo-static limit equilibrium slope stability analysis methods were applied using the program Slope/W (Geo-Slope, 2012) and the design parameters noted in Table 2.1.

The analysis assumes that the peat layer will be removed from beneath the footprint of the embankment and replaced with pit run fill and the embankment will be constructed with pit run fill.

The pseudo-static stability analysis of the embankment slope considered seismic loading of 0.015, which is one-half of the Site Adjusted Peak Ground Acceleration (PGA).

The slope stability evaluation results indicate that the estimated factor of safety against critical failure is greater than 1.5 for static conditions using a design high water level at elevation 272.9 m. The factor of safety against critical failure meets the required target value of 1.1 (seismic) for highway embankments.

2.6 EROSION AND SCOUR PROTECTION

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. All slopes within 3 m of the culvert inlet and outlet should be surfaced with rip-rap at least 300 mm thick placed on a non-woven filter fabric such as Terrafix 270R or approved equivalent; the rip-rap should extend up the slope to 0.3 m above the design high water level. Rip-rap aprons are shown on the Preliminary General Layout Plan at the culvert inlet and outlet. Where embankment construction includes earth fill, normal slope vegetation should be established as soon as possible after completion of the embankment fills in order to control surficial erosion.

Two 4.86 m thick (two times the culvert diameter) clay seals or approved equivalent are shown on Section A-A of the Preliminary General Layout Plan. Clay seals should be provided near the culvert inlet and outlet to prevent seepage through the backfill material. Clay seals should be constructed as follows:

- Clay seals should extend 5 m into the embankment.
- Extend from at least 0.3 m above the high water level to the full depth of excavation.
- Clay seals should not be located beneath the travelled portion of the lanes.

Material for the clay seal should meet the following specifications (Ontario Provincial Standard Specification, 2009):

- The coefficient of permeability as determined in the flexible wall permeameter according to ASTM D5084 should not exceed 1×10^{-6} cm/s.
- Liquid limit should be > 40%.
- Plasticity index should be > 0.73 x (Liquid Limit - 20%).

Alternatively, a geosynthetic clay liner may be used (sodium bentonite clay sandwiched between two protective geotextiles). Material specifications containing the physical, mechanical, and hydraulic properties of the geosynthetic clay liner should be obtained from the manufacturer. The material specification should include a manufacturer's certification and warranty.

The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediment from running off the site.

2.7 CLIMATE CHANGE SENSITIVITY AND PERMAFROST DEGRADATION RISK

Thermistor results from BH17-16C suggest permafrost is not present at the culvert location, therefore permafrost degradation due to climate change is not a design consideration for the culvert. Long term monitoring of the thermistor should be carried out as part of the evaluation of the performance of the culvert and embankment. If the existing thermistor cannot be maintained during construction, a new multibead thermistor should be installed to a depth of 15 m to provide long-term ground temperature monitoring. If additional monitoring results suggest the presence of permafrost, then the assessment as outlined below is applicable.

The 2010 CSA Technical Guide titled "Infrastructure in Permafrost: A Guideline for Climate Change Adaption" provides guidance on assessing the potential impacts of climate change on infrastructure in permafrost. As per Table 5.2 in CSA (2010), seasonal mean temperature change under moderate (A1B) green-house gas scenarios, the mean annual temperatures for the Arctic Sector C1 are projected to be 1.3 °C (2011-2040), 2.7 °C (2041-2070), and 3.7 °C (2071 – 2100) respectively. A warming climate could cause a change in depth of the active soil layer (where present). A deepened active layer can also initiate thaw settlement of the embankments. Frost jacking or thaw settlement of the soils and road will negatively impact the performance of embankments. The sensitivity of the site to climate change was assessed as "high" and the consequence of permafrost degradation is assessed to be "minor" assuming the organic soil is removed and replaced with crushed aggregate below the culverts. The assessed site sensitivity and consequence suggests a risk level of "B", which suggests a semi-quantitative analysis should be completed.

2.8 CEMENT TYPE AND CORROSION PROTECTION

One sample of the native soil was submitted to Maxxam Analytics in Edmonton for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The testing was completed to determine the potential for degradation of concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in buried infrastructure. The analysis results are summarized in Table 4.1 in the Geotechnical Data Report.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. The soluble sulphate concentrations for the sample was 0.0028 %. Soluble sulphate concentrations less than 0.1 % generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. Type GU (General Use) Portland Cement should therefore be suitable for use in concrete at this site, if applicable.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH value was 7.9, which is within what is considered the normal range for soil pH of 5.5 to 9.0. The pH level of the tested soil does not indicate a highly corrosive environment. The resistivity result was 28 Ohm-m, which suggests a moderate degree of corrosiveness for steel. The test results provided in Table 4.1 in the Geotechnical Data Report may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

3.0 CONSTRUCTION CONSIDERATIONS

3.1 EXCAVATION AND BACKFILLING

Side slopes for open cut excavations should have a gradient of one horizontal to one vertical, or shallower, sloped from the bottom of the excavation.

Excavation and backfill for the culvert structures should be carried out in accordance with Section 7, Buried Structures of the 2014 CHBDC, which specifies but not limited to, the following:

- Structural backfill shall be placed between multi-conduit structure.
- A minimum transverse distance of backfill equal to ½ the horizontal diameter of culvert (measured at mid-height) for structure constructed in trench in which the natural soil is poorer than the engineered soil.
- The material for structural backfill shall be boulder free and shall be selected from the Group I or II soils specified in Table 7.4 of the CHDBC, with compaction corresponding to the modulus of soil stiffness used in the design. The backfill shall be placed and compacted in layers not exceeding 200 mm of compacted thickness, with each layer compacted to the required density prior to the addition of the next layer. The difference in levels of structural backfill on the two sides of a conduit at any transverse section shall not exceed 200 mm. The structural backfill within 300 mm of the conduit walls shall be free of stones exceeding 75 mm in any dimension. Heavy equipment shall not be allowed within 1 m of the conduit walls. The structural backfill adjacent to the conduit wall and to within the frost penetration depth shall be free of frost-susceptible soils.

All vegetation, organic soils and other deleterious materials must be removed from beneath the proposed culverts. Where deleterious materials are encountered, the material should be excavated, wasted and replaced. The lateral extent of such excavation should include all deleterious material within the influence zone of the culverts.

The Preliminary General Layout Plan notes a minimum of 0.6 m depth below the pipe should be excavated and replaced with crushed aggregate material. Section B-B of the plan shows a

10.4 m wide box of structural backfill surrounding the culverts that consists of 1.5 m of structural backfill at the sides of the culverts, 2.5 m of structural backfill between the two culverts, and 0.6 m of structural backfill directly above the culverts. Section B-B shows Pit Run Fill above the structural backfill up to finished road top. The structural backfill details meet or exceed the CHBDC specifications noted above.

Bedding, leveling and cover material for the culverts should consist of structural backfill meeting the grading specifications outlined in Table 3.1

Table 3.1: Aggregate Specifications for Structural Backfill

DESIGNATION		Percent Passing
Class (mm)		**25**
Percent Passing Metric Sieve (CGSB 8-GP-2M) • m	25.000	100
	20.000	82-97
	16.000	70-94
	12.500	
	10.000	52-79
	8.000	
	5.000	35-64
	1.250	18-43
	0.630	12-34
	0.315	8-26
	0.160	5-18
	0.080	2-8
% FRACTURE BY WEIGHT (2 FACES)	ALL +5.000	60+
PLASTICITY INDEX (PI)		Non-plastic
L.A. ABRASION LOSS PERCENT MAX.		50

Note: Aggregate specifications for structural backfill adapted from the Alberta Transportation Standard Specification for Highway Construction, Table 3.2.3.1 Specification for Aggregate (Alberta Transportation, 2013).

3.2 REUSE OF EXCAVATED MATERIAL

The native material in the vicinity of the project site consists of peat, silty sand and lean sandy clay. This material will not be suitable as backfill for the proposed culverts. The silty sand may be used for embankments if properly processed and compacted and only where potential frost heaving will not negatively impact the performance of the culvert or roadway.

3.3 TEMPORARY CONSTRUCTION DEWATERING

Groundwater was not encountered in the open boreholes during the investigation completed in winter. Fluctuations in the groundwater due to seasonal changes or in response to a particular precipitation event should be anticipated. It is noted that satellite imagery shows a seasonal watercourse crossing at the site location.

Depending on the time of year of construction, installation of the culvert may require excavation below the groundwater level. Control of groundwater during construction may be required. The groundwater level should be lowered to at least 0.5 m below the subgrade level of the culvert and the subcut for the granular bedding material to provide a stable base during placement of culvert bedding material.

The native soils within the anticipated depth of excavation have a low to moderate hydraulic conductivity, in the order of 10^{-3} to 10^{-5} cm/s. Significant groundwater flow should be anticipated within unfrozen organic soil and peat layers. Dewatering of the culvert excavation using conventional sump and pump techniques should be adequate. If high groundwater levels are present during construction, cofferdams enclosing the work area may be used as required.

For reference, the results of the grain size distribution tests (and Unified Soil Classifications) completed on the predominant soil strata encountered in the boreholes have been compared to the grain size curves and soil types referenced in Supplementary Standard SB-6 of the 2012 Ontario Building Code (OBC). The OBC has been used as a guideline to estimate the likely range in the coefficient of permeability of the soils encountered in the investigation. It is noted that the industry typically refers to "hydraulic conductivity" rather than "coefficient of permeability" in this respect. The terms are often considered interchangeable, but for purposes of this report the values provided are in the form of "length/time" (cm/sec) and are therefore considered strictly applicable to "hydraulic conductivity", and hence "hydraulic conductivity" is used herein.

Based on the comparison conducted, the following values are provided:

Unfrozen Soil Type	**Estimated Hydraulic Conductivity**	**Comment**
Silty Sand (SM)	10^{-3} to 10^{-5} cm/sec	Medium to Low Permeability
Poorly Graded Sand (SP)	10^{-2} to 10^{-3} cm/sec	Permeable
Clayey Sand (SC)	10^{-2} to 10^{-3} cm/sec	Medium to Low Permeability
Lean Clay (CL)	10^{-6} and less cm/sec	Low Permeability

The OBC states, in part, that "it must be emphasized that, particularly for fine-grained soils, there is no consistent relationship (between coefficient of permeability and soils of various types) due to the many factors involved". Such factors as structure, mineralogy, density (compactness or consistency), plasticity, and organic contents of the soil can have a large influence on the hydraulic conductivity; variations in excess of an "order of magnitude" are common place in this respect.

It is recommended that the contract documents for this site include a special provision to address issues related to groundwater control during construction. A Notice to Contractor is provided in Appendix D that alerts the contractor to the presence of high permeability soils at the site.

4.0 DESIGN UNCERTAINTIES

A primary uncertainty for the design of this culvert structure is the variability of foundation conditions. This includes the potential presence of buried massive ice under the culvert location. The geotechnical drilling program was not able to penetrate to significant depths due to auger refusal. Such refusal may be caused by many factors including encountering bedrock, or well-bonded permafrost soils. Experience on the reconstruction of Highway 3 between Behchoko and Yellowknife found that many culvert crossings were underlain by massive ice, which negatively impacted the performance of the road embankment and culvert. To address the potential for the presence of massive ice at this culvert site several recommendations are provided to the Client for their consideration:

- Conducting an additional geotechnical program at the time of construction consisting of test pits or additional drilling using a more powerful drill than what was used for the initial geotechnical program.
- Conducting a geophysical survey along the road alignment to provide additional information on the subsurface conditions at depth.
- Developing a construction contingency plan for the presence of massive ice, prior to construction, so that the plan is in place and can be readily implemented should the need arise.

This design report has not considered the hydraulic characteristics of the culvert placements. In northern and permafrost terrain the seasonal freezing of culverts is a persistent issue, in that the culverts fill with ice and snow in the fall and early winter, and remain plugged well into the spring and summer after snow melt and runoff has begun. Thus the road embankment and ice-filled culverts act as a dam, restricting the passage of runoff. To address this issue, one strategy is to install two culverts with one culvert vertically higher than the other so that it will remain ice-free over the winter. If the Client and Owners have concerns regarding potential for ice plugs in the culverts, the above strategy or other strategies should be considered.

5.0 DESIGN REVIEW AND CONSTRUCTION MONITORING

Stantec Consulting Ltd. should review the design details, specifications and drawings prior to construction. Quality assurance and construction monitoring should be provided during construction in order to confirm that the contractor is following the recommendations in this Report. Long term monitoring should be completed to monitor for settlement and performance of the culverts and embankments.

6.0 CLOSURE

A soil investigation is a limited sampling of a site. The recommendations given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered that differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information and its effects on the above recommendations. Use of this report is subject to the Statement of General Conditions provided in Appendix A. It is the responsibility of Tlicho Engineering & Environmental Services Ltd., who is identified as "the Client" within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec Consulting Ltd. should any of these not be satisfied. The Statement of General Conditions addresses the following:

- Use of the report
- Basis of the report
- Standard of care
- Interpretation of site conditions
- Varying or unexpected site conditions
- Planning, design or construction

We trust the information presented herein meets your present requirements. Should you have any questions or require additional information, please do not hesitate to contact us.

This report has been prepared by Zachary Popper and reviewed by Christopher McGrath and Jim Oswell.

Respectfully submitted,

STANTEC CONSULTING LTD.

Zachary Popper, B.Eng.
Geotechnical Engineering

Christopher McGrath, P.Eng.
Associate- Senior Geotechnical Engineer

Jim Oswell, PhD, P.Eng.
Senior Geotechnical Advisor

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7.0 REFERENCES

Alberta Transportation, 2013. Alberta Transportation Standard Specification for Highway Construction, Table 3.2.3.1 Specification for Aggregate, Edmonton, Alberta.

Andersland, O.B., and Ladanyi, B. 1994. An Introduction to Frozen Ground Engineering. Chapman & Hall Inc., New York, NY, USA.

ASTM. 2000. Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter D5084. ASTM International, West Conshohocken, PA.

Canadian Standards Association (CSA). 2010. Technical Guide Infrastructure in permafrost: A guideline for climate change adaptation. Canadian Standards Association, Mississauga, ON, Canada.

CHBDC. 2014. Canadian Highway Bridge Design Code. Canadian Standards Association, Mississauga, Ontario.

Geo-Slope International, Ltd. 2012. GeoStudio 2012 (Slope/W 2012), Calgary, Alberta.

Geological Survey of Canada, Seismic Hazard Deaggregation calculated by the Canadian Hazards Information Service, April 21, 2017, Canada.

GNWT DOT, 2016. Proposed Tlicho All-season Road, Project Description Report. March 2016

Natural Resources Canada, 2015 National Building Code Seismic Hazard Calculation (2017, April 20). Retrieved from http://www.earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/index_2015-en.php

Ontario Building Code. 2012. Ministry of Municipal Affairs and Housing, Building and Development Branch.

Ontario Provincial Standard Specification, 2009. Material Specification for Clay Seal OPSS 1205, November 2009.

Rocscience, 2009. Settle3D Settlement and Consolidation Analysis, v 3.009: Theory Manual, Rocscience, Inc.

8.0 BIBLIOGRAPHY

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2000. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

ASTM. 2000. Standard Practice for Description of Frozen Soils (Visual-Manual Procedure) (ASTM D4083). ASTM International, West Conshohocken, PA.

Canadian Foundation Engineering Manual (CFEM). 2006. Fourth Edition. Canadian Geotechnical Society, 488 p.

Environment Canada. Warming Trends °C/Decade, Based on homogenized temperature data – the most recent 30 yr record (1981 – 2010); Environment Canada.

Environment Canada. (2016, September 1) Canadian Climate Normals 1981–2010. Yellowknife Station. Retrieved from http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProv&lstProvince=NT&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=1706&dispBack=0

GNWT, 2008. Ecosystem Classification Group (ECG) 2008. Ecological Regions of the Northwest Territories: Taiga Shield. Department of Environment and Natural Resources, GNWT. Yellowknife, NT.

GSC, 1965. Glacial Lake McConnell and the surficial geology of parts of Slave River and Redstone River map areas, District of Mackenzie; Craig, B G. Geological Survey of Canada, Bulletin 122, 1965,; 44 pages, doi:10.4095/100639. Natural Resources Canada. 1995: Canada Permafrost; The National Atlas of Canada 5th Edition, scale 1:7 500 000.

GSC, 1989. Glacial Features Around the Keewatin Ice Divide, Northwest Territories; Aylsworth, J M; Shilts, W W. Geological Survey of Canada, Preliminary Map 24-1987, 1989, ; 2 sheets, doi:10.4095/126992.

Heginbottom, J.A., Dubreuil, M.A., and P.A. Harker. 1995. Canada-Permafrost; National Atlas of Canada, 5th edition, Plate 2.1. Geomatics Canada, National Atlas Information Service and Geological Survey of Canada (MCR 4177).

Kavik AXYS Inc. 2008a. Multi-Level Mapping and Route Analysis – Tlicho Transportation Corridor. Route Identification and Evaluation. Yellowknife, NT. January 2008.Project No. Project No. 144902005.

Kerr and Wilson, 2000. 2000-C3. Preliminary surficial geology studies and mineral exploration considerations in the Yellowknife area, Northwest Territories. D.E. Kerr and P. Wilson.

Natural Resources Canada. 1995: Canada Permafrost; The National Atlas of Canada 5th Edition, scale 1:7 500 000.

Stantec, 2015.Tli Cho Road Alignment, Hydrologic and Hydraulic Study. Project No. 144902005.

Wolfe, 1998. Living with frozen ground : a field guide to permafrost in Yellowknife, Northwest Territories, edited by Stephen A. Wolfe ; contributions by Stephen A. Wolfe

S.A. Wolfe, P.D. Morse, T.E. Hoeve, W.E Sladen, S.V. Kokelj, L.U. Arenson, 2015. Disequilibrium permafrost conditions on NWT Highway 3

APPENDIX A

Statement of General Conditions

STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec Consulting Ltd. and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec Consulting Ltd.'s present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec Consulting Ltd. is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec Consulting Ltd. at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec Consulting Ltd. must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec Consulting Ltd. will not be responsible to any party for damages incurred as a result of failing to notify Stantec Consulting Ltd. that differing site or sub-surface conditions are present upon becoming aware of such conditions.

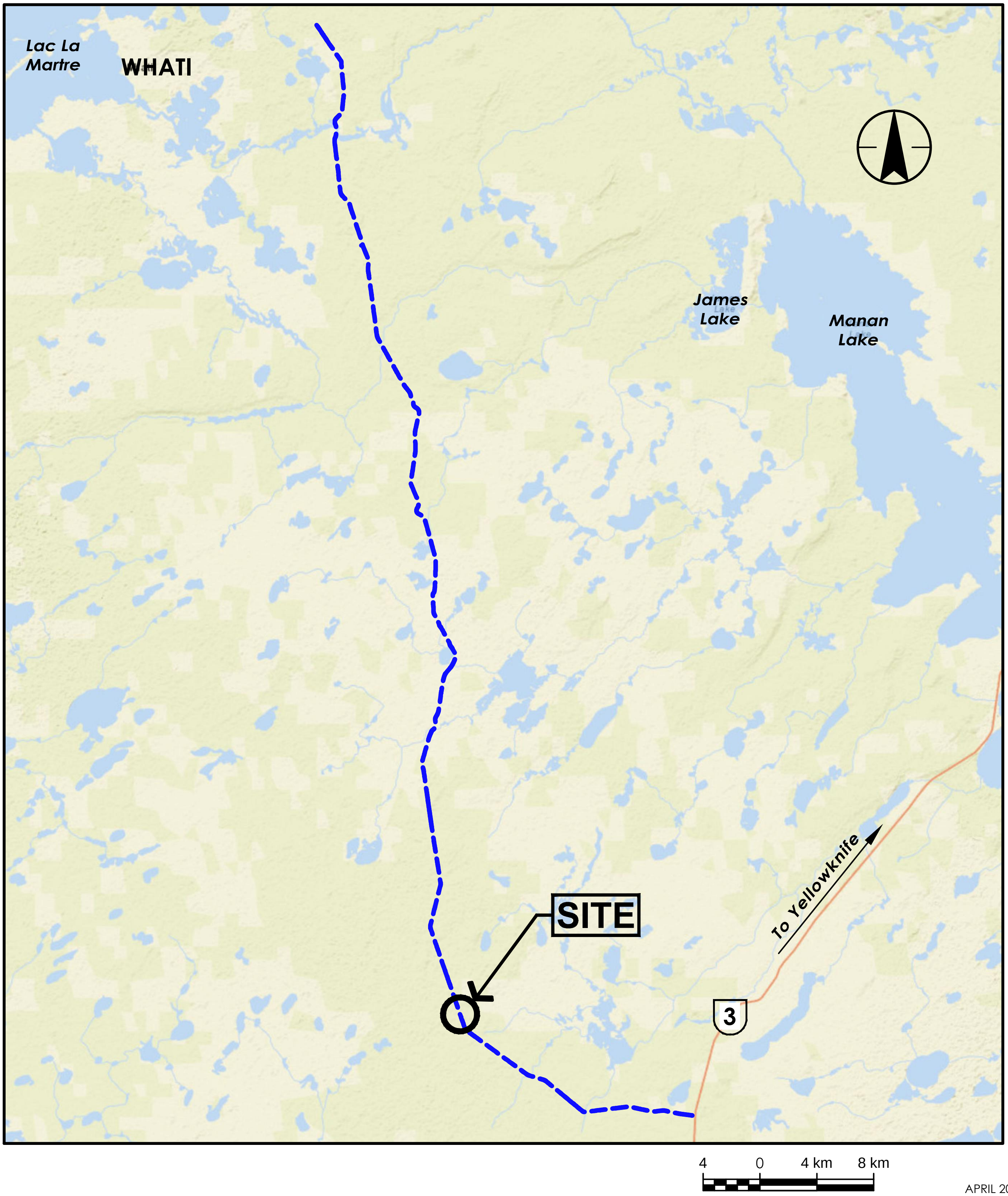
PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec Consulting Ltd., sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec Consulting Ltd. cannot be responsible for site work carried out without being present.

APPENDIX B

Drawing No. 1 – Key Plan

Drawing No. 2 – General Layout and Borehole Location Plan

Site Photos



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2017/04/28 3:06 PM By: Briones, Gliceria

APRIL 2017
Project No. 144902448

Stantec

400 - 1331 Clyde Avenue
Ottawa, ON, Canada K2C 3G4
www.stantec.com

LEGEND

PROPOSED ALIGNMENT

NOTES

IMAGERY: ESRI ©2017.

Client/Project

TLICHO ENGINEERING & ENVIRONMENTAL SERVICES LTD.

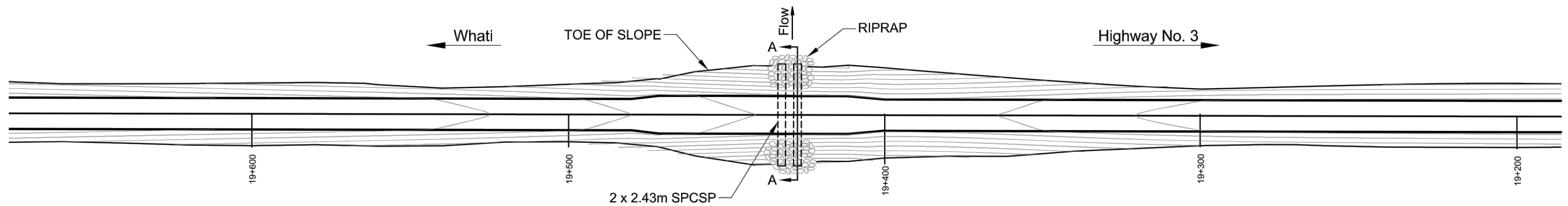
GEOTECHNICAL INVESTIGATION
CROSSING #6 CULVERT, NWT

Drawing No.

1

Title

KEY PLAN



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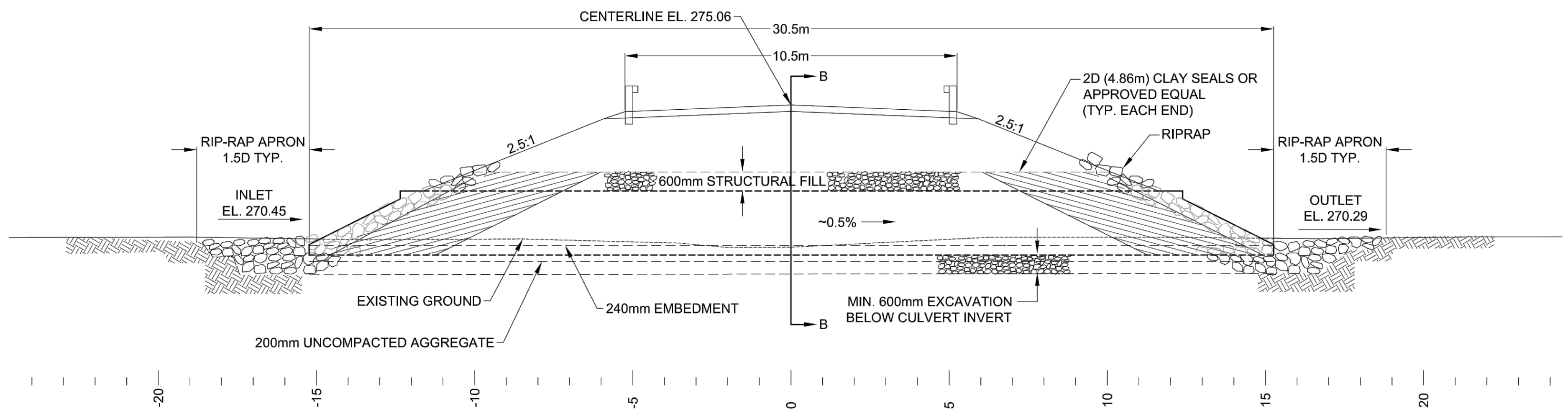

CULVERT PROFILE A-A @ 19+427
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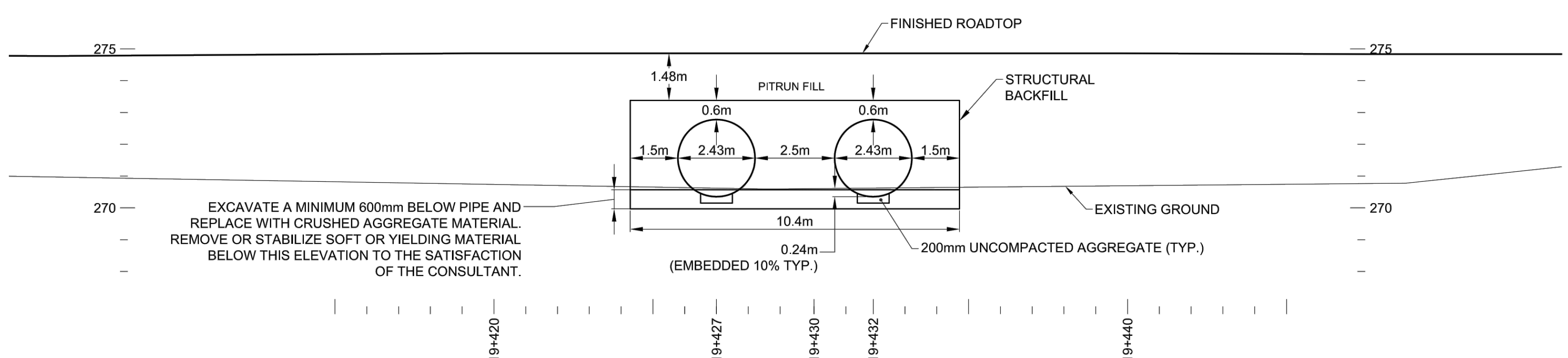

SECTION B-B
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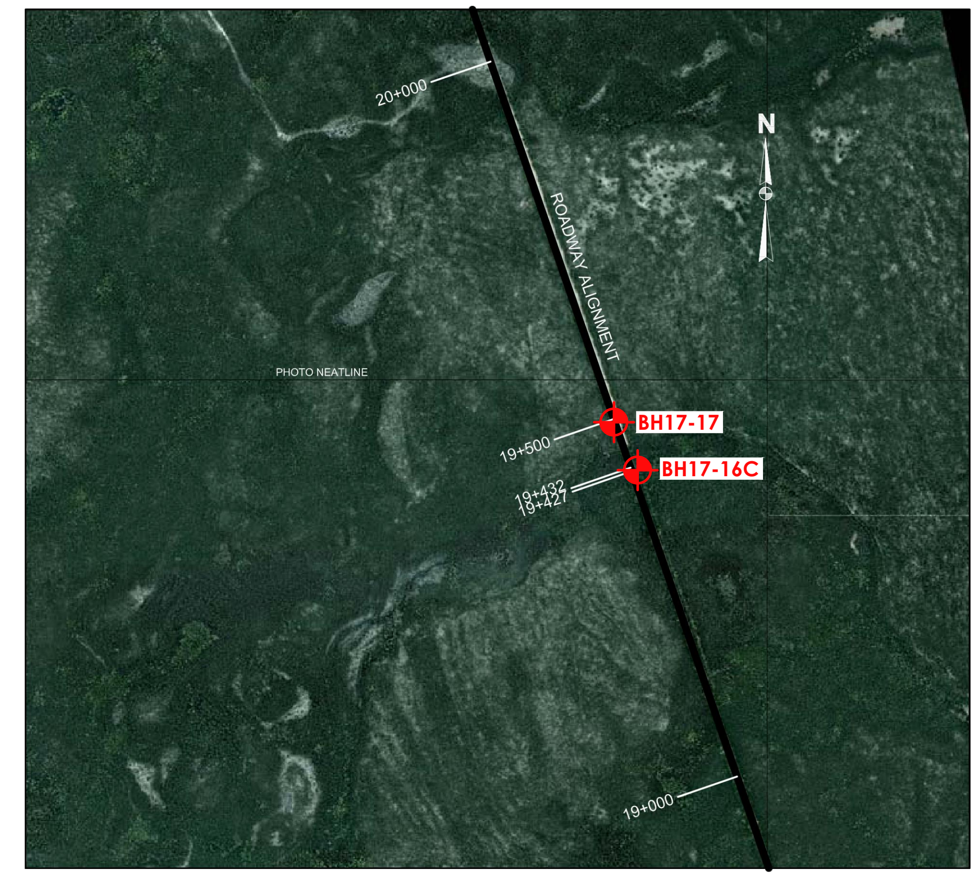

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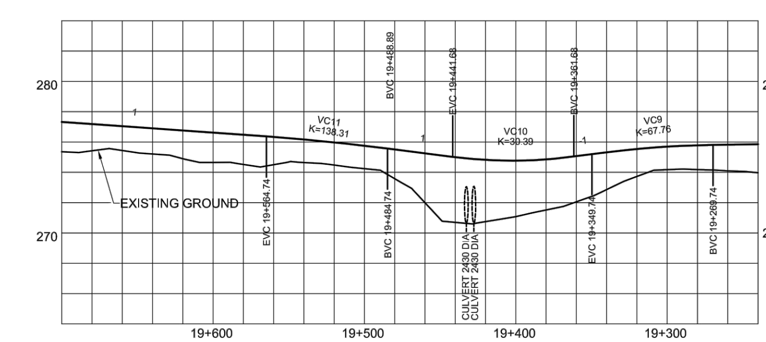

ROADWAY PROFILE
H 1:5,000 V 1:500

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2017/04/28 3:09 PM By: Briones, Gliceria

APRIL 2017
PROJECT No. 144902448

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LEGEND

APPROXIMATE BOREHOLE LOCATION

NOTES

1. DRAWING PROVIDED BY DOT TECHNICAL SERVICES (TASR-03-16 (CROSSING#6).

Client/Project

TLICHO ENGINEERING & ENVIRONMENTAL SERVICES LTD.
GEOTECHNICAL INVESTIGATION
CROSSING #6 CULVERT, NWT

Drawing No.
2

Title

GENERAL LAYOUT AND BOREHOLE LOCATION PLAN

Photo No. 1: Borehole BH17-16C location.

Photo No. 2: Borehole BH17-16C location.

Photo No. 3: Borehole BH17-16C with thermistor cables and PVC pipe.

Photo No. 4: Borehole BH17-17 location looking northwest.

Photo No. 5: Borehole BH17-17 location looking southeast towards culvert Crossing No. 6.

Photo No. 6: Borehole BH17-17 location.

APPENDIX C

NBC Seismic Hazard Calculation Sheet
Seismic Hazard Deaggregation

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

April 20, 2017

Site: 62.5482 N, 116.8059 W User File Reference: Tlicho All Season Road, Northwest Territories

Requested by: , Stantec Consulting Ltd.

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.05)	Sa(0.1)	**Sa(0.2)**	Sa(0.3)	**Sa(0.5)**	**Sa(1.0)**	**Sa(2.0)**	**Sa(5.0)**	**Sa(10.0)**	**PGA (g)**	**PGV (m/s)**
0.040	0.056	**0.052**	0.044	**0.040**	**0.033**	**0.021**	**0.0072**	**0.0034**	**0.030**	**0.034**

Notes. Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. ***These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.***

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.0025	0.011	0.020
Sa(0.1)	0.0040	0.016	0.029
Sa(0.2)	0.0057	0.018	0.029
Sa(0.3)	0.0070	0.018	0.027
Sa(0.5)	0.0076	0.019	0.026
Sa(1.0)	0.0065	0.016	0.023
Sa(2.0)	0.0040	0.010	0.015
Sa(5.0)	0.0014	0.0035	0.0049
Sa(10.0)	0.0008	0.0016	0.0023
PGA	0.0023	0.0089	0.016
PGV	0.0059	0.015	0.022

References

National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français

62.5˚N

117.5˚W 117˚W 116.5˚W 116˚W

Natural Resources Canada Ressources naturelles Canada

Canada

Seismic Hazard Deaggregation

calculated by the Canadian Hazards Information Service

INFORMATION: *EarthquakesCanada.nrcan.gc.ca*

Eastern Canada (613) 995-5548 Western Canada (250) 363-6500

Requested by: Zach Popper, Stantec 2017/04/21

For site Tlicho All Season Road, NT at 62.548 N 116.806 W

For ground motion parameter peak ground acceleration (PGA)

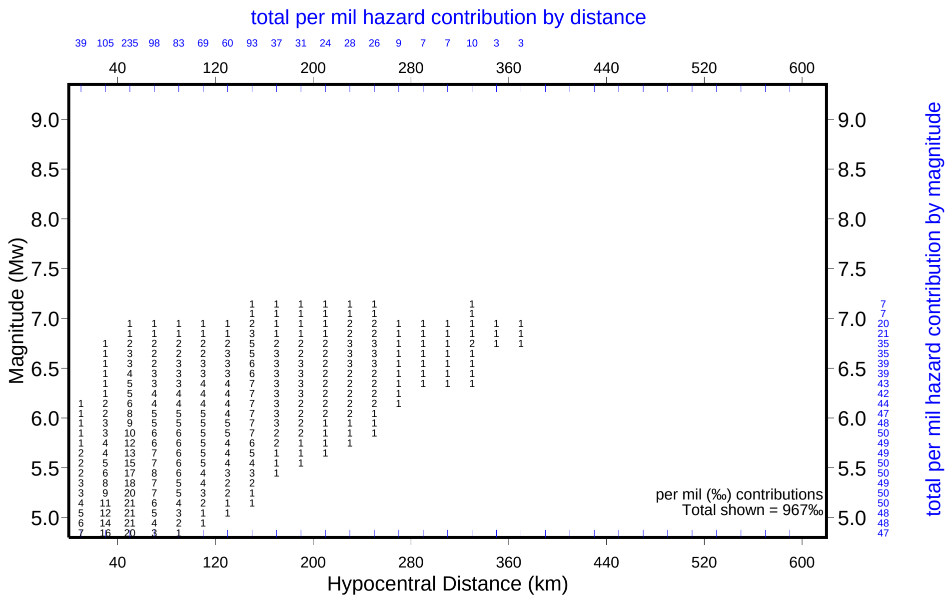
at a probability of 0.000404 per annum, seismic hazard = 0.030 g

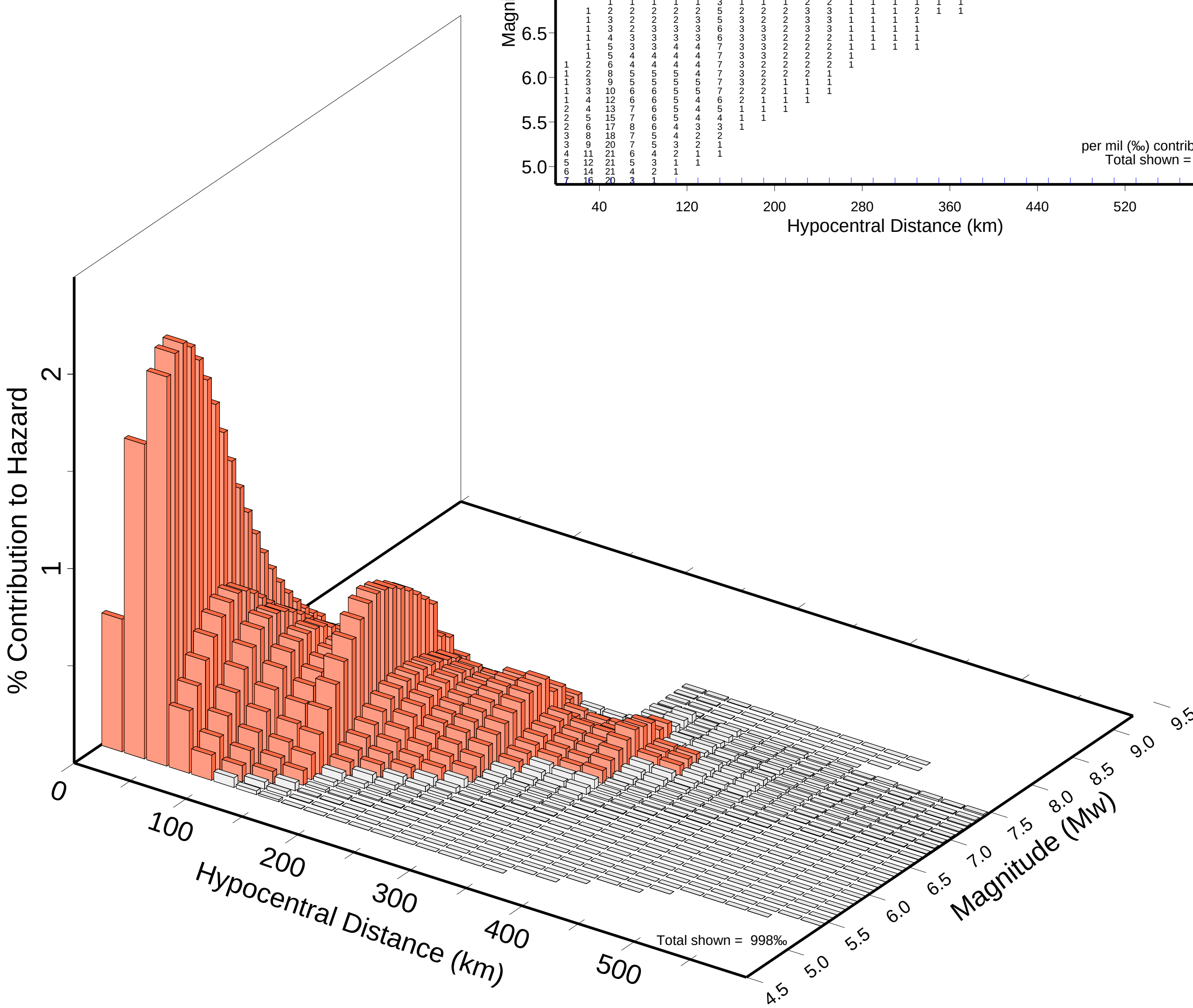
Mean magnitude (Mw) 5.84 Mean distance 112 km

Mode magnitude (Mw) 5.050 Mode distance 50 km

Deaggregation of mean hazard

Model: WArctic_g2015clC.model





Aussi disponible en francais

Natural Resources Canada Ressources naturelles Canada

Canada

APPENDIX D

Notice to Contractor – Groundwater Control

Stantec

NOTICE TO CONTRACTOR – GROUNDWATER CONTROL

Special Provision

PRESENCE OF HIGH PERMEABILITY SOILS

The work required for the above tender item shall include consideration of dewatering to provide a stable working platform during construction of the culvert.

The contractor is advised of the following:

- Excavation is required for the construction of new culverts.
- The contractor shall consider that seasonal groundwater fluctuations may result in high groundwater levels and that higher groundwater levels may result in an unstable working earth platform.
- The estimated hydraulic conductivity for the native soil at the site is expected to range from $1x10^{-3}$ cm/s to $1x10^{-5}$ cm/s.
- The anticipated excavation level may be below the groundwater level at the time of construction.
- The presence of cohesionless sand can render the soils susceptible to unbalanced hydrostatic head, soil sloughing and cave-in.
- The contractor shall consider the site conditions, sequence of work and schedule when assessing requirements for dewatering.

Geotechnical Data Report
Proposed Bridge Crossing #8
Station 40+400

Geotechnical Investigation,
Proposed Tlicho All-Season Road,
Northwest Territories

Prepared for:
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Project No. 144902448

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1.0 INTRODUCTION

Acting at the authorization of Tlicho Engineering and Environmental Services Ltd. (Tlicho), Stantec Consulting Ltd. (Stantec) carried out a geotechnical investigation in support of the proposed bridge planned at Crossing #8 along the proposed Tlicho All Season Access Road (TASR). The purpose of the investigation was to characterize subsurface conditions and provide geotechnical comments and recommendations to assist with proposed bridge design and site development.

The investigation was carried out in general accordance with Stantec's proposal dated January 12, 2017, as part of an overall geotechnical program by Tlicho for the Government of the Northwest Territories (GNWT) along the proposed 94 km TASR alignment extending from the Yellowknife Highway (Highway 3) to the Settlement of Whati on the south shore of Lac La Martre (RFP Event ID: EV000000001132). The scope of work outlined in the GNWT Request for Proposal includes the geotechnical investigation and design of the 94 km long TASR corridor, four bridges and three structural culverts. Tlicho was responsible for management and execution of the overall project and team as the Prime Contractor, with Stantec acting as sub-consultant providing geotechnical engineering and technical services to the project, including:

- Provision of geotechnical field personnel to log subsurface conditions during drilling operations at eighty-one (81) geotechnical boreholes in accordance with the RFP:
  - Thirteen (13) boreholes at the four (4) proposed major bridge crossings:
    - Crossing #8, Station 40+400 - Duport River Crossing
    - Crossing #9, Station 45+175 - (unnamed)
    - Crossing #14, Station 69+666 - James River Crossing
    - Crossing #15, Station 85+397 - La Martre River
  - Three (3) boreholes at the three (3) proposed major bridge culvert crossings:
    - Crossing #5, Station 16+532
    - Crossing #6, Station 19+427
    - Crossing #10a, Station 48+208
  - Sixty-five (65) boreholes to observe the subsurface conditions along the road alignment;
- Installation and reading of thermistors;
- Borehole layout and as-drilled survey;
- Completion of a laboratory testing program on the recovered borehole samples as specified in the RFP; and
- Geotechnical engineering assessment and reporting on the field and laboratory findings in two reports (Geotechnical Data Report and Geotechnical Recommendations Report) for each crossing location and for the overall roadway alignment.
  - These documents should be read in conjunction with the Statement of General Conditions, Appendix A.

This Geotechnical Data Report contains the factual findings from the geotechnical investigation undertaken at the Crossing #8 site by Stantec including: a summary of the field and laboratory procedures; Borehole Records; laboratory test results; and a discussion of the factual findings.

The Geotechnical Recommendation Report for Crossing #8, presenting the results of our geotechnical analysis with discussion and recommendations for design purposes is provided under separate cover.

2.0 SITE DESCRIPTION AND GEOLOGY AND CLIMATE

2.1 SITE DESCRIPTION

The 'Crossing #8' bridge is proposed at Duport River located at approximately the 40.4 km station mark along the TASR corridor as shown on Drawing No. 1 – Site Location Plan, provided in Appendix B. At this location, the proposed road center line is not aligned with the original Lac La Martre winter road. This new proposed alignment is offset from the original ice road by approximately 150 m to 200 m to the east.

Based on a previous hydrologic study (Stantec, 2015), it is understood that the watercourse is a braided, meandering channel. The well-defined channel is approximately 1.5 m wide however there are oxbow ponds located adjacent to the channel from normal flooding events. The floodplain is approximately 50 to 75 m wide. At the time of the investigation, the watercourse channel(s) were not visible during the walk around inspection of the bridge location due to snow and ice cover. The floodplain area immediately surrounding the roadway was vegetated with grasses and shrubs. Larger trees border the floodplain. Snow cover depths of approximately 50 to 55 cm was measured in surrounding areas. Photographs showing the general site conditions at the proposed bridge crossing are provided in Appendix B.

It is understood that the original Lac La Martre overland winter road was established by the military in the 1950s, and used as a public winter road for the northern Tlicho communities up until the late 1980s. More recently it has been used by the local communities for travel using all-terrain vehicles including snowmobiles, dog sleds, ATVs, and trucks (GNWT DOT, 2016). Given that the crossing will be offset from the existing winter road alignment it is understood that this area has not be developed in the past and exists in its native, undisturbed state.

2.2 PHYSIOGRAPHY AND GEOLOGY

The site is located within the Great Slave Plain High Boreal Ecoregion (ECG, 2009 and GNWT DOT, 2016). In this section of the TASR corridor (GNWT DOT, 2016), regional topography is generally subdued with plains and gently rolling hills. Drainage ranges from 'well' to 'moderately well' with occasional seasonal tributaries. Vegetation includes regenerating jack pine forest, ephemeral stream crossing/swampland, dwarf shrub and mixed stands. The general area was subjected to forest fires within the last decade.

Based on available surficial geology mapping conducted by the Geological Survey of Canada, and previous project terrain mapping (Kavik AXYS Inc, 2008 and GNWT DOT, 2016), natural overburden material in the area has been mapped as till, coarse beach glacio-lacustrine and fine glacio-lacustrine material associated with glacial Lake McConnell, and occasional veneers of organic or fluvial materials overlying bedrock. Within stream channels and floodplains, recent fluvial deposits are expected. Based on geological mapping published by the Geological Survey of Canada (Okulitch, A.V, 2006), the site is mapped within the Interior Platform geologic province, situated over Paleozoic aged sedimentary rocks of the Lonely Bay Formation consisting of brown limestone and minor dolostone.

2.3 CLIMATE & PERMAFROST

2.3.1 Climate

Based on a review of historic climate data completed using the Yellowknife Airport (Climate Reference ID: 2204100), Whatì meteorological station (Lac la Martre, Climate Reference ID: 2202678) and other sources (GNWT, 2016), it is understood that the TASR area has a subarctic climate (Dfc according to the Köppen climate classification system) characterized by generally relatively cold winters followed by short summers. It is noted that the Whatì station is located approximately 13 km west of the northern limit of the TASR and the Yellowknife station is located approximately 100 km east of the southern limit of the TASR.

Average annual daily mean temperatures are about -4.3°C (Yellowknife Station) to -4.7°C (Whatì Station), with the lowest average daily winter temperatures generally occurring in January, while the warmest month (based on the average temperature) occurs in July. The average annual precipitation is estimated on the order of 288.6 mm, with an average annual rainfall of 170.7 mm generally occurring throughout June through September, and an average annual snowfall of 157.6 cm generally occurring from September through May (Yellowknife Station).

The average freezing and thawing indices between 1981 and 2010 have been 3343.1 C° days and 1813.3 C° days, respectively (Yellowknife Station). A study completed by Holubec, et. al., using data from 1978 to 2008 in their model was adapted by CSA (2010). The CSA study suggests a warming trend of 0.58°C per decade within the Central Arctic region (including the TASR site). As per Table 5.2 in CSA (2010), seasonal mean temperature change under moderate (A1B) green-house gas scenarios, the mean annual temperatures for the Arctic Sector C1 are projected to be 1.3°C (2011-2040), 2.7°C (2041-2070), and 3.7°C (2071 – 2100) respectively. It is noted that the TASR site is located near the margins of the C1 and W1 sectors, therefore the temperatures will likely be some combination of the two sector predictions. This report references the temperatures for Artic Sector C1 which are warmer temperatures compared to Artic Sector C2.

2.3.2 Permafrost

Canada Permafrost mapping from the National Atlas of Canada (Heginbottom et al. 1995) shows the TASR site lies within the zone of extensive discontinuous permafrost, with an estimated 50% and 90% of the landscape covered. It is understood that no public thermistor or intrusive investigation records exist for the immediate vicinity of the TASR. Previous reconnaissance trips by earlier terrain mapping crews and GNWT personnel did not encounter any apparent permafrost landforms or thermokarst zones within the corridor, however a zone affected by thermokarst processes was noted between Whati, Behchoko, and the area north of Slemon Lake Kavik (AXYS Inc, 2008 and GNWT DOT, 2016).

Based on regional studies completed in surrounding areas (GNWT, 2016), permafrost is anticipated to be relatively warm and correlated with forest cover type areas underlain by finer-textured glacial and post-glacial sediments such as glaciolacustrine and lacustrine deposits, as well as peatlands where organic material contribute to the forming and preservation of permafrost. Ground ice content, if present in these finer grained deposits in the upper 10 to 20 m is anticipated to be <10% to 20% ice by volume (Heginbottom et al. 1995). Ground ice is generally expected to be less common in areas of exposed bedrock and where the underlying sediments are coarse and vegetation cover is thin.

Permafrost near Yellowknife is reported to be generally warm (>-2°C), less than 50 m thick with active layer thickness <1 to up to 3 m (Wolfe, 1998). Permafrost conditions along the nearby Highway 3 have been reported as typically warmer than -1°C, with an active layer thickness varying from <0.7 m to 1.5 m. Extensive permafrost degradation has been noted along the Highway in recent years with settlements in soil-covered areas generally attributed to the degradation of the ice-rich permafrost subgrade particularly where it was constructed adjacent to a water body and where the road crossed over the old alignment (Stirling et al, 2015; BGC, 2011; Wolfe et al, 2015;). Permafrost, where present, will be susceptible to degradation due to ground disturbance, such as removal of trees and surface vegetation or earthworks.

Recent studies commissioned by GNWT have reported that climate change trends have negatively impacted and are projected to continue to negatively impact permafrost conditions in the region (Dillon 2007; BGC, 2011). Continued warming, changes in freeze-thaw patterns, and ultimately degradation of permafrost in the region are anticipated due to increasing temperatures and amounts of precipitation, and decreases in snow and ice cover.

3.0 INVESTIGATION PROCEDURES

3.1 FIELD INVESTIGATION

The geotechnical field investigation for the bridge, conducted as part of the overall TASR alignment geotechnical program between March 2 and March 13, 2017, consisted of three geotechnical holes as shown on the General Layout and Borehole Location Plan, Drawing No. 2 in Appendix B. It is to be noted that the layout is conceptual and the final design details will be determined at a later date. Two boreholes were advanced at the proposed bridge abutments (BH17-31B and BH17-33B) and one borehole (BH17-32B) was advanced at the proposed center pier location within the floodplain. Borehole locations were selected by GNWT and were established in the field by Stantec using a Trimble Geo XH GPS unit.

Boreholes were completed using a skid mounted drill rig capable of auger and diamond drilling. The drill rig was provided and operated by Northtech Drilling Ltd. Boreholes were to be advanced to a target depth of 30 m below existing ground surface using solid stem augurs and

NW casing with regular sampling using conventional 50 mm split spoon samplers during the performance of the Standard Penetration Test (SPT), or 3 m into bedrock, whichever came first. Between 4.3 m and 13 m of rock was cored using a NQ core bit. The drilling depth was increased to allow for additional sampling based on the quality of the rock obtained at site.

The field work was conducted under the part-time monitoring of a GNWT field representative and full-time supervision of Justin Matthew, P.Eng., and Jim Oswell, PhD., P.Eng. (Stantec) who maintained detailed logs and obtained representative samples from the various strata encountered. Subsurface conditions were classified in general accordance with the procedures outlined in the attached explanatory key: Symbol and Terms Used on Borehole and Test Pit Records with soil descriptions prepared in accordance with ASTM D2487 and D2488. Temperatures of soils samples were measured by a handheld infrared thermometer on recovery at surface. Our observations of the temperature readings suggest the drilling process altered the temperature of the soil samples and that these measurements should not be considered representative of in situ conditions. For example, soil samples collected from the augers within the seasonal frost layer (denoted as AS) had temperature readings greater than 0° C. Frozen soils were classified in accordance with ASTM D4083 and D7099. Groundwater levels were estimated in the open boreholes at the time of drilling with water level tape and/or the moisture condition of the recovered samples.

On completion of drilling, thermistor strings were installed in all three boreholes and backfilled with cuttings and sand. Frozen sand was broken up mechanically so that the material could be placed in contact with the instrument without larger frozen fragments damaging the thermistor beads.

3.2 LOCATION AND ELEVATION SURVEY

Final borehole locations and geodetic elevations were surveyed in the field by Stantec personnel using a Trimble Geo XH GPS with decimeter accuracy capability. The accuracy of the Trimble unit may be affected by satellite coverage at the time of the survey. Table 3.1 summarizes the borehole information.

Table 3.1: Borehole Summary

	Boreholes		
	BH17-31B	**BH17-32B**	**BH17-33B**
NAD83 / UTM Zone 11N Coordinates Northing Easting	 6955478 508207	 6955504 508219	 6955522 508225
Ground Surface Elevation, m	260.3	259.8	260.7
Total Depth Drilled, m	19.8	19.0	24.6
End of Borehole Elevation, m	240.5	240.8	236.1
Number of Soil Samples	11	14	13
Number of Rock Core Samples	8	7	7

3.3 LABORATORY TESTING

All samples were taken to the Stantec Edmonton or Calgary laboratories for detailed classification and testing. Sample preservation and handling of frozen samples was in general accordance with industry standard practices (ASTM WK24243, ASTM Special Technical Publication, no 599:88-112).

Selected soil samples underwent gradation analysis, Atterberg Limits, and moisture content testing. The laboratory testing summary is shown in Table 3.2 below.

Table 3.2: Laboratory Testing for Crossing #8

Laboratory Testing	Moisture Content	Gradation Analysis	Atterberg Limits	Compression
Number of Tests	48	19	6	4

To assess the potential for corrosion of buried steel elements and potential for sulphate attack on buried concrete elements, three samples of the native overburden material was tested at Maxxam Analytics for pH, water soluble sulphate and chloride concentrations, and resistivity. The results are reported in Section 4.4.

Samples remaining after testing will be placed in storage for a period of one year after issuance of the final report. After the storage period, the samples will be discarded unless we are directed otherwise by Tlicho Engineering and Environmental Services Ltd.

4.0 SUBSURFACE CONDITIONS

4.1 SUBSURFACE PROFILE

The subsurface conditions observed in the boreholes are presented in detail on the Borehole Records provided in Appendix C with further discussion below on the individual soil units encountered. An explanation of the symbols and terms used to describe the Borehole Records is provided in Appendix C.

The temperature of soil samples was measured in the field using an infrared thermometer and are provided on the Borehole Records. Ground temperatures inferred from temperature measurements of soil samples should be considered with extreme caution. Soil sample temperatures may be either warmer than in-situ due to drilling disturbance or be colder than in-situ due to cold air temperature exposure of the soil samples prior to temperature measurement.

It should be noted that the blow counts and relative density/consistency descriptions of frozen soils in the Appendix C should be used with caution. It is highly likely, particularly for cohesive soils, that the strengths implied by the blow counts will be significantly reduced by thawing.

In general, the subsurface stratigraphy at the bridge location consisted of overburden materials overlying relatively shallow bedrock. The overburden soils were frozen to depths of 1.5 m to 2.4 m at BH17-31B and BH17-32B and up to 5.5 m at BH17-33B. The overburden soils ranged widely from silt and clay at BH17-31B to sands and silts at BH17-32B and BH17-33B. There was significant organic content in the uppermost 3 m of BH17-32B. The stratigraphic profile of the site is shown on Drawing No. 3 in Appendix B.

4.1.1 Organic Soil

A surficial layer of frozen rootmat/topsoil was encountered at BH17-31B and BH17-33B and ranged between 100 mm and 305 mm in thickness. A 3 m thick layer of dark grey to black sandy silt with organics was encountered immediately beneath the ice at BH17-32B. The material encountered within BH17-32B is a recent alluvial deposit and likely very similar in composition to the topsoil encountered at the abutments, on higher ground.

Moisture contents of 68% and 184% was measured in the sandy silt with organics in borehole BH17-32B.

4.1.2 Silty Sand

At BH17-33B frozen brown to rusty brown silty sand was encountered at ground surface and extends to a depth of 1.7 m. Temperatures of the soil samples obtained from the infrared thermometer ranged from -6.2 to -2.3°C. The frozen soil description of the layer was N_f to N_{bn}.

The SPT N-value of the silty sand was 54 blows for 0.3 m. In unfrozen soil this corresponds to a relative density of very dense, however it is likely that this soil will be less dense after thawing.

Grain size distribution and moisture content tests carried out on a representative sample of the material yielded the following results:

Gravel:	0%
Sand:	52%
Fines:	48%
Moisture content:	36%

The grain size distribution curve is provided in Figure 1, Appendix D. The Unified Soil Classification System (USCS) group symbol for this layer is SM (silty sand).

4.1.3 Silt to Sandy Silt

Sandy Silt was encountered in all three borings. Silt was encountered at boring BH17-33B.

BH17-31B

Sandy silt was encountered in borehole BH17-31B immediately below the surficial organic soil. Temperatures of the sandy silt samples were not recorded at the time of drilling however based on the observations made in the field the frozen ground description of the layer was N_{be} to V_X.

The SPT N-values for the sandy silt ranged between 8 and 13 per 0.3 m.

Grain size distribution, moisture content, and Atterberg limit tests carried out on representative samples of the sandy silt yielded the following results:

Gravel:	0%
Sand:	47%
Fines (silt and clay):	53%
Silt size:	43%
Clay size:	10%
Moisture Content:	17% to 115%

Atterberg limit test carried out on one representative sample from this layer indicated a plasticity index of 9. The USCS group symbol for this layer is ML (sandy silt). Representative grain size distribution plots for this layer are given in Figure 2 and the corresponding plasticity chart is given in Figure 13 of Appendix D.

BH17-32B

Sandy silt was encountered in borehole BH17-32B immediately below the surficial organic soil and transitioned to silt at approximately 4.5 m depth. Temperatures of the sandy silt and silt samples obtained from the infrared thermometer at the time of drilling ranged from +4.0 to +2.5°C.

The SPT N-values for the sandy silt ranged between 0 and 1 per 0.3 m for the unfrozen soils, and between 2 and 16 blows per 0.3 m for the frozen portion of the deposit. These blow counts indicate that the unfrozen soils have a very loose consistency and become compact when frozen. The zone where very low blow counts were measured also corresponds to a moisture content of 167% and an organic odor noted during the drilling. These factors are all consistent with the presence of organics at approximately 4.2 m depth below ground surface.

Grain size distribution, moisture content, and Atterberg limit tests carried out on representative samples of the sandy silt yielded the following results:

Gravel:	0%
Sand:	38 to 46%
Fines (silt and clay):	55 to 62%
Silt size:	43 to 48%
Clay size:	12 to 14%
Moisture Content:	36 to 167%

Atterberg limit test carried out on one representative sample from this layer indicated a plasticity index of 11. The USCS group symbol for this layer is ML (sandy silt/silt). Representative grain size distribution plots for this layer are given in Figures 3 to 5 and the corresponding plasticity chart is given in Figure 13 of Appendix D.

<u>BH17-33B</u>

Sandy silt was encountered in borehole BH17-33B immediately below the silty sand at a depth of approximately 1.7 m. An interbedded silty sand layer was observed at the transition from silt to underlying clay layer. Silt was encountered below the lean clay with sand below a depth of approximately 10.4 m depth. Temperatures of the sandy silt obtained from the infrared thermometer at the time of drilling ranged from less than 0 to +4.0°C. Temperatures of the silt obtained from the infrared thermometer at the time of drilling were approximately 0°C. The frozen ground description of the layer was $V_{x,}$ and N_{be}. It is observed that the soils sampled from the frozen zone have moisture contents in excess of 100%, which is indicative of significant proportions of ice within the sample.

The SPT N-values of the frozen sandy silt and silty sand ranged between 50 and 61 blows per 0.3 m suggesting hard/very dense relative density. It is anticipated that the high blow counts are associated with the frozen state and will be less if thawing occurs.

Grain size distribution and moisture content tests carried out on representative samples of the sandy silt and silt yielded the following results:

Gravel:	0 to 6%
Sand:	13 to 36%
Fines (silt and clay):	58 to 87%
Silt:	80%
Clay:	7%
Moisture Content:	55 to 191%

The USCS group symbol for this layer is ML (sandy silt/silt). Representative grain size distribution plots for this layer are given in Figures 6 and 7 of Appendix D.

4.1.4 Gravelly Lean Clay with Sand to Sandy Lean Clay

Gravelly lean clay with sand was observed in borings BH17-31B and BH17-32B. Sandy lean clay was observed in boring BH17-33B.

BH17-31B

Gravelly lean clay with sand was encountered in borehole BH17-31B between depths of 3.9 m and 9.7 m. Some gravel was noted within the clay layer. The clay was observed to be unfrozen at the time of drilling.

The SPT N-values of the unfrozen gravelly clay ranged between 5 and 12 blows per 0.3 m suggesting firm to stiff consistency.

Grain size distribution, moisture content, and Atterberg Limit tests carried out on representative samples of the gravelly lean clay with sand yielded the following results:

Gravel:	27%
Sand:	16%
Fines (silt and clay):	56%
Silt size:	46%
Clay size:	10%
Moisture Content:	11% to 27%

Atterberg limits tests carried out on one representative sample from this layer indicated a plasticity index of 11. The USCS group symbol for this layer is CL (gravelly lean clay with sand). Representative grain size distribution plots for this layer are given in Figure 8 and the corresponding plasticity charts are given in Figure 14 of Appendix D.

BH17-32B

Gravelly lean clay with sand was encountered in borehole BH17-32B between depths of 6.7 m and 10.7 m below ground surface. Some cobbles were noted within the clay layer. Temperatures of the clay samples obtained from the infrared thermometer at the time of drilling ranged from +4.5 to +6.5°C.

The SPT N-values of the unfrozen gravelly clay ranged between 6 and 11 blows per 0.3 m suggesting firm to stiff consistency.

Grain size distribution, moisture content, and Atterberg limit tests carried out on representative samples of the lean clay with sand yielded the following results:

Gravel:	20 to 26%
Sand:	17 to 18%
Fines (silt and clay):	56 to 63%
Silt size:	46%
Clay size:	10%
Moisture Content:	8% and 14%

Atterberg limits tests carried out on one representative sample from this layer indicated a plasticity index of 10. The USCS group symbol for this layer is CL (gravelly lean clay with sand). Representative grain size distribution plots for this layer are given in Figures 9 and 10 and the corresponding plasticity chart is given in Figure 14 of Appendix D.

<u>BH17-33B</u>

At BH17-33B frozen grey sandy lean clay was encountered at a depth of 5.2 m below the ground surface. Temperatures of the soil samples obtained from the infrared thermometer ranged from +4.0 to <0°C. The frozen ground description of the layer was V_X.

The SPT N-values of the frozen sandy clay ranged between 95 and 98 blows per 0.3 m suggesting hard consistency. It is anticipated that the high blow counts are associated with the frozen state and will be less if thawing occurs. It was also noted that blow counts of 100 for 0.1 m were measured at a depth of 8.9 m below ground surface, however this is believed to be associated with the presence of gravel and is not representative of the soil stratum.

Grain size distribution, moisture content, and Atterberg limit tests carried out on a representative sample of the material yielded the following results:

Gravel:	10%
Sand:	26%
Fines:	64%
Silt:	56%
Clay	8%
Moisture content:	18 to 41%

Atterberg limits test carried out on a representative sample of the layer indicated a plasticity index of 10. The USCS group symbol for this layer is CL (sandy lean clay). Representative grain size distribution plots for this layer are given in Figure 11 and the corresponding plasticity results are given in Figure 14 of Appendix D.

4.1.5 Glacial TILL

Glacial till was observed in the boreholes overlying bedrock. Glacial till deposits are heterogeneous, unstratified deposits of gravel, sand, and silt and clay sized particles deposited directly by glaciers. The mineralogy and lithology of till is dependent on the source of the materials, therefore may vary widely (Holtz et. al., 2011).

BH17-31B

Clayey gravel with sand till was encountered between 9.7 m and 11.6 m below ground surface. The gravel was observed to be unfrozen at the time of drilling.

Pocket pen tests were completed on the clayey portions of the sample at the time of drilling with results of greater than 150 kPa and 200 kPa, which corresponds to a very stiff to hard consistency. SPT N-values of 33 and 87 blows per 0.3 m were measured in the till.

Grain size distribution, moisture content, and Atterberg limit tests carried out on representative samples of the clayey gravel with sand yielded the following results:

Gravel:	31%
Sand:	23%
Fines (silt and clay):	46%
Silt size:	38%
Clay size:	8%
Moisture Content:	10 to 21%

An Atterberg limits test carried out on one representative sample from this layer indicated a plasticity index of 17. The USCS group symbol for this layer is GC (clayey gravel with sand). Representative grain size distribution plots for this layer are given in Figure 12 and the corresponding plasticity charts are given in Figure 15 of Appendix D.

BH17-32B

Sandy silt to silty sand till was encountered between 10.7 m and 15.1 m below ground surface. The till is described as sandy silt (ML) to silty sand (SM) based on the Unified Soil Classification System (USCS). Cobbles were observed below 10.7 m depth and described as frequent below 11.7 m depth. Rock fragments were observed below 12.5 m depth. The till was observed to be unfrozen at the time of drilling.

Soil gradation testing was not completed on a sample of this material due to poor sample recovery, therefore classification is based on visual observations.

Moisture contents of the recovered soil samples ranged from 7% to 32%.

BH17-33B

Clay with gravel till was encountered between 11.3 m and 11.5 m below ground surface. The till is described as clay (CL) based on the Unified Soil Classification System (USCS). Calcite and chalk inclusions were observed within the samples during drilling. The till was observed to be unfrozen at the time of drilling.

Soil gradation testing was not completed on a sample of this material due to poor sample recovery, therefore classification is based on visual observations.

Moisture contents of the recovered soil samples ranged from 28% to 32%.

4.1.6 Bedrock

Bedrock was encountered in all three borings. The bedrock surface was encountered at depths of 11.6 m, 12.8 m, and 11.5 m below ground surface, respectively, in boreholes BH17-31B, BH17-32B, and BH17-33B. The bedrock consisted predominantly of grey and white dolomite with occasional clay seams. A detailed description of the rock core is provided in the Field Bedrock Core Logs in Appendix C. Rock core photographs are also provided in Appendix C.

Rock Quality Designation (RQD) values measured on the retrieved bedrock core ranged between 0% and 100%, indicating a very poor to excellent rock mass quality. The Total Core Recovery (TCR) of the bedrock ranged from 18% to 100%. The bedrock was highly weathered to fresh. Weathered seams with clay infilling were observed in both boreholes; the thickness of the seams ranged from about 25 mm to up to 100 mm.

Unconfined compressive strength tests were carried out on four bedrock samples. The results of these tests are summarized in Table 4.1. The unconfined compressive strength from the four tests ranged between 6.7 MPa and 13.5 MPa which indicates the bedrock is typically weak. Five bedrock samples from boreholes BH17-31B, BH17-32B, and BH17-33B at depths between 15.6 m and 24.4 m were only slightly reactive in response to hydrochloric acid tests.

Table 4.1: Results of Unconfined Compressive Strength of Rock Cores

Borehole No	Depth (m)	Test Elevation (m)	Unconfined Compressive Strength (MPa)
BH17-31B	13.7 to 13.8	246.6	13.5
BH17-31B	15.6 to 15.7	244.6	6.7
BH17-31B	12.1 to 12.2	248.2	7.4
BH17-32B	18.3 to 18.4	241.4	10.3

4.2 PERMAFROST CONDITIONS

Infrared thermometer readings were taken of samples throughout the drilling. The readings ranged between +6.6 to -6°C, as indicated on the borehole logs (Appendix C).

Thermistors were installed in each of the three borings (BH17-31B to BH17-33B) between March 9 and 14, 2017. Calibration sheets for the thermistors are included in Appendix E. Several readings taken between the installation date and April 4, 2017 and are plotted in Figures 16 to 18 in Appendix E. Due to the temperature differential between the backfill and the boring sidewalls the initial readings appear to behave erratically, however, with time the thermistor responses have become more representative of the subsurface temperatures.

The thermistor readings are considered to be a more reliable indication of the temperature of the soils compared to the infrared thermometer readings. The infrared thermometer was used during sampling when the soils have been heated by friction generated by the action of the drill. The sample temperatures measured when samples were exposed to very cold air temperatures also displayed erratic values. Therefore, the reported infrared temperature readings should be used with caution.

Based on the visual examination and infrared thermometer readings of the recovered auger and split spoon samples, frozen soil conditions were inferred to depths of 2.4 m in BH17-31B, 1.5 m in BH17-32B, and to 11.5 m in BH17-33B.

The April 4, 2017 thermistor readings from BH17-31B indicate that the soil temperature is near freezing, 0.2 to 0.8 °C to a depth of approximately 8.0 m (see Figure 16, Appendix E). The thermistor readings from BH17-32B indicate that the soils range between +0.1 and +1.3°C on April 4, 2017 (see Figure 17, Appendix E). The thermistor readings obtained from BH17-33B (see Figure 18, Appendix E) indicate that the temperatures are well below freezing in the uppermost 2 m but below that point many of the readings are between -1°C and +1°C. The results suggest that permafrost conditions are likely present at the abutment locations (BH17-31B and BH17-33B) but the soils at the proposed center pier (BH17-32) are unfrozen. Additional readings are recommended until the thermal profile of the soils at this location can be confirmed to be stable.

4.3 GROUNDWATER

Groundwater was encountered in the open boreholes at the time of drilling at the proposed abutment locations (BH17-31B and BH17-33B). The groundwater was inferred to be at surface within the floodplain at borehole BH17-32B. The groundwater depths observed during the drilling are summarized in Table 4.2.

The groundwater levels were recorded in winter conditions and will likely vary seasonally. Changes in the groundwater, and the water levels of the Duport River, due to seasonal fluctuations in response to precipitation events should be anticipated. In permafrost terrain, groundwater will be confined to the seasonal active layer.

Table 4.2: Summary of Groundwater Levels

Borehole No.	Observation/Measurement Date	Groundwater Depth (m)	Ground Surface Elevation (m)	Groundwater Elevation (m)
BH17-31B	March 9, 2017	0.7	260.3	259.6
BH17-32B	March 5, 2017	Ground surface	259.8	259.8
BH17-33B	March 15, 2017	2.4	260.7	258.3

4.4 CHEMICAL TEST RESULTS

Three samples of the native overburden material at Boreholes 17-31B, 17-32B, and 17-33B was tested for pH, water soluble sulphate and chloride concentrations, and resistivity at Maxxam Analytics. The analysis results are provided in Table 4.3 and in Appendix D.

Table 4.3: Results of Chemical Analysis

Borehole No	Sample No.	Depth (m)	pH	Chloride (%)	Sulphate (%)	Resistivity (Ohm-m)
BH17-31B	SS2	1.5 to 2.0	7.6	0.0015	0.13	4.4
BH17-32B	AS3	1.0 to 1.5	7.8	0.012	0.11	3.9
BH17-33B	SS4	3.0 to 3.5	7.6	0.018	0.16	3.9

5.0 CLOSURE

Use of this report is subject to the Statement of General Conditions provided in Appendix A. It is the responsibility of Tlicho Engineering and Environmental Services Ltd., who is identified as "the Client" within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec Consulting Ltd. should any of these not be satisfied. The Statement of General Conditions addresses the following:

- Use of the report
- Basis of the report
- Standard of care
- Interpretation of site conditions
- Varying or unexpected site conditions
- Planning, design or construction

This report was written by Sylvia Dooley, M.ScE. and reviewed by Christopher McGrath, P.Eng. and Jim Oswell, P.Eng. Mr. McGrath and Dr. Oswell are registered members of the Northwest Territories and Nunavut Association of Professional Engineers and Geoscientists. We trust that the information contained in this report is adequate for your present purposes. If you have any questions about the contents of the report or if we can be of any other assistance, please contact us at your convenience.

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6.0 REFERENCES

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2009. Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) (ASTM D2488). ASTM International, West Conshohocken, PA.

ASTM. 2010. Standard Terminology Relating to Frozen Soil and Rock (ASTM D7099). ASTM International, West Conshohocken, PA.

ASTM. 2011. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

ASTM. 2016. Standard Practice for Description of Frozen Soils (Visual-Manual Procedure) (ASTM D4083). ASTM International, West Conshohocken, PA.

BGC Engineering Inc. 2011. Highway 3 – Climate Change Vulnerability Assessment – Final Report.

Canadian Standards Association (CSA). 2010. Technical Guide Infrastructure in permafrost: A guideline for climate change adaptation. Canadian Standards Association, Mississauga, ON, Canada.

Dillon Consulting Ltd. 2007. Climate Change and Transportation in the NWT. March 2007.

Environment Canada. Warming Trends °C/Decade, Based on homogenized temperature data – the most recent 30 yr record (1981 – 2010); Environment Canada.

Environment Canada. (2016, September 1) Canadian Climate Normals 1981–2010. Yellowknife Station. Retrieved from http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProv&lstProvince=NT&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=1706&dispBack=0

GNWT, 2009. Ecosystem Classification Group (ECG) 2009. Ecological Regions of the Northwest Territories: Taiga Shield. Department of Environment and Natural Resources, GNWT. Yellowknife, NT.

GNWT DOT, 2016. Proposed Tlicho All-season Road, Project Description Report. March 2016

Heginbottom, J.A., Dubreuil, M.A., and P.A. Harker. 1995. Canada-Permafrost; National Atlas of Canada, 5th edition, Plate 2.1. Geomatics Canada, National Atlas Information Service and Geological Survey of Canada (MCR 4177).

Kavik AXYS Inc. 2008a. Multi-Level Mapping and Route Analysis – Tlicho Transportation Corridor. Route Identification and Evaluation. Yellowknife, NT. January 2008.Project No. Project No. 144902005.

Okulitch, A.V. 2004. Geological compilation of Phanerozic Bedrock Geology (Map NP-11/12-G), Slave River District of MacKenzie, Northwest Territories. Geological Survey of Canada, Open File 5281.

Stantec, 2015.Tli Cho Road Alignment, Hydrologic and Hydraulic Study. Project No. 144902005.

Wolfe, 1998. Living with frozen ground : a field guide to permafrost in Yellowknife, Northwest Territories, edited by Stephen A. Wolfe ; contributions by Stephen A. Wolfe

S.A. Wolfe, P.D. Morse, T.E. Hoeve, W.E Sladen, S.V. Kokelj, L.U. Arenson, 2015. Disequilibrium permafrost conditions on NWT Highway 3

7.0 BIBLIOGRAPHY

Andersland, O.B., and Ladanyi, B. 1994. An Introduction to Frozen Ground Engineering. Chapman & Hall Inc., New York, NY, USA.

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2000. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

ASTM. 2000. Standard Practice for Description of Frozen Soils (Visual-Manual Procedure) (ASTM D4083). ASTM International, West Conshohocken, PA.

Canadian Foundation Engineering Manual (CFEM). 2006. Fourth Edition. Canadian Geotechnical Society, 488 p.

CHBDC. 2014. Canadian Highway Bridge Design Code. Canadian Standards Association, Mississauga, Ontario.

GSC, 1965. Glacial Lake McConnell and the surficial geology of parts of Slave River and Redstone River map areas, District of Mackenzie; Craig, B G. Geological Survey of Canada, Bulletin 122, 1965,; 44 pages, doi:10.4095/100639. Natural Resources Canada. 1995: Canada Permafrost; The National Atlas of Canada 5th Edition, scale 1:7 500 000.

GSC, 1989. Glacial Features Around the Keewatin Ice Divide, Northwest Territories; Aylsworth, J M; Shilts, W. Geological Survey of Canada, Preliminary Map 24-1987, 1989, ; 2 sheets, doi:10.4095/126992.

Kerr and Wilson, 2000. 2000-C3. Preliminary surficial geology studies and mineral exploration considerations in the Yellowknife area, Northwest Territories. D.E. Kerr and P. Wilson.

APPENDIX A

Statement of General Conditions

STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec Consulting Ltd. and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec Consulting Ltd.'s present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec Consulting Ltd. is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec Consulting Ltd. at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec Consulting Ltd. must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec Consulting Ltd. will not be responsible to any party for damages incurred as a result of failing to notify Stantec Consulting Ltd. that differing site or sub-surface conditions are present upon becoming aware of such conditions.

PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec Consulting Ltd., sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec Consulting Ltd. cannot be responsible for site work carried out without being present.

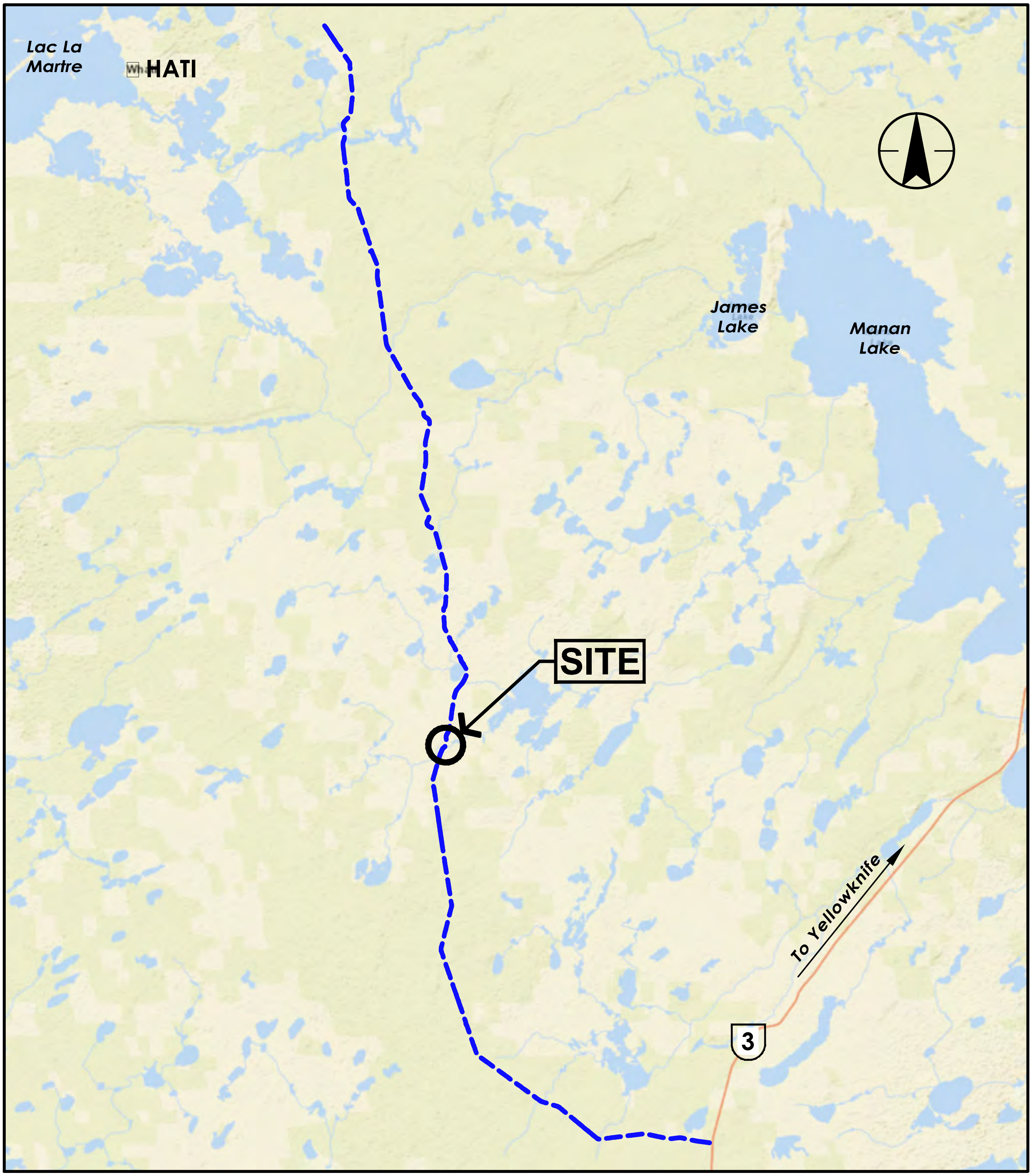
APPENDIX B

Drawing No. 1 – Site Location Plan

Drawing No. 2 - Borehole Location Plan

Drawing No. 3 – Subsurface Profile

Site Photos



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PROPOSED ALIGNMENT

NOTES

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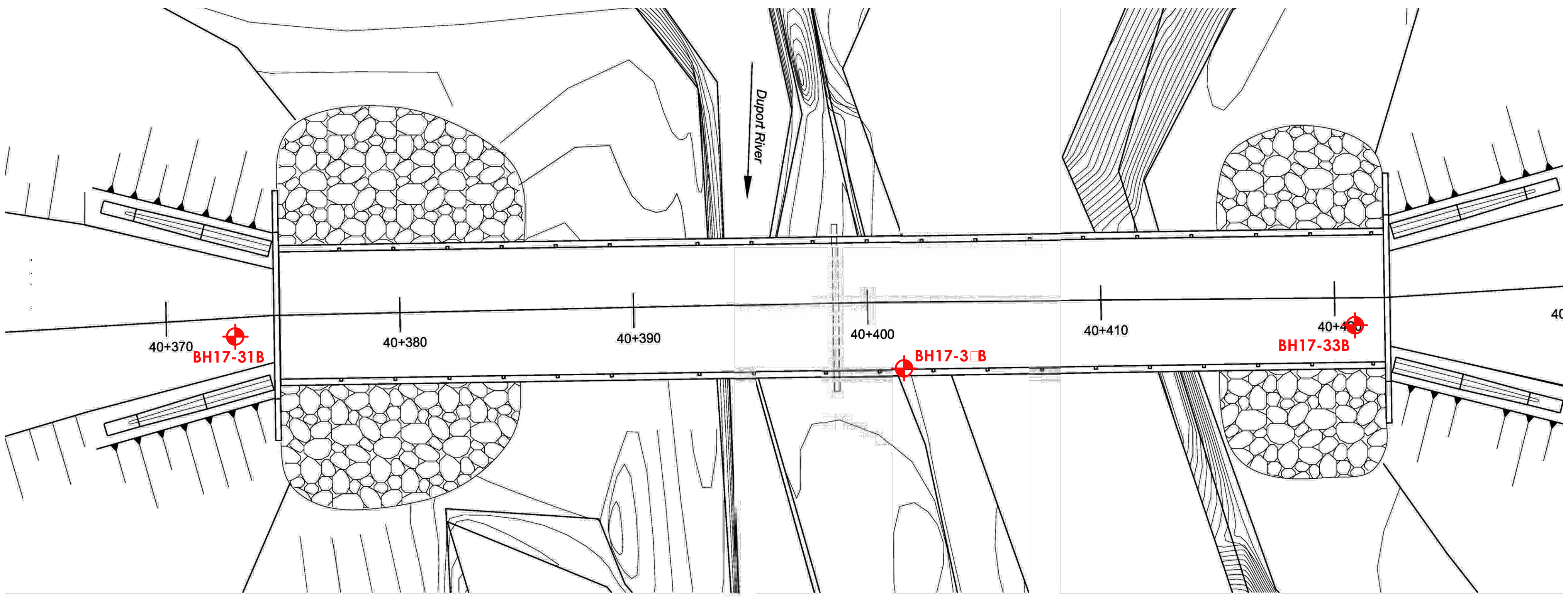
BRIDGE CROSSING #8, DUPONT RIVER, NWT

Drawing No.

1

Title

□EY PLAN



SITE PLAN
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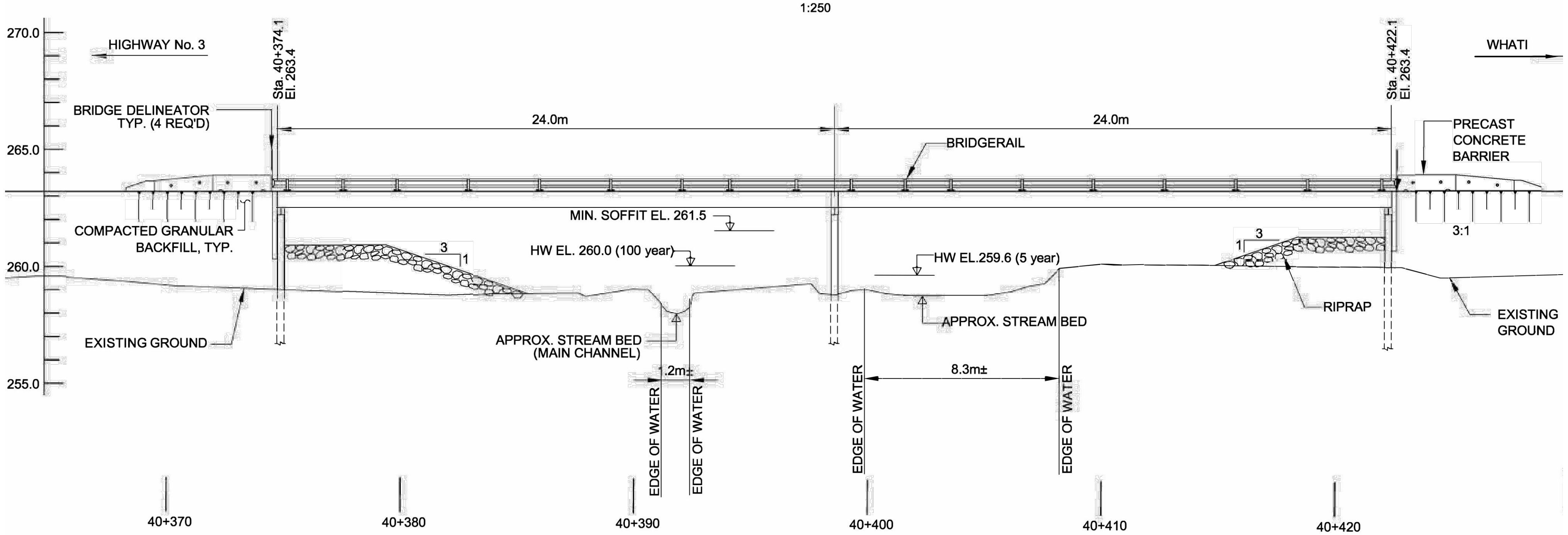

ELEVATION
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PLAN
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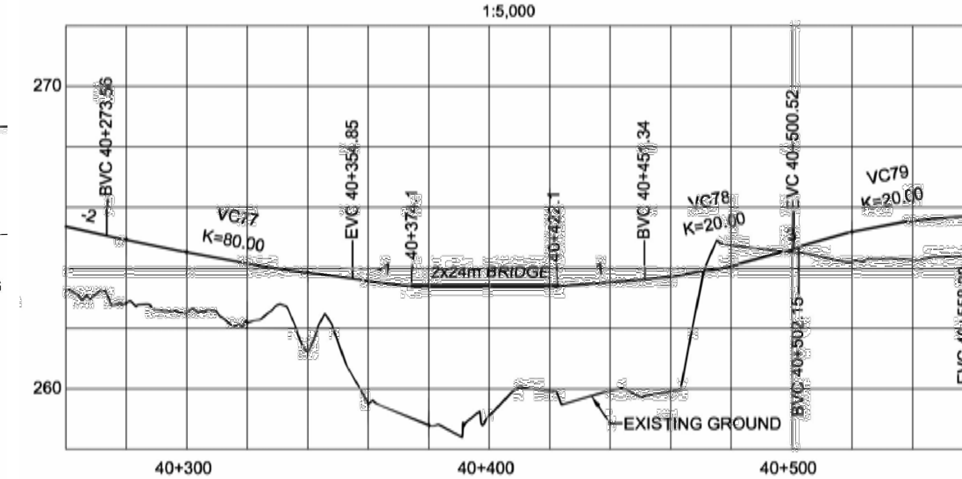

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APPROXIMATE BOREHOLE LOCATION

NOTES

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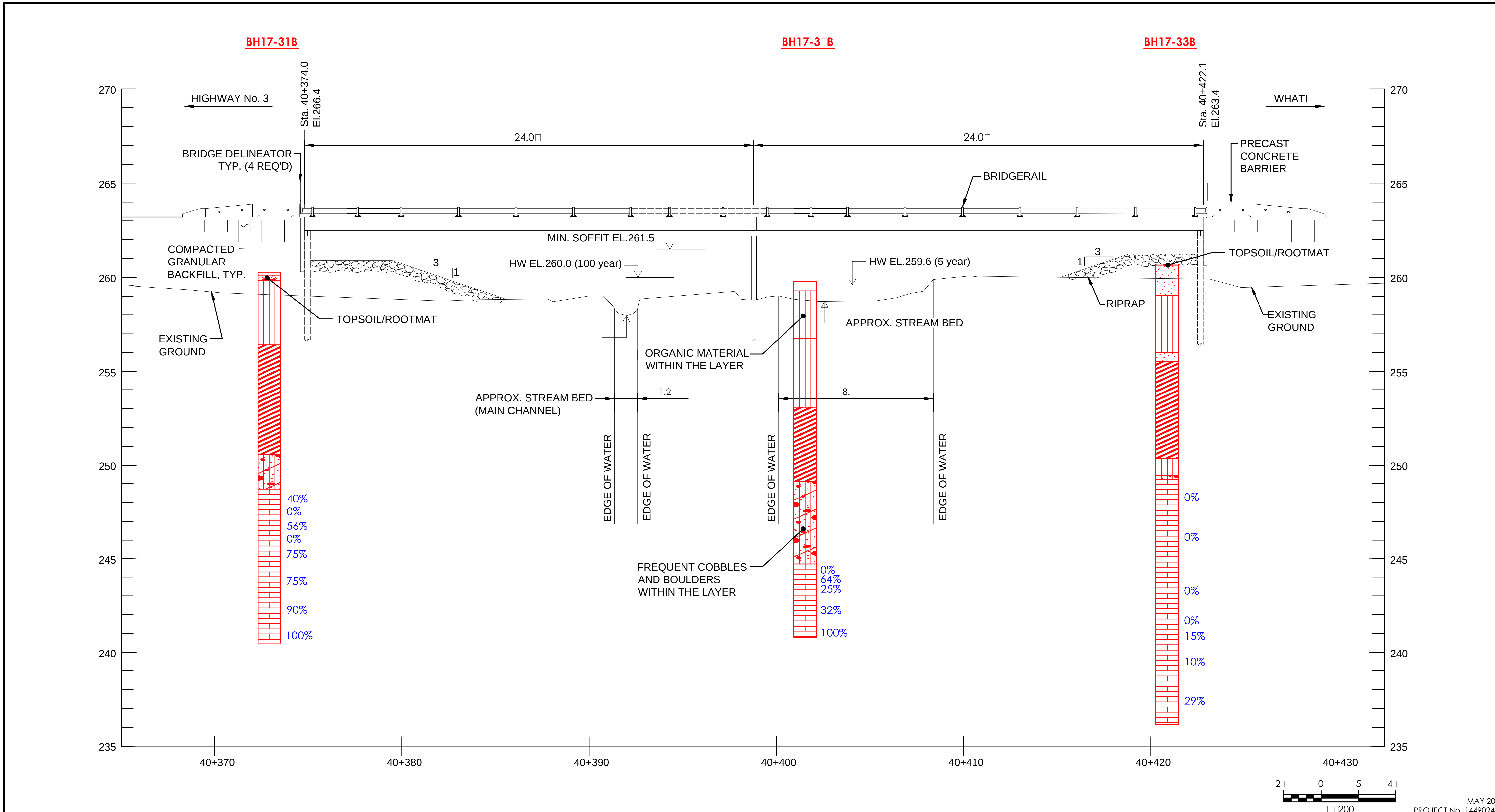
Drawing No.

2

Title

GENERAL LAYOUT AND BOREHOLE LOCATION PLAN



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- □9□ R□D (ROC□ □UALITY DESIGNATION)
- TOPSOIL □ROOTMAT
- SANDY LEAN CLAY TO GRAVELLY LEAN CLAY WITH SAND
- SANDY SILT
- SILTY SAND
- TILL□SANDY SILT, SILTY SAND, CLAYEY GRAVEL WITH SAND
- DOLOMITE MUDSTONE

NOTES

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BRIDGE CROSSING #8, NWT

Drawing No.

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SUBSUR□ACE PRO□ILE

Photo No. 1: Borehole Location BH17-31B

Photo No. 2: Borehole Location BH17-31B

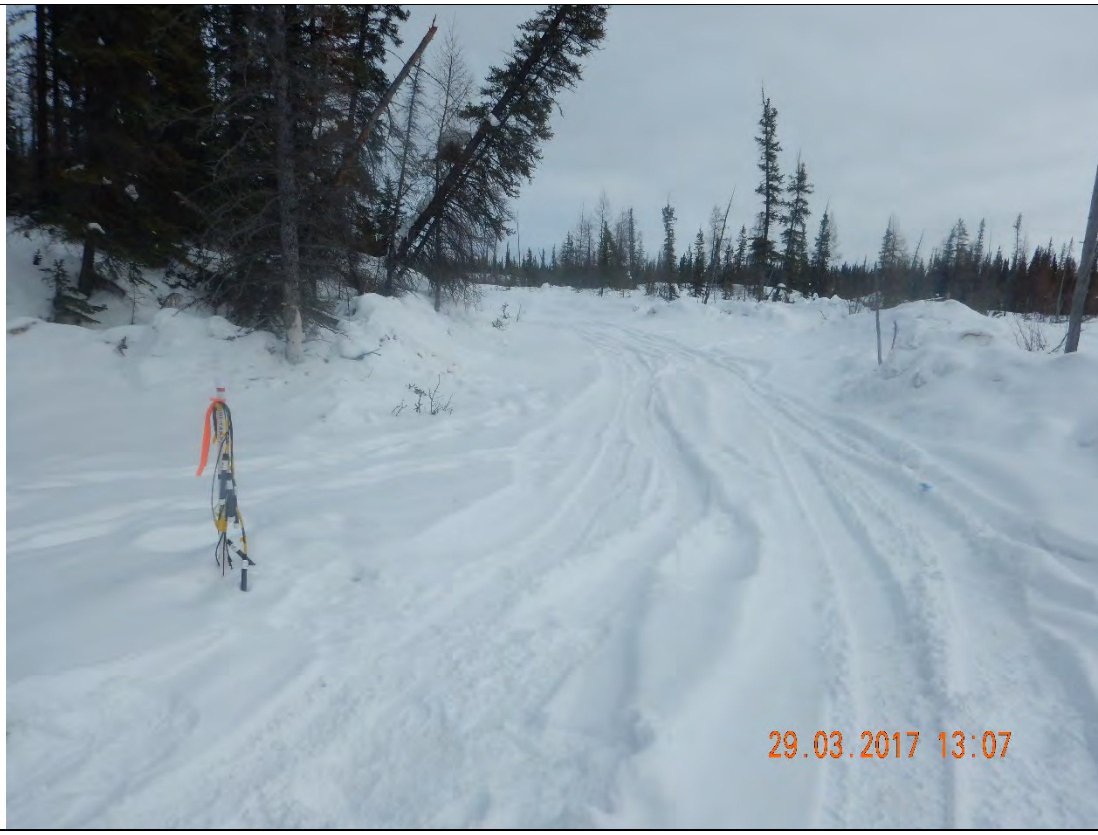


Photo No. 3: Borehole Location BH17-32B

Photo No. 4: Borehole Location BH17-32B

Photo No. 5: Borehole Location BH17-33B

APPENDIX C

Symbols and Terms Used on Borehole Records

Stantec Borehole Records

Field Bedrock Core Logs

Bedrock Core Photos

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

Rootmat	- vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
Topsoil	- mixture of soil and humus capable of supporting vegetative growth
Peat	- mixture of visible and invisible fragments of decayed organic matter
Till	- unstratified glacial deposit which may range from clay to boulders
Fill	- material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

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

Terminology describing soil types:
The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4th Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):
Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

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

Terminology describing compactness of cohesionless soils:
The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. A relationship between compactness condition and N-Value is shown in the following table.

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

Terminology describing consistency of cohesive soils:
The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	Undrained Shear Strength		Approximate SPT N-Value
	kips/sq.ft.	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25 - 0.5	12.5 - 25	2-4
Firm	0.5 - 1.0	25 - 50	4-8
Stiff	1.0 - 2.0	50 – 100	8-15
Very Stiff	2.0 - 4.0	100 - 200	15-30
Hard	>4.0	>200	>30

ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Terminology describing rock quality:

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

Alternate (Colloquial) Rock Mass Quality	
Very Severely Fractured	*Crushed*
Severely Fractured	*Shattered or Very Blocky*
Fractured	*Blocky*
Moderately Jointed	*Sound*
Intact	*Very Sound*

RQD (Rock Quality Designation) denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 in.) long are summed and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

SCR (Solid Core Recovery) denotes the percentage of solid core (cylindrical) retrieved from a borehole of any orientation. All pieces of solid (cylindrical) core are summed and divided by the total length of the core run (It excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

Fracture Index (FI) is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

Terminology describing rock with respect to discontinuity and bedding spacing:

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

Terminology describing rock strength:

Strength Classification	Grade	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	<1
Very Weak	R1	1 – 5
Weak	R2	5 – 25
Medium Strong	R3	25 – 50
Strong	R4	50 – 100
Very Strong	R5	100 – 250
Extremely Strong	R6	>250

Terminology describing rock weathering:

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

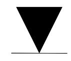
STRATA PLOT

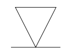
Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.

SAMPLE TYPE

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

WATER LEVEL MEASUREMENT


measured in standpipe, piezometer, or well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RECOVERY

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

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to 'A' size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

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

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

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BOREHOLE RECORD

N: 6 955 478 E: 508 207

BH17-31B

CLIENT: Tlicho Engineering and Environmental Services Ltd.
BOREHOLE No.: BH17-31B
LOCATION: Northwest Territories, Canada
PROJECT No.: 144902448
DATES: BORING: March 9, 2017
WATER LEVEL: 0.7 m (Mar 11)
DATUM: Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	WATER LEVEL	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	260.28						
	260.1	150 mm SNOW					
	259.8	305 mm FROZEN TOPSOIL					
		Brown to grey, frozen sandy SILT (ML) - Frozen soil description: Nbe to Vx - Unfrozen below 2.4 m depth	∇	AS	1	-	
				SS	2	-	13
				AS	3	-	
3				SS	4	0%	8
	256.4	Firm to stiff grey to brown, unfrozen, gravelly lean CLAY with sand (CL)		AS	5	-	
				SS	6	-	12
				SS	7	-	7
8				SS	8	-	5

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

115.2

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

STN13-STAN-GEO 144902448 TLICHO ALL SEASON ROAD INVESTIGATION.GPJ SMART.GDT 5/23/17

Stantec

BOREHOLE RECORD

N: 6 955 478 E: 508 207

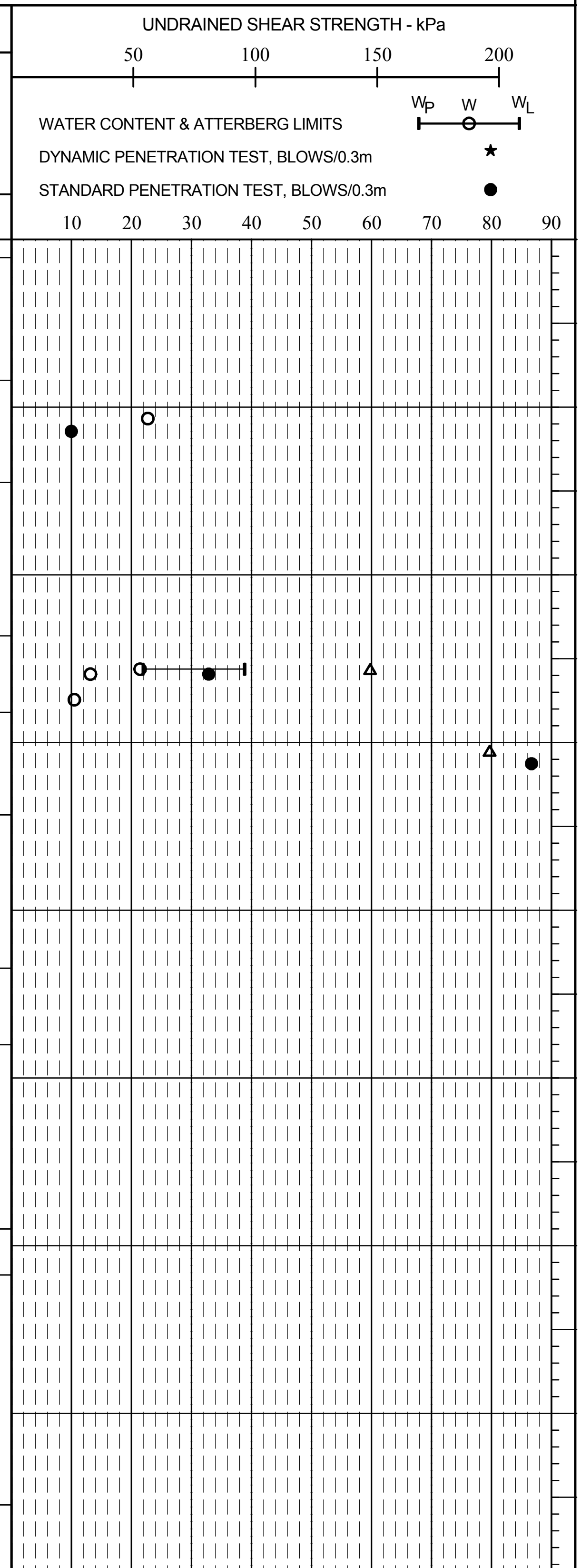
BH17-31B

CLIENT Tlicho Engineering and Environmental Services Ltd. BOREHOLE No. BH17-31B

LOCATION Northwest Territories, Canada PROJECT No. 144902448

DATES: BORING March 9, 2017 WATER LEVEL 0.7 m (Mar 11) DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
8 – 9.75			SS	9	-	10
9.75	250.5	Hard, grey, unfrozen clayey gravel with sand (GC) TILL SS10: PP= >150kPa SS11: PP= >200kPa	SS	10	-	33
			SS	11	-	87
11.6	248.7	Very poor to excellent quality, white to grey DOLOSTONE - Slightly weathered near surface - Regular clay infilled discontinuities (Typ. 0.2 m) - See field bedrock core logs for details	NQ	12	86%	40%
			NQ	13	18%	0%
			NQ	14	86%	56%
			NQ	15	100%	0%
			NQ	16	70%	75%



Inferred Groundwater Level

Groundwater Level Measured in Standpipe

Field Vane Test, kPa

Remoulded Vane Test, kPa

Pocket Penetrometer Test, kPa

App'd

Date

Stantec

BOREHOLE RECORD

N: 6 955 478 E: 508 207

BH17-31B

CLIENT Tlicho Engineering and Environmental Services Ltd.
BOREHOLE No. BH17-31B

LOCATION Northwest Territories, Canada
PROJECT No. 144902448

DATES: BORING March 9, 2017 WATER LEVEL 0.7 m (Mar 11)
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
16					NQ	17	77%	75%
17–18					NQ	18	97%	90%
19					NQ	19	100%	100%
	240.5	End of Borehole						
20								
21								
22								
23								
24								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Stantec

BOREHOLE RECORD

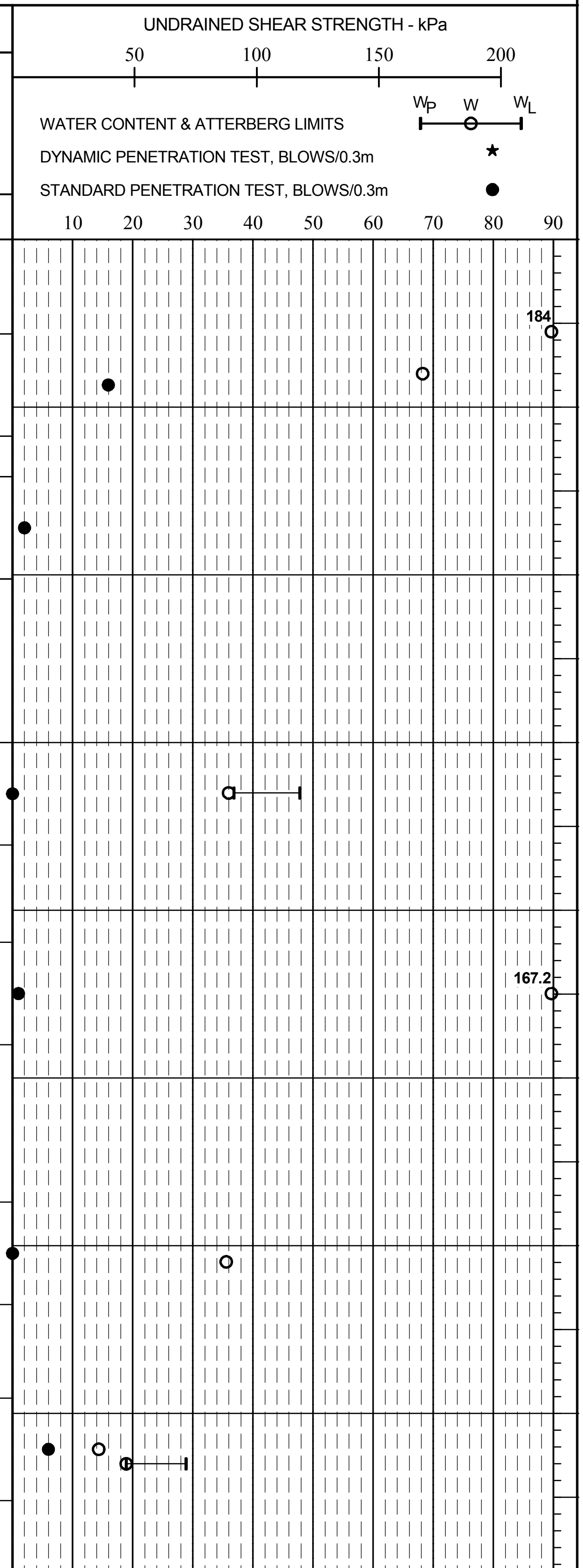
N: 6 955 504 E: 508 219

BH17-32B

CLIENT Tlicho Engineering and Environmental Services Ltd.
LOCATION Northwest Territories, Canada
DATES: BORING March 5, 2017 WATER LEVEL 0.0 m (Mar 5)

BOREHOLE No. BH17-32B
PROJECT No. 144902448
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	259.78	0.5 m ICE		∇	AS	1	-	-
	259.3	Dark grey-black, frozen sandy SILT (ML), with organic material			SS	2	-	16
1		- Approx. sample temperature: SS2: +4°C GS3: +4°C SS4: +4°C			AS	3	-	-
					SS	4	-	2
2		- Unfrozen below 1.5 m depth			AS	5	-	-
3	256.7	Very loose, grey, unfrozen sandy SILT (ML)			SS	6	-	0
4		- Approx. sample temperature: SS6: +4.5°C SS7: +2.5 to +4.3°C SS8: +4.7 to 5.0°C - Organic odour at 4.2 m depth			SS	7	38	1
5		- Increasing silt content below 4.5 m						
6		- Trace gravel below 5.7 m depth			SS	8	229	0
7	253.1	Firm to stiff, grey, solid, unfrozen gravelly lean CLAY with sand (CL) - Occasional cobbles			SS	9	279	6
8								



∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ______
Date ______

Stantec

BOREHOLE RECORD

N: 6 955 504 E: 508 219

BH17-32B

CLIENT Tlicho Engineering and Environmental Services Ltd. BOREHOLE No. BH17-32B

LOCATION Northwest Territories, Canada PROJECT No. 144902448

DATES: BORING March 5, 2017 WATER LEVEL 0.0 m (Mar 5) DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
8		- Approx. sample temperature: SS9: +4.5 to 5.2°C SS10: +5.8 to +6.2°C				
9			SS	10	305	11
10	249.1					
11		White to light grey, dense to very dense, unfrozen sandy silt (ML) to silty sand (SM) TILL - Occasional cobbles at 10.7 m depth - Approx. sample temperature: SS16: +6.4°C to +6.6°C - Frequent cobbles below 11.7 m depth - Rock fragments below 12.5 m depth	SS	11	38	
12			SS	12	152	70/0.1m
			SS	13	0	100/0.1m
			NQ	14	100%	0%
13–14			NQ	15	42%	N/A
15	244.7		SS	16	406	50/0.1m
		Very poor to excellent quality, white to grey DOLOSTONE - Fresh to moderately weathered	NQ	17	100%	0%
			NQ	18	100%	64%
16						

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P W W_L)

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Stantec

BOREHOLE RECORD

N: 6 955 504 E: 508 219

BH17-32B

CLIENT Tlicho Engineering and Environmental Services Ltd.

LOCATION Northwest Territories, Canada

DATES: BORING March 5, 2017 WATER LEVEL 0.0 m (Mar 5)

BOREHOLE No. BH17-32B

PROJECT No. 144902448

DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
16		- See field Bedrock Core Logs for details			NQ	19	97%	25%
17					NQ	20	97%	32%
18					NQ	21	100%	100%
19	240.8	End of Borehole						
20								
21								
22								
23								
24								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ________

Date ________

BOREHOLE RECORD

N: 6 955 522 E: 508 225

BH17-33B

CLIENT: Tlicho Engineering and Environmental Services Ltd. — BOREHOLE No.: BH17-33B

LOCATION: Northwest Territories, Canada — PROJECT No.: 144902448

DATES: BORING: March 11, 2017 — WATER LEVEL: 2.4 m (Mar 15) — DATUM: Geodetic

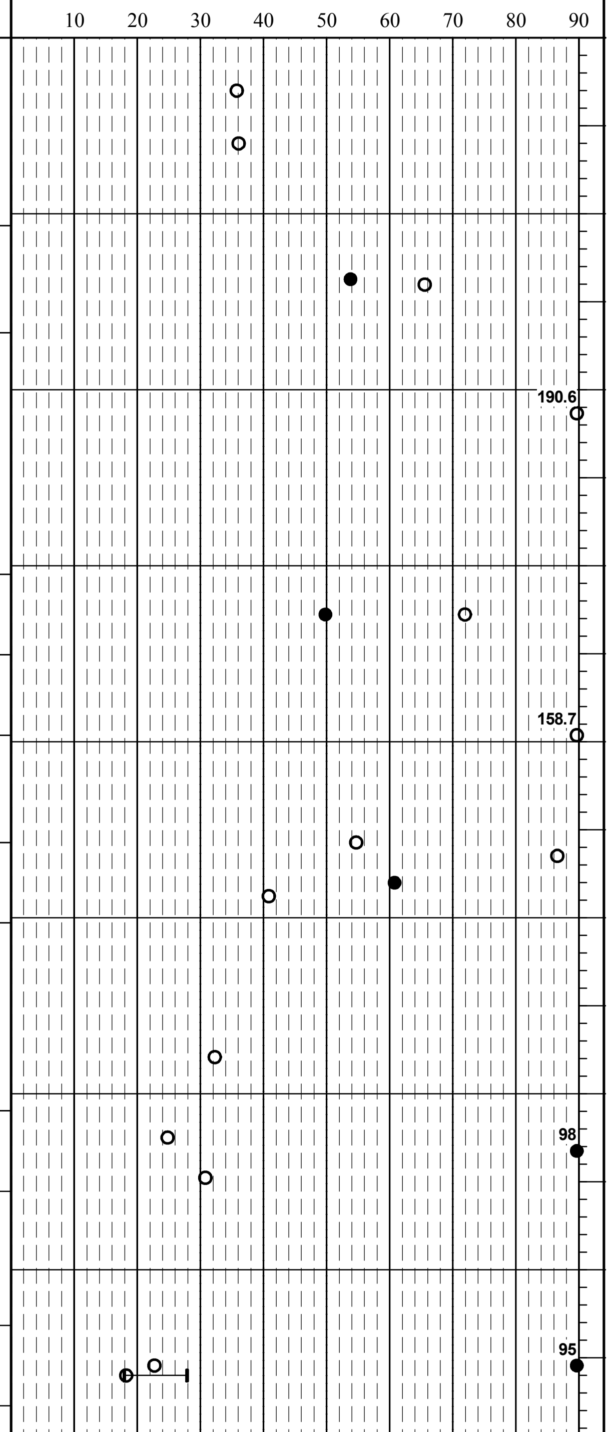
DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	WATER LEVEL	SAMPLE TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	260.70						
0.1	260.6	100 mm FROZEN TOPSOIL					
		Brown to rusty brown, frozen silty SAND (SM) - Occasional rootlets - Approx. sample temperature: AS1: -6.2 to -2.3°C		AS	1	-	-
				SS	2	610	54
1.7	259.0	- Frozen soil description: Nf to Nbn					
		Brown, frozen sandy SILT (ML) - Approx. sample temperature: AS3: +4°C SS4: <0°C - Frozen soil description: Vs to Nbe	∇ (2.4 m)	AS	3		-
				SS	4		50
				AS	5	-	-
				AS	6	-	-
4.7	256.0	Grey, frozen, silty SAND (SM) - Trace organics - Approx. sample temperature: SS7: <0°C		SS	7		61
5.2	255.5	- Frozen soil description: Vx to Nbe		AS	8	-	-
		Grey, frozen, sandy lean CLAY (CL) - Approx. sample temperature: SS9: +3°C SS10: +4.0°C SS12: <0°C SS13: >0°C		SS	9		98
				SS	10		95
8							

UNDRAINED SHEAR STRENGTH - kPa (50, 100, 150, 200)

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●



∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Stantec

BOREHOLE RECORD

N: 6 955 522 E: 508 225

BH17-33B

CLIENT Tlicho Engineering and Environmental Services Ltd. BOREHOLE No. BH17-33B

LOCATION Northwest Territories, Canada PROJECT No. 144902448

DATES: BORING March 11, 2017 WATER LEVEL 2.4 m (Mar 15) DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
8		- Frozen soil description: Vx - White to grey calcite-like gravel at 6.1 m depth - Calcite and quartzite gravel from 7.3 m to 9.0 m depth						
9					SS	11		100/0.1m
10	250.3	Grey, frozen SILT occasional gravel (ML) - Approx. sample temperature: SS12: <0°C			SS	12	152	4
11	249.4							
	249.2	Hard, white to grey, clay with calcite/chalk inclusions TILL (CL) - Approx. sample temperature: SS13: >0°C			SS	13		100/0.1m
12		Very poor to poor quality, grey-white, DOLOSTONE - Highly to moderately weathered - Horizontal fractures - Infilling not observed, poor recovery maybe be due to washing of clay seams - See Field Bedrock Core logs for details			NQ	14	20%	0%
14					NQ	15	19%	0%
16								

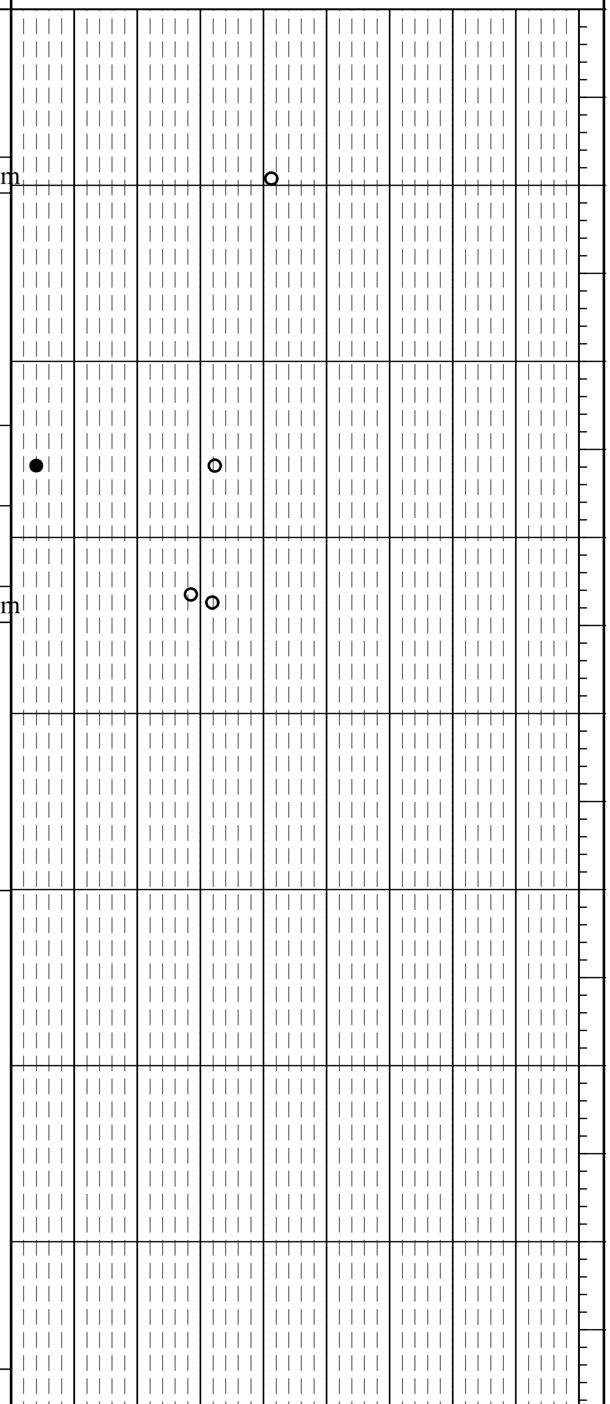
UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90



∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Stantec

BOREHOLE RECORD

N: 6 955 522 E: 508 225

BH17-33B

CLIENT Tlicho Engineering and Environmental Services Ltd.

LOCATION Northwest Territories, Canada

DATES: BORING March 11, 2017 WATER LEVEL 2.4 m (Mar 15)

BOREHOLE No. BH17-33B

PROJECT No. 144902448

DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
16								
17					NQ	16	18%	0%
18					NQ	17	100%	0%
19					NQ	18	100%	15%
20								
21					NQ	19	75%	10%
22								
23					NQ	20	62%	29%
24								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

▣ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ________

Date ________

Stantec

BOREHOLE RECORD

N: 6 955 522 E: 508 225

BH17-33B

CLIENT Tlicho Engineering and Environmental Services Ltd. BOREHOLE No. BH17-33B

LOCATION Northwest Territories, Canada PROJECT No. 144902448

DATES: BORING March 11, 2017 WATER LEVEL 2.4 m (Mar 15) DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY (mm)	SAMPLES: N-VALUE OR RQD	UNDRAINED SHEAR STRENGTH - kPa (50, 100, 150, 200); WATER CONTENT & ATTERBERG LIMITS W_P W W_L; DYNAMIC PENETRATION TEST, BLOWS/0.3m ★; STANDARD PENETRATION TEST, BLOWS/0.3m ● (10 20 30 40 50 60 70 80 90)
24	236.1	End of Borehole							
25									
26									
27									
28									
29									
30									
31									
32									

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ________

Date ________

Stantec

Field Bedrock Core Log

Client:	Tlicho E&E Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	20-Apr-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-31B
		Logger:	JMO/JGM/SR

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
11.4	NQ 12	86	40	12.3	Poor quality, grey and white DOLOSTONE	R2	W2	1	JN	F	C	RU/RP	C-O	Si/NC	Weathered seams with clay infilling (25 to 50 mm wide).	Bedrock starts at approximate depth of 11.6 m
12.3	NQ 13	18	0	12.8	Very poor quality, grey and white DOLOSTONE	R2	W2	1	JN	F	C	RU/RP	O	Si/NC	Weathered seams with clay infilling (approx. 50 mm wide).	Greyish brown wash water
12.8	NQ 14	86	56	13.9	Fair quality, grey and white DOLOSTONE	R2	W2	1	JN	F	C	RU/RP	G-O	Si/NC		
13.9	NQ 15	100	0	14.2	Very poor quality, grey and white DOLOSTONE	R2	W2	1	JN	F	C	RU/RP	G-O	Si	Highly weathered area from 14.0 m to 14.2 m depth	

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
3	RU = Rough, Irregular, Undulating
1.5	SU = Smooth, Undulating
1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

Stantec

Field Bedrock Core Log

Client:	Tlicho E&E Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	20-Apr-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-31B
		Logger:	JMO/JGM/SR

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
14.2	NQ 16	70	75	15.5	Fair to good quality, grey and white DOLOSONE	R2	W2	1	JN	F	C	RU/RP	G-O	NC	Weathered seams with clay infilling (80 to 100 mm wide).	Greyish brown wash water
15.5	NQ 17	77	75	17.1	Fair to good quality, grey and white DOLOSONE	R2	W2	1	JN	F	C	RU/RP	G-O	NC	Weathered seams with clay infilling (Approx. 100 mm wide).	Greyish brown wash water
17.1	NQ 18	97	90	18.6	Exellent quality, grey and white DOLOSTONE	R2	W2	1	JN	F	C	RU/RP	C-O	NC	Weathered seams with clay infilling (Approx. 150 mm wide).	Greyish brown wash water
18.6	NQ 19	100	100	19.8	Exellent quality, grey and white DOLOSTONE	R2	W2	1	JN	F	C	RU/RP	G	None		

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
3	RU = Rough, Irregular, Undulating
1.5	SU = Smooth, Undulating
1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

Stantec

Field Bedrock Core Log

Client: Tlicho E&E Services Ltd.
Project: Tlicho All Season Road
Contractor: Northtech Drilling Ltd.

Project No.: 144902448
Date: 20-Apr-17
Borehole No.: BH17-32B
Logger: JMO/JGM/SR

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
15.2	NQ 17	100	0	15.5	Very poor quality, grey and white DOLOSTONE	R2	W4	1	JN	F	VC	RU/RP	G	None	Highly weathered throughout core run	Bedrock starts at approximate depth of 14.9 m
15.5	NQ 18	100	64	15.8	Fair to good quality, grey and white DOLOSTONE	R2	W3	1	JN	F-D	VC	RU/RP	G	None		
15.8	NQ 19	97	25	16.5	Poor quality, grey and white DOLOSTONE	R2	W3	1	JN	F-D	VC-C	RU/RP	G	None	Highly weathered area from 15.6 m to 16.1 m depth & from 16.4 m to 16.6 m depth	
16.5	NQ 20	97	32	18.1	Poor quality, grey and white DOLOSTONE	R2	W5 to W2	1	JN	F-D	C	RU/RP	G	None	Extremely weathered zone at start of run	Pushed core barrel, described as decomposed

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE
BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

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

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
3	RU = Rough, Irregular, Undulating
1.5	SU = Smooth, Undulating
1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

Field Bedrock Core Log

Stantec

Client:	Tlicho E&E Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	20-Apr-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-32B
		Logger:	JMO/JGM/SR

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
18.1	NQ 21	100	100	19.0	Exellent quality, grey and white DOLOSTONE	R2	W2	1	JN	F	M	RU/RP	G	None		

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

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0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

Field Bedrock Core Log

Stantec

Client:	Tlicho E&E Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	20-Apr-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-33B
		Logger:	JMO/JGM/SR

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
11.5	NQ 14	20	0	13.0	Very poor quality, grey and white DOLOSTONE	R2	W3/W4	1	JN	F	VC	RU/RP	G	None		Bedrock starts at approximate depth of 15.1 m, No water return
13	NQ 15	19	0	15.7		R2	W1	1	JN	F	VC	RU	G	None		No water return
15.7	NQ 16	18	0	18.7		R2	W1	1	JN	F	VC-C	RU/RP	G	None		No water return
18.7	NQ 17	100	0	18.9		R2	W1	1	JN	F	VC-C	RU/RP	G	None		

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
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W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
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W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
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Field Bedrock Core Log

Stantec

Client:	Tlicho E&E Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	20-Apr-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-33B
		Logger:	JMO/JGM/SR

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
18.9	NQ 18	100	15	20.4	Very poor quality, grey and white DOLOSTONE	R2	W1	1	JN	F	VC-C	RU/RP	G	None	Gravel size wide pieces to 230 mm	
20.4	NQ 19	75	10	21.6	Very poor quality, grey and white DOLOSTONE	R2	W1	1	JN	F	VC-C	RU/RP	G	None	Highly fractured pieces from 8 mm wide to 100 mm wide	
21.6	NQ 20	62	29	24.6	Poor quality, grey and white DOLOSTONE	R2	W1	1	JN	F	VC-C	RU/RP	G-C	None		

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE
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JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

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

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

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Grade/Classification	Description
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DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

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1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #8	

Rock Core Photo No.: 1	Borehole: BH 17-31B	Depth: 11.4 m to 19.8 m

Rock Core Photo No.: 2	Borehole: BH 17-31B	Depth: 16.5 to 16.9 m (upper) 18.0 to 18.3 m (lower)

Stantec	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #8	

Rock Core Photo No.:	3	Borehole:	BH 17-31B	Depth:	19.5 to 19.8 m (lower)

Rock Core Photo No.:	4	Borehole:	BH 17-31B	Depth:	16.5 to 16.9 m (upper) 18.0 to 18.3 m (lower)

Stantec	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #8	

Rock Core Photo No.: 5	Borehole: BH 17-31B	Depth: 17.1 to 17.2 m (upper) 18.3 to 18.6 m (lower)

Rock Core Photo No.: 6	Borehole: BH 17-31B	Depth: 18.6 to 18.9 m (lower)

Stantec	**Project No.: 144902448**	**Rock Core Photographs**
	Project Name: Tlicho All Season Road – Crossing #8	

Rock Core Photo No.: 7	**Borehole: BH 17-31B**	**Depth: 17.6 to 18.0 m (upper) 18.9 to 19.3 m (lower)**

Rock Core Photo No.: 8	**Borehole: BH 17-31B**	**Depth: 19.3 to 19.6 m**

Stantec	**Project No.: 144902448**	**Rock Core Photographs**
	Project Name: Tlicho All Season Road – Crossing #8	

Rock Core Photo No.: 9	**Borehole: BH 17-32B**	**Depth: 15.2 to 18.9 m**

Rock Core Photo No.: 10	**Borehole: BH 17-32B**	**Depth: 12.2 to 12.5 m**

	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #8	

Rock Core Photo No.: 11	Borehole: BH 17-32B	Depth: 16.6 to 16.9 m

Rock Core Photo No.: 12	Borehole: BH 17-32B	Depth: 16.9 to 17.2 m

Stantec	**Project No.: 144902448**	**Rock Core Photographs**
	Project Name: Tlicho All Season Road – Crossing #8	

Rock Core Photo No.:	**13**	**Borehole:**	**BH 17-32B**	**Depth:**	**17.2 to 17.8 m**

Rock Core Photo No.:	**14**	**Borehole:**	**BH 17-32B**	**Depth:**	**17.8 to 18.1 m**

	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #8	

Rock Core Photo No.:	15	Borehole:	BH 17-32B	Depth:	As noted

Rock Core Photo No.:	16	Borehole:	BH 17-32B	Depth:	As noted

	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #8	

Rock Core Photo No.: 17	Borehole: BH 17-33B	Depth: As noted

Rock Core Photo No.: 18	Borehole: BH 17-33B	Depth: As noted

Stantec	**Project No.: 144902448** **Project Name: Tlicho All Season Road – Crossing #8**	**Rock Core Photographs**

Rock Core Photo No.: 19	**Borehole:** BH 17-33B	**Depth:** As noted

Rock Core Photo No.: 20	**Borehole:** BH 17-33B	**Depth:** As noted

APPENDIX D

Laboratory Test Results

Grain Size Analysis

ASTM C136, ASTM C117

Client: Tlicho Engineering & Environmental Services

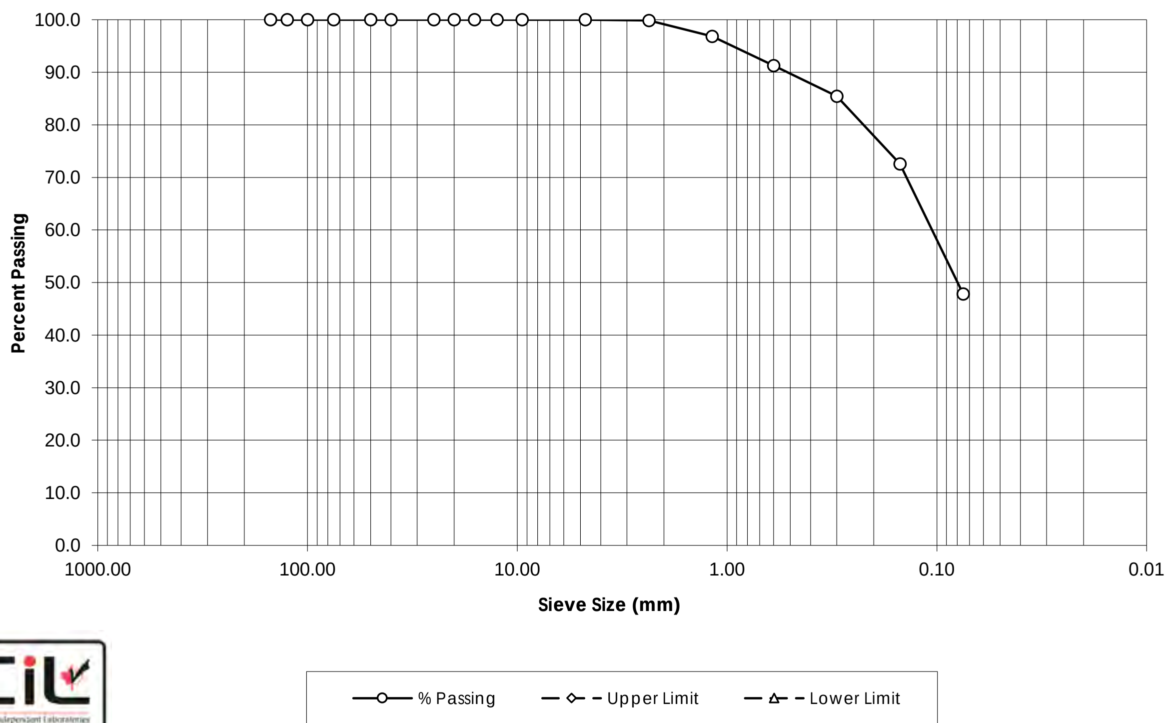
Project Name: Tlicho AllSeason Rd.Investig.

Project No: 144902448

OFFICE	LABORATORY
10160 - 112 ST	10575 106 ST
Edmonton, Alberta	Edmonton, Alberta
Canada T5K 2L6	Canada T5H 2X5
Tel: (780) 917-7000	Tel: (780) 917-7463

SAMPLE No.: AS1
SOURCE: BH17-33B
TESTED BY: RP

DATE RECEIVED: March 27, 2017
DATE TESTED: April 14, 2017
SAMPLE DESCRIPTION: Silty sand



Sieve (mm)	Sample % Passing	Specifications Lower	Specifications Upper
150.0	100.0	-	-
125.0	100.0	-	-
100.0	100.0	-	-
75.0	100.0	-	-
50.0	100.0	-	-
40.0	100.0	-	-
25.0	100.0	-	-
20.0	100.0	-	-
16.0	100.0	-	-
12.5	100.0	-	-
9.5	100.0	-	-
4.75	100.0	-	-
2.36	99.9	-	-
1.18	96.8	-	-
0.600	91.3	-	-
0.300	85.5	-	-
0.150	72.6	-	-
0.075	47.9	-	-

Cobble:	0.0%	D_{10}:	-
Gravel:	0.0%	D_{30}:	-
Sand:	52.1%	D_{60}:	0.1157
Fines:	47.9%	C_u:	-
		C_c:	-

CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Comments:

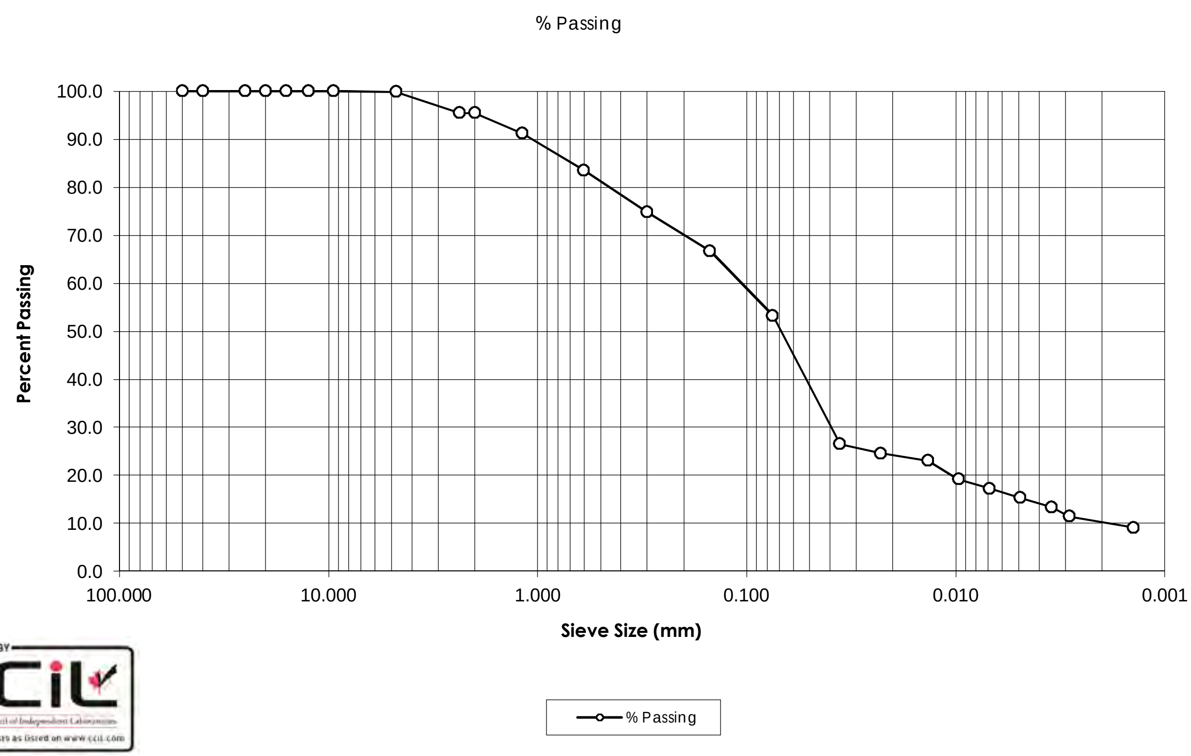
Figure 1

Reviewed by:

Stantec	**Grain Size Analysis** Hydrometer Report ASTM D422 CANFEM	Client: Tlicho Engineering&Environmental Services Ltd Project Name: Tlicho AllSeason Rd.Investig. Project No: 144902448	**OFFICE** 10160 - 112 ST Edmonton, Alberta Canada T5K 2L6 Tel: (780) 917-7000
			LABORATORY 10575 106 ST Edmonton, Alberta Canada T5H 2X5 Tel: (780) 917-7463

SAMPLE No.: AS1
SOURCE: BH17-31B
TESTED BY: JA

DATE TESTED: April 16, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy silt



CERTIFIED BY CCIL

Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0069	17.2
40.0	100.0	0.0049	15.3
25.0	100.0	0.0035	13.3
20.0	100.0	0.0029	11.4
16.0	100.0	0.0014	9.1
12.5	100.0		
9.5	100.0		
4.75	99.9		
2.36	95.4		
2.00	95.4		
1.18	91.2		
0.600	83.5		
0.300	74.8		
0.150	66.7		
0.075	53.3		
0.0358	26.5		
0.0228	24.5		
0.0135	23.0		
0.0097	19.1		
Gravel:	0.1%	D_{10}:	0.0020
Sand:	46.6%	D_{30}:	0.0428
Silt:	43.0%	D_{60}:	0.1146
Clay:	10.3%	C_u:	56.64
		C_c:	7.91

Comments:

Figure 2

Reviewed by:

Reporting of these test results constitutes a testing service only. Engineering interpretation or evaluation of the test results is provided only on written request. The data presented above is for the sole use of the client stipulated above. Stantec is not responsible, nor can be held liable, for the use of this report by any other party, with or without the knowledge of Stantec.

Grain Size Analysis

Hydrometer Report
ASTM D422
CANFEM

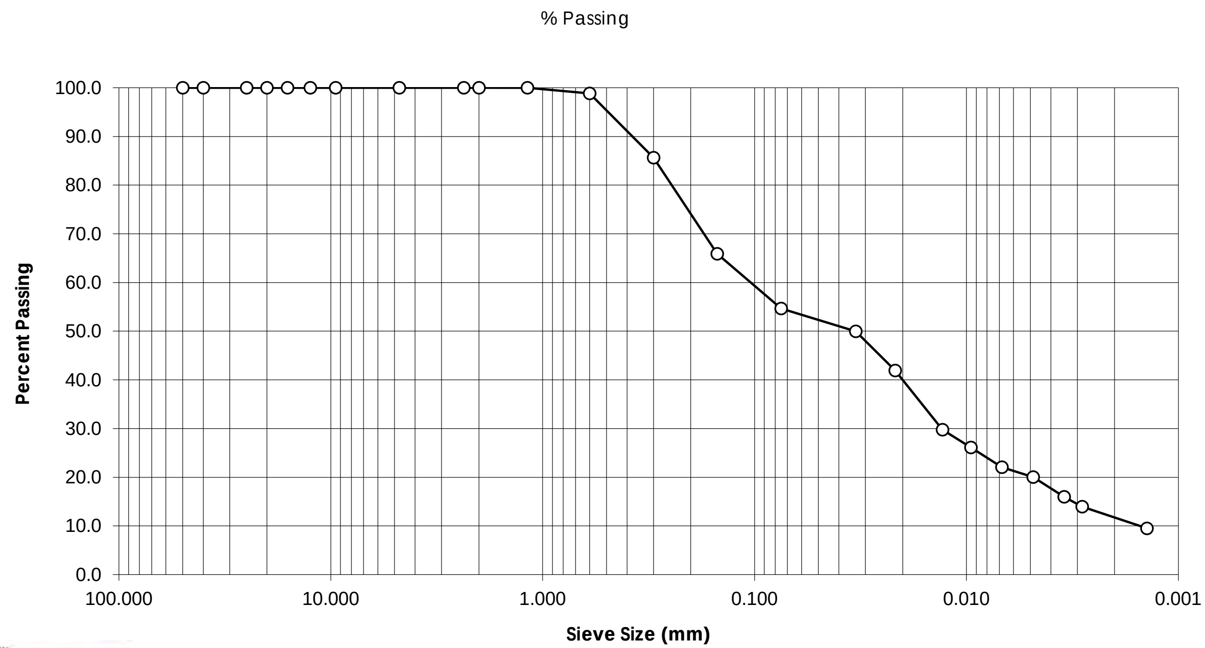
Client: Tlicho Engineering&Environmental Services Ltd
Project Name: Tlicho AllSeason Rd.Investig.
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: SS2
SOURCE: BH17-32B
TESTED BY: JA

DATE TESTED: April 16, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy silt



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0068	22.1
40.0	100.0	0.0049	20.0
25.0	100.0	0.0035	16.0
20.0	100.0	0.0028	14.0
16.0	100.0	0.0014	9.5
12.5	100.0		
9.5	100.0		
4.75	100.0		
2.36	100.0		
2.00	100.0		
1.18	100.0		
0.600	98.8		
0.300	85.6		
0.150	65.9		
0.075	54.7		
0.0333	50.0		
0.0217	41.9		
0.0130	29.8		
0.0095	26.1		

Gravel:	0.0%	D_{10}:	0.0016
Sand:	45.3%	D_{30}:	0.0132
Silt:	42.9%	D_{60}:	0.1124
Clay:	11.8%	C_u:	70.48
		C_c:	0.97

CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Comments:

Figure 3

Reviewed by:

Stantec

Grain Size Analysis

Hydrometer Report

ASTM D422

CANFEM

Client: Tlicho Engineering&Environmental Services Ltd

Project Name: Tlicho AllSeason Rd.Investig.

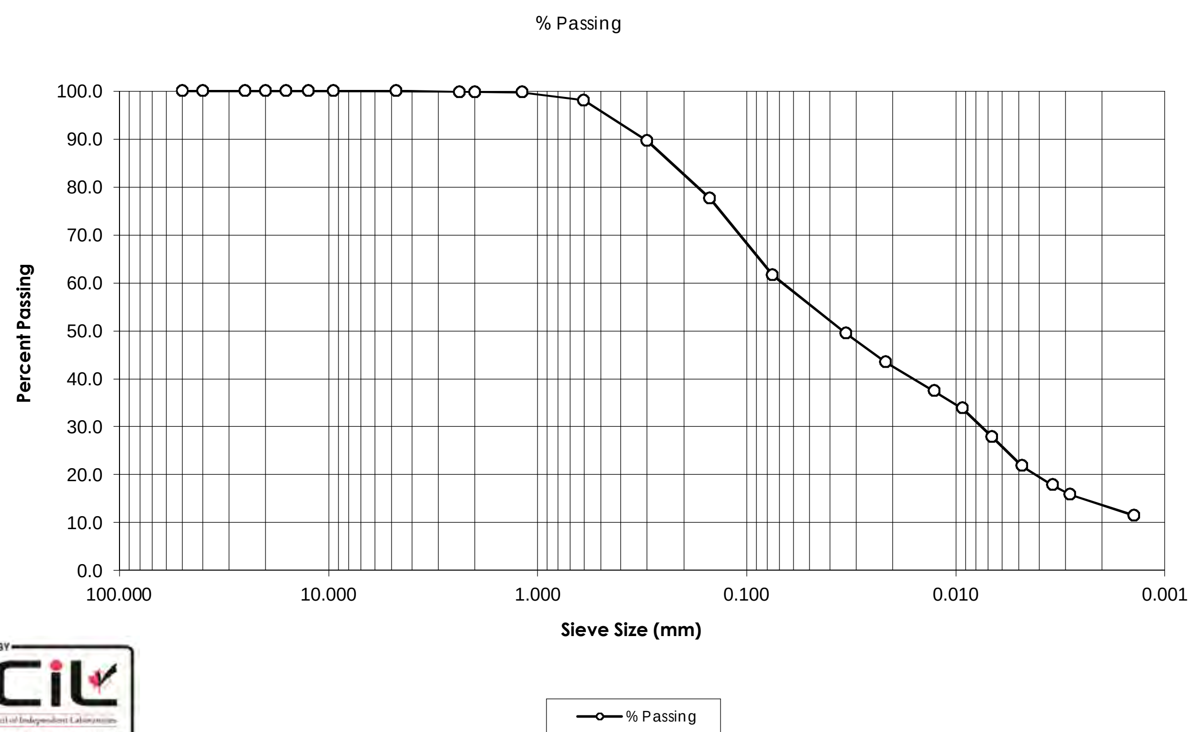
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: SS6
SOURCE: BH17-32B
TESTED BY: JA

DATE TESTED: April 16, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy silt



CERTIFIED BY CCIL

Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0067	27.8
40.0	100.0	0.0048	21.8
25.0	100.0	0.0034	17.8
20.0	100.0	0.0028	15.8
16.0	100.0	0.0014	11.4
12.5	100.0		
9.5	100.0		
4.75	100.0		
2.36	99.8		
2.00	99.8		
1.18	99.8		
0.600	98.1		
0.300	89.6		
0.150	77.6		
0.075	61.6		
0.0333	49.5		
0.0215	43.4		
0.0127	37.4		
0.0093	33.8		

Gravel:	0.0%	D_{10}:	-
Sand:	38.4%	D_{30}:	0.0077
Silt:	47.9%	D_{60}:	0.0701
Clay:	13.7%	C_u:	-
		C_c:	-

Comments:

Figure 4

Reviewed by:

Grain Size Analysis

ASTM C136, ASTM C117

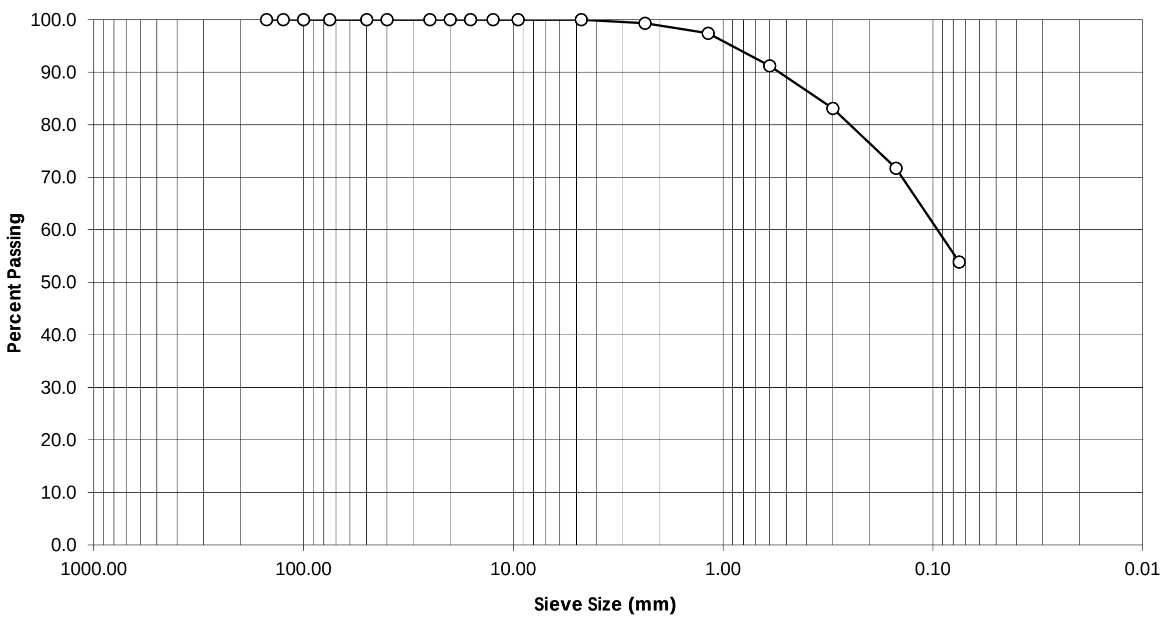
Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho AllSeason Rd.Investig.
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: SS7
SOURCE: BH17-32B
TESTED BY: RP

DATE RECEIVED: March 27, 2017
DATE TESTED: April 20, 2017
SAMPLE DESCRIPTION: Sandy silt



Sieve (mm)	Sample % Passing	Specifications Lower	Specifications Upper
150.0	100.0	-	-
125.0	100.0	-	-
100.0	100.0	-	-
75.0	100.0	-	-
50.0	100.0	-	-
40.0	100.0	-	-
25.0	100.0	-	-
20.0	100.0	-	-
16.0	100.0	-	-
12.5	100.0	-	-
9.5	100.0	-	-
4.75	100.0	-	-
2.36	99.4	-	-
1.18	97.4	-	-
0.600	91.2	-	-
0.300	83.1	-	-
0.150	71.8	-	-
0.075	53.9	-	-

Cobble:	0.0%	D_{10}:	-
Gravel:	0.0%	D_{30}:	-
Sand:	46.1%	D_{60}:	0.1031
Fines:	53.9%	C_u:	-
		C_c:	-

Comments:

Figure 5

Reviewed by:

Grain Size Analysis
ASTM C136, ASTM C117

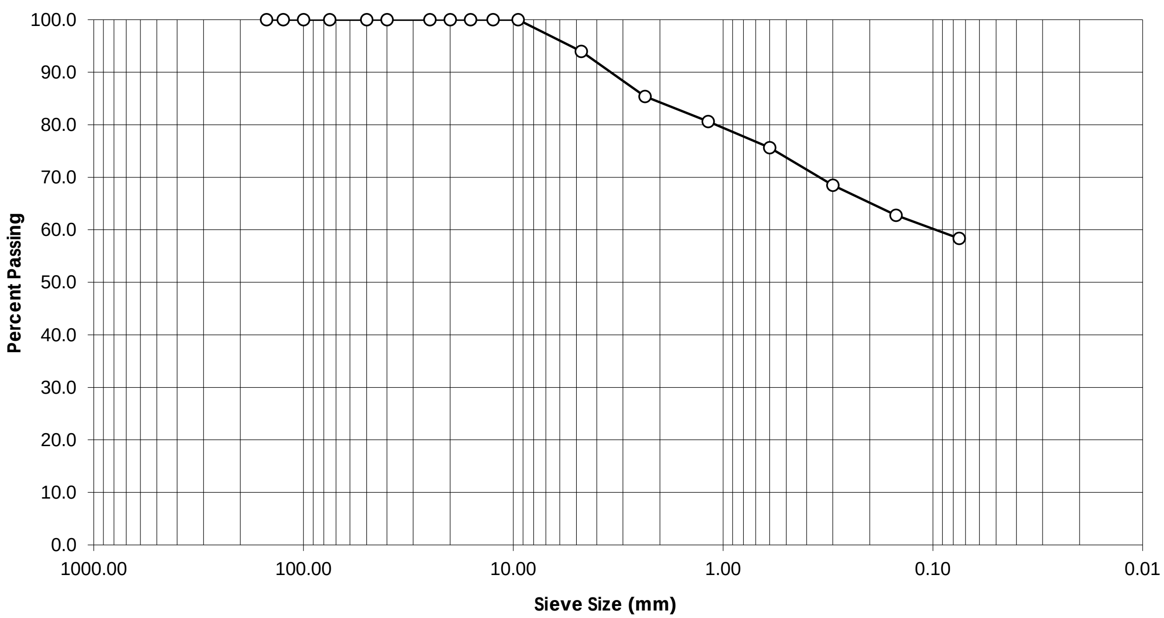
Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho AllSeason Rd.Investig.
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: AS3
SOURCE: BH17-33B
TESTED BY: RP

DATE RECEIVED: March 27, 2017
DATE TESTED: April 20, 2017
SAMPLE DESCRIPTION: Sandy silt



Sieve (mm)	Sample % Passing	Specifications Lower	Specifications Upper
150.0	100.0	-	-
125.0	100.0	-	-
100.0	100.0	-	-
75.0	100.0	-	-
50.0	100.0	-	-
40.0	100.0	-	-
25.0	100.0	-	-
20.0	100.0	-	-
16.0	100.0	-	-
12.5	100.0	-	-
9.5	100.0	-	-
4.75	94.0	-	-
2.36	85.4	-	-
1.18	80.6	-	-
0.600	75.6	-	-
0.300	68.5	-	-
0.150	62.8	-	-
0.075	58.4	-	-

Cobble:	0.0%	D_{10}:	-
Gravel:	6.0%	D_{30}:	-
Sand:	35.6%	D_{60}:	0.1035
Fines:	58.4%	C_u:	-
		C_c:	-

Comments:

Figure 6

Reviewed by:

Stantec

Grain Size Analysis

Hydrometer Report
ASTM D422
CANFEM

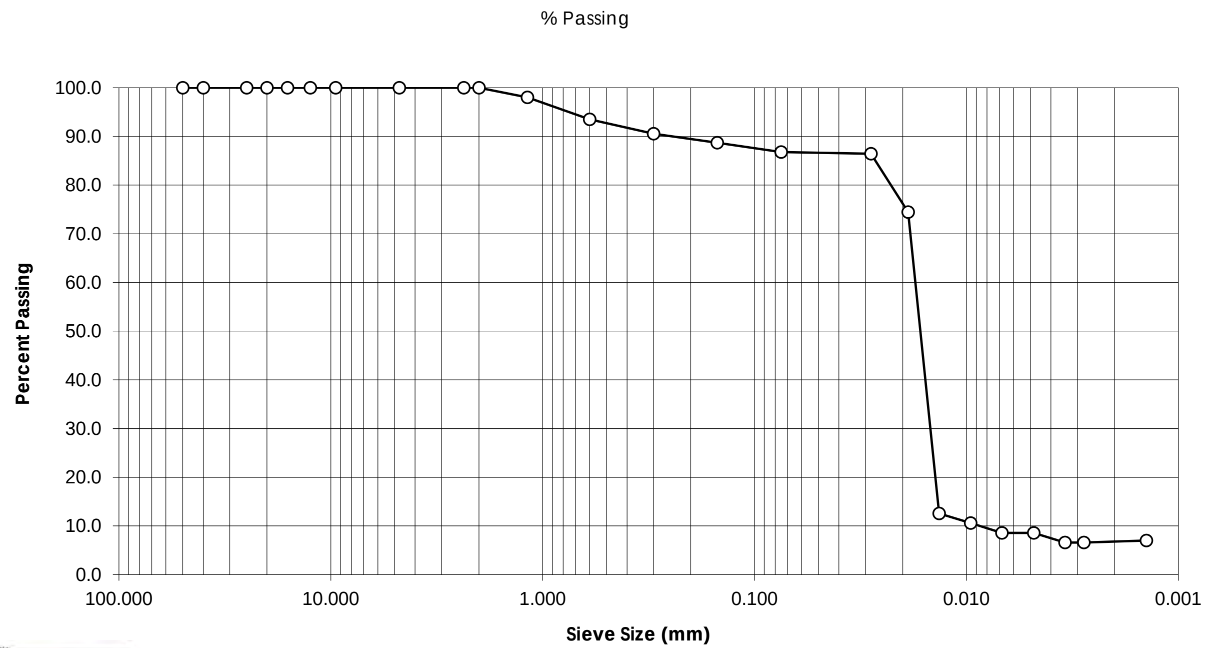
Client: Tlicho Engineering&Environmental Services Ltd
Project Name: Tlicho AllSeason Rd.Investig.
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: SS12 & SS13
SOURCE: BH17-33B
TESTED BY: JA

DATE TESTED: April 17, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Silt



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	**100.0**	**0.0068**	**8.6**
40.0	**100.0**	**0.0048**	**8.6**
25.0	**100.0**	**0.0034**	**6.6**
20.0	**100.0**	**0.0028**	**6.6**
16.0	**100.0**	**0.0014**	**7.0**
12.5	**100.0**		
9.5	**100.0**		
4.75	**100.0**		
2.36	**100.0**		
2.00	**100.0**		
1.18	**98.0**		
0.600	**93.5**		
0.300	**90.5**		
0.150	**88.7**		
0.075	**86.8**		
0.0282	**86.4**		
0.0189	**74.5**		
0.0135	**12.6**		
0.0096	**10.6**		

Gravel:	0.0%	D_{10}:	0.0088
Sand:	13.2%	D_{30}:	0.0161
Silt:	80.0%	D_{60}:	0.0182
Clay:	6.8%	C_u:	2.06
		C_c:	1.62

Comments: Hygroscopic moisture weight lost, oven dry used.

Figure 7

Reviewed by:

Grain Size Analysis

Hydrometer Report
ASTM D422
CANFEM

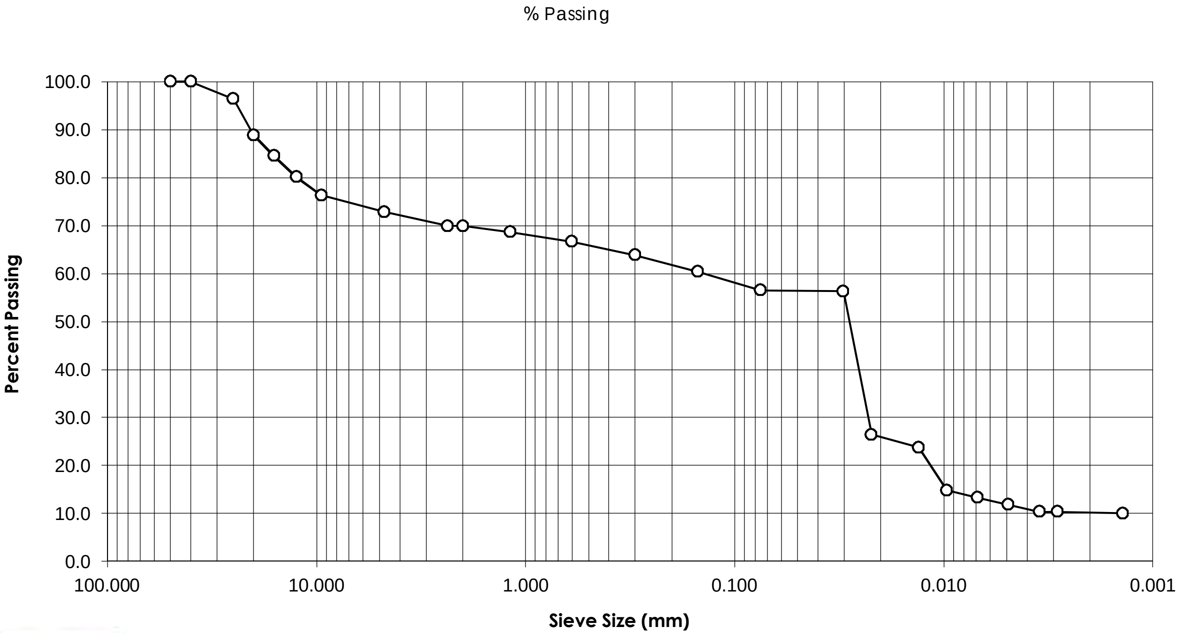
Client: Tlicho Engineering&Environmental Services Ltd
Project Name: Tlicho AllSeason Rd.Investig.
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: AS 19' & SS7
SOURCE: BH17-31B
TESTED BY: JA

DATE TESTED: April 16, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Gravelly lean clay with sand



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0069	13.3
40.0	100.0	0.0049	11.8
25.0	96.4	0.0035	10.3
20.0	88.8	0.0028	10.3
16.0	84.5	0.0014	10.0
12.5	80.1		
9.5	76.3		
4.75	72.9		
2.36	69.9		
2.00	69.9		
1.18	68.6		
0.600	66.6		
0.300	63.8		
0.150	60.4		
0.075	56.5		
0.0302	56.3		
0.0221	26.4		
0.0132	23.8		
0.0097	14.8		

Gravel:	27.1%	D_{10}:	-
Sand:	16.4%	D_{30}:	0.0235
Silt:	46.3%	D_{60}:	0.1426
Clay:	10.2%	C_u:	-
		C_c:	-

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Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Comments:

Figure 8

Reviewed by:

Stantec

Grain Size Analysis

Hydrometer Report
ASTM D422
CANFEM

Client: Tlicho Engineering&Environmental Services Ltd
Project Name: Tlicho AllSeason Rd.Investig.
Project No: 144902448

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10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: SS9
SOURCE: BH17-32B
TESTED BY: JA

DATE TESTED: April 16, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Gravelly lean clay with sand

Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0069	12.2
40.0	100.0	0.0049	10.7
25.0	100.0	0.0035	10.7
20.0	95.3	0.0028	10.7
16.0	93.0	0.0014	8.8
12.5	82.8		
9.5	79.1		
4.75	74.4		
2.36	73.3		
2.00	73.3		
1.18	71.8		
0.600	68.7		
0.300	64.6		
0.150	59.8		
0.075	56.2		
0.0307	55.3		
0.0206	47.9		
0.0131	27.7		
0.0096	18.4		

Gravel:	25.6%	D_{10}:	0.0023
Sand:	18.2%	D_{30}:	0.0142
Silt:	46.4%	D_{60}:	0.1576
Clay:	9.8%	C_u:	67.27
		C_c:	0.54

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Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Comments:

Figure 9

Reviewed by:

Stantec

Grain Size Analysis

ASTM C136, ASTM C117

Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho AllSeason Rd.Investig.
Project No: 144902448

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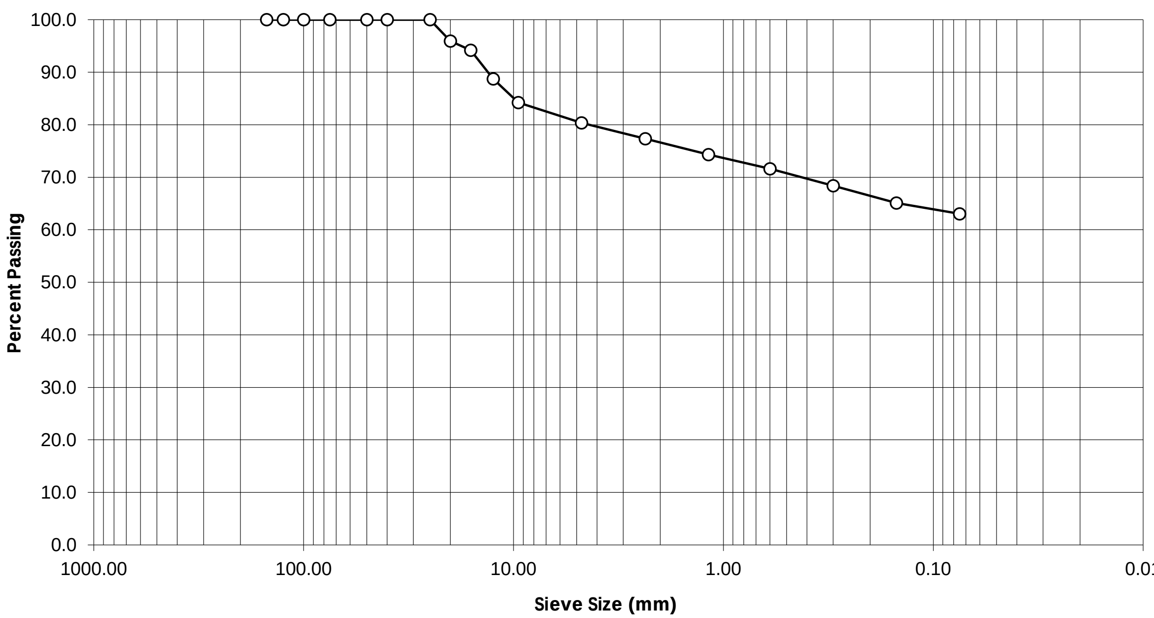
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: SS10
SOURCE: BH17-32B
TESTED BY: RP

DATE RECEIVED: March 27, 2017
DATE TESTED: April 20, 2017
SAMPLE DESCRIPTION: Gravely lean clay with sand



Sieve (mm)	Sample % Passing	Specifications Lower	Specifications Upper
150.0	100.0	-	-
125.0	100.0	-	-
100.0	100.0	-	-
75.0	100.0	-	-
50.0	100.0	-	-
40.0	100.0	-	-
25.0	100.0	-	-
20.0	95.9	-	-
16.0	94.2	-	-
12.5	88.7	-	-
9.5	84.3	-	-
4.75	80.3	-	-
2.36	77.4	-	-
1.18	74.3	-	-
0.600	71.6	-	-
0.300	68.4	-	-
0.150	65.1	-	-
0.075	63.1	-	-

Cobble:	0.0%	D_{10}:	-
Gravel:	19.7%	D_{30}:	-
Sand:	17.3%	D_{60}:	-
Fines:	63.0%	C_u:	-
		C_c:	-

Comments:

Figure 10

Reviewed by:

Reporting of these test results constitutes a testing service only. Engineering interpretation or evaluation of the test results is provided only on written request. The data presented above is for the sole use of the client stipulated above. Stantec is not responsible, nor can be held liable, for the use of this report by any other party, with or without the knowledge of Stantec.

OFFICE	LABORATORY
10160 - 112 ST	10575 106 ST
Edmonton, Alberta	Edmonton, Alberta
Canada T5K 2L6	Canada T5H 2X5
Tel: (780) 917-7000	Tel: (780) 917-7463

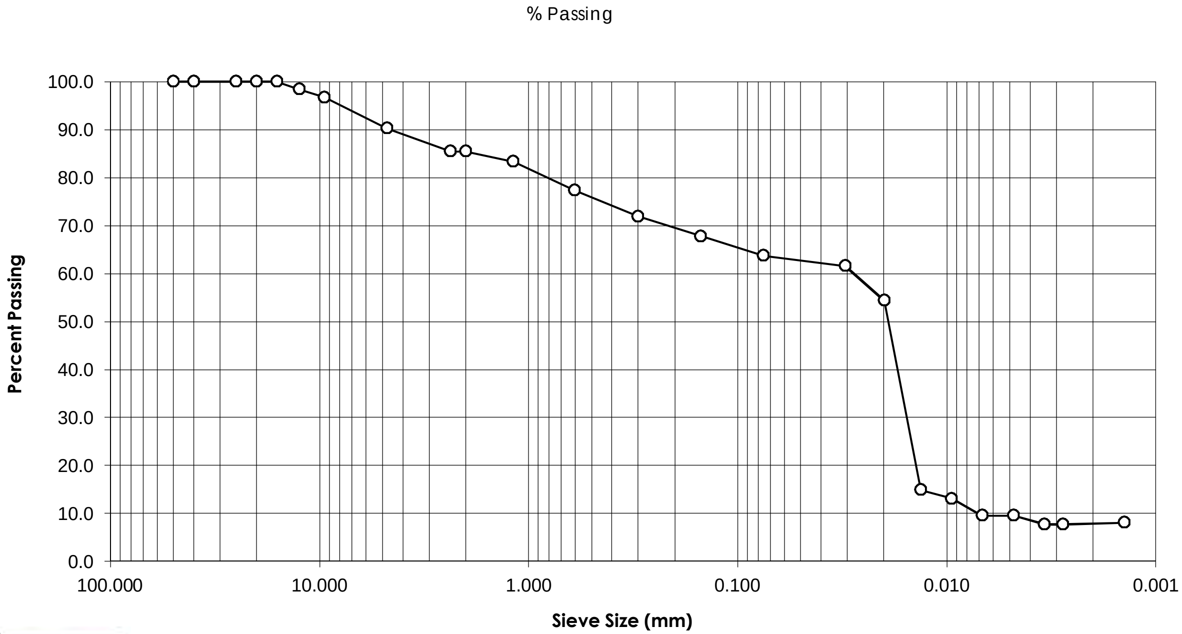
Grain Size Analysis

Hydrometer Report
ASTM D422
CANFEM

Client: Tlicho Engineering&Environmental Services Ltd
Project Name: Tlicho AllSeason Rd.Investig.
Project No: 144902448

SAMPLE No.: SS10
SOURCE: BH17-33B
TESTED BY: JA

DATE TESTED: April 17, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy lean clay



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0068	9.5
40.0	100.0	0.0048	9.5
25.0	100.0	0.0034	7.7
20.0	100.0	0.0028	7.7
16.0	100.0	0.0014	8.1
12.5	98.4		
9.5	96.7		
4.75	90.3		
2.36	85.5		
2.00	85.5		
1.18	83.4		
0.600	77.3		
0.300	71.9		
0.150	67.8		
0.075	63.7		
0.0306	61.5		
0.0199	54.4		
0.0133	14.9		
0.0095	13.1		

Gravel:	9.7%	D_{10}:	0.0072
Sand:	26.6%	D_{30}:	0.0169
Silt:	55.8%	D_{60}:	0.0284
Clay:	7.9%	C_u:	3.95
		C_c:	1.39

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For specific tests as listed on www.ccil.com

Comments:

Figure 11

Reviewed by:

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

Client: Tlicho Engineering&Environmental Services Ltd
Project Name: Tlicho AllSeason Rd.Investig.
Project No: 144902448

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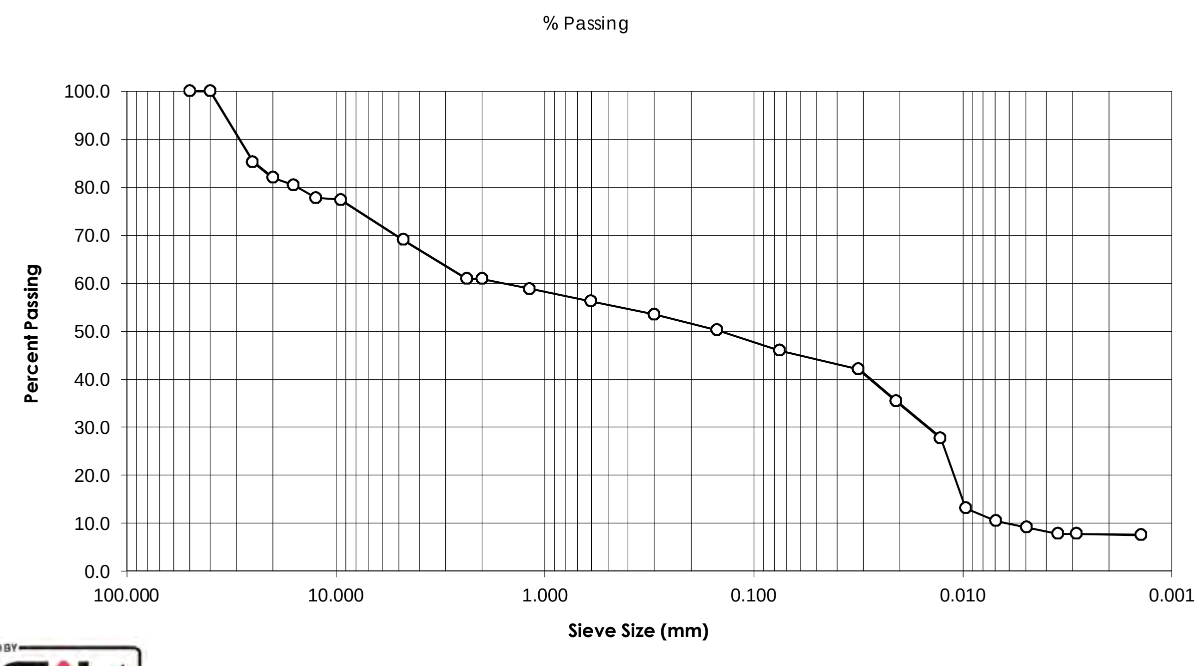
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: SS10 & SS11
SOURCE: BH17-31B
TESTED BY: JA

DATE TESTED: April 16, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Clayey gravel with sand



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0069	10.5
40.0	100.0	0.0049	9.2
25.0	85.3	0.0035	7.8
20.0	82.0	0.0029	7.8
16.0	80.5	0.0014	7.6
12.5	77.8		
9.5	77.4		
4.75	69.0		
2.36	60.9		
2.00	60.9		
1.18	58.9		
0.600	56.2		
0.300	53.5		
0.150	50.2		
0.075	46.0		
0.0316	42.1		
0.0208	35.4		
0.0128	27.7		
0.0097	13.1		

Gravel:	31.0%	D_{10}:	0.0062
Sand:	23.1%	D_{30}:	0.0154
Silt:	38.3%	D_{60}:	1.6379
Clay:	7.6%	C_u:	262.80
		C_c:	0.02

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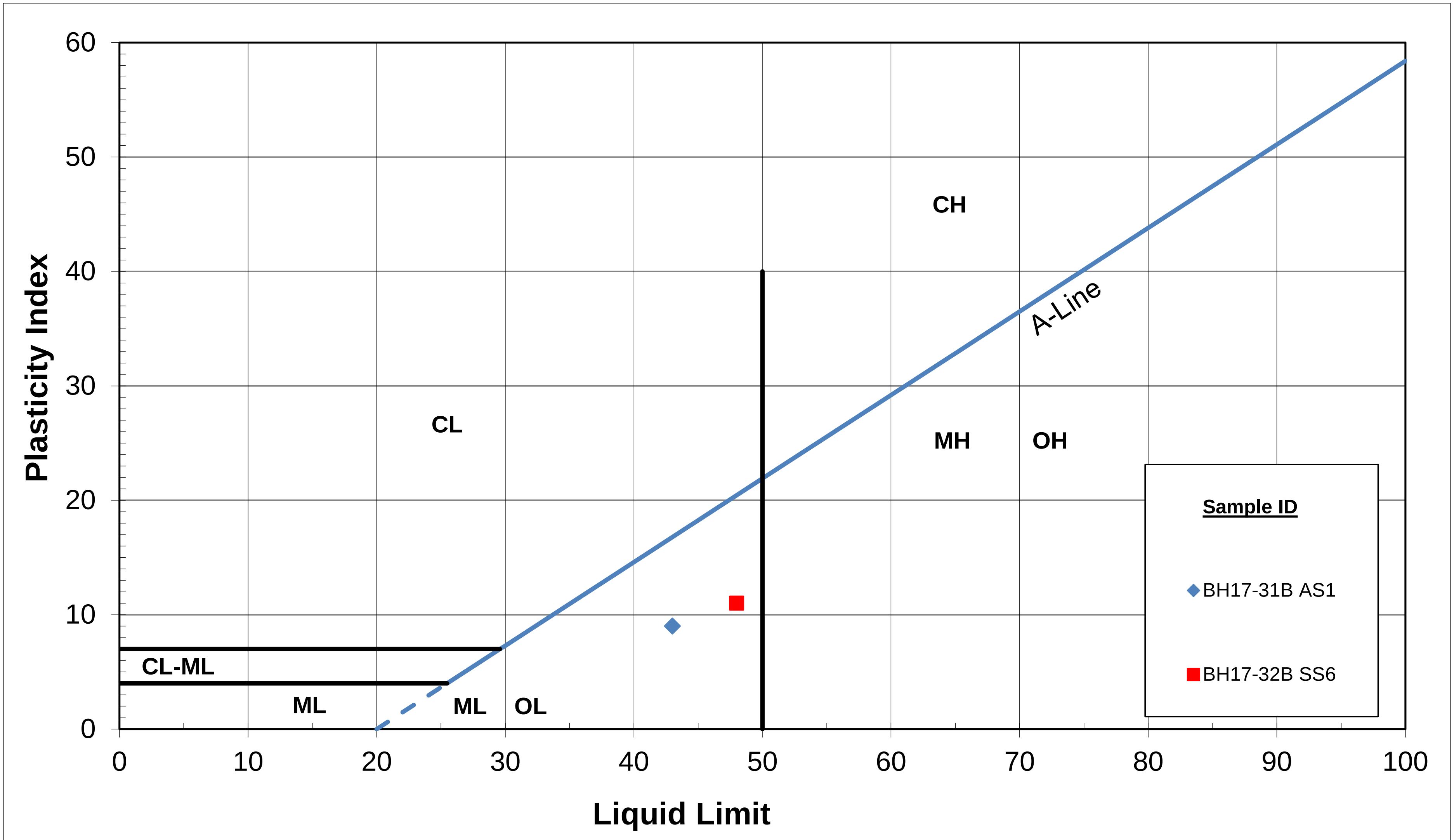
Comments:

Figure 12

Reviewed by:



Stantec

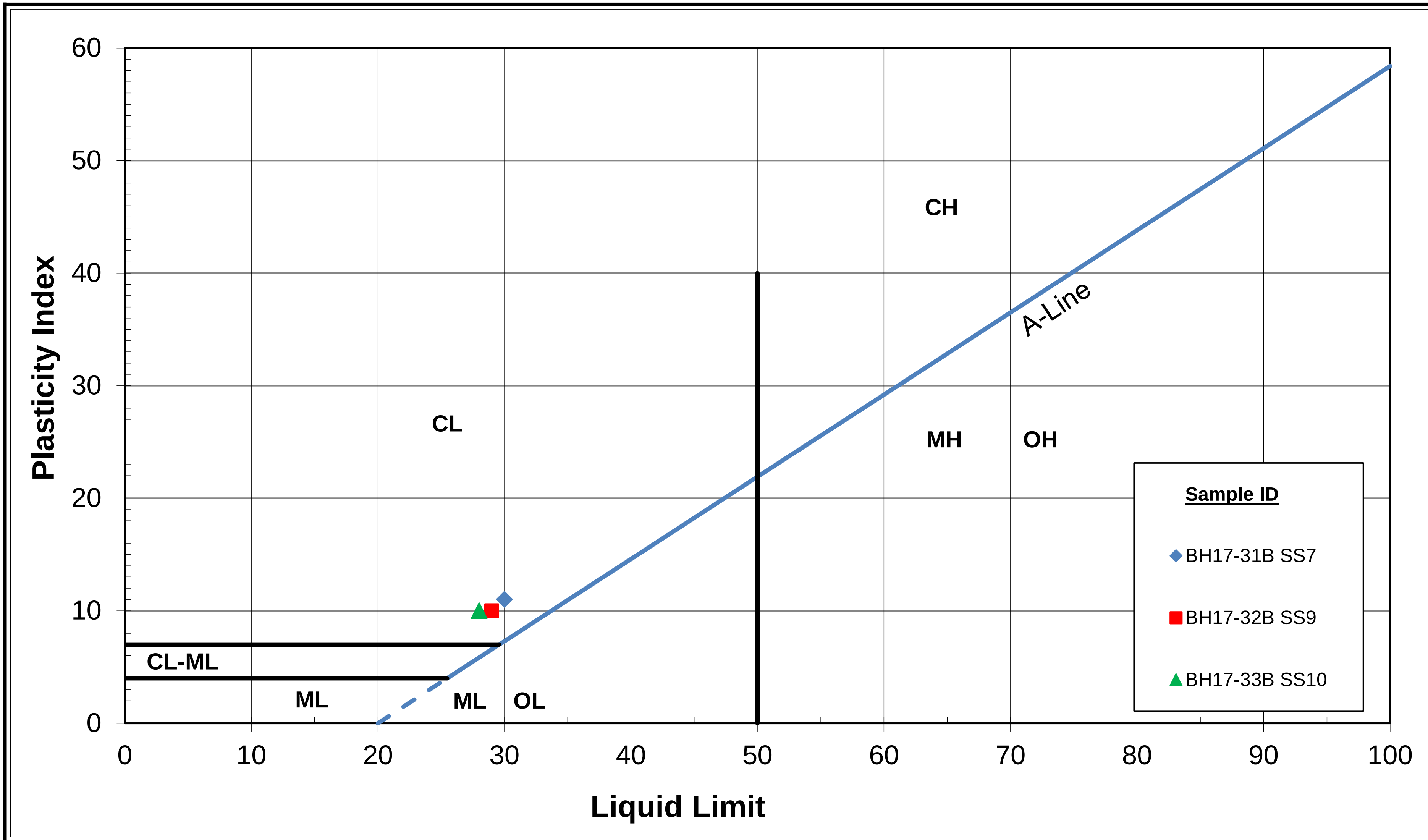
Tlicho Engineering & Environmental Services

Tlicho All Season Road

PLASTICITY CHART

Figure No. 13

Project No. 144902448



Stantec

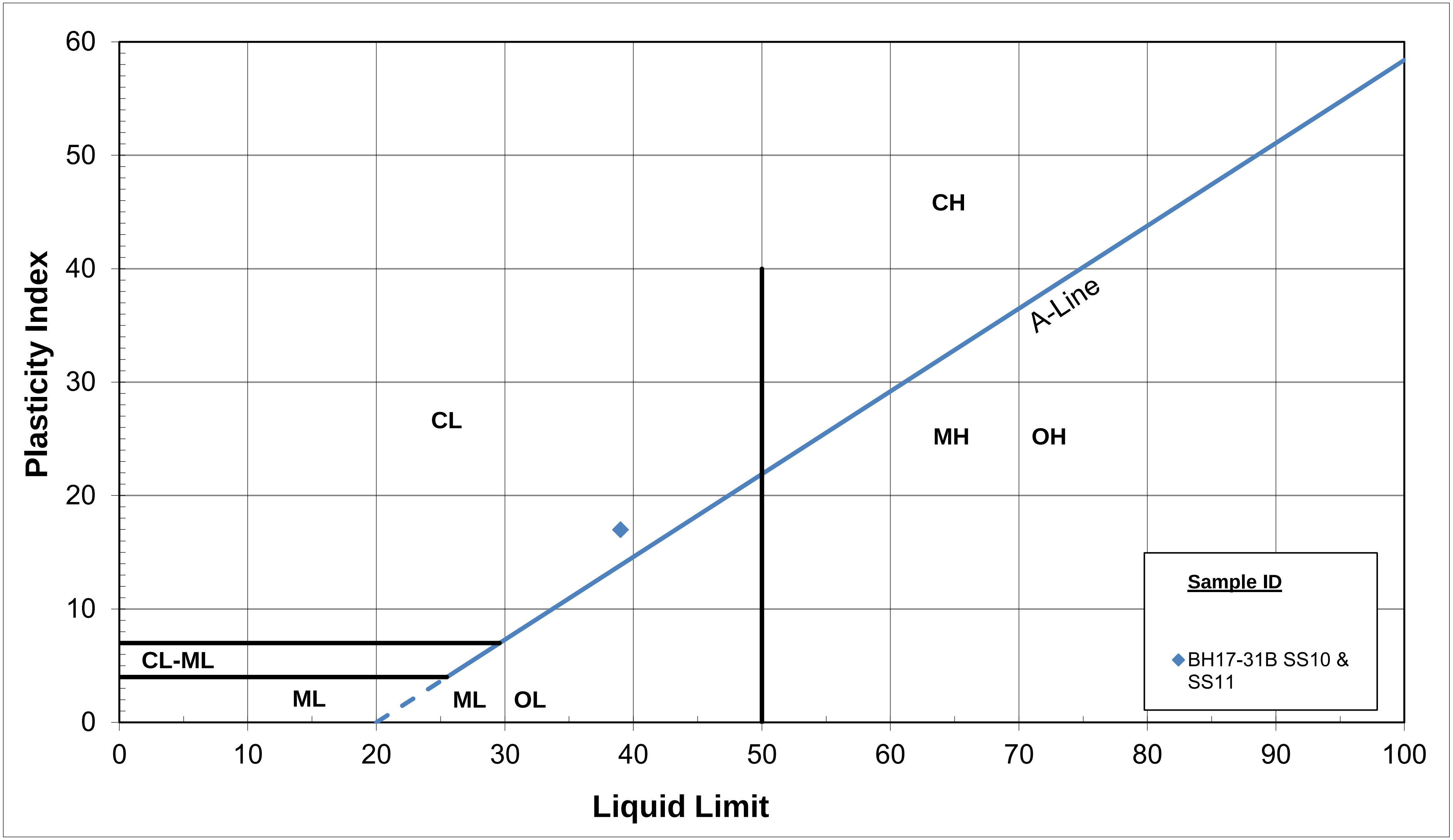
Tlicho Engineering & Environmental Services

Tlicho All Season Road

PLASTICITY CHART

Figure No. 14

Project No. 144902448



Stantec	Tlicho Engineering & Environmental Services Tlicho All Season Road **PLASTICITY CHART**	Figure No. 15 Project No. 144902448

Maxxam
A Bureau Veritas Group Company

Success Through Science®

Your Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Your C.O.C. #: A174619

Attention:RYLEY PROZNIK

STANTEC CONSULTING LTD
10160-112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2017/04/20
Report #: R2371968
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B728026
Received: 2017/04/17, 14:30

Sample Matrix: Soil
Samples Received: 12

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Chloride (Soluble)	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00020	SM 22 4500-Cl G m
Resistivity	9	N/A	2017/04/18	AB WI-00065	Auto Calc
Conductivity @25C (Soluble)	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00004	SM 22 2510 B m
Total Organic Carbon by Combustion-Sub (1)	3	2017/04/20	2017/04/20		
pH @25C (Soluble)	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00006	SM 22 4500 H+B m
Soluble Ions	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00042	EPA 200.7 CFR 2012 m
Soluble Paste	9	2017/04/18	2017/04/18	AB SOP-00033	Carter 2nd ed 15.2m
Soluble Ions Calculation	9	N/A	2017/04/18	AB WI-00065	Auto Calc

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
(1) This test was performed by Maxxam Ontario (From Edmonton)

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Your Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Your C.O.C. #: A174619

Attention:RYLEY PROZNIK

STANTEC CONSULTING LTD
10160-112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2017/04/20
Report #: R2371968
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B728026
Received: 2017/04/17, 14:30

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Wendy Sears, Project manager
Email: WSears@maxxam.ca
Phone# (403)735-2277
==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam
A Bureau Veritas Group Company

Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		QW8655	QW8656		QW8657		QW8658		
Sampling Date		2017/02/24	2017/03/12		2017/03/24		2017/03/22		
COC Number		A174619	A174619		A174619		A174619		
	UNITS	**BH17-16C AS1-A**	**BH17-33B 10'-11.5'**	**RDL**	**BH17-74B AS1**	**RDL**	**BH17-60B AS4**	**RDL**	**QC Batch**
CONVENTIONALS									
Total Organic Carbon (C)	mg/kg	ATTACHED	N/A	500	N/A	500	N/A	500	8608469
Calculated Parameters									
Resistivity @ 25 °C	ohm-m	N/A	3.9	0.050	24	0.050	7.9	0.050	8605241
Calculated Chloride (Cl)	%	N/A	0.018	0.00044	0.0027	0.0010	0.0030	0.00026	8604932
Calculated Sulphate (SO4)	%	N/A	0.16	0.00044	0.0049	0.0010	0.036	0.00026	8604932
Soluble Parameters									
Soluble Chloride (Cl)	mg/L	N/A	210	5.0	13	5.0	57	5.0	8605786
Soluble Conductivity	dS/m	N/A	2.5	0.020	0.41	0.020	1.3	0.020	8605626
Soluble pH	pH	N/A	7.57	N/A	7.28	N/A	7.47	N/A	8605629
Saturation %	%	N/A	88	N/A	210	N/A	52	N/A	8605356
Soluble Sulphate (SO4)	mg/L	N/A	1900	5.0	24	5.0	700	5.0	8605816

RDL = Reportable Detection Limit
N/A = Not Applicable

Maxxam ID		QW8659		QW8660		QW8661	QW8661		
Sampling Date		2017/03/20		2017/03/09		2017/03/21	2017/03/21		
COC Number		A174619		A174619		A174619	A174619		
	UNITS	**BH17-57B 40'-42'**	**RDL**	**BH17-31B 5'-6.5'**	**RDL**	**BH17-59B AS2**	**BH17-59B AS2 Lab-Dup**	**RDL**	**QC Batch**
Calculated Parameters									
Resistivity @ 25 °C	ohm-m	3.5	0.050	4.4	0.050	12	N/A	0.050	8605241
Calculated Chloride (Cl)	%	0.0011	0.00033	0.0015	0.00045	0.0031	N/A	0.00027	8604932
Calculated Sulphate (SO4)	%	0.13	0.00033	0.13	0.00045	0.023	N/A	0.00027	8604932
Soluble Parameters									
Soluble Chloride (Cl)	mg/L	17	5.0	17	5.0	57	52	5.0	8605786
Soluble Conductivity	dS/m	2.9	0.020	2.3	0.020	0.83	0.91	0.020	8605626
Soluble pH	pH	7.95	N/A	7.56	N/A	7.51	7.52	N/A	8605629
Saturation %	%	65	N/A	91	N/A	55	54	N/A	8605356
Soluble Sulphate (SO4)	mg/L	2000	5.0	1400	5.0	430	N/A	5.0	8605816

RDL = Reportable Detection Limit
Lab-Dup = Laboratory Initiated Duplicate
N/A = Not Applicable

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Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		QW8662		QW8663		QW8664	QW8665		
Sampling Date		2017/03/05		2017/03/17		2017/02/24	2017/02/27		
COC Number		A174619		A174619		A174619	A174619		
	UNITS	**BH17-32B AS3**	**RDL**	**BH17-38B AS1**	**RDL**	**BH17-16C AS3**	**BH17-25 GS1**	**RDL**	**QC Batch**
CONVENTIONALS									
Total Organic Carbon (C)	mg/kg	N/A	500	N/A	500	N/A	ATTACHED	500	8608469
Calculated Parameters									
Resistivity @ 25 °C	ohm-m	3.9	0.050	16	0.050	28	N/A	0.050	8605241
Calculated Chloride (Cl)	%	0.012	0.00032	0.00080	0.00034	<0.00023	N/A	0.00023	8604932
Calculated Sulphate (SO4)	%	0.11	0.00032	0.0027	0.00034	0.0028	N/A	0.00023	8604932
Soluble Parameters									
Soluble Chloride (Cl)	mg/L	190	5.0	12	5.0	<5.0	N/A	5.0	8605786
Soluble Conductivity	dS/m	2.5	0.020	0.62	0.020	0.35	N/A	0.020	8605626
Soluble pH	pH	7.81	N/A	7.70	N/A	7.93	N/A	N/A	8605629
Saturation %	%	65	N/A	68	N/A	46	N/A	N/A	8605356
Soluble Sulphate (SO4)	mg/L	1800	5.0	39	5.0	61	N/A	5.0	8605816

RDL = Reportable Detection Limit
N/A = Not Applicable

Maxxam ID		QW8666		
Sampling Date		2017/02/17		
COC Number		A174619		
	UNITS	**BH17-12 AS1**	**RDL**	**QC Batch**
CONVENTIONALS				
Total Organic Carbon (C)	mg/kg	ATTACHED	500	8608469

RDL = Reportable Detection Limit

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	18.3°C

TOC by Combustion results are attached to this report file. The reference number from Maxxam Campobello for these results is B777170

Results relate only to the items tested.

Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

QUALITY ASSURANCE REPORT

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
8605356	LX	QC Standard	Saturation %	2017/04/18		101	%	89 - 111
8605356	LX	RPD	Saturation %	2017/04/18	0.93		%	12
8605356	LX	RPD [QW8661-01]	Saturation %	2017/04/18	0.65		%	12
8605626	ACZ	QC Standard	Soluble Conductivity	2017/04/18		93	%	75 - 125
8605626	ACZ	Spiked Blank	Soluble Conductivity	2017/04/18		99	%	90 - 110
8605626	ACZ	Method Blank	Soluble Conductivity	2017/04/18	<0.020		dS/m	
8605626	ACZ	RPD [QW8661-01]	Soluble Conductivity	2017/04/18	9.0		%	20
8605629	BJO	QC Standard	Soluble pH	2017/04/18		99	%	97 - 103
8605629	BJO	Spiked Blank	Soluble pH	2017/04/18		100	%	97 - 103
8605629	BJO	RPD [QW8661-01]	Soluble pH	2017/04/18	0.13		%	N/A
8605786	CH7	Matrix Spike [QW8661-01]	Soluble Chloride (Cl)	2017/04/18		107	%	75 - 125
8605786	CH7	QC Standard	Soluble Chloride (Cl)	2017/04/18		100	%	75 - 125
8605786	CH7	Spiked Blank	Soluble Chloride (Cl)	2017/04/18		106	%	80 - 120
8605786	CH7	Method Blank	Soluble Chloride (Cl)	2017/04/18	<5.0		mg/L	
8605786	CH7	RPD [QW8661-01]	Soluble Chloride (Cl)	2017/04/18	7.9		%	30
8605816	CJ5	QC Standard	Soluble Sulphate (SO4)	2017/04/18		89	%	75 - 125
8605816	CJ5	Method Blank	Soluble Sulphate (SO4)	2017/04/18	<5.0		mg/L	

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Micheline Piche, Project Manager

Suwan Fock, B.Sc., QP, Inorganics Senior Analyst

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Chain of Custody

A174619

Page: ____ of ____

475

	Invoice To:	C/O Report Address ☐
Company:	STANTEC CONSULTING LTD.	
Contact:	RYLEY PROZNIK	
Address:	Prov: AB	PC: 1233
Contact #s:	Ph: 780-239-1498	Cell:

Report To:	Same as Invoice ☑
Prov:	PC:
Ph:	Cell:

Report Distribution (E-Mail): RYLEY.PROZNIK@STANTEC.COM

REGULATORY GUIDELINES:
- ☐ AT1
- ☐ CCME
- ☐ Regulated Drinking Water
- ☐ Other:

All samples are held for 60 calendar days after sample receipt, unless specified otherwise.

PO #:	144902448
Project # / Name:	144902448 / TLICHO ALL SEASON ROAD
Site Location:	NORTHWEST TERRITORIES
Quote #:	
Sampled By:	JM / KP

SERVICE REQUESTED: ☐ RUSH (Contact lab to reserve) Date Required: ____ ☐ REGULAR (5 to 7 Days)

See reverse for package specifics

SOIL: BTEX F1-F4 | Sieve (75 micron) | Regulated Metals (CCME / AT1) | Salinity 4 | Assessment ICP Metals | Basic Class II Landfill | Resistivity | pH | Sulphates & Chlorides

WATER: ☐BTEX F1 / ☐VOCs | ☐BTEX F1-F2 / ☐BTEX F1-F4 | ☐ Routine Water ☐ Turb ☐ F | ☐ TOC / ☐ DOC | Regulated Metals (CCME / AT1): Total, Dissolved | Mercury ☐ Total ☐ Dissolved

Other Analysis: ORGANIC CONTENT

#	Sample ID	Depth (unit)	Matrix GW / SW Soil	Date/Time Sampled YY/MM/DD 24:00	Resistivity	pH	Sulphates & Chlorides	ORGANIC CONTENT	HOLD - Do not Analyze	# of Containers Submitted
1	BH17-16C AS1-A							✓		
2	BH17-33B 10'-11.5'				✓	✓	✓			
3	BH17-74B AS1				✓	✓	✓			
4	BH17-60B AS4				✓	✓	✓			
5	BH17-57B 40'-42'				✓	✓	✓			
6	BH17-31B 5'-6.5'				✓	✓	✓			
7	BH17-59B AS2				✓	✓	✓			
8	BH17-32B AS3				✓	✓	✓			
9	BH17-38B AS1				✓	✓	✓			
10	BH17-16C AS3				✓	✓	✓			
11	BH17-25 GS1							✓		
12	BH17-12 AS1							✓		

Please indicate Filtered, Preserved or Both (F, P, F/P) F/P

Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):
/ NIKO NAVAL	17/04/07	
/ Ryley Proznik	17/04/17	14:30

Special Instructions:

# of Jars Used & Not Submitted

LAB USE ONLY

Received By:	Date:	Time:	Maxxam Job #:
David Tidman	20170417	1430	B728026

Lab Comments:

Custody Seal	Temperature	Ice
No	Bags 18, 19, 18	No

AB FCD-00331 Rev3 2010/05

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APPENDIX E

Thermistor Resistance versus Temperature Table

Thermistor Readings

Resistance versus Temperature Relationship 3000 Ohm NTC Thermistors

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	30	525.4	70	153.2	110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.99K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-35	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	282.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	56.92	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965	53	250.9	93	83.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	3000	25	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

Temperature calculated using:

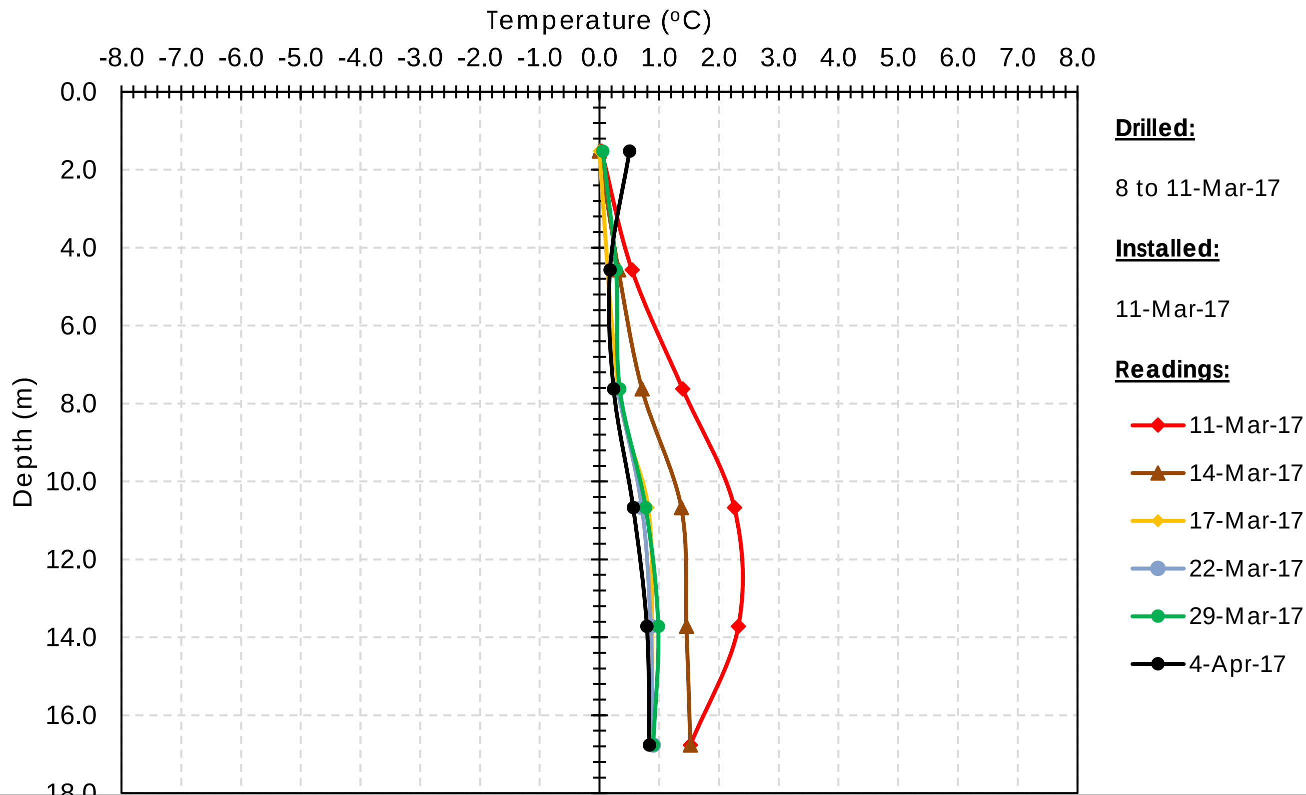
Steinhart-Hart Linearization

$$T_C = \frac{1}{C_0 + C_1(\ln R) + C_3(\ln R)^3} - 273.15$$

3000 Ohm @ 25C NTC Thermistor

C_0= 0.0014051
C_1= 0.0002369
C_3= 0.0000001019
lnR= Natural Log of Resistance
T_C= Temperature in °C

Document THL0006A



Borehole	**BH17-31B**								
Drilled:	8 to 11-Mar-17			Drilled Depth:			18.90	m	
Installed:	11-Mar-17								
Reading			**Bead**	TS4363	TS4368	TS4393	TS4392	TS4427	TS4425
Date		**Days**	**Depth (m)**	1.52	4.57	7.62	10.67	13.72	16.76
Post-Install	11-Mar-17	0	**R (Kilo Ω)**	9.77	9.52	9.12	8.73	8.70	9.06
			T (°C)	0.0	0.5	1.4	2.3	2.3	1.5
2	14-Mar-17	3	**R (Kilo Ω)**	9.79	9.63	9.44	9.13	9.09	9.06
			T (°C)	0.0	0.3	0.7	1.4	1.5	1.5
3	17-Mar-17	6	**R (Kilo Ω)**	9.79	-	9.63	9.39	9.36	9.36
			T (°C)	0.0	-	0.3	0.8	0.9	0.9
4	22-Mar-17	11	**R (Kilo Ω)**	-	-	9.64	9.44	9.37	9.35
			T (°C)	-	-	0.3	0.7	0.9	0.9
5	29-Mar-17	18	**R (Kilo Ω)**	9.76	9.65	9.62	9.41	9.31	9.35
			T (°C)	0.1	0.3	0.3	0.8	1.0	0.9
6	4-Apr-17	24	**R (Kilo Ω)**	9.54	9.7	9.67	9.51	9.4	9.38
			T (°C)	0.5	0.2	0.2	0.6	0.8	0.8

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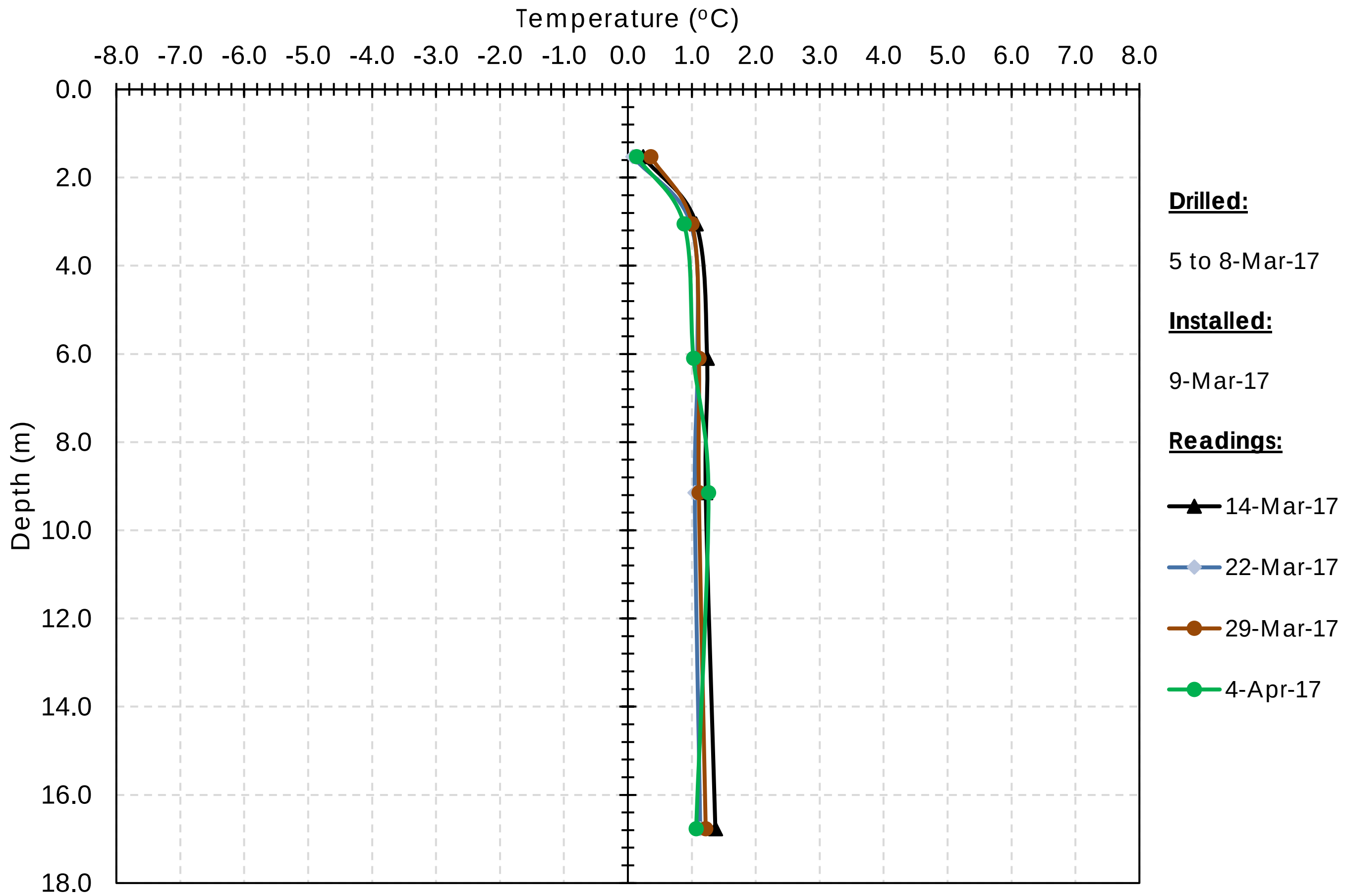
Thermistor Readings BH17-31B

Figure No. 16

Project No. 144902448



Borehole	**BH17-32B**							
Drilled:	5 to 8-Mar-17			Drilled Depth:			19.00	m
Installed:	9-Mar-17							
Reading			**Bead**	TS4424	TS4441	TS4444	TS4435	TS4440
Date		**Days**	**Depth (m)**	1.52	3.05	6.10	9.14	16.76
Post-Install	14-Mar-17	5	**R (Kilo Ω)**	9.67	9.27	9.19	9.2	9.13
			T (°C)	0.2	1.1	1.2	1.2	1.4
2	22-Mar-17	13	**R (Kilo Ω)**	9.75	9.31	9.26	9.28	9.24
			T (°C)	0.1	1.0	1.1	1.0	1.1
3	29-Mar-17	20	**R (Kilo Ω)**	9.61	9.3	9.25	9.25	9.2
			T (°C)	0.4	1.0	1.1	1.1	1.2
4	4-Apr-17	26	**R (Kilo Ω)**	9.72	9.36	9.29	9.18	9.27
			T (°C)	0.1	0.9	1.0	1.3	1.1

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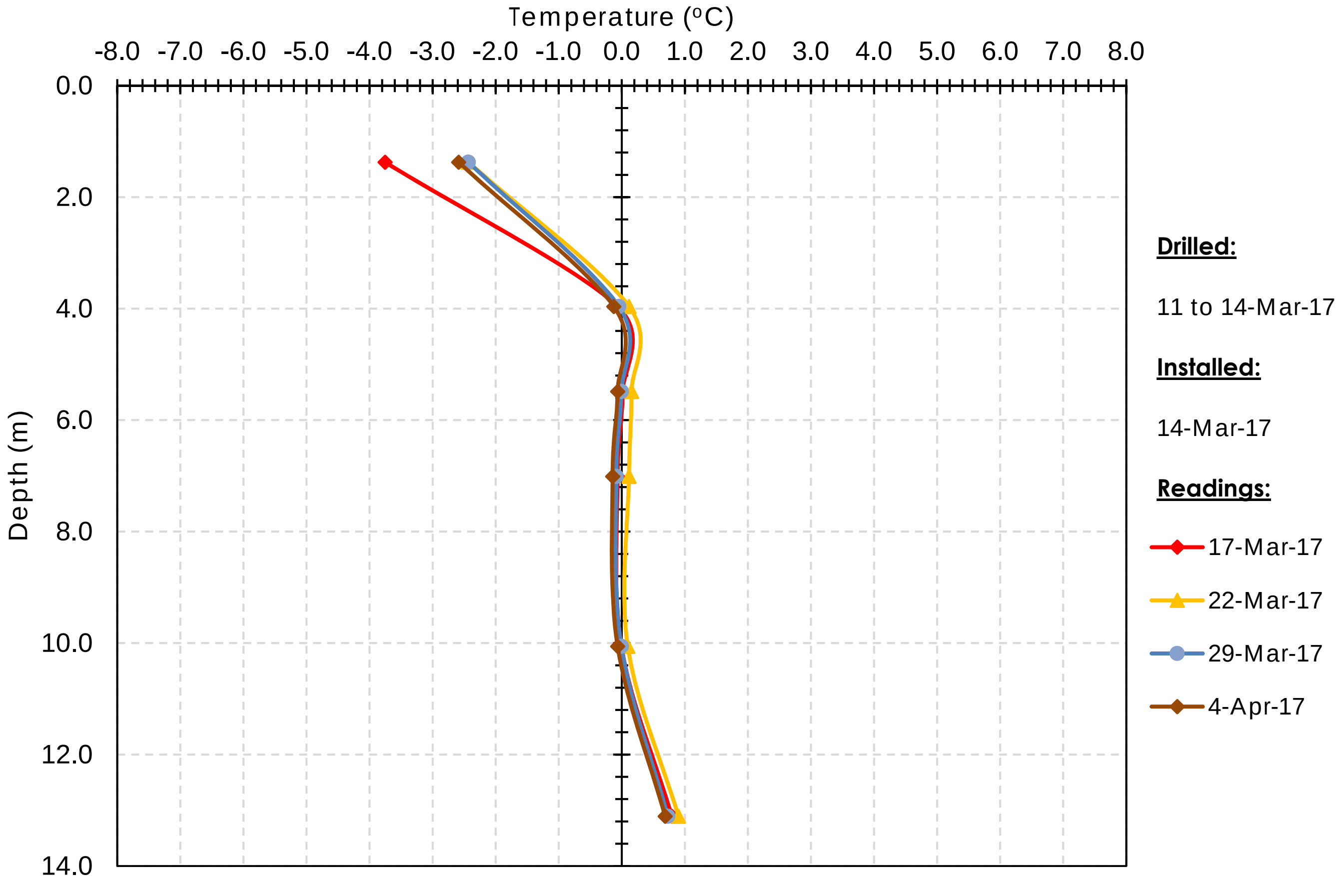
Thermistor Readings BH17-32B

Figure No. 17

Project No. 144902448



Borehole	**BH17-33B**								
Drilled:	11 to 14-Mar-17				Drilled Depth:			24.61	m
Installed:	14-Mar-17								
Reading			**Bead**	TS4329	TS4328	TS4394	TS4395	TS4407	TS4413
Date		**Days**	**Depth (m)**	1.37	3.96	5.49	7.01	10.06	13.11
Post-Install	17-Mar-17	3	**R (Kilo Ω)**	11.88	9.82	9.78	9.82	9.79	9.40
			T (°C)	-3.8	-0.1	0.0	-0.1	0.0	0.8
2	22-Mar-17	8	**R (Kilo Ω)**	11.09	9.73	9.71	9.73	9.74	9.35
			T (°C)	-2.4	0.1	0.2	0.1	0.1	0.9
3	29-Mar-17	15	**R (Kilo Ω)**	11.09	9.81	9.79	9.83	9.79	9.43
			T (°C)	-2.4	0.0	0.0	-0.1	0.0	0.7
4	4-Apr-17	21	**R (Kilo Ω)**	11.18	9.85	9.82	9.86	9.82	9.45
			T (°C)	-2.6	-0.1	-0.1	-0.1	-0.1	0.7

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Thermistor Readings
BH17-33B

Figure No. 18

Project No. 144902448

Geotechnical Data Report
Proposed Bridge Crossing #9
Station 45+175

Geotechnical Investigation,
Proposed Tlicho All-Season Road,
Northwest Territories

Prepared for:
Tlicho Engineering and
Environmental Services Ltd.

Prepared by:
Stantec Consulting Ltd.
400 – 1331 Clyde Avenue
Ottawa, ON K2C 3G4

Project No. 144902448

May 2017

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Stantec Borehole Records
Field Bedrock Core Logs
Bedrock Core Photos

APPENDIX D Laboratory Test Results

APPENDIX E Thermistor Resistance versus Temperature
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1.0 INTRODUCTION

Acting under the authorization of Tlicho Engineering and Environmental Services Ltd. (Tlicho), Stantec Consulting Ltd. (Stantec) carried out a geotechnical investigation in support of the bridge planned at 'Crossing #9' along the proposed Tlicho All Season Access Road (TASR). The purpose of the investigation was to characterize subsurface conditions and provide geotechnical comments and recommendations to assist with bridge design and site development.

The investigation was carried out in general accordance with Stantec's proposal dated January 12, 2017, as part of an overall geotechnical program by Tlicho for the Government of the Northwest Territories (GNWT) along the proposed 94 km TASR alignment extending from the Yellowknife Highway (Highway 3) to the Settlement of Whatì on the south shore of Lac La Martre (RFP Event ID: EV000000001132). The scope of work outlined in the GNWT Request for Proposal includes the geotechnical investigation and design of the 94 km long TASR corridor, four bridges and three structural culverts. Tlicho was responsible for management and execution of the overall project and team as the Prime Contractor, with Stantec acting as sub-consultant providing geotechnical engineering and technical services to the project, including:

- Provision of geotechnical field personnel to log subsurface conditions during drilling operations at eighty-one (81) geotechnical boreholes in accordance with the RFP:
  - Thirteen (13) boreholes at the four (4) proposed major bridge crossings:
    - Crossing #8, Station 40+400 - Duport River Crossing
    - Crossing #9, Station 45+175 - (unnamed)
    - Crossing #14, Station 69+666 - James River Crossing
    - Crossing #15, Station 85+397 - La Martre River
  - Three (3) boreholes at the three (3) proposed major bridge culvert crossings:
    - Crossing #5, Station 16+532
    - Crossing #6, Station 19+427
    - Crossing #10a, Station 48+208
  - Sixty-five (65) boreholes to observe the subsurface conditions along the road alignment;
- Installation and reading of thermistors;
- Borehole layout and as-drilled survey;
- Completion of a laboratory testing program on the recovered borehole samples as specified in the RFP; and
- Geotechnical engineering assessment and reporting on the field and laboratory findings in two reports (Geotechnical Data Report and Geotechnical Recommendations Report) for each crossing location and for the overall roadway alignment.
  - These documents should be read in conjunction with the Statement of General Conditions, Appendix A.

This Report has been prepared specifically and solely for the proposed bridge crossing at Crossing #9 of the Tlicho All Season Road in the Northwest Territories, Canada.

2.0 SITE DESCRIPTION AND GEOLOGY AND CLIMATE

2.1 SITE DESCRIPTION

The site location is shown on the Key Plan, Drawing No. 1 provided in Appendix B. The site for the proposed bridge crossing is along the alignment of the proposed Tlicho All Season Road and in proximity to the currently abandoned winter road from Highway 3 to Whatì. The proposed alignment follows the old winter road alignment, which was abandoned in favour of a new winter road some decades ago. The site location is approximately 45 km north of Highway 3 and 62 km south of the Community of Whatì along the TASR alignment in the Northwest Territories, Canada. Photographs showing the general site conditions of the proposed bridge location are provided in Appendix B.

The proposed bridge site runs approximately northeast-southwest at the project location; chainage increases in the northern direction towards Whatì. The proposed bridge location is at Station 45+175. Based on the General Layout drawing, the location of the proposed bridge crossing is at a low point on the road profile and crosses an 8.3 m wide creek with an approximate stream bed elevation of 262.5 m. The creek flows from west to east from a lake source about 0.3 km west. The area on both the east and west sides of the existing road and the creek is covered with brush and trees. On March 16, 2017, the watercourse channel(s) was visible, however, the flow conditions were not observed due to ice and snow cover. Snow cover depths of approximately 60 cm were measured in surrounding undisturbed areas.

It is understood that the Old Lac La Martre overland winter road was established by the military in the 1950s, and used as a public winter road for the northern Tlicho communities up until the late 1980s. More recently it has been used by the local communities for travel using all-terrain vehicles including snowmobiles, dog sleds, ATVs, and trucks (GNWT DOT, 2016). Given that the crossing will be offset from the non-maintained winter road alignment it is understood that this area has not be developed in the past and exists in its native, undisturbed state.

2.2 PHYSIOGRAPHY AND GEOLOGY

The site is located within the Great Slave Plain High Boreal Ecoregion (ECG, 2009 and GNWT DOT, 2016). In this section of the TASR corridor (GNWT DOT, 2016), regional topography is generally subdued with plains and gently rolling hills. Drainage ranges from 'imperfect' to 'moderately well' with occasional seasonal tributaries. Vegetation includes regenerating jack pine forest, riparian areas, graminoid fen, dense spruce, and spruce-tamarack stands. The general area was subjected to forest fires in the last decade.

Based on available surficial geology mapping conducted by the Geological Survey of Canada, and previous project terrain mapping (Kavik AXYS Inc, 2008 and GNWT DOT, 2016), natural overburden material in the area has been mapped as till, coarse glacio-lacustrine and fine glacio-lacustrine material associated with glacial Lake McConnell, and occasional veneers of organic or fluvial materials overlying bedrock. Based on geological mapping published by the Geological Survey of Canada (Okulitch, A.V, 2006), the site is mapped within the Interior Platform geologic province, situated over Paleozoic aged sedimentary rocks of the Chinchaga Formation consisting of interbedded anhydrite-mudstone, grey, thin-bedded; and dolomite-mudstone, anhydritic, brown, thin-bedded.

2.3 CLIMATE AND PERMAFROST

2.3.1 Climate

Based on a review of historic climate data completed using the Yellowknife Airport (Climate Reference ID: 2204100), Whatì meteorological station (Lac la Martre, Climate Reference ID: 2202678) and other sources (GNWT, 2016), it is understood that the TASR area has a subarctic climate (Dfc, according to the Köppen climate classification system) characterized by generally relatively cold winters followed by short summers. It is noted that the Whatì station is located approximately 13 km west of the northern limit of the TASR and the Yellowknife station is located approximately 100 km east of the southern limit of the TASR.

Average annual daily mean temperatures are on the order of -4.3 °C (Yellowknife Station) to - 4.7°C (Whatì Station), with the lowest average daily winter temperatures generally occuring in January, while the warmest month (based on the average temperature) occurs in July. The average annual precipitation is estimated on the order of 290 mm, with an average annual rainfall of 170 mm generally occurring throughout June through September, and an average annual snowfall of 157.6 cm generally occurring from September through May (Yellowknife Station).

The average freezing and thawing indices between 1981 and 2010 have been 3343 C° days and 1813 C° days, respectively (Yellowknife Station). A study completed by Holubec, et. al., using data from 1978 to 2008 in their model was adapted by CSA (2010). The CSA study suggests a warming trend of 0.58 °C per decade within the Central Arctic region (including the TASR site). As per Table 5.2 in CSA (2010), the seasonal mean temperature change under moderate (A1B) green-house gas scenarios for the Arctic Sector C1 are projected to be 1.3 °C (2011-2040), 2.7 °C (2041-2070), and 3.7 °C (2071 – 2100), respectively.

2.3.2 Permafrost

Canada permafrost mapping from the National Atlas of Canada (Heginbottom et al. 1995) shows the TASR site lies within the zone of extensive discontinuous permafrost, with an estimated 50% and 90% of the landscape covered. It is understood that no public thermistor or intrusive investigation records exist for the immediate vicinity of the TASR. Previous reconnaissance trips by earlier AXYS terrain mapping crews and GNWT personnel did not identify any apparent permafrost landforms or thermokarst zones within the corridor, however a zone affected by thermokarst processes was noted between Whatì, Behchoko and the area north of Slemon Lake Kavik (AXYS Inc, 2008 and GNWT DOT, 2016).

Based on regional studies completed in surrounding areas (GNWT, 2016), permafrost is anticipated to be relatively warm and correlated with forest cover type areas underlain by finer-textured glacial and post-glacial sediments such as glaciolacustrine and lacustrine deposits, as well as peatlands where organic material contributes to the forming and preservation of permafrost. Ground ice content, if present in these finer grained deposits in the upper 10 to 20 m is anticipated to be less than 10% to 20% ice by volume (Heginbottom et al. 1995). Ground ice is generally expected to be less common in areas of exposed bedrock and where the underlying sediments are coarse and vegetation cover is thin.

Permafrost near Yellowknife is reported to be generally warm (>-2°C), less than 50 m thick with active layer thickness less than 1 to up to 3 m (Wolfe, 1998). Permafrost conditions along the nearby Highway 3 have been reported as typically warmer than -1°C, with an active layer thickness varying from less than 0.7 m to 1.5 m. Permafrost degradation has been noted along the Highway in recent years with settlements in soil-covered areas generally attributed to the degradation of the ice-rich permafrost subgrade, particularly where it was constructed adjacent to a water body and where the road crossed over the old alignment (BGC, 2011; and Wolfe et al, 2015;). Permafrost, where present, will be susceptible to degradation due to ground disturbance, such as removal of trees and surface vegetation or earthworks.

Recent studies commissioned by GNWT have reported that climate change trends have negatively impacted and are projected to continue to negatively impact infrastructure supported on permafrost in the region (Dillon 2007; BGC, 2011). Continued warming, changes in freeze-thaw patterns, and ultimately degradation of permafrost in the region are anticipated due to increasing temperatures and amounts of precipitation, and decreases in snow and ice cover.

3.0 INVESTIGATION PROCEDURES

3.1 FIELD INVESTIGATION

A geotechnical field investigation for the proposed bridge consisting of two boreholes was carried out for this assignment as part of the overall TASR alignment geotechnical field program between February 12 and March 29, 2017. The boreholes were designated BH17-38B and BH17-39B and their locations are shown on the General Layout and Borehole Location Plan, Drawing No. 2 in Appendix B. The General Layout drawing is based on the Tlicho All Season Road Predesign Report and was designed by DOT Structures and drawn/drafted by DOT Technical Services. It is to be noted that the layout is conceptual and the final design details will be determined at a later date.

The field drilling program at this crossing was carried out from March 14 to 16, 2017. Boreholes BH17-38B and BH17-39B were advanced with solid 150 mm augers and NW casing using a track mounted Foremost CME drill rig equipped for soil sampling and operated by Northtech Drilling Ltd.

The field work was conducted under the supervision of Justin Matthew, B.Eng. and Jim Oswell, PhD., P.Eng. (Stantec) who maintained detailed logs and obtained samples from the various strata encountered. Subsurface conditions were classified in general accordance with the procedures outlined in the attached explanatory key: Symbol and Terms Used on Borehole and Test Pit Records with soil descriptions prepared in accordance with ASTM D2487 and D2488. Temperatures of select soil samples were measured by a handheld infrared thermometer on recovery at surface. Our observations of the temperature readings suggest the drilling process altered the temperature of the soil samples and that these measurements should not be considered representative of in situ conditions. For example, soil samples collected from the augers within the seasonal frost layer (denoted as AS) had temperature readings greater than 0° C. Frozen soils were classified in accordance with ASTM D4083 and D7099. Groundwater levels were estimated in the open boreholes at the time of drilling with water level tape and/or the moisture condition of the recovered samples.

Six single-bead thermistor cables with 3000 Ohm thermistors manufactured by RST Instruments Ltd. were installed in boreholes BH17-38B and BH17-39B at depths of ranging from 1.1 m to 9.0 m below ground surface. Initial thermistor resistance readings were taken on installation with a digital multimeter. Three readings were completed between 1 day and 20 days after installation. The boreholes were backfilled to the original ground surface level with auger cuttings and with sand. A 25 mm PVC pipe with approximately 1 m stickup was installed in each borehole in order to install the thermistor beads at the correct depths below ground surface.

3.2 LOCATION AND ELEVATION SURVEY

The borehole locations and geodetic elevations were surveyed in the field by Stantec personnel using a Trimble Geo XH GPS with decimeter accuracy capability. The accuracy of the Trimble unit may be affected by satellite coverage at the time of survey. Table 3.1 summarizes the borehole information.

Table 3.1: Borehole Summary

	Boreholes	
	BH17-38B	**BH17-39B**
NAD83 / UTM Zone 11 V Coordinates Northing Easting	 6959989 509480	 6960008 509490
Ground Surface Elevation, m	263.3	263.6
Depth of Overburden, m	4.9	5.1
Depth of Bedrock Cored, m	4.9	4.7
Total Depth Drilled, m	9.8	9.8
End of Borehole Elevation, m	253.5	253.8
Number of Soil Samples	7	6

3.3 LABORATORY TESTING

All samples were taken to the Stantec Edmonton and Calgary laboratories for detailed classification and testing. Selected soil samples underwent gradation analysis, Atterberg Limits, and moisture content testing. The laboratory testing summary is shown in Table 3.2 below.

Table 3.2: Laboratory Testing for Bridge Site

Laboratory Testing	Moisture Content	Gradation Analysis	Atterberg Limits
Number of Tests	9	9	3

Unconfined compressive strength tests were conducted on two rock core specimens. Two soil samples were tested for pH, soluble sulphate content, chloride content, and resistivity. Samples remaining after testing will be placed in storage for a period of one year after issuance of the final report. After the storage period, the samples will be discarded unless we are directed otherwise by Tlicho Engineering and Environmental Services Ltd.

4.0 SUBSURFACE CONDITIONS

4.1 SUBSURFACE PROFILE

The subsurface conditions observed in the Stantec boreholes are presented in detail on the Borehole Records provided in Appendix C. An explanation of the symbols and terms used to describe the Borehole Records is provided in Appendix C.

The temperature of each soil sample was measured in the field using an infrared thermometer and is provided on the Borehole Records. Temperatures inferred from temperature measurements of soil samples should be considered with extreme caution. Soil sample temperatures may be either warmer than in-situ due to drilling disturbance or be colder than in-situ due to cold air temperature exposure of the soil samples prior to temperature measurement.

It should be noted that the blow counts and relative density/consistency descriptions of frozen soils in the following section and in Appendix C should be used with caution. It is highly likely, particularly for cohesive soils, that the strengths implied by the blow counts will be significantly reduced by thawing.

In general, the subsurface stratigraphy at the site consisted of organic material at the surface, over clayey sand to lean clay, over lean clay with varying amounts of sand, silt and gravel, underlain by dolomite-mudstone bedrock. Given the proximity of the two boreholes to the stream, the upper deposits may be fluvial in origin. Occasional cobbles were observed in the upper material and frequent cobbles and boulders were inferred in the deeper material above the bedrock. The borehole locations are shown on Drawing No. 2 and the subsurface stratigraphy is shown on Drawing No. 3 in Appendix B.

4.1.1 Organic Soil

Organic soil described as topsoil and/or rootmat was encountered in boreholes BH17-38B and BH17-39B from surface to 0.15 m below ground surface.

4.1.2 Sand

A frozen sand layer with varying amounts of gravel and clay (fines) was encountered in boreholes BH17-39B. The SPT N-values for the sand deposit were 64 and 68 blows per 0.3 m.

The sand deposit extended from 0.15 m to 1.5 m below ground surface in borehole BH17-39B. The sand is described as clayey sand (SC) based on the Unified Soil Classification System (USCS). Cobbles were noted within the sand layer. Temperatures of the sand obtained from the infrared thermometer at the time of drilling were recorded as less than 0 °C. The frozen soil description of the layer was N_{bn} and V_x.

Grain size distribution and moisture content tests carried out on representative samples of the clayey sand yielded the following results:

Gravel:	11%
Sand:	50%
Silt size:	20%
Clay size:	19%
Moisture Content:	15 and 31%

Atterberg limits tests carried out on one representative sample from this layer indicated a liquid limit of 31 and a plasticity index of 11. The grain size distribution curve for the clayey sand material is provided in Figure 1 of Appendix D and the corresponding plasticity chart is given in Figure 6 of Appendix D.

4.1.3 Clay

A frozen clay layer consisting of lean clay with varying amounts of sand, silt, and gravel was encountered below the sand in borehole BH17-39B and below the rootmat layer in borehole BH17-38B. Cobbles were inferred within the clay. Temperatures of the clay samples obtained from the infrared thermometer at the time of drilling were recorded as less than 0 °C. The frozen soil description of the layer was N_{bn}.

The SPT N-values for this deposit ranged from 16 to 32 blows per 0.3 m. Pocket penetrometer tests yielded shear strength values of 150 kPa to over 200 kPa.

Grain size distribution and moisture content tests carried out on representative samples of the clay yielded the following results:

Gravel:	0 and 11%
Sand:	25 and 26%
Silt size:	35 and 40%
Clay size:	28 and 35%
Moisture Content:	13 to 27%

Atterberg limits tests carried out on one representative sample from this layer indicated a liquid limit of 30 and a plasticity index of 15. The USCS group symbol for this layer is CL (lean clay with sand and sandy lean clay). Representative grain size distribution plots for this layer are given in Figures 2 and 3 and the corresponding plasticity chart is given in Figure 6 of Appendix D.

The clay layer become coarser with higher amounts of sand, silt and gravel was encountered. More frequent cobbles and boulders were inferred by grinding of the drill. Temperatures of the clay samples obtained from the infrared thermometer at the time of drilling ranged from 3.2 to 4.3 °C.

The SPT N-values for this deposit ranged from 29 to over 50 blows per 0.3 m. Pocket penetrometer tests yielded shear strength values of over 200 kPa, suggesting a hard consistency.

Grain size distribution and moisture content tests carried out on representative samples of the clay yielded the following results:

Gravel:	2 and 5%
Sand:	20 and 27%
Fines (silt and clay):	71%
Silt size:	33%
Clay size:	42%
Moisture Content:	10 to 19%

Atterberg limits tests carried out on one representative sample from this layer indicated a liquid limit of 41 and a plasticity index of 25. The USCS group symbol for the layer is CL (lean clay with sand). Representative grain size distribution plots for this layer are given in Figures 4 and 5 and the corresponding plasticity chart is given in Figure 6 of Appendix D.

4.1.4 Bedrock

Bedrock was encountered beneath the clay in boreholes BH17-38B and BH17-39B. The bedrock surface was encountered at approximately 4.9 m and 5.1 m below ground surface, respectively. The bedrock consisted predominantly of grey and white dolomite-mudstone. A detailed description of the rock core is provided in the Field Bedrock Core Logs in Appendix C. Rock core photographs are also provided in Appendix C.

Rock Quality Designation (RQD) values measured on the retrieved bedrock core ranged between 0% and 85%, indicating a very poor to good rock mass quality. The Total Core Recovery (TCR) of the bedrock ranged from 84% to 100%. The bedrock was moderately weathered to fresh. Weathered seams with clay infilling were observed in both boreholes; the thickness of the seams ranged from about 25 mm to 75 mm.

Unconfined compressive strength tests were carried out on two bedrock samples. The results of these tests are summarized in Table 4.1. The unconfined compressive strength from the two tests were 10 MPa and 27 MPa, which indicates the bedrock is typically weak to medium strong. Bedrock samples from boreholes BH17-38B and BH17-39B at depths of 9.7 m and 8.5 m were highly reactive in response to hydrochloric acid tests.

Table 4.1: Results of Unconfined Compressive Strength of Rock Cores

Borehole No	Depth (m)	Test Elevation (m)	Unconfined Compressive Strength (MPa)
BH17-38B	7.3 m	256.0	10
BH17-39B	7.3 m	256.2	27

4.2 PERMAFROST CONDITIONS

Based on field observations of frozen soil recoveries during advancement of the boreholes, frozen soil was encountered within boreholes BH17-38B and BH17-39B. The frozen soil was encountered in boreholes BH17-38B and BH17-39B from ground surface to 2.4 m and 3.0 m below the existing ground surface, respectively. The frozen soils were described as having no visible ice, N_{bn} and in two samples visible ice less than 30 mm thick, V_x in accordance with ASTM D4083. Temperatures of soil samples recorded in the field were recorded as less than 0 °C within the frozen zone of borehole BH17-39B. Warmer soil sample temperatures of 3.2 to 4.3 °C were measured below a depth of 3.4 m in borehole BH17-39B.

Six single-bead thermistor cables with 3000 Ohm thermistors manufactured by RST Instruments Ltd. were installed in boreholes BH17-38B and BH17-39B. The thermistors were installed to depths of about 1.4 m, 2.9 m, 4.4 m, 5.9 m, 7.5 m, and 9.0 m below ground surface in borehole BH17-38B. The thermistors were installed to depths of about 1.1 m, 2.1 m, 3.4 m, 4.6 m, 6.1 m, and 7.9 m below ground surface in borehole BH17-39B. Initial thermistor readings were taken at installation with a digital multimeter. Three readings from 1 day to 20 days after installation were also completed. The resistance versus temperature relationship for the thermistors is included in Appendix E. Figures 7 and 8 in Appendix E present the Depth versus Temperature as determined by the thermistor readings for boreholes BH17-38B and BH17-39B, respectively.

The thermistor readings are considered to be a more reliable indication of the temperature of the soils compared to the infrared thermometer readings. The infrared thermometer was used during sampling when the soils have been heated by friction generated by the action of the drill. It was also observed during the field work that when outside temperatures ranged between -20 °C and -30 °C that readings indicated that the sample was colder than the actual air temperature which was not likely. Therefore, the reported infrared temperature readings should be used with caution.

The temperature of the soil samples obtained using the infrared thermometer suggests a frozen layer approximately 2.4 m to 3.0 m thick is present within the embankment. The temperature of the soil samples suggests the absence of permafrost at the bridge location. The thermistor readings suggest permafrost is not likely present at the bridge location. It is noted that the geothermal regime may have been altered from drilling activities (use of water for coring) and the thermal profile in the boreholes were not stabilized at the time of the readings.

4.3 GROUNDWATER

Groundwater was not encountered in the open boreholes during the investigation. Fluctuations in the groundwater due to seasonal changes or in response to a particular precipitation event should be anticipated. It is noted that at the time of the investigation, the watercourse channel was visible, however, the flow conditions were not observed due to ice and snow cover. Based on the General Layout drawing the approximate stream bed elevation of the creek is 262.5 m.

4.4 CHEMICAL TEST RESULTS

Two samples of the native soil material were tested for pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis results are provided in Table 4.2. The results and certificates of analysis from Maxxam Analytics are provided in Appendix D.

Table 4.2: Results of Chemical Analysis

Borehole No	Sample No.	Depth (m)	pH	Chloride (%)	Sulphate (%)	Resistivity (Ohm-m)
BH17-38B	AS1	0 to 1.52	7.70	0.00080	0.0027	16.0
BH17-39B	SS3	1.21 to 1.66	7.56	0.00120	0.1000	2.0

5.0 CLOSURE

A subsurface investigation is a limited sampling of a site. The subsurface conditions given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered that differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information. Use of this report is subject to the Statement of General Conditions provided in Appendix A. It is the responsibility of Tlicho Engineering and Environmental Services Ltd., who is identified as "the Client" within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec Consulting Ltd. should any of these not be satisfied. The Statement of General Conditions addresses the following:

- Use of the report
- Basis of the report
- Standard of care
- Interpretation of site conditions
- Varying or unexpected site conditions
- Planning, design or construction

This report was written by Zachary Popper, B.Eng. and reviewed by Christopher McGrath, P.Eng. and Jim Oswell, P.Eng. Mr. McGrath and Dr. Oswell are registered members of the Northwest Territories and Nunavut Association of Professional Engineers and Geoscientists. We trust that the information contained in this report is adequate for your present purposes. If you have any questions about the contents of the report or if we can be of any other assistance, please contact us at your convenience.

Respectfully Submitted;

STANTEC CONSULTING LTD.

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6.0 REFERENCES

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2009. Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) (ASTM D2488). ASTM International, West Conshohocken, PA.

ASTM. 2010. Standard Terminology Relating to Frozen Soil and Rock (ASTM D7099). ASTM International, West Conshohocken, PA.

ASTM. 2011. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

ASTM. 2016. Standard Practice for Description of Frozen Soils (Visual-Manual Procedure) (ASTM D4083). ASTM International, West Conshohocken, PA.

BGC Engineering Inc. 2011. Highway 3 – Climate Change Vulnerability Assessment – Final Report.

Canadian Standards Association (CSA). 2010. Technical Guide Infrastructure in permafrost: A guideline for climate change adaptation. Canadian Standards Association, Mississauga, ON, Canada.

Dillon Consulting Ltd. 2007. Climate Change and Transportation in the NWT. March 2007.

Environment Canada. Warming Trends °C/Decade, Based on homogenized temperature data – the most recent 30 yr record (1981 – 2010); Environment Canada.

Environment Canada. (2016, September 1) Canadian Climate Normals 1981–2010. Yellowknife Station. Retrieved from http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProv&lstProvince=NT&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=1706&dispBack=0

GNWT, 2009. Ecosystem Classification Group (ECG) 2009. Ecological Regions of the Northwest Territories: Taiga Shield. Department of Environment and Natural Resources, GNWT. Yellowknife, NT.

GNWT DOT, 2016. Proposed Tlicho All-season Road, Project Description Report. March 2016

Heginbottom, J.A., Dubreuil, M.A., and P.A. Harker. 1995. Canada-Permafrost; National Atlas of Canada, 5th edition, Plate 2.1. Geomatics Canada, National Atlas Information Service and Geological Survey of Canada (MCR 4177).

Kavik AXYS Inc. 2008a. Multi-Level Mapping and Route Analysis – Tlicho Transportation Corridor. Route Identification and Evaluation. Yellowknife, NT. January 2008.Project No. Project No. 144902005.

Okulitch, A.V. 2004. Geological compilation of Phanerozic Bedrock Geology (Map NP-11/12-G), Slave River District of MacKenzie, Northwest Territories. Geological Survey of Canada, Open File 5281.

Stantec, 2015.Tli Cho Road Alignment, Hydrologic and Hydraulic Study. Project No. 144902005.

Wolfe, 1998. Living with frozen ground : a field guide to permafrost in Yellowknife, Northwest Territories, edited by Stephen A. Wolfe ; contributions by Stephen A. Wolfe

S.A. Wolfe, P.D. Morse, T.E. Hoeve, W.E Sladen, S.V. Kokelj, L.U. Arenson, 2015. Disequilibrium permafrost conditions on NWT Highway 3

7.0 BIBLIOGRAPHY

Andersland, O.B., and Ladanyi, B. 1994. An Introduction to Frozen Ground Engineering. Chapman & Hall Inc., New York, NY, USA.

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2000. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

ASTM. 2000. Standard Practice for Description of Frozen Soils (Visual-Manual Procedure) (ASTM D4083). ASTM International, West Conshohocken, PA.

Canadian Foundation Engineering Manual (CFEM). 2006. Fourth Edition. Canadian Geotechnical Society, 488 p.

CHBDC. 2014. Canadian Highway Bridge Design Code. Canadian Standards Association, Mississauga, Ontario.

GSC, 1965. Glacial Lake McConnell and the surficial geology of parts of Slave River and Redstone River map areas, District of Mackenzie; Craig, B G. Geological Survey of Canada, Bulletin 122, 1965,; 44 pages, doi:10.4095/100639. Natural Resources Canada. 1995: Canada Permafrost; The National Atlas of Canada 5th Edition, scale 1:7 500 000.

GSC, 1989. Glacial Features Around the Keewatin Ice Divide, Northwest Territories; Aylsworth, J M; Shilts, W W. Geological Survey of Canada, Preliminary Map 24-1987, 1989, ; 2 sheets, doi:10.4095/126992.

Kerr and Wilson, 2000. 2000-C3. Preliminary surficial geology studies and mineral exploration considerations in the Yellowknife area, Northwest Territories. D.E. Kerr and P. Wilson.

APPENDIX A

Statement of General Conditions

STATEMENT OF GENERAL CONDITIONS

<u>*USE OF THIS REPORT*</u>: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec Consulting Ltd. and the Client. Any use which a third party makes of this report is the responsibility of such third party.

<u>*BASIS OF THE REPORT*</u>: The information, opinions, and/or recommendations made in this report are in accordance with Stantec Consulting Ltd.'s present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec Consulting Ltd. is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

<u>*STANDARD OF CARE*</u>: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

<u>*INTERPRETATION OF SITE CONDITIONS*</u>: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec Consulting Ltd. at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

<u>*VARYING OR UNEXPECTED CONDITIONS*</u>: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec Consulting Ltd. must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec Consulting Ltd. will not be responsible to any party for damages incurred as a result of failing to notify Stantec Consulting Ltd. that differing site or sub-surface conditions are present upon becoming aware of such conditions.

<u>*PLANNING, DESIGN, OR CONSTRUCTION*</u>: Development or design plans and specifications should be reviewed by Stantec Consulting Ltd., sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec Consulting Ltd. cannot be responsible for site work carried out without being present.

APPENDIX B

Drawing No. 1 – Key Plan

Drawing No. 2 – General Layout and Borehole Location Plan

Drawing No. 3 – Subsurface Profile

Site Photos

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MAY 2017
Project No. 144902448

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LEGEND

PROPOSED ALIGNMENT

NOTES

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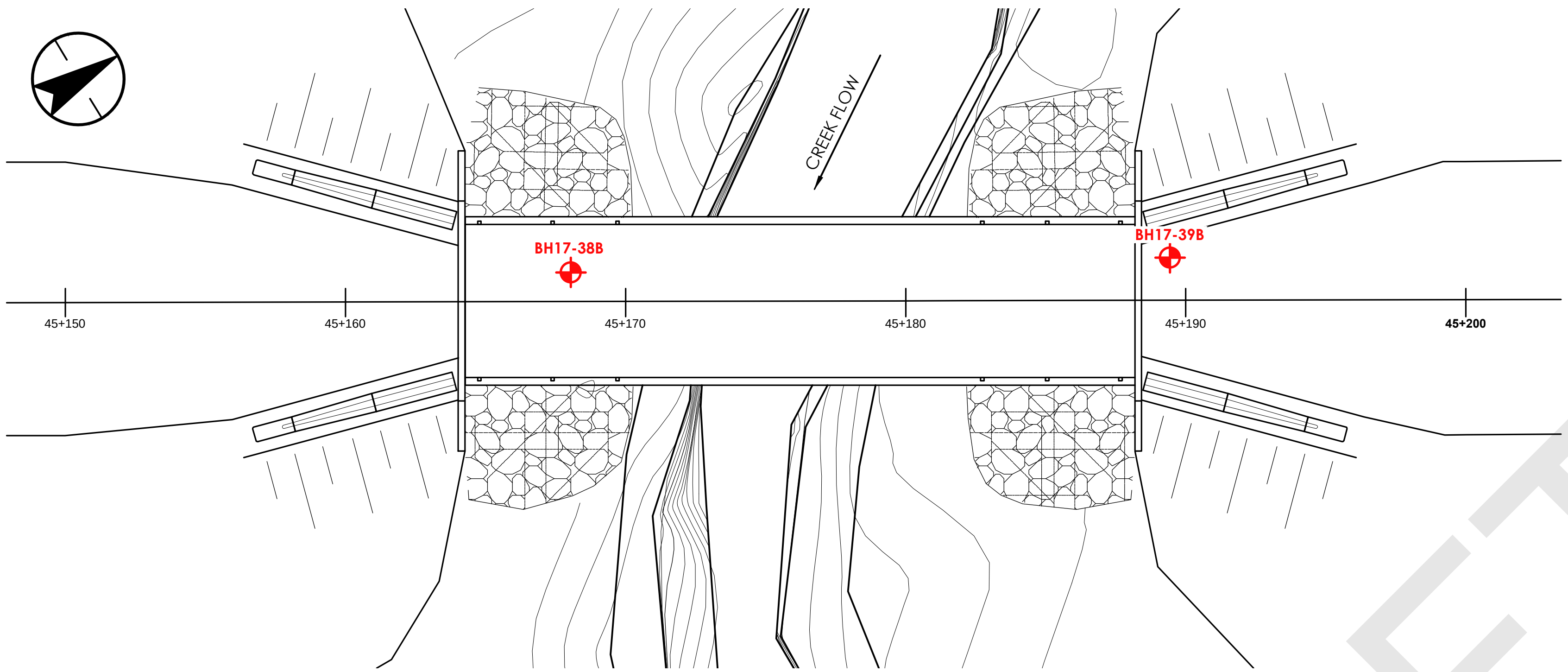
GEOTECHNICAL INVESTIGATION
BRIDGE CROSSING #9, NWT

Drawing No.
1

Title
KEY PLAN



SITE PLAN
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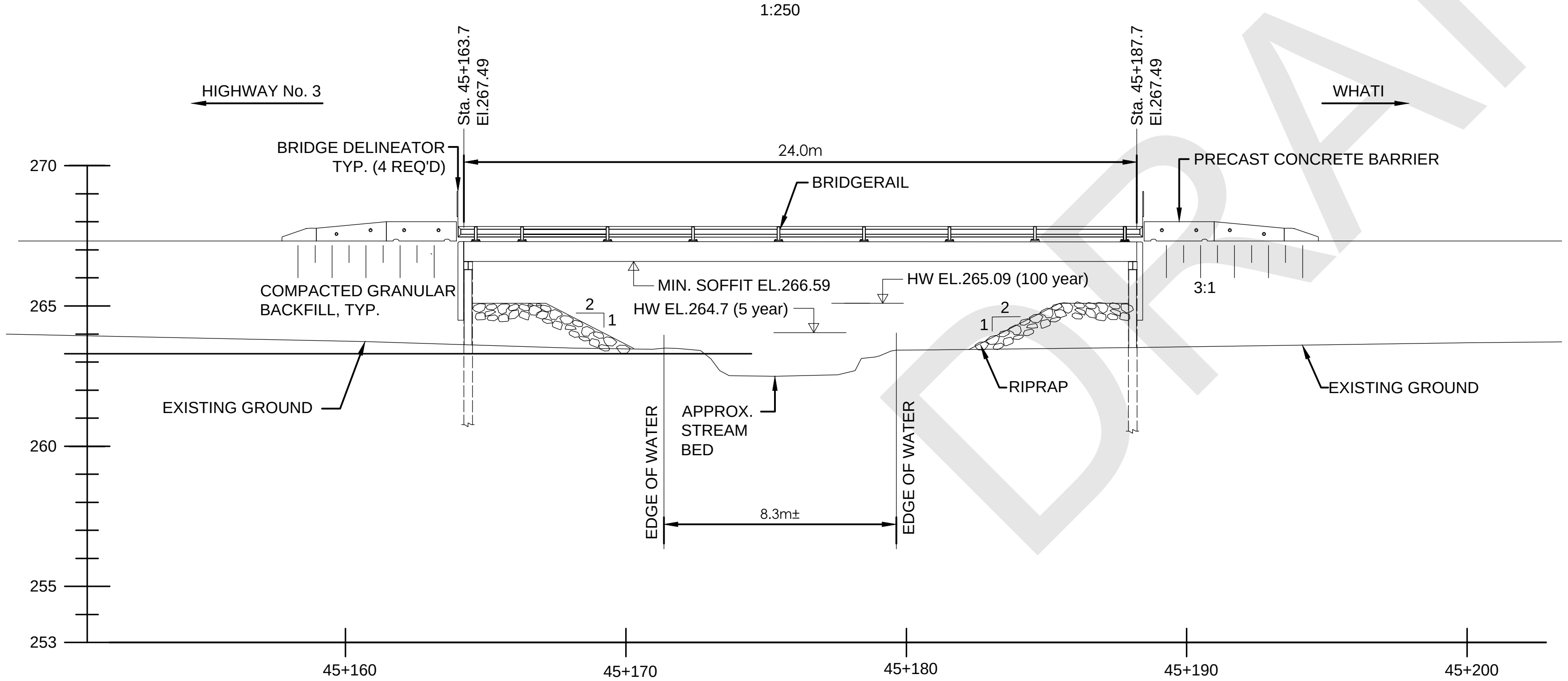

ELEVATION
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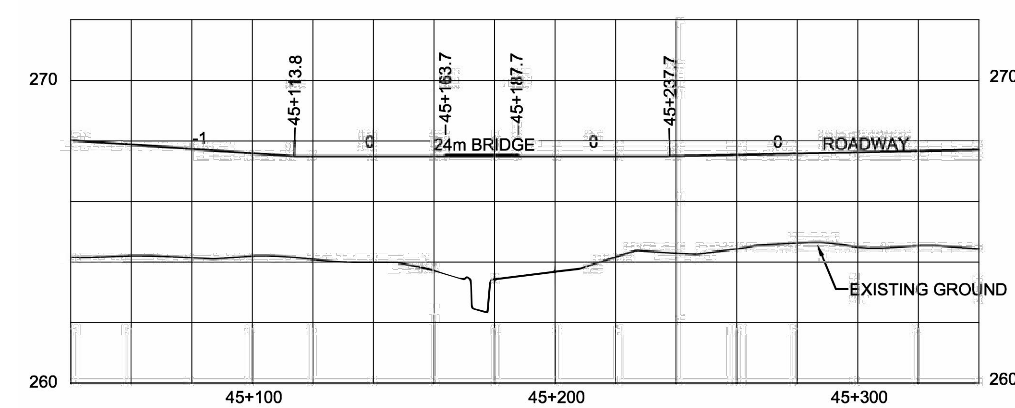
PLAN
1:5,000



ROADWAY PROFILE
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PROJECT No. 144902448

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LEGEND

APPROXIMATE BOREHOLE LOCATION

NOTES

1. DRAWING PROVIDED BY DOT TECHNICAL SERVICES (TASR-06-16 (CROSSING#9).

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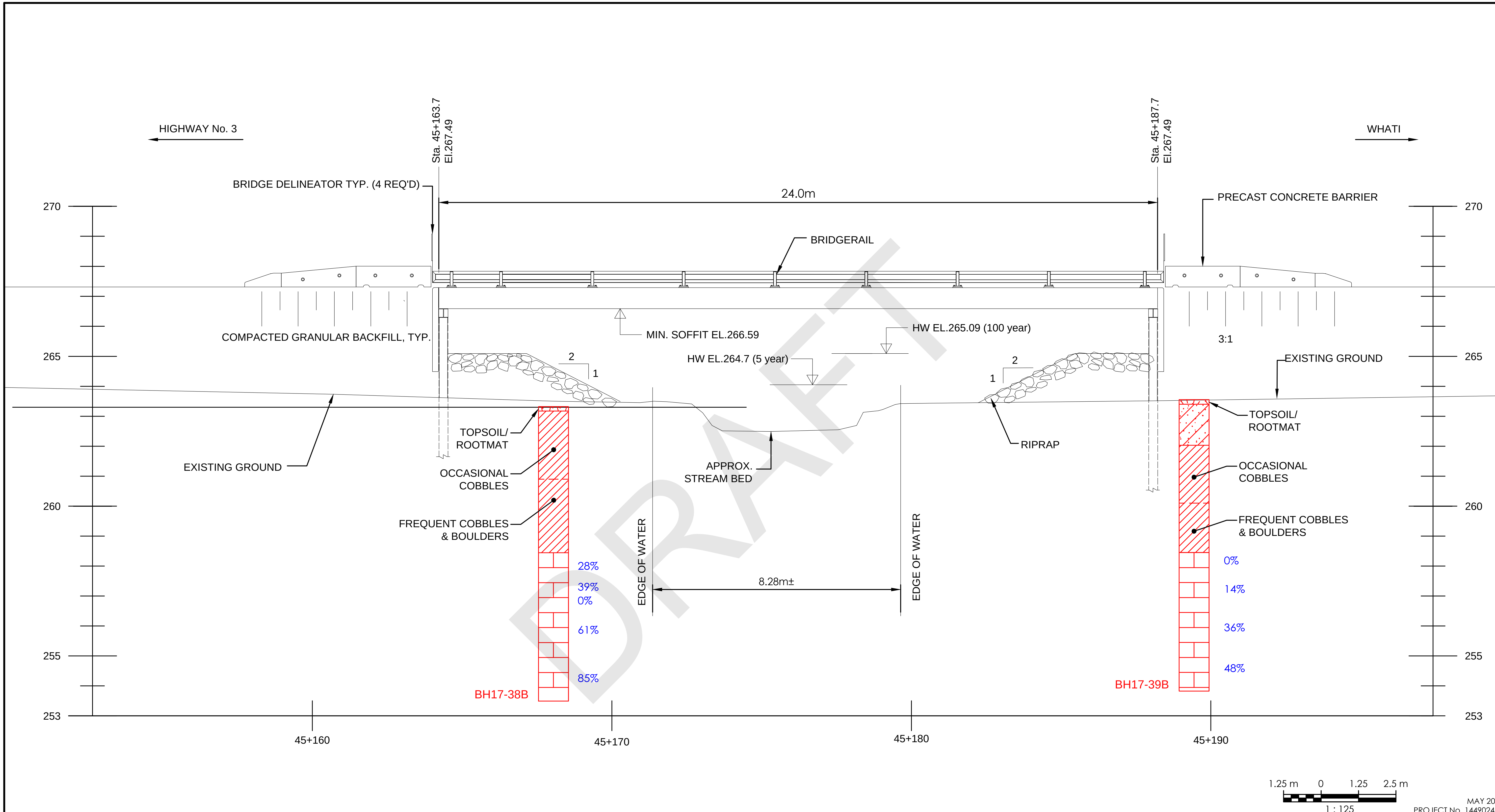
GEOTECHNICAL INVESTIGATION
BRIDGE CROSSING #9, NWT

Drawing No.

2

Title

GENERAL LAYOUT AND BOREHOLE LOCATION PLAN



MAY 2017
PROJECT No. 144902448

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2017/05/09 1:56 PM By: Briones, Gliceria

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LEGEND

- 39% RQD (ROCK QUALITY DESIGNATION)
- TOPSOIL / ROOTMAT
- CLAYEY SAND (SC)
- LEAN CLAY WITH SAND TO SANDY LEAN CLAY (CL)
- DOLOMITE MUDSTONE

NOTES

1. DRAWING PROVIDED BY DOT TECHNICAL SERVICES (TASR-06-16 (CROSSING#9).

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GEOTECHNICAL INVESTIGATION
BRIDGE CROSSING #9, NWT

Drawing No.

3

Title

SUBSURFACE PROFILE

Photo No. 1: Borehole Location BH17-38B

Photo No. 2: Borehole Location BH17-38B

Photo No. 3: Borehole Location BH17-38B

Photo No. 4: Borehole Location BH17-38B

Photo No. 5: Borehole Location BH17-38B

Photo No. 6: Borehole Location BH17-39B

Photo No. 7: Borehole Location BH17-39B

Photo No. 8: Borehole Location BH17-39B

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APPENDIX C

Symbols and Terms Used on Borehole Records

Stantec Borehole Records

Field Bedrock Core Logs

Bedrock Core Photos

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

Rootmat	- vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
Topsoil	- mixture of soil and humus capable of supporting vegetative growth
Peat	- mixture of visible and invisible fragments of decayed organic matter
Till	- unstratified glacial deposit which may range from clay to boulders
Fill	- material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

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

Terminology describing soil types:
The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4th Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):
Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

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

Terminology describing compactness of cohesionless soils:
The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. A relationship between compactness condition and N-Value is shown in the following table.

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

Terminology describing consistency of cohesive soils:
The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	Undrained Shear Strength		Approximate SPT N-Value
	kips/sq.ft.	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25 - 0.5	12.5 - 25	2-4
Firm	0.5 - 1.0	25 - 50	4-8
Stiff	1.0 - 2.0	50 – 100	8-15
Very Stiff	2.0 - 4.0	100 - 200	15-30
Hard	>4.0	>200	>30

ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Terminology describing rock quality:

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

Alternate (Colloquial) Rock Mass Quality	
Very Severely Fractured	*Crushed*
Severely Fractured	*Shattered or Very Blocky*
Fractured	*Blocky*
Moderately Jointed	*Sound*
Intact	*Very Sound*

RQD (Rock Quality Designation) denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 in.) long are summed and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

SCR (Solid Core Recovery) denotes the percentage of solid core (cylindrical) retrieved from a borehole of any orientation. All pieces of solid (cylindrical) core are summed and divided by the total length of the core run (It excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

Fracture Index (FI) is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

Terminology describing rock with respect to discontinuity and bedding spacing:

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

Terminology describing rock strength:

Strength Classification	Grade	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	<1
Very Weak	R1	1 – 5
Weak	R2	5 – 25
Medium Strong	R3	25 – 50
Strong	R4	50 – 100
Very Strong	R5	100 – 250
Extremely Strong	R6	>250

Terminology describing rock weathering:

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

STRATA PLOT

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

Boulders Cobbles Gravel	Sand	Silt	Clay	Organics	Asphalt	Concrete	Fill	Igneous Bedrock	Meta-morphic Bedrock	Sedi-mentary Bedrock

SAMPLE TYPE

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

WATER LEVEL MEASUREMENT

▼ measured in standpipe, piezometer, or well

▽ inferred

RECOVERY

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

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to ‘A’ size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

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

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

Stantec BOREHOLE RECORD

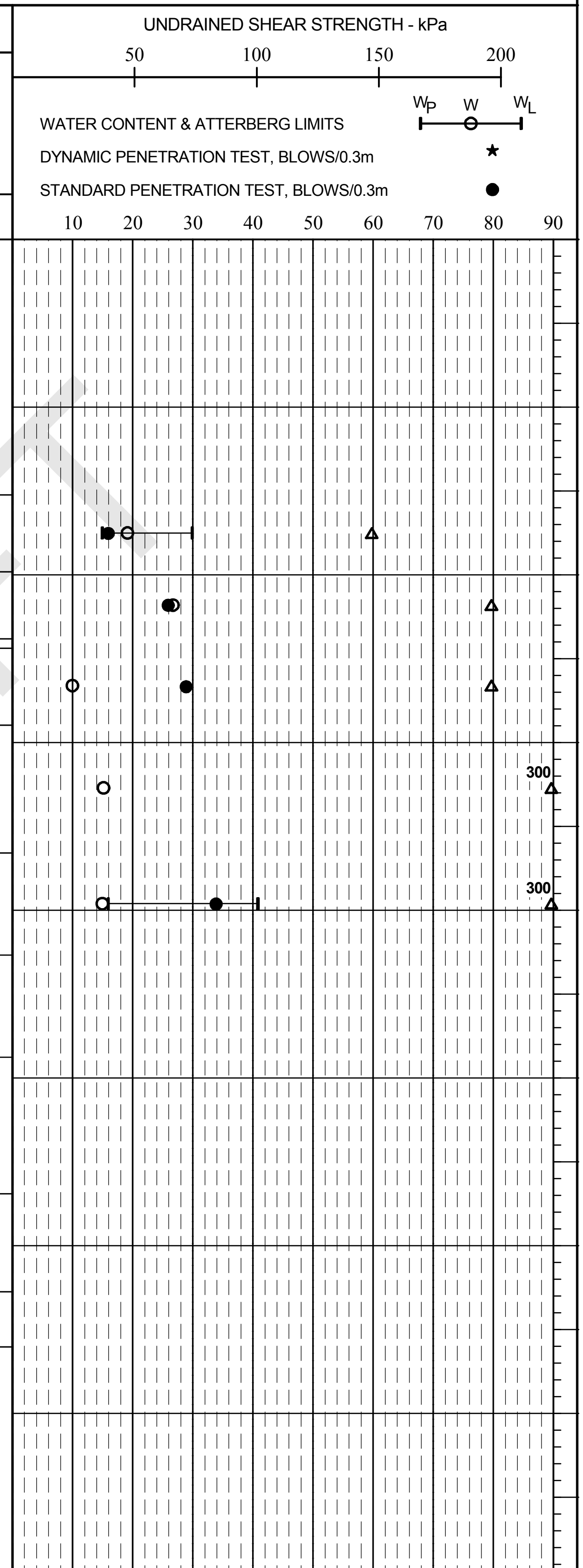
N: 6 959 989 E: 509 480

BH17-38B

CLIENT: Tlicho Engineering and Environmental Services Ltd.
LOCATION: Northwest Territories, Canada
DATES: BORING: March 15, 2017 WATER LEVEL: N/A

BOREHOLE No.: BH17-38B
PROJECT No.: 144902448
DATUM: Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLE TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	263.32					
0.1	263.2	150 mm TOPSOIL/ROOTMAT				
		Brown to grey, frozen, lean CLAY with sand to sandy lean CLAY (CL), trace gravel - Occasional cobbles - Frozen soil description: Nbn	AS	1	-	-
			SS	2	330	16
			SS	3	380	26
2.4	260.9		AS	4	-	-
		Hard, brown to grey, lean CLAY with sand to sandy lean CLAY (CL), trace gravel - Unfrozen below 2.4 m depth - Frequent cobbles and boulders	SS	5	300	29
			NQ	6	28%	-
			SS	7	280	34
4.9	258.4	Very poor to good quality, white to grey DOLOMITE MUDSTONE - See Field Bedrock Core Logs for details	NQ	8	94%	28%
			NQ	9	96%	39%
			NQ	10	100%	0%
			NQ	11	92%	61%



∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

Field Vane Test, kPa
Remoulded Vane Test, kPa
Pocket Penetrometer Test, kPa

App'd ______
Date ______

BOREHOLE RECORD

N: 6 959 989 E: 509 480

BH17-38B

CLIENT	Tlicho Engineering and Environmental Services Ltd.
LOCATION	Northwest Territories, Canada
DATES: BORING	March 15, 2017
WATER LEVEL	N/A
BOREHOLE No.	BH17-38B
PROJECT No.	144902448
DATUM	Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
8		Very poor to good quality, white to grey DOLOMITE MUDSTONE - See Field Bedrock Core Logs for details						
9					NQ	12	97%	85%
	253.5							
10		End of Borehole - Thermistor Installed						
11								
12								
13								
14								
15								
16								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS: W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

DRAFT

Inferred Groundwater Level

Groundwater Level Measured in Standpipe

Field Vane Test, kPa

Remoulded Vane Test, kPa

Pocket Penetrometer Test, kPa

App'd

Date

Stantec

BOREHOLE RECORD

N: 6 960 008 E: 509 490

BH17-39B

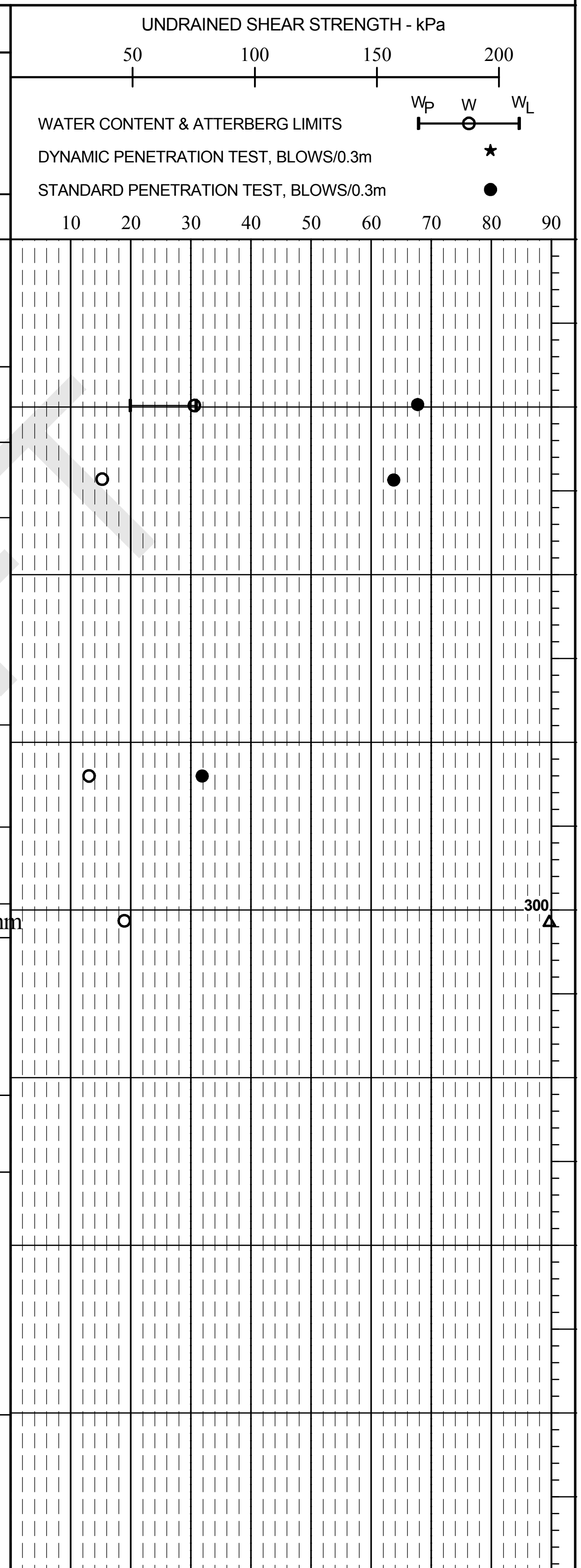
CLIENT: Tlicho Engineering and Environmental Services Ltd.
LOCATION: Northwest Territories, Canada
DATES: BORING March 16, 2017 WATER LEVEL N/A

BOREHOLE No.: BH17-39B
PROJECT No.: 144902448
DATUM: Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION
0	263.55	
	263.4	150 mm frozen TOPSOIL/ROOTMAT
		Brown to grey, frozen, clayey SAND (SC), trace gravel - Occasional cobbles - Frozen soil description: Sample AS1: Nbn Sample SS2/3: Vx
	262.0	- Approx. sample temperature: AS1: <0°C SS2: <0°C SS3: <0°C
		Brown to grey, frozen, lean CLAY with sand to sandy lean CLAY (CL), trace gravel
	260.1	- Occasional cobbles - Frozen soil description: Nbn - Approx. sample temperature: SS4: <0°C
	258.4	Hard, grey, lean CLAY with sand to sandy lean CLAY (CL), trace gravel - Frequent cobbles and boulders - Unfrozen below 3.0 m depth - Approx. sample temperature: SS5: +3.2 to +4.3°C
		Very poor to poor quality, white to grey DOLOMITE MUDSTONE
8		

SAMPLES

TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
AS	1	-	
SS	2	460	68
SS	3	460	64
SS	4	460	32
SS	5	180	50/50 mm
NQ	6A	100%	
NQ	6B	100%	0%
NQ	7	84%	14%
NQ	8	100%	36%



Inferred Groundwater Level
Groundwater Level Measured in Standpipe

Field Vane Test, kPa
Remoulded Vane Test, kPa
Pocket Penetrometer Test, kPa

App'd
Date

Stantec

BOREHOLE RECORD

BH17-39B

N: 6 960 008 E: 509 490

CLIENT Tlicho Engineering and Environmental Services Ltd.
BOREHOLE No. BH17-39B

LOCATION Northwest Territories, Canada
PROJECT No. 144902448

DATES: BORING March 16, 2017 WATER LEVEL N/A
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
8		Very poor to poor quality, white to grey DOLOMITE MUDSTONE - See Field Bedrock Core Logs for details			NQ	9	100%	48%
9	253.8							
		End of Borehole - Thermistor Installed						
10								
11								
12								
13								
14								
15								
16								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

DRAFT

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Stantec

Field Bedrock Core Log

Client:	Tlicho Engineering & Environmental Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	15-Mar-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-38B
		Logger:	JMO/JGM/ZP

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
4.9	NQ8	94%	28%	5.7	Very poor quality grey and white Dolomite - mudstone	R2	W3	1	JN	F-D	VC	RU/RP	C-O	SA/NC	Weathered seams with clay infilling (25 to 75 mm wide).	Bedrock starts at approximate depth of 4.9 m
5.7	NQ9	96%	39%	6.3	Poor quality grey and white Dolomite - mudstone	R2	W3	1	JN	F-D	VC-C	RU/RP	C-O	SA/NC	Weathered seams with clay infilling (25 to 75 mm wide). PP = 200kPa	Greyish brown wash water
6.3	NQ10	100%	0%	6.6	Very poor quality grey and white Dolomite - mudstone	R2	W3	1	JN	F-D	VC	RU/RP	C-O	SA/NC	Weathered seams with clay infilling (25 to 40 mm wide).	Greyish brown wash water
6.6	NQ11	92%	61%	8.2	Fair quality grey and white Dolomite - mudstone	R2	W1	1	JN	F	C-M	RU/RP	C-G	SA	Rock core compressive strength test result of 10 Mpa at 7.3 m	Greyish brown wash water

DRAFT

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
3	RU = Rough, Irregular, Undulating
1.5	SU = Smooth, Undulating
1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

Field Bedrock Core Log

Stantec

Client:	Tlicho Engineering & Environmental Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	15-Mar-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-38B
		Logger:	JMO/JGM/ZP

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
8.2	NQ12	97%	85%	9.8	Good quality grey and white Dolomite - mudstone	R2	W1	2	JN	F	M	RU/RP	C-O	SA/NC	Weathered seam with clay infilling at 9.4 m depth (25 mm wide).	
									JN	V	-	RU/RP	C	SA		

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
3	RU = Rough, Irregular, Undulating
1.5	SU = Smooth, Undulating
1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

Stantec

Field Bedrock Core Log

Client:	Tlicho Engineering & Environmental Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	16-Mar-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-39B
		Logger:	JMO/JGM/ZP

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
4.2	NQ6A	-	-	5.1	Hard, grey, sandy lean clay with gravel (CL) -Frequent cobbles and boulders											Bedrock starts at approximate depth of 5.1 m
5.1	NQ6B	100%	0%	5.6	Very poor quality grey and white Dolomite - mudstone	R2	W3	2	JN	F-D	VC	RU/RP	C-O	Si		Greyish brown wash water
									JN	V	-	RU/RP	C	SA		
5.6	NQ7	84%	14%	7.0	Very poor quality grey and white Dolomite - mudstone	R2	W2	1	JN	F-D	VC	RU/RP	C-O	NC	Frequent light grey clay seams (25 to 75 mm wide) PP= 100 to 250 kPa	Greyish brown wash water
7.0	NQ8	100%	36%	8.1	Poor quality grey and white Dolomite - mudstone	R3	W2	1	JN	F-D	VC-C	RU/RP	C-O	SA/NC	Three light grey clay seams (25 to 50 mm wide)	Rock core compressive strength test result of 27 Mpa at 7.3 m depth

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
3	RU = Rough, Irregular, Undulating
1.5	SU = Smooth, Undulating
1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

Field Bedrock Core Log

Stantec

Client:	Tlicho Engineering & Environmental Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	16-Mar-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-39B
		Logger:	JMO/JGM/ZP

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES							OCCASIONAL FEATURES	DRILLING OBSERVATIONS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING		
8.1	NQ9	100%	48%	9.7	Poor quality grey and white Dolomite - mudstone	R3	W2	1	JN	F	VC-C	RU/RP	C	SA		No clay seams or decomposed rock

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
3	RU = Rough, Irregular, Undulating
1.5	SU = Smooth, Undulating
1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

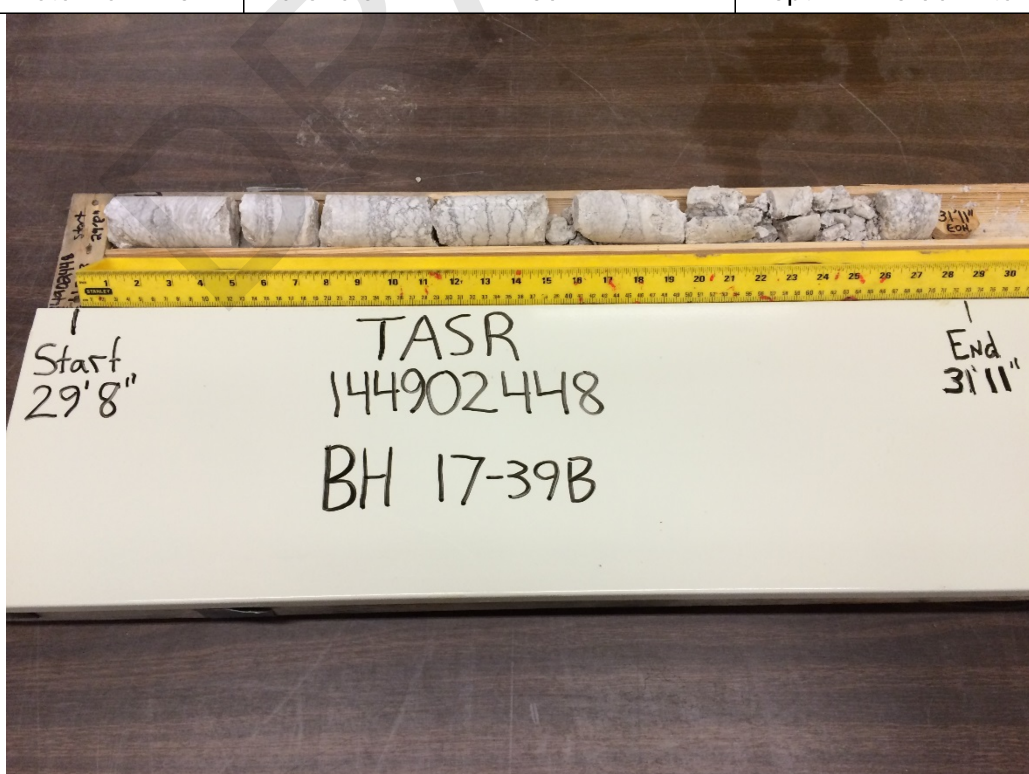
	Project No.: 144902448	Rockcore Photographs
Stantec	Project Name: Tlicho All Season Road – Crossing #9	

Rock Core Photo No.: 1	Borehole: BH 17-38B	Depth: 4.88 m to 9.29 m

Rock Core Photo No.: 2	Borehole: BH 17-38B	Depth: 9.29 m to 9.83 m

Stantec	Project No.: 144902448	Rockcore Photographs
	Project Name: Tlicho All Season Road – Crossing #9	

Rock Core Photo No.: 3	Borehole: BH 17-39B	Depth: 3.96 m to 9.04 m



Rock Core Photo No.: 4	Borehole: BH 17-39B	Depth: 9.04 m to 9.73 m

APPENDIX D

Laboratory Test Results

Stantec

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

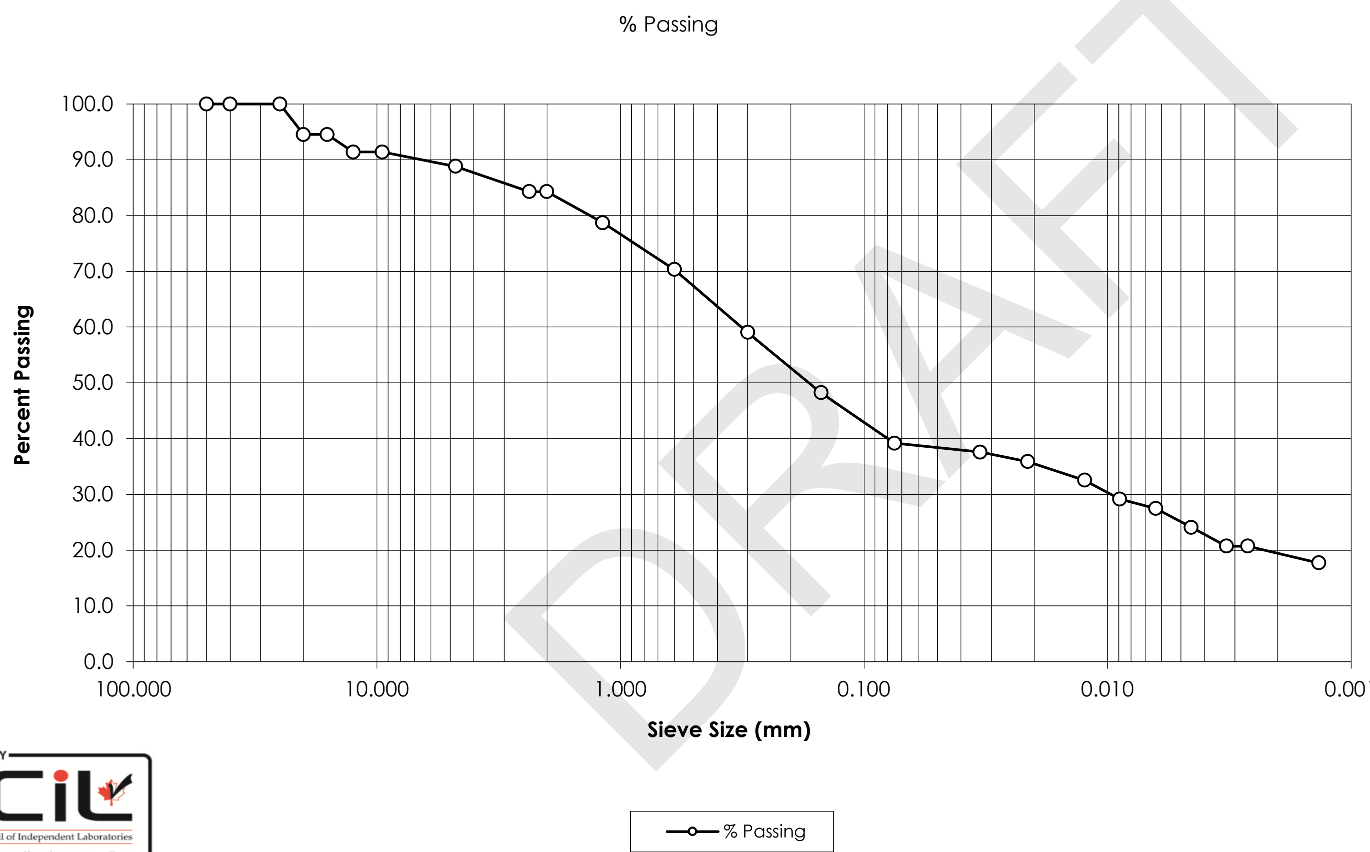
Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho All Season Road
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: SS2
SOURCE: BH17-39B
TESTED BY: JA

DATE TESTED: April 17, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Clayey sand



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	**100.0**	**0.0063**	**27.5**
40.0	**100.0**	**0.0045**	**24.1**
25.0	**100.0**	**0.0033**	**20.7**
20.0	**94.5**	**0.0027**	**20.7**
16.0	**94.5**	**0.0014**	**17.7**
12.5	**91.4**		
9.5	**91.4**		
4.75	**88.8**		
2.36	**84.3**		
2.00	**84.3**		
1.18	**78.7**		
0.600	**70.3**		
0.300	**59.0**		
0.150	**48.2**		
0.075	**39.2**		
0.0333	**37.6**		
0.0213	**35.9**		
0.0124	**32.5**		
0.0089	**29.2**		

Gravel:	11.2%	D_{10}:	-
Sand:	49.6%	D_{30}:	0.0098
Silt:	19.7%	D_{60}:	0.3276
Clay:	19.5%	C_u:	-
		C_c:	-

Comments:

Figure No. 1

Reviewed by:

Stantec

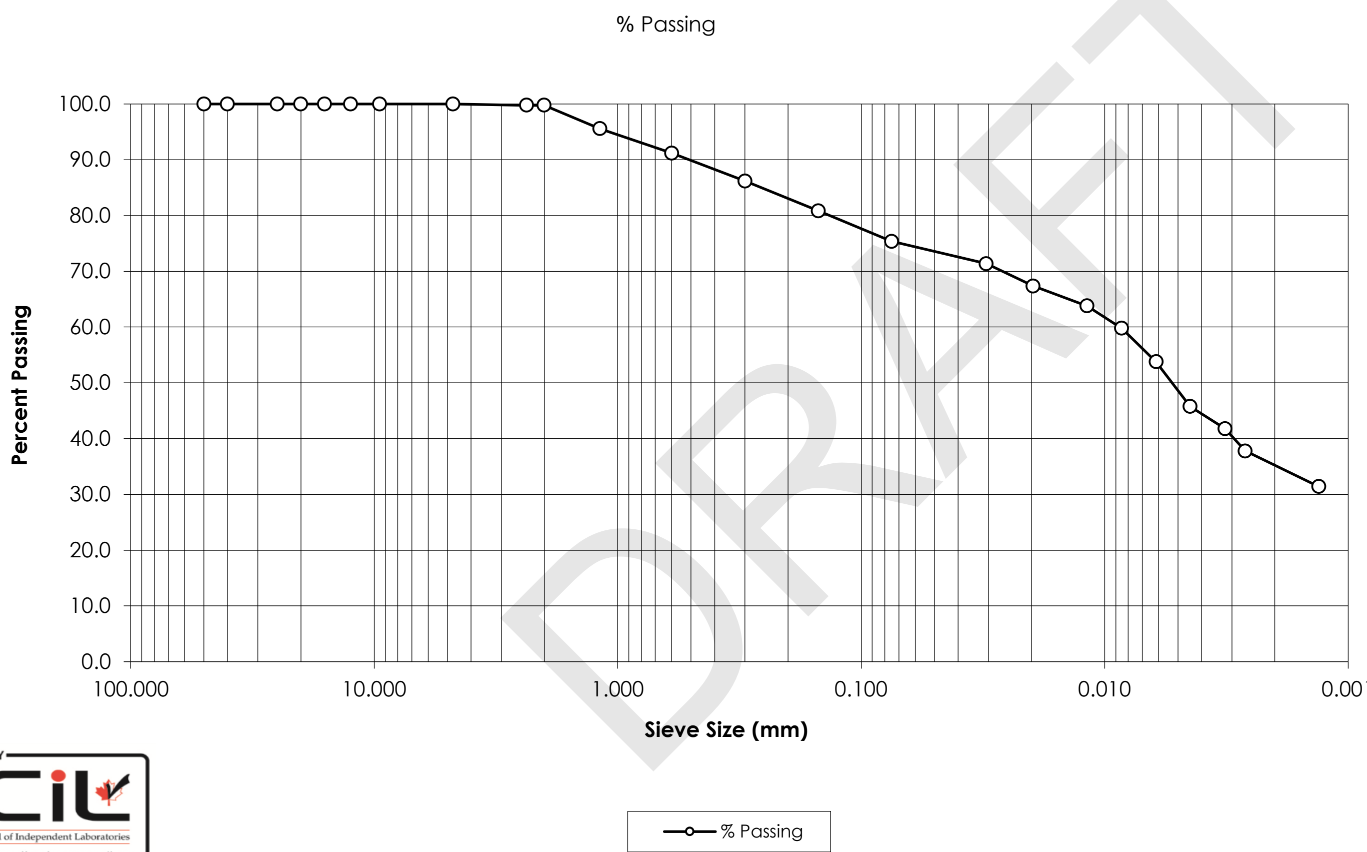
Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho All Season Road
Project No: 144902448

OFFICE	LABORATORY
10160 - 112 ST	10575 106 ST
Edmonton, Alberta	Edmonton, Alberta
Canada T5K 2L6	Canada T5H 2X5
Tel: (780) 917-7000	Tel: (780) 917-7463

SAMPLE No.: SS2
SOURCE: BH17-38B
TESTED BY: JA

DATE TESTED: April 16, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Lean clay with sand



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0061	53.8
40.0	100.0	0.0045	45.8
25.0	100.0	0.0032	41.8
20.0	100.0	0.0026	37.8
16.0	100.0	0.0013	31.4
12.5	100.0		
9.5	100.0		
4.75	100.0		
2.36	99.8		
2.00	99.8		
1.18	95.5		
0.600	91.2		
0.300	86.2		
0.150	80.8		
0.075	75.4		
0.0307	71.4		
0.0197	67.4		
0.0118	63.8		
0.0085	59.8		

Gravel:	0.0%	D_{10}:	-
Sand:	24.6%	D_{30}:	-
Silt:	40.2%	D_{60}:	0.0087
Clay:	35.2%	C_u:	-
		C_c:	-

Comments:

Figure No. 2

Reviewed by:

Stantec

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

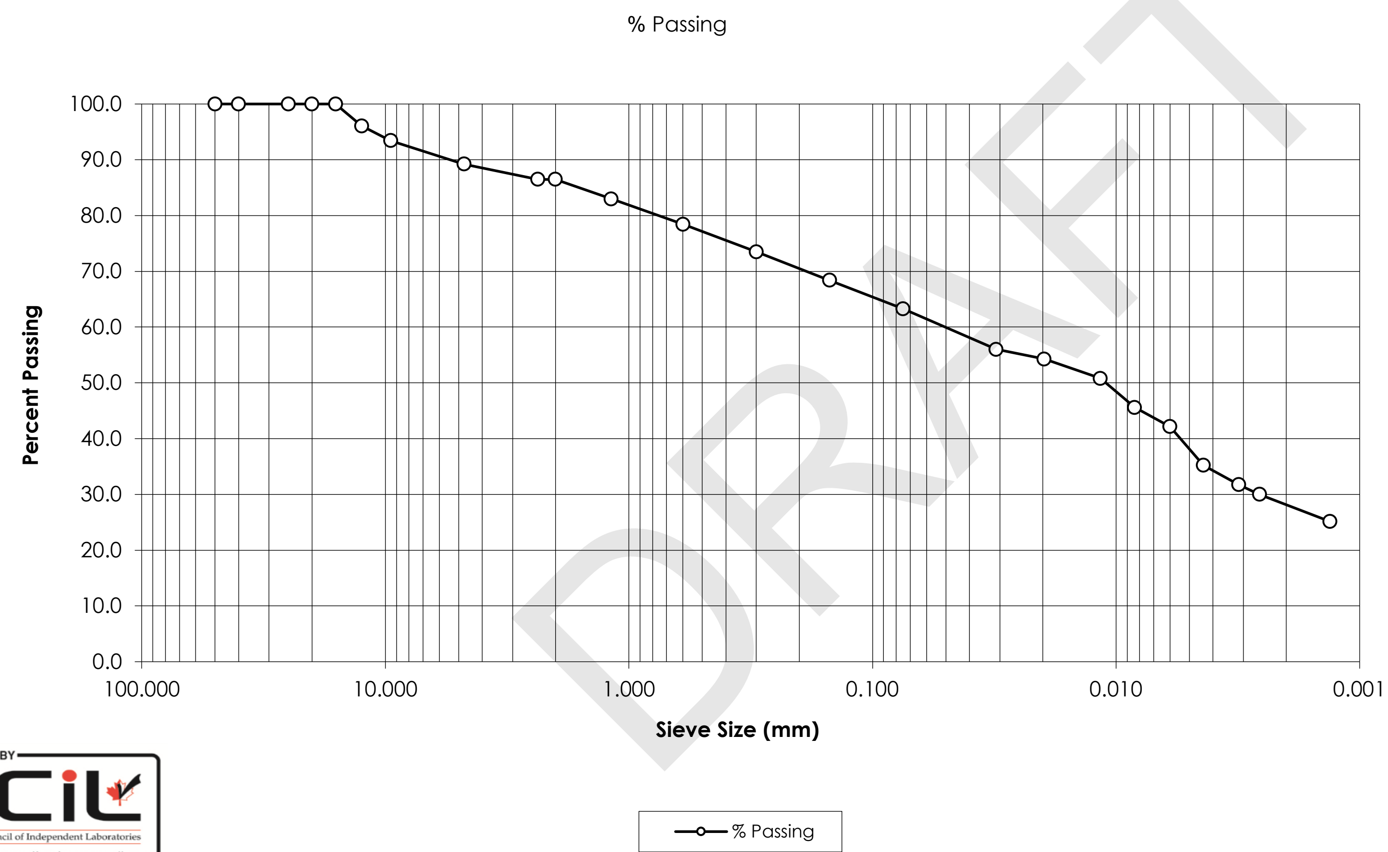
Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho All Season Road
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: SS4
SOURCE: BH17-39B
TESTED BY: JA

DATE TESTED: April 17, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy lean clay



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	**100.0**	**0.0060**	**42.1**
40.0	**100.0**	**0.0044**	**35.2**
25.0	**100.0**	**0.0031**	**31.7**
20.0	**100.0**	**0.0026**	**30.0**
16.0	**100.0**	**0.0013**	**25.1**
12.5	**96.1**		
9.5	**93.4**		
4.75	**89.2**		
2.36	**86.5**		
2.00	**86.5**		
1.18	**83.0**		
0.600	**78.4**		
0.300	**73.5**		
0.150	**68.4**		
0.075	**63.3**		
0.0310	**56.0**		
0.0197	**54.3**		
0.0116	**50.8**		
0.0084	**45.6**		

Gravel:	10.8%	D_{10}:	-
Sand:	25.9%	D_{30}:	0.0026
Silt:	35.1%	D_{60}:	0.0558
Clay:	28.2%	C_u:	-
		C_c:	-

CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Comments:

Figure No. 3

Reviewed by:

Grain Size Analysis
ASTM C136, ASTM C117

Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho All Season Road
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
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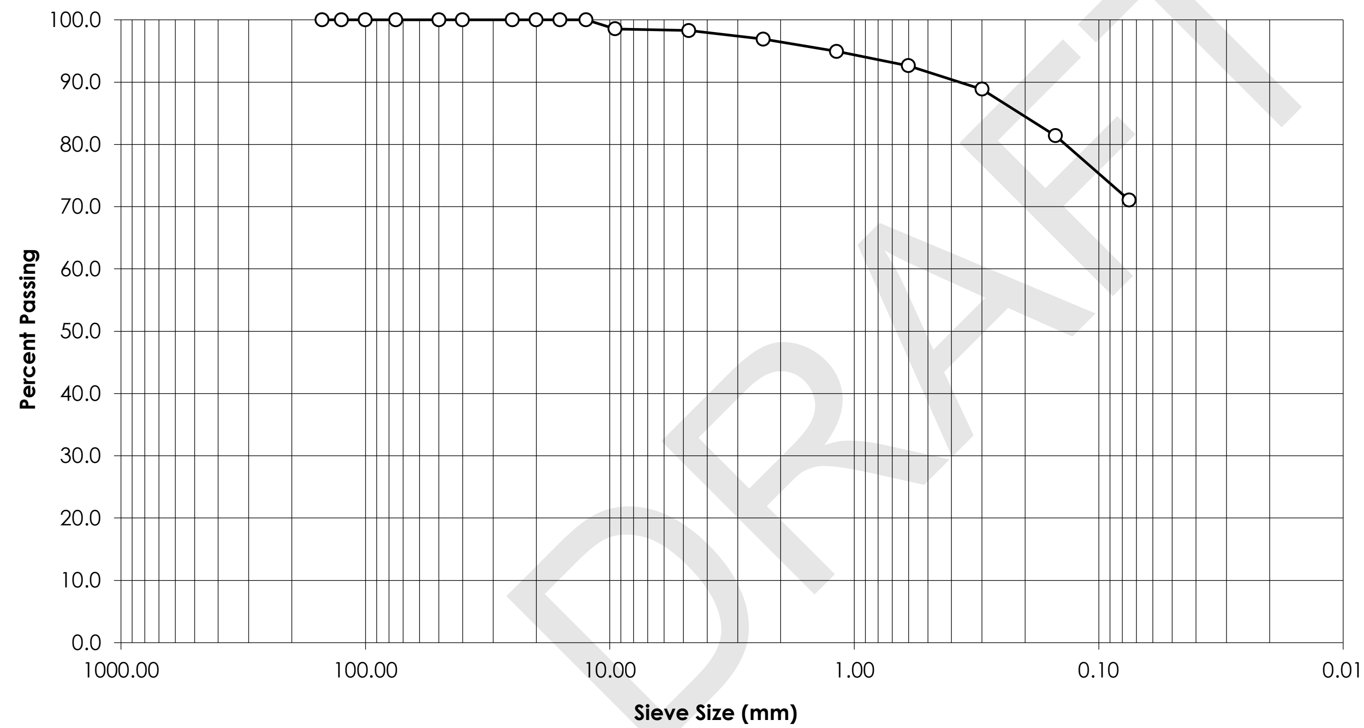
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: AS4
SOURCE: BH17-38B
TESTED BY: RP

DATE RECEIVED: March 27, 2017
DATE TESTED: April 20, 2017
SAMPLE DESCRIPTION: Lean clay with sand



Sieve (mm)	Sample % Passing	Specifications Lower	Specifications Upper
150.0	100.0	-	-
125.0	100.0	-	-
100.0	100.0	-	-
75.0	100.0	-	-
50.0	100.0	-	-
40.0	100.0	-	-
25.0	100.0	-	-
20.0	100.0	-	-
16.0	100.0	-	-
12.5	100.0	-	-
9.5	98.5	-	-
4.75	98.3	-	-
2.36	96.9	-	-
1.18	94.9	-	-
0.600	92.6	-	-
0.300	88.8	-	-
0.150	81.4	-	-
0.075	71.0	-	-

Cobble:	0.0%	D_{10}:	-
Gravel:	1.7%	D_{30}:	-
Sand:	27.2%	D_{60}:	-
Fines:	71.1%	C_u:	-
		C_c:	-

Comments:

Figure No. 4

Reviewed by:

Stantec

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

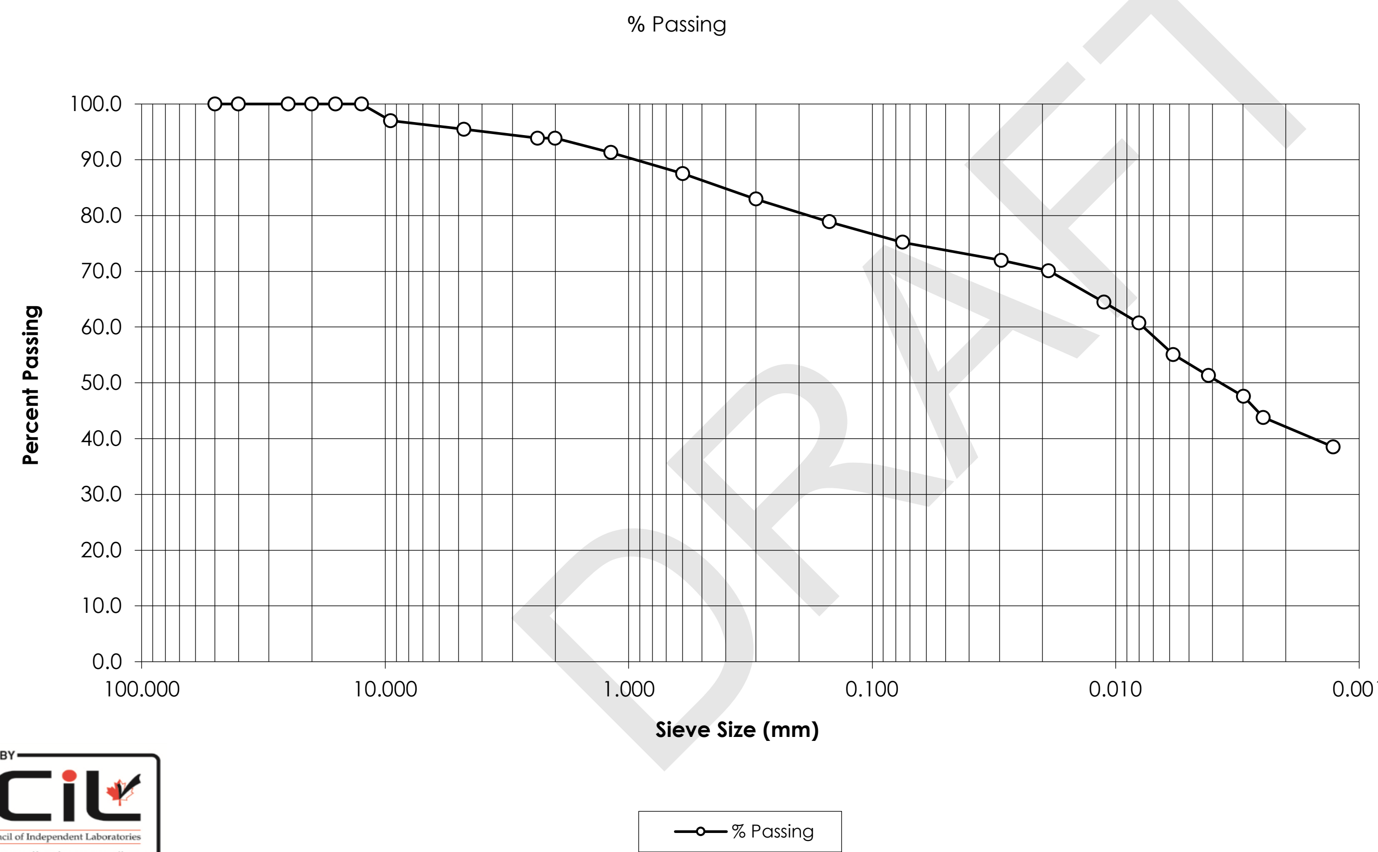
Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho All Season Road
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: SS7
SOURCE: BH17-38B
TESTED BY: JA

DATE TESTED: April 17, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Lean clay with sand



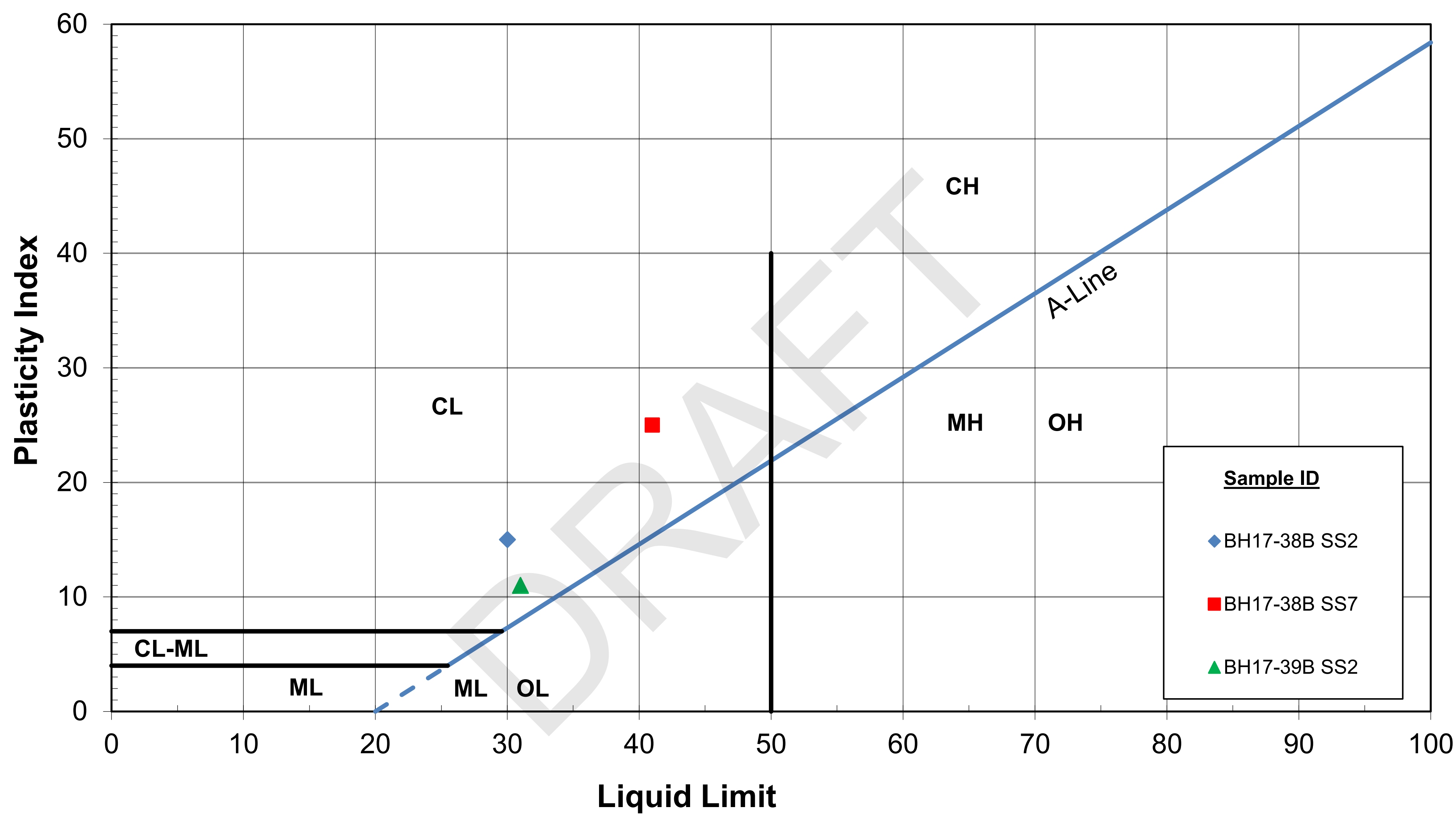
Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	**100.0**	**0.0058**	**55.1**
40.0	**100.0**	**0.0042**	**51.3**
25.0	**100.0**	**0.0030**	**47.5**
20.0	**100.0**	**0.0025**	**43.8**
16.0	**100.0**	**0.0013**	**38.5**
12.5	**100.0**		
9.5	**97.0**		
4.75	**95.4**		
2.36	**93.9**		
2.00	**93.9**		
1.18	**91.3**		
0.600	**87.5**		
0.300	**83.0**		
0.150	**78.9**		
0.075	**75.2**		
0.0295	**72.0**		
0.0189	**70.1**		
0.0112	**64.5**		
0.0080	**60.7**		

Gravel:	4.6%	D_{10}:	-
Sand:	20.2%	D_{30}:	-
Silt:	33.1%	D_{60}:	0.0078
Clay:	42.1%	C_u:	-
		C_c:	-

Comments:

Figure No. 5

Reviewed by:



Stantec

Tlicho Engineering & Environmental Services

Tlicho All Season Road

PLASTICITY CHART

Figure No. 6

Project No. 144902448

Maxxam
A Bureau Veritas Group Company

Success Through Science®

Your Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Your C.O.C. #: A174619

Attention:RYLEY PROZNIK

STANTEC CONSULTING LTD
10160-112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2017/04/20
Report #: R2371968
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B728026
Received: 2017/04/17, 14:30

Sample Matrix: Soil
Samples Received: 12

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Chloride (Soluble)	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00020	SM 22 4500-Cl G m
Resistivity	9	N/A	2017/04/18	AB WI-00065	Auto Calc
Conductivity @25C (Soluble)	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00004	SM 22 2510 B m
Total Organic Carbon by Combustion-Sub (1)	3	2017/04/20	2017/04/20		
pH @25C (Soluble)	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00006	SM 22 4500 H+B m
Soluble Ions	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00042	EPA 200.7 CFR 2012 m
Soluble Paste	9	2017/04/18	2017/04/18	AB SOP-00033	Carter 2nd ed 15.2m
Soluble Ions Calculation	9	N/A	2017/04/18	AB WI-00065	Auto Calc

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
(1) This test was performed by Maxxam Ontario (From Edmonton)

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Your Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Your C.O.C. #: A174619

Attention:RYLEY PROZNIK

STANTEC CONSULTING LTD
10160-112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2017/04/20
Report #: R2371968
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B728026
Received: 2017/04/17, 14:30

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Wendy Sears, Project manager
Email: WSears@maxxam.ca
Phone# (403)735-2277
===
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		QW8655	QW8656		QW8657		QW8658		
Sampling Date		2017/02/24	2017/03/12		2017/03/24		2017/03/22		
COC Number		A174619	A174619		A174619		A174619		
	UNITS	**BH17-16C AS1-A**	**BH17-33B 10'-11.5'**	**RDL**	**BH17-74B AS1**	**RDL**	**BH17-60B AS4**	**RDL**	**QC Batch**
CONVENTIONALS									
Total Organic Carbon (C)	mg/kg	ATTACHED	N/A	500	N/A	500	N/A	500	8608469
Calculated Parameters									
Resistivity @ 25 °C	ohm-m	N/A	3.9	0.050	24	0.050	7.9	0.050	8605241
Calculated Chloride (Cl)	%	N/A	0.018	0.00044	0.0027	0.0010	0.0030	0.00026	8604932
Calculated Sulphate (SO4)	%	N/A	0.16	0.00044	0.0049	0.0010	0.036	0.00026	8604932
Soluble Parameters									
Soluble Chloride (Cl)	mg/L	N/A	210	5.0	13	5.0	57	5.0	8605786
Soluble Conductivity	dS/m	N/A	2.5	0.020	0.41	0.020	1.3	0.020	8605626
Soluble pH	pH	N/A	7.57	N/A	7.28	N/A	7.47	N/A	8605629
Saturation %	%	N/A	88	N/A	210	N/A	52	N/A	8605356
Soluble Sulphate (SO4)	mg/L	N/A	1900	5.0	24	5.0	700	5.0	8605816

RDL = Reportable Detection Limit
N/A = Not Applicable

Maxxam ID		QW8659		QW8660		QW8661	QW8661		
Sampling Date		2017/03/20		2017/03/09		2017/03/21	2017/03/21		
COC Number		A174619		A174619		A174619	A174619		
	UNITS	**BH17-57B 40'-42'**	**RDL**	**BH17-31B 5'-6.5'**	**RDL**	**BH17-59B AS2**	**BH17-59B AS2 Lab-Dup**	**RDL**	**QC Batch**
Calculated Parameters									
Resistivity @ 25 °C	ohm-m	3.5	0.050	4.4	0.050	12	N/A	0.050	8605241
Calculated Chloride (Cl)	%	0.0011	0.00033	0.0015	0.00045	0.0031	N/A	0.00027	8604932
Calculated Sulphate (SO4)	%	0.13	0.00033	0.13	0.00045	0.023	N/A	0.00027	8604932
Soluble Parameters									
Soluble Chloride (Cl)	mg/L	17	5.0	17	5.0	57	52	5.0	8605786
Soluble Conductivity	dS/m	2.9	0.020	2.3	0.020	0.83	0.91	0.020	8605626
Soluble pH	pH	7.95	N/A	7.56	N/A	7.51	7.52	N/A	8605629
Saturation %	%	65	N/A	91	N/A	55	54	N/A	8605356
Soluble Sulphate (SO4)	mg/L	2000	5.0	1400	5.0	430	N/A	5.0	8605816

RDL = Reportable Detection Limit
Lab-Dup = Laboratory Initiated Duplicate
N/A = Not Applicable

Maxxam
A Bureau Veritas Group Company

Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		QW8662		QW8663		QW8664	QW8665		
Sampling Date		2017/03/05		2017/03/17		2017/02/24	2017/02/27		
COC Number		A174619		A174619		A174619	A174619		
	UNITS	**BH17-32B AS3**	**RDL**	**BH17-38B AS1**	**RDL**	**BH17-16C AS3**	**BH17-25 GS1**	**RDL**	**QC Batch**
CONVENTIONALS									
Total Organic Carbon (C)	mg/kg	N/A	500	N/A	500	N/A	ATTACHED	500	8608469
Calculated Parameters									
Resistivity @ 25 °C	ohm-m	3.9	0.050	16	0.050	28	N/A	0.050	8605241
Calculated Chloride (Cl)	%	0.012	0.00032	0.00080	0.00034	<0.00023	N/A	0.00023	8604932
Calculated Sulphate (SO4)	%	0.11	0.00032	0.0027	0.00034	0.0028	N/A	0.00023	8604932
Soluble Parameters									
Soluble Chloride (Cl)	mg/L	190	5.0	12	5.0	<5.0	N/A	5.0	8605786
Soluble Conductivity	dS/m	2.5	0.020	0.62	0.020	0.35	N/A	0.020	8605626
Soluble pH	pH	7.81	N/A	7.70	N/A	7.93	N/A	N/A	8605629
Saturation %	%	65	N/A	68	N/A	46	N/A	N/A	8605356
Soluble Sulphate (SO4)	mg/L	1800	5.0	39	5.0	61	N/A	5.0	8605816

RDL = Reportable Detection Limit
N/A = Not Applicable

Maxxam ID		QW8666		
Sampling Date		2017/02/17		
COC Number		A174619		
	UNITS	**BH17-12 AS1**	**RDL**	**QC Batch**
CONVENTIONALS				
Total Organic Carbon (C)	mg/kg	ATTACHED	500	8608469

RDL = Reportable Detection Limit

Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	18.3°C

TOC by Combustion results are attached to this report file. The reference number from Maxxam Campobello for these results is B777170

Results relate only to the items tested.

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Success Through Science®

Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

QUALITY ASSURANCE REPORT

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
8605356	LX	QC Standard	Saturation %	2017/04/18		101	%	89 - 111
8605356	LX	RPD	Saturation %	2017/04/18	0.93		%	12
8605356	LX	RPD [QW8661-01]	Saturation %	2017/04/18	0.65		%	12
8605626	ACZ	QC Standard	Soluble Conductivity	2017/04/18		93	%	75 - 125
8605626	ACZ	Spiked Blank	Soluble Conductivity	2017/04/18		99	%	90 - 110
8605626	ACZ	Method Blank	Soluble Conductivity	2017/04/18	<0.020		dS/m	
8605626	ACZ	RPD [QW8661-01]	Soluble Conductivity	2017/04/18	9.0		%	20
8605629	BJO	QC Standard	Soluble pH	2017/04/18		99	%	97 - 103
8605629	BJO	Spiked Blank	Soluble pH	2017/04/18		100	%	97 - 103
8605629	BJO	RPD [QW8661-01]	Soluble pH	2017/04/18	0.13		%	N/A
8605786	CH7	Matrix Spike [QW8661-01]	Soluble Chloride (Cl)	2017/04/18		107	%	75 - 125
8605786	CH7	QC Standard	Soluble Chloride (Cl)	2017/04/18		100	%	75 - 125
8605786	CH7	Spiked Blank	Soluble Chloride (Cl)	2017/04/18		106	%	80 - 120
8605786	CH7	Method Blank	Soluble Chloride (Cl)	2017/04/18	<5.0		mg/L	
8605786	CH7	RPD [QW8661-01]	Soluble Chloride (Cl)	2017/04/18	7.9		%	30
8605816	CJ5	QC Standard	Soluble Sulphate (SO4)	2017/04/18		89	%	75 - 125
8605816	CJ5	Method Blank	Soluble Sulphate (SO4)	2017/04/18	<5.0		mg/L	

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Micheline Piche, Project Manager

Suwan Fock, B.Sc., QP, Inorganics Senior Analyst

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

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Maxxam

Calgary: 4000 19st St. NE, T2E 6P8. Ph: (403) 291-3077, Fax: (403) 735-2240, Toll free: (800) 386-7247
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www.maxxamanalytics.com

Chain of Custody

A174619

Page: ______ of ______

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	Invoice To:	C/O Report Address ☐
Company:	STANTEC CONSULTING LTD.	
Contact:	RYLEY PROZNIK	
Address:		
	Prov: AB	PC: 1233
Contact #s:	Ph: 780-239-1498	Cell:

Report To:	Same as Invoice ☑
Prov:	PC:
Ph:	Cell:

Report Distribution (E-Mail): RYLEY.PROZNIK@STANTEC.COM

REGULATORY GUIDELINES:
- ☐ AT1
- ☐ CCME
- ☐ Regulated Drinking Water
- ☐ Other:

All samples are held for 60 calendar days after sample receipt, unless specified otherwise.

PO #:	144902448
Project # / Name:	144902448 / TLICHO ALL SEASON ROAD
Site Location:	NORTHWEST TERRITORIES
Quote #:	
Sampled By:	JM / KP

SERVICE REQUESTED: ☐ RUSH (Contact lab to reserve) Date Required: ______ ☐ REGULAR (5 to 7 Days)

See reverse for package specifics

#	Sample ID	Depth (unit)	Matrix GW / SW Soil	Date/Time Sampled YY/MM/DD 24:00	SOIL: BTEX F1-F4	Sieve (75 micron)	Regulated Metals (CCME / AT1)	Salinity 4	Assessment ICP Metals	Basic Class II Landfill	Resistivity	pH	Sulphates & Chlorides	WATER: ☐VOCs ☐BTEX F1	☐BTEX F1-F4 ☐BTEX F1-F2	Routine Water ☐ Turb ☐ F	☐ DOC ☐ TOC	Regulated Metals (CCME / AT1) Total	Dissolved	Mercury ☐ Total ☐ Dissolved	Other Analysis: ORGANIC CONTENT	HOLD - Do not Analyze	# of Containers Submitted
1	BH17-16C AS1-A										✓	✓	✓								✓		
2	BH17-33B 10'-11.5'										✓	✓	✓										
3	BH17-74B AS1										✓	✓	✓										
4	BH17-60B AS4										✓	✓	✓										
5	BH17-57B 40'-42'										✓	✓	✓										
6	BH17-31B 5'-6.5'										✓	✓	✓										
7	BH17-59B AS2										✓	✓	✓										
8	BH17-32B AS3										✓	✓	✓										
9	BH17-38B AS1										✓	✓	✓										
10	BH17-16C AS3										✓	✓	✓										
11	BH17-25 GS1																				✓		
12	BH17-12 AS1																				✓		

Please indicate Filtered, Preserved or Both (F, P, F/P) → F/P

Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):
/NIKO NAVAL	17/04/07	
/Ryley Proznik	17/04/17	14:30

Special Instructions:

# of Jars Used & Not Submitted

LAB USE ONLY

Received By:	Date:	Time:	Maxxam Job #:
David Tidman	20170417	1430	B728026 D-T

Custody Seal	Temperature	Ice
No	Bags 18, 19, 18	No

Lab Comments:

DRAFT

AB FCD-00331 Rev3 2010/05

Maxxam Analytics International Corporation o/a Maxxam Analytics

Your P.O. #: 144902448
Your Project #: 144902448/TLICHO ALLSEASONROAD
Site Location: NORTHWEST TERRITORIES
Your C.O.C. #: A174621

Attention:RYLEY PROZNIK

STANTEC CONSULTING LTD
10160-112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2017/04/28
Report #: R2375456
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B729557
Received: 2017/04/21, 09:15

Sample Matrix: Soil
Samples Received: 3

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Chloride (Soluble)	3	2017/04/24	2017/04/24	AB SOP-00033 / AB SOP-00020	SM 22 4500-Cl E m
Resistivity	3	N/A	2017/04/24	AB WI-00065	Auto Calc
Conductivity @25C (Soluble)	3	2017/04/24	2017/04/24	AB SOP-00033 / AB SOP-00004	SM 22 2510 B m
pH @25C (Soluble)	3	2017/04/24	2017/04/24	AB SOP-00033 / AB SOP-00006	SM 22 4500 H+B m
Soluble Ions	3	2017/04/24	2017/04/24	AB SOP-00033 / AB SOP-00042	EPA 200.7 CFR 2012 m
Soluble Paste	3	2017/04/24	2017/04/24	AB SOP-00033	Carter 2nd ed 15.2m
Soluble Ions Calculation	3	N/A	2017/04/24	AB WI-00065	Auto Calc

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Success Through Science®

Your P.O. #: 144902448
Your Project #: 144902448/TLICHO ALLSEASONROAD
Site Location: NORTHWEST TERRITORIES
Your C.O.C. #: A174621

Attention:RYLEY PROZNIK

STANTEC CONSULTING LTD
10160-112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2017/04/28
Report #: R2375456
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B729557
Received: 2017/04/21, 09:15

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Wendy Sears, Project manager
Email: WSears@maxxam.ca
Phone# (403)735-2277
==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B729557
Report Date: 2017/04/28

STANTEC CONSULTING LTD
Client Project #: 144902448/TLICHO ALLSEASONROAD
Site Location: NORTHWEST TERRITORIES
Your P.O. #: 144902448
Sampler Initials: JM

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		QX5271	QX5271		QX5272		QX5273		
Sampling Date									
COC Number		A174621	A174621		A174621		A174621		
	UNITS	**BH17-58B SS6**	**BH17-58B SS6 Lab-Dup**	**RDL**	**BH17-39B 4'-5'**	**RDL**	**BH17-42C SS2**	**RDL**	**QC Batch**
Calculated Parameters									
Resistivity @ 25 °C	ohm-m	5.8	N/A	0.050	2.0	0.050	7.0	0.050	8609269
Calculated Chloride (Cl)	%	0.00083	N/A	0.00032	0.0012	0.00013	0.00084	0.00014	8609253
Calculated Sulphate (SO4)	%	0.067	N/A	0.00032	0.10	0.00013	0.021	0.00014	8609253
Soluble Parameters									
Soluble Chloride (Cl)	mg/L	13	N/A	5.0	48	5.0	30	5.0	8610713
Soluble Conductivity	dS/m	1.7	1.8	0.020	5.1	0.020	1.4	0.020	8610259
Soluble pH	pH	7.78	7.75	N/A	7.56	N/A	8.16	N/A	8610258
Saturation %	%	65	64	N/A	26	N/A	28	N/A	8610243
Soluble Sulphate (SO4)	mg/L	1000	1100	5.0	4000	5.0	720	5.0	8610720

RDL = Reportable Detection Limit
Lab-Dup = Laboratory Initiated Duplicate
N/A = Not Applicable

Maxxam Job #: B729557
Report Date: 2017/04/28

STANTEC CONSULTING LTD
Client Project #: 144902448/TLICHO ALLSEASONROAD
Site Location: NORTHWEST TERRITORIES
Your P.O. #: 144902448
Sampler Initials: JM

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	17.7°C

TOC results are attached to this report. The reference number for these results from Maxxam Campobello is B780528.

Results relate only to the items tested.

Success Through Science®

Maxxam Job #: B729557
Report Date: 2017/04/28

STANTEC CONSULTING LTD
Client Project #: 144902448/TLICHO ALLSEASONROAD
Site Location: NORTHWEST TERRITORIES
Your P.O. #: 144902448
Sampler Initials: JM

QUALITY ASSURANCE REPORT

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
8610243	NP4	QC Standard	Saturation %	2017/04/24		101	%	89 - 111
8610243	NP4	RPD	Saturation %	2017/04/24	0.69		%	12
8610243	NP4	RPD [QX5271-01]	Saturation %	2017/04/24	1.1		%	12
8610258	ACZ	QC Standard	Soluble pH	2017/04/24		100	%	98 - 102
8610258	ACZ	Spiked Blank	Soluble pH	2017/04/24		100	%	97 - 103
8610258	ACZ	RPD [QX5271-01]	Soluble pH	2017/04/24	0.39		%	N/A
8610259	BJO	QC Standard	Soluble Conductivity	2017/04/24		93	%	75 - 125
8610259	BJO	Spiked Blank	Soluble Conductivity	2017/04/24		99	%	90 - 110
8610259	BJO	Method Blank	Soluble Conductivity	2017/04/24	<0.020		dS/m	
8610259	BJO	RPD [QX5271-01]	Soluble Conductivity	2017/04/24	4.7		%	20
8610713	AF6	Matrix Spike	Soluble Chloride (Cl)	2017/04/24		NC	%	75 - 125
8610713	AF6	QC Standard	Soluble Chloride (Cl)	2017/04/24		103	%	75 - 125
8610713	AF6	Spiked Blank	Soluble Chloride (Cl)	2017/04/24		106	%	80 - 120
8610713	AF6	Method Blank	Soluble Chloride (Cl)	2017/04/24	<5.0		mg/L	
8610713	AF6	RPD	Soluble Chloride (Cl)	2017/04/24	2.4		%	30
8610720	CJ5	QC Standard	Soluble Sulphate (SO4)	2017/04/24		83	%	75 - 125
8610720	CJ5	Method Blank	Soluble Sulphate (SO4)	2017/04/24	<5.0		mg/L	
8610720	CJ5	RPD [QX5271-01]	Soluble Sulphate (SO4)	2017/04/24	2.6		%	30

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

Maxxam Job #: B729557
Report Date: 2017/04/28

STANTEC CONSULTING LTD
Client Project #: 144902448/TLICHO ALLSEASONROAD
Site Location: NORTHWEST TERRITORIES
Your P.O. #: 144902448
Sampler Initials: JM

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Suwan Fock, B.Sc., QP, Inorganics Senior Analyst

Sandy Yuan, M.Sc., Scientific Specialist

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Maxxam

Calgary: 4000 19st St. NE, T2E 6P8. Ph: (403) 291-3077, Fax: (403) 735-2240, Toll free: (800) 386-7247
Edmonton: 9331 - 48 Street, T6B 2R4. Ph: (780) 577-7100, Fax: (780) 450-4187, Toll free: (877) 465-8889
www.maxxamanalytics.com

617

Chain of Custody

A174621

Page: ____ of ____

	Invoice To:	C/O Report Address ☐
Company:	Stantec Consulting Ltd	
Contact:	Ryley Proznik	
Address:		
	Prov: AB	PC: 1233
Contact #s:	Ph:	Cell: 780-239-1498

Report To:	Same as Invoice ☒
Prov:	PC:
Ph:	Cell:

Report Distribution (E-Mail): Ryley.Proznik@Stantec.com

REGULATORY GUIDELINES:
- ☐ AT1
- ☐ CCME
- ☐ Regulated Drinking Water
- ☐ Other:

All samples are held for 60 calendar days after sample receipt, unless specified otherwise.

PO #: 114902448
Project # / Name: 144902448/Tlicho All Season Road
Site Location: Northwest Territories
Quote #:
Sampled By: JM

SERVICE REQUESTED: ☒ RUSH (Contact lab to reserve) Date Required: ______
☒ REGULAR (5 to 7 Days)

See reverse for package specifics

#	Sample ID	Depth (unit)	Matrix GW / SW Soil	Date/Time Sampled YY/MM/DD 24:00	SOIL: BTEX F1-F4	Sieve (75 micron)	Regulated Metals (CCME / AT1)	Salinity 4	Assessment ICP Metals	Basic Class II Landfill	Resistivity	pH	Sulphates + Chlorides	WATER: ☐BTEX F1 ☐VOCs	☐BTEX F1-F2 ☐BTEX F1-F4	☐ Routine Water ☐ Turb ☐ F	☐ TOC ☐ DOC	Regulated Metals (CCME / AT1): Total	Dissolved	Mercury ☐ Total ☐ Dissolved	Other Analysis: Organic Content										HOLD - Do not Analyze	# of Containers Submitted
1	BH17-58B SS6										✓	✓	✓																			
2	BH17-39B 4'-5'										✓	✓	✓																			
3	BH17-42C SS2										✓	✓	✓																			
4	BH17-61 SS1																				✓											
5																																
6																																
7																																
8																																
9																																
10																																
11																																
12																																

Please indicate Filtered, Preserved or Both (F, P, F/P) → F/P

Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):
Ryley Proznik	17/04/21	8:47
Relinquished By (Signature/Print): MIKE TRAUT	Date (YY/MM/DD): 17/04/21	Time (24:00): 9:15

Special Instructions:

\# of Jars Used & Not Submitted

LAB USE ONLY

Received By:	Date:	Time:	Maxxam Job #: B729557		
Jenna Walter	20170421	0915	Custody Seal	Temperature	Ice
Lab Comments:			No	18,17,18	No

AB FCD-00331 Rev3 2010/05

Maxxam Analytics International Corporation o/a Maxxam Analytics

DRAFT

APPENDIX E

Thermistor Resistance versus Temperature Table

Thermistor Readings

Resistance versus Temperature Relationship 3000 Ohm NTC Thermistors

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	30	525.4	70	153.2	110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.99K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-35	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	282.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	56.92	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965	53	250.9	93	83.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	3000	25	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

Temperature calculated using:

Steinhart-Hart Linearization

$$T_C = \frac{1}{C_0 + C_1(\ln R) + C_3(\ln R)^3} - 273.15$$

3000 Ohm @ 25C NTC Thermistor

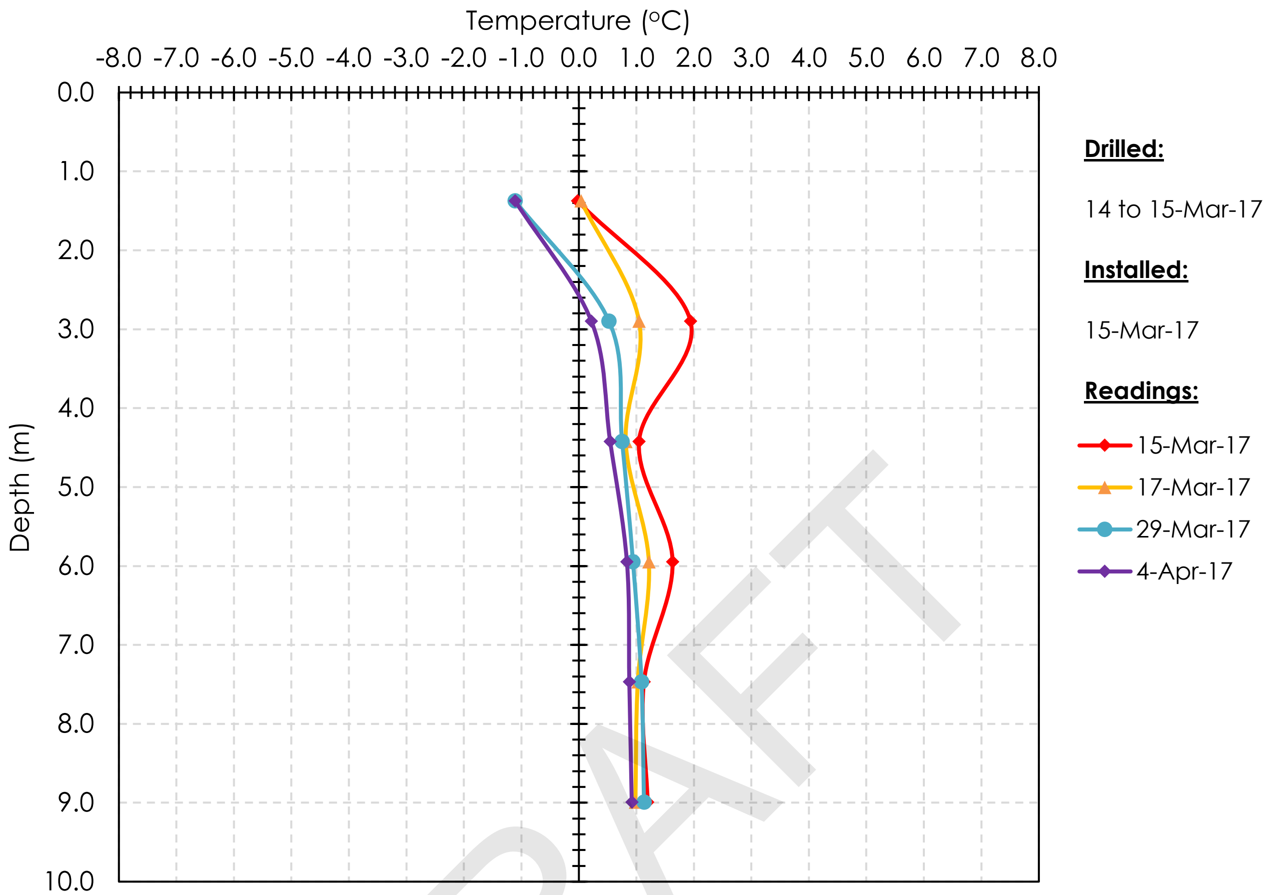
C_0= 0.0014051

C_1= 0.0002369

C_3= 0.0000001019

lnR= Natural Log of Resistance

T_c= Temperature in °C



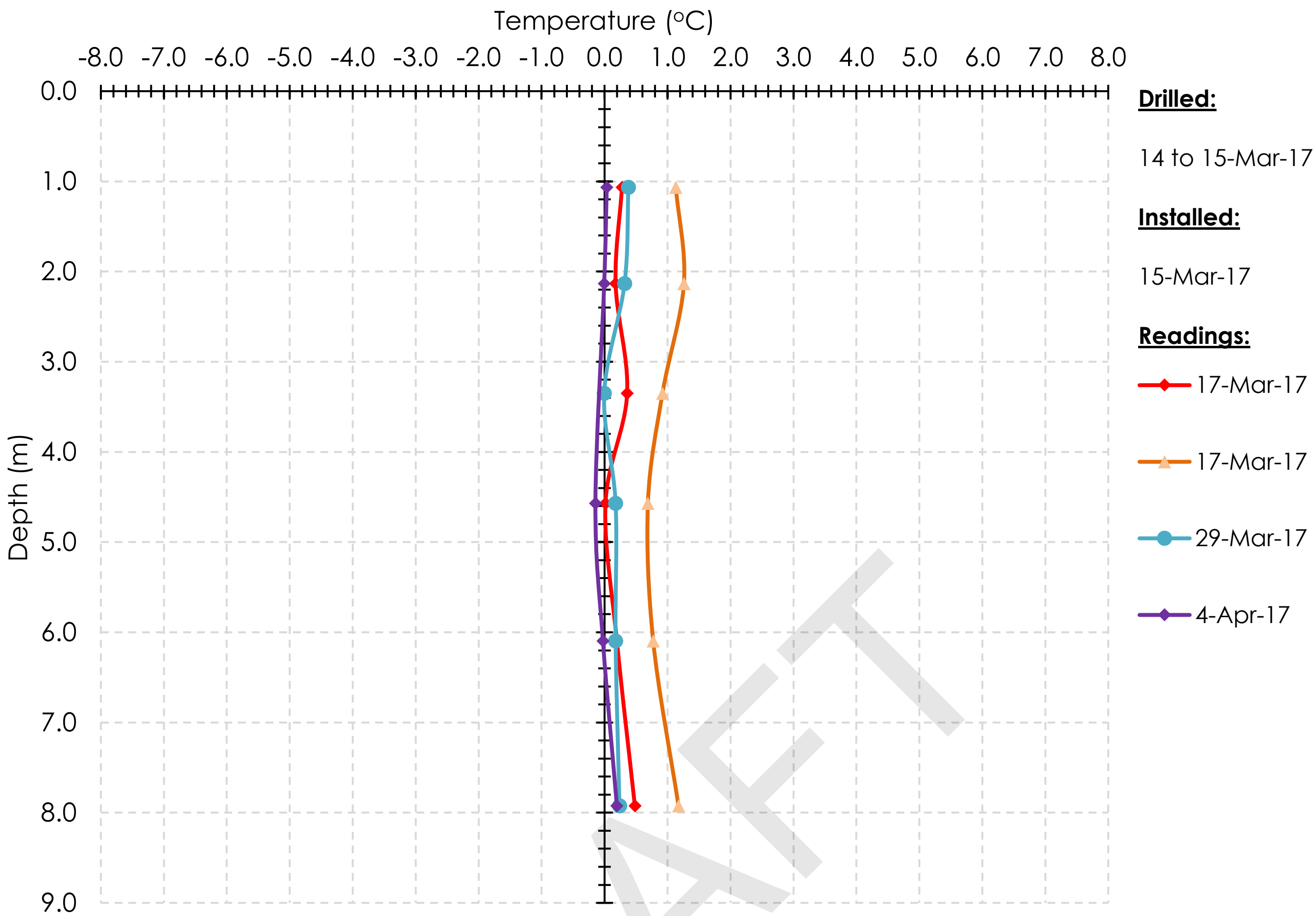
Borehole	**BH17-38B**									
Drilled:	14 to 15-Mar-17		Drilled Depth:		9.83	m				
Installed:	15-Mar-17									
Reading			**Bead**	TS4333	TS4332	TS4400	TS4398	TS4396	TS4397	
Date		**Days**	**Depth (m)**	1.37	2.90	4.42	5.94	7.47	8.99	
Post-Install	15-Mar-17	0	**R (Kilo Ω)**	9.80	8.87	9.28	9.01	9.24	9.21	
			T (°C)	0.0	1.9	1.0	1.6	1.1	1.2	
2	17-Mar-17	2	**R (Kilo Ω)**	9.77	9.28	9.39	9.2	9.29	9.31	
			T (°C)	0.0	1.0	0.8	1.2	1.0	1.0	
4	29-Mar-17	14	**R (Kilo Ω)**	10.36	9.53	9.42	9.33	9.26	9.24	
			T (°C)	-1.1	0.5	0.8	0.9	1.1	1.1	
5	4-Apr-17	20	**R (Kilo Ω)**	10.36	9.68	9.52	9.38	9.36	9.34	
			T (°C)	-1.1	0.2	0.5	0.8	0.9	0.9	

Stantec

Thermistor Readings BH17-38B

Figure No. 7

Project No. 144902448



Borehole	**BH17-39B**								
Drilled:	15 to 16-Mar-17				Drilled Depth:			9.75	m
Installed:	16-Mar-17								
Reading			**Bead**	TS4326	TS4324	TS4403	TS4402	TS4399	TS4401
Date		**Days**	**Depth (m)**	1.07	2.13	3.35	4.57	6.10	7.92
1	17-Mar-17	1	**R (Kilo Ω)**	9.65	9.70	9.61	9.78	9.69	9.55
			T (°C)	0.3	0.2	0.4	0.0	0.2	0.5
2	17-Mar-17	1	**R (Kilo Ω)**	9.24	9.18	9.34	9.45	9.41	9.22
			T (°C)	1.1	1.3	0.9	0.7	0.8	1.2
3	29-Mar-17	13	**R (Kilo Ω)**	9.60	9.63	9.79	9.7	9.7	9.67
			T (°C)	0.4	0.3	0.0	0.2	0.2	0.2
4	4-Apr-17	19	**R (Kilo Ω)**	9.77	9.79	-	9.86	9.8	9.69
			T (°C)	0.0	0.0	-	-0.1	0.0	0.2

Stantec

Thermistor Readings
BH17-39B

Figure No. 8

Project No. 144902448

Geotechnical Data Report
Proposed Arch Culvert
Crossing #10a Station 48+209

Geotechnical Investigation,
Proposed Tlicho All Season Road,
Northwest Territories

Prepared for:
Tlicho Engineering and
Environmental Services Ltd.

Prepared by:
Stantec Consulting Ltd.
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Project No. 144902448

June 2017

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1.0 INTRODUCTION

Acting under the authorization of Tlicho Engineering and Environmental Services Ltd. (Tlicho), Stantec Consulting Ltd. (Stantec) carried out a geotechnical investigation in support of the arch culvert planned at 'Crossing #10a' along the proposed Tlicho All Season Access Road (TASR). The purpose of the investigation was to characterize subsurface conditions and provide geotechnical comments and recommendations to assist with arch culvert design and site development.

The investigation was carried out in general accordance with Stantec's proposal dated January 12, 2017, as part of an overall geotechnical program by Tlicho for the Government of the Northwest Territories (GNWT) along the proposed 94 km TASR alignment extending from the Yellowknife Highway (Highway 3) to the Settlement of Whatì on the south shore of Lac La Martre (RFP Event ID: EV000000001132). The scope of work outlined in the GNWT Request for Proposal includes the geotechnical investigation and design of the 94 km long TASR corridor, four bridges and three structural culverts. Tlicho was responsible for management and execution of the overall project and team as the Prime Contractor, with Stantec acting as sub-consultant providing geotechnical engineering and technical services to the project, including:

- Provision of geotechnical field personnel to log subsurface conditions during drilling operations at eighty-one (81) geotechnical boreholes in accordance with the RFP:
  - Thirteen (13) boreholes at the four (4) proposed major bridge crossings:
    - Crossing #8, Station 40+400 - Duport River Crossing
    - Crossing #9, Station 45+175 - (unnamed)
    - Crossing #14, Station 69+666 - James River Crossing
    - Crossing #15, Station 85+397 - La Martre River
  - Three (3) boreholes at the three (3) proposed major bridge culvert crossings:
    - Crossing #5, Station 16+532
    - Crossing #6, Station 19+427
    - Crossing #10a, Station 48+208
  - Sixty-five (65) boreholes to observe the subsurface conditions along the road alignment;
- Installation and reading of thermistors;
- Borehole layout and as-drilled survey;
- Completion of a laboratory testing program on the recovered borehole samples as specified in the RFP; and
- Geotechnical engineering assessment and reporting on the field and laboratory findings in two reports (Geotechnical Data Report and Geotechnical Recommendations Report) for each crossing location and for the overall roadway alignment.
  - These documents should be read in conjunction with the Statement of General Conditions, Appendix A.

This Report has been prepared specifically and solely for the proposed arch culvert crossing at 'Crossing #10a' of the Tlicho All Season Road in the Northwest Territories, Canada.

2.0 SITE DESCRIPTION AND GEOLOGY AND CLIMATE

2.1 SITE DESCRIPTION

The site location of the proposed arch culvert crossing ‘Crossing #10a’ is shown on the Key Plan, Drawing No. 1 provided in Appendix B. The proposed arch culvert is located along the alignment of the Tlicho All Season Road and former winter road from Highway 3 to Whatì. It is located approximately 46 km northwest of Highway 3 and 44 km southeast of the Community of Whatì in the Northwest Territories, Canada. Photographs showing the general site conditions of the proposed arch culvert location are provided in Appendix B.

The original winter road alignment has been cleared of large trees and runs approximately north-south at the project location; chainage increases in the northern direction towards Whatì. The proposed arch culvert location is at Station 48+209. The areas on both the east and west sides of the former winter road are covered with brush and trees. At the time of the investigation at this specific location (March 11 & 13, 2017), the watercourse channel(s) were not visible from walk around inspection of the culvert location due to snow cover and/or dry, no-flow conditions.

It is understood that the original Lac La Martre Whatì overland winter road was established by the military in the 1950s, and used as a public winter road for the northern Tlicho communities up until the late 1980s. More recently it has been used by the local communities for travel using all-terrain vehicles including snowmobiles, dog sleds, ATVs, and trucks (GNWT DOT, 2016). Previous site development for the road at this location appears to be limited. The roadbed is approximately level with the surrounding undisturbed vegetated areas with no significant historic ground disturbance (regrading cut/fill) apparent.

2.2 PHYSIOGRAPHY AND GEOLOGY

The site is located within the Great Slave Plain High Boreal Ecoregion (ECG, 2009 and GNWT DOT, 2016). In this section of the TASR corridor (GNWT DOT, 2016), regional topography is generally subdued with plains and gently rolling hills. Drainage ranges from ‘well’ to ‘moderately well’ with occasional seasonal tributaries. Vegetation includes regenerating jack pine forest, ephemeral stream crossing/swampland, dwarf shrub and mixed stands. The general area was subjected to forest fires in the last decade.

Based on surficial geology mapping published by the Geological Survey of Canada, and previous project terrain mapping (Kavik AXYS Inc, 2008 and GNWT DOT, 2016), natural overburden material in the area has been mapped as till, coarse beach glacio-lacustrine and fine glacio-lacustrine material associated with glacial Lake McConnell, and occasional veneers of organic or fluvial materials overlying bedrock. Within stream channels and floodplains, recent fluvial deposits are expected. Based on geological mapping published by the Geological Survey of Canada (Okulitch, A.V., 2006), the site has been mapped within the Interior Platform geologic province, situated over Paleozoic aged sedimentary rocks of the Chinchaga Formation consisting of interbedded anhydrite-mudstone, grey, thin-bedded; and dolomite-mudstone, anhydritic, brown, thin-bedded.

2.3 CLIMATE

2.3.1 Climate

Based on a review of historic climate data completed using the Yellowknife Airport (Climate Reference ID: 2204100), Whatì meteorological station (Lac la Martre, Climate Reference ID: 2202678) and other sources (GNWT, 2016), the TASR area has a subarctic climate (Dfc, according to the Köppen climate classification system) characterized by generally relatively cold winters followed by short summers. It is noted that the Whatì station is located approximately 13 km west of the northern limit of the TASR and the Yellowknife station is located approximately 100 km east of the southern limit of the TASR.

Average annual daily mean temperatures are on the order of -4.3°C (Yellowknife Station) to -4.7 °C (Whatì Station), with the lowest average daily winter temperatures generally occurring in January, while the warmest month (based on the average temperature) occurs in July. The average annual precipitation is estimated on the order of 290 mm, with an average annual rainfall of 171 mm generally occurring throughout June through September, and an average annual snowfall of 158 cm generally occurring from September through May (Yellowknife Station).

The average freezing and thawing indices between 1981 and 2010 have been 3343.1 °C days and 1813.3 °C days, respectively (Yellowknife Station). A study completed by Holubec, et. al., in 2009 using data from 1978 to 2008 in their model was adapted by CSA (2010). The CSA study suggests a warming trend of 0.58 °C per decade within the Central Arctic region (including the TASR site). As per Table 5.2 in CSA (2010), seasonal mean temperature change under moderate (A1B) green-house gas scenarios, the mean annual temperatures for the Arctic Sector C1 are projected to be 1.3 °C (2011-2040), 2.7 °C (2041-2070), and 3.7 °C (2071 – 2100) respectively.

2.3.2 Permafrost

Permafrost mapping from the National Atlas of Canada (Heginbottom et al. 1995) shows the TASR site lies within the zone of extensive discontinuous permafrost (estimated 50% to 90% areal extent of the landscape), ‘low’ ice content in the upper 10 to 20 m, with possible ‘sparse’ ice wedges and massive ice bodies present.

It is understood that no public thermistor or intrusive investigation records exist for the immediate vicinity of the TASR. Previous reconnaissance trips by earlier AXYS terrain mapping and GNWT personnel did not identify permafrost landforms or thermokarst zones within the corridor at this location, however a large zone affected by thermokarst processes was noted between Whatì, Behchoko and the area north of Slemon Lake Kavik (AXYS Inc, 2008 and GNWT DOT, 2016). Based on regional studies completed in surrounding areas (GNWT, 2016), permafrost is anticipated to be relatively warm and correlated with forest cover type areas underlain by finer-textured glacial and post-glacial sediments such as glaciolacustrine and lacustrine deposits, as well as peatlands where organic material contribute to the forming and preservation of permafrost. Ground ice is generally expected to be less common in areas of exposed bedrock and where the underlying sediments are coarse and vegetation cover is thin.

Permafrost near Yellowknife is reported to be generally warm (> -2°C), less than 50 m thick with active layer thickness less than 1 to up to 3 m (Wolfe, 1998). Permafrost conditions along the nearby Highway 3 have been reported as typically warmer than -1°C, with an active layer thickness varying from less than 0.7 m to 1.5 m. Extensive permafrost degradation has been noted along the highway in recent years with settlements in soil-covered areas generally attributed to the degradation of the ice-rich permafrost subgrade particularly where it was constructed adjacent to a water body and where the road crossed over the old alignment (BGC, 2011; and Wolfe et al, 2015;). Permafrost, where present, will be susceptible to degradation due to ground disturbance, such as removal of trees and surface vegetation or earthworks.

Recent studies commissioned by GNWT have reported that climate change trends have negatively impacted infrastructure supported on permafrost and are projected to continue to negatively impact permafrost conditions in the region (Dillon 2007; BGC, 2011). Continued warming, changes in freeze-thaw patterns, and ultimately degradation of permafrost in the region are anticipated due to increasing temperatures and amounts of precipitation, and decreases in snow and ice cover.

3.0 INVESTIGATION PROCEDURES

3.1 FIELD INVESTIGATION

A geotechnical field investigation for the proposed arch culvert consisting of two boreholes was carried out for this assignment as part of the overall TASR alignment geotechnical field program between February 12 and March 29, 2017. The boreholes were designated BH17-41 and BH17-42C and their locations are shown on the General Layout and Borehole Location Plan, Drawing No. 2 in Appendix B. The General Layout drawing is based on the Tlicho All Season Road Predesign Report and was designed by DOT Structures and drawn/drafted by DOT Technical Services. It is noted that the layout is conceptual and the final design details will be determined at a later date.

The field drilling program at this crossing was carried out on March 11 and 13, 2017. Boreholes BH17-41 and BH17-42C were drilled using a track mounted Foremost auger drill rig provided and operated by Northtech Drilling Ltd. Boreholes were to be advanced to a target depth of 8 m below existing ground surface, or practical auger refusal using 150 mm solid mm stem augurs and NW casing techniques with regular sampling using conventional 50 mm split spoon samplers during the performance of the Standard Penetration Test (SPT). Auger refusal prior to the target depth was checked with two additional auger probe holes completed at the offset distances of several meters from the initial borehole location.

The field work was conducted under the supervision of Stantec personnel, Kyle Polito (C.Tech.), who maintained detailed logs and obtained samples from the various strata encountered. Subsurface conditions were classified in general accordance with the procedures outlined in the attached explanatory key to Appendix C: Symbol and Terms Used on Borehole Records with soil descriptions prepared in accordance with ASTM D2487 and D2488. Temperatures of soil samples were measured by a handheld infrared thermometer on recovery at surface. Our observations of the temperature readings suggest that the drilling process might alter the temperature of the soil samples and that these measurements should not be considered representative of in situ conditions. For example, soil samples collected from the augers within the seasonal frost layer (e.g., sample AS3 in both boreholes) had temperature readings greater than 0° C. Frozen soils were classified in accordance with ASTM D4083 and D7099. Groundwater levels were estimated in the open boreholes at the time of drilling with water level tape and/or the moisture condition of the recovered samples.

A single-bead thermistor cable with 3000 Ohm thermistors manufactured by RST Instruments Ltd. was installed in the initial borehole and two additional probe holes of BH17-42C at depths of 4.0 m, 2.4 m and 1.4 m, respectively below ground surface. Initial thermistor resistance readings were taken upon installation with a digital multimeter. Three readings at 2, 16 and 22 days after installation were also completed. The borehole was backfilled to the original ground surface level with auger cuttings and with sand 0.3 m above and below the thermistor beads. A PVC protective casing with approximately 1 m stickup was installed at the thermistor location.

3.2 LOCATION AND ELEVATION SURVEY

The borehole locations and geodetic elevations were surveyed in the field by Stantec personnel using a Trimble Geo XH GPS with decimeter accuracy capability. The accuracy of the Trimble unit may be affected by satellite coverage at the time of survey. Table 3.1 summarizes the borehole information.

Table 3.1: Borehole Summary

	Boreholes	
	BH17-41	**BH17-42C**
UTM Zone 11 V Coordinates Northing Easting	(Staked Location)[(1)] 6962528 508721	(Drilled Location)[(2)] 6962702 508613
Ground Surface Elevation, m	Not recorded	276.52
Total Depth Drilled, m	1.5	3.96
End of Borehole Elevation, m	Not available	272.56
Depth of Casing, m	0	0
Number of Soil Samples	3	6

(1)The coordinate refers to the initially staked location of the borehole. The actual drilled location of the borehole was not surveyed with GPS.

(2)The coordinate refers to the drilled location of the borehole.

3.3 LABORATORY TESTING

All samples were taken to the Stantec Edmonton and Calgary laboratories for detailed classification and testing. Selected soil samples underwent gradation analysis, Atterberg Limits, and moisture content testing. The laboratory testing summary is shown in Table 3.2 below.

Table 3.2: Laboratory Testing for Arch Culvert Site

Laboratory Testing	Moisture Content	Gradation Analysis	Atterberg Limits
Number of Tests	7	3	1

One soil sample was also tested for pH, soluble sulphate content, chloride content, and resistivity by Maxxam Analytics.

Samples remaining after testing will be placed in storage for a period of one year after issuance of the final report. After the storage period, the samples will be discarded unless we are directed otherwise by Tlicho Engineering and Environmental Services Ltd.

4.0 SUBSURFACE CONDITIONS

4.1 SUBSURFACE PROFILE

The subsurface conditions observed in the Stantec boreholes are presented in detail on the Borehole Records provided in Appendix C. An explanation of the symbols and terms used to describe the Borehole Records is provided in Appendix C.

The temperature of each soil sample was measured in the field using an infrared thermometer and is provided on the Borehole Records.

It should be noted that the blow counts and relative density/consistency descriptions of frozen soils in the following section and in Appendix C should be used with caution. It is highly likely, particularly for cohesive soils, that the strengths implied by the blow counts will be significantly reduced by thawing.

In general, the subsurface stratigraphy at the site consisted of root mat at the surface, over peat, which was underlain by sand with varying amounts of silt, clay and gravel. Cobbles were also inferred in the sand.

4.1.1 Root Mat

Root mat was encountered at the surface of the boreholes BH17-41 and BH17-42C. Its thickness was 75 mm and 100 mm, respectively.

4.1.2 Organic Soil (Peat)

Frozen peat was encountered in borehole BH17-42C below the root mat, and extended to a depth of 0.8 m below ground surface. Temperatures of the peat samples recorded from the infrared thermometer at the time of drilling ranged from -3.6 to -1.0 °C. The frozen peat soil was described in the field as Vx to Vc based on ASTM D4083.

4.1.3 Silty Sand to Silty, Clayey Sand

A sand layer with varying amounts of gravel and clay was encountered in boreholes BH17-41 and BH17-42C. The SPT N-values for the sand deposit were greater than 50 blows per 0.3 m, which suggest a very dense relative density.

<u>BH17-41</u>

The sand deposit was encountered below the root mat, and extended to the depth of 1.5 m below the ground surface where auger refusal was encountered. It was described as brown, silty sand (SM) with gravel based on the Unified Soil Classification System (USCS). Cobbles, gravel and clay were noted within the silty sand layer. Temperatures of the sand recorded from the infrared thermometer at the time of drilling ranged from –1.9 to 19.5 °C. Frozen soil description of the retrieved soil samples was not possible; temperature of the samples was significantly altered from the drilling process.

Grain size distribution and moisture content tests carried out on representative samples of the sand yielded the following results:

Gravel:	9%
Sand:	42%
Fines (silt and clay):	49%
Silt size:	35%
Clay size:	14%
Moisture Content:	4 to 13%

The grain size distribution curve for the sand soil is provided in Figure 1 of Appendix D.

<u>BH17-42C</u>

Sand was also encountered from the depth of 0.8 m to 4.0 m (end of borehole) below ground surface in borehole BH17-42C. The soil was described as silty, clayey sand with gravel (SC-SM) based on the USCS. Temperatures of the sand samples recorded from the infrared thermometer at the time of drilling ranged from -3.6 to 1.8 °C. Frozen soil description of the retrieved soil samples was not possible; temperature of the samples was significantly altered from the drilling process. The undrained shear strength from Pocket Penetrometer reading from samples SS2 and SS4 were 245 kPa and 25 kPa, respectively.

Grain size distribution and moisture content tests carried out on representative samples of the sand yielded the following results:

Gravel:	19%
Sand:	45%
Fines (silt and clay):	36%
Silt size:	24%
Clay size:	12%
Moisture Content:	15 to 18%

The grain size distribution curve for the sand is provided in Figure 2 of Appendix D.

Atterberg limit test was also conducted on the fine portion of a sand soil sample. The liquid limit and plastic limit were 20 and 13, respectively, indicating that the material was a CL-ML, according to the USCS classification. The Atterberg Limit result is provided in Figure 3 of Appendix D.

4.2 PERMAFROST CONDITIONS

Based on field observations of frozen soil recoveries during advancement of the boreholes, frozen soil was encountered within boreholes BH17-41 and BH17-42C. The frozen soil was inferred in the boreholes BH17-41 and BH17-42C from ground surface to about 1.0 m (refusal) and 1.3 m, respectively below the existing ground surface. The frozen organic soil in borehole BH17-42C was described as having individual ice inclusions (Vx) to ice coatings on particles (V_c) in accordance with ASTM D4083. Temperatures of soil samples recorded in the field within the frozen zone ranged from -1.9 to -1.4 °C in BH17-41 and -3.6 to -1.0 °C in BH17-42C. Warmer soil sample temperatures of 0.2 to 1.8 °C were measured below a depth of 1.3 m in BH17-42C. High temperatures of 17.0 to 19.5 °C were also recorded below the depth of 1.0 m in sample AS3 in BH17-41. The recorded high temperature was most likely due to the effect of the drilling activity.

A single-bead thermistor cable with 3000 Ohm thermistors manufactured by RST Instruments Ltd. was installed in the initial borehole and two auger probe holes of BH17-42C at depths of 4.0 m, 2.4 m and 1.4 m, respectively. Initial thermistor resistance readings were taken upon installation with a digital multimeter. Three resistance readings at 2, 16 and 22 days after installation were also completed. The resistance versus temperature conversion table for the thermistors is included in Appendix E. Figure 4 in Appendix E presents the Temperature versus Depth as determined by the thermistor readings for borehole BH17-42C. The figure presents temperature readings which increased with depth from about -1 °C at the depth of 1.4 m to near 0 °C at the depth of 4.0 m.

The thermistor readings are considered to be a more reliable indication of the temperature of the soils compared to the infrared thermometer readings. The infrared thermometer was used during field sampling when the soils were heated by friction generated by the action of the drill. It was also observed during the field work that the infrared thermometer readings were affected when the outside temperatures were very low in the range of -20 °C to -30 °C. Therefore, the reported infrared temperature readings should be used with caution.

Based on the available thermistor data, we are unable to confirm if permafrost is present at this site. For design purposes, it may be conservative and precautionary to assume permafrost is present.

4.3 GROUNDWATER

Groundwater was encountered at the depth of 2.6 m in the borehole BH17-42C during the investigation. The observed groundwater level could be an indication of the absence of permafrost. Fluctuations in the groundwater due to seasonal changes or in response to a particular precipitation event should be anticipated. In permafrost terrain, shallow groundwater will be confined to the seasonal active layer and below the permafrost layer.

4.4 CHEMICAL TEST RESULTS

One sample of the native sand soil material was tested for pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis results are provided in Table 4.1. The results and certificates of analysis from Maxxam Analytics are provided in Appendix D.

Table 4.1: Results of Chemical Analysis

Borehole No	Sample No.	Depth (m)	pH	Chloride (%)	Sulphate (%)	Resistivity (Ohm-m)
BH17-42C	SS4	2.28 to 2.9	8.16	0.00084	0.021	7

5.0 CLOSURE

A subsurface investigation is a limited sampling of a site. The subsurface conditions given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered that differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information. Use of this report is subject to the Statement of General Conditions provided in Appendix A. It is the responsibility of Tlicho Engineering and Environmental Services Ltd., who is identified as "the Client" within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec Consulting Ltd. should any of these not be satisfied. The Statement of General Conditions addresses the following:

- Use of the report
- Basis of the report
- Standard of care
- Interpretation of site conditions
- Varying or unexpected site conditions
- Planning, design or construction

This report was written by Abraham Mineneh, PhD and reviewed by Christopher McGrath, P.Eng. and Jim Oswell, P.Eng. Mr. McGrath and Dr. Oswell are registered members of the Northwest Territories and Nunavut Association of Professional Engineers and Geoscientists. We trust that the information contained in this report is adequate for your present purposes. If you have any questions about the contents of the report or if we can be of any other assistance, please contact us at your convenience.

Respectfully Submitted;

STANTEC CONSULTING LTD.

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6.0 REFERENCES

ASTM. 2011. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

ASTM. 2009a. Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) (ASTM D2488). ASTM International, West Conshohocken, PA.

ASTM . 2009b. New Practice for Handling, Transportation, and Storage of Frozen Soil and Rock Samples (Draft Under Development) (ASTM WK24243). ASTM ASTM International, West Conshohocken, PA.

ASTM. 2016. Standard Practice for Description of Frozen Soils (Visual-Manual Procedure) (ASTM D4083). ASTM International, West Conshohocken, PA.

ASTM. 2010. Standard Terminology Relating to Frozen Soil and Rock (ASTM D7099). ASTM International, West Conshohocken, PA.

BGC Engineering Inc. 2011. Highway 3 – Climate Change Vulnerability Assessment – Final Report.

Canadian Standards Association (CSA). 2010. Technical Guide Infrastructure in permafrost: A guideline for climate change adaptation. Canadian Standards Association, Mississauga, ON, Canada.

Dillon Consulting Ltd. 2007. Climate Change and Transportation in the NWT. March 2007.

Ecosystem Classification Group (ECG). 2009. Ecological Regions of the Northwest Territories - Taiga Plains. Department of Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT, Canada.

Environment Canada. Warming Trends °C/Decade, Based on homogenized temperature data – the most recent 30 yr record (1981 – 2010); Environment Canada.

Environment Canada. (2016, September 1) Canadian Climate Normals 1981–2010. Yellowknife Station. Retrieved from http://climate.weather.gc.ca/climate_normals/ results_1981_2010_e.html?searchType=stnProv&lstProvince=NT&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=1706&dispBack=0

GNWT DOT, 2016. Proposed Tlicho All-season Road, Project Description Report. March 2016

Heginbottom, J.A., Dubreuil, M.A., and P.A. Harker. 1995. Canada-Permafrost; National Atlas of Canada, 5th edition, Plate 2.1. Geomatics Canada, National Atlas Information Service and Geological Survey of Canada (MCR 4177).

Kavik AXYS Inc. 2008. Multi-Level Mapping and Route Analysis – Tlicho Transportation Corridor. Route Identification and Evaluation. Yellowknife, NT. January 2008.Project No. Project No. 144902005.

Wolfe, 1998. Living with frozen ground : a field guide to permafrost in Yellowknife, Northwest Territories, edited by Stephen A. Wolfe ; contributions by Stephen A. Wolfe

S.A. Wolfe, P.D. Morse, T.E. Hoeve, W.E Sladen, S.V. Kokelj, L.U. Arenson, 2015. Disequilibrium permafrost conditions on NWT Highway 3

7.0 BIBLIOGRAPHY

Andersland, O.B., and Ladanyi, B. 1994. An Introduction to Frozen Ground Engineering. Chapman & Hall Inc., New York, NY, USA.

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

Canadian Foundation Engineering Manual (CFEM). 2006. Fourth Edition. Canadian Geotechnical Society, 488 p.

CHBDC. 2014. Canadian Highway Bridge Design Code. Canadian Standards Association, Mississauga, Ontario.

GSC, 1965. Glacial Lake McConnell and the surficial geology of parts of Slave River and Redstone River map areas, District of Mackenzie; Craig, B G. Geological Survey of Canada, Bulletin 122, 1965,; 44 pages, doi:10.4095/100639. Natural Resources Canada. 1995: Canada Permafrost; The National Atlas of Canada 5th Edition, scale 1:7 500 000.

GSC, 1989. Glacial Features Around the Keewatin Ice Divide, Northwest Territories; Aylsworth, J M; Shilts, W W. Geological Survey of Canada, Preliminary Map 24-1987, 1989; 2 sheets, doi:10.4095/126992.

Kerr and Wilson, 2000. 2000-C3. Preliminary surficial geology studies and mineral exploration considerations in the Yellowknife area, Northwest Territories. D.E. Kerr and P. Wilson.

APPENDIX A

Statement of General Conditions

STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec Consulting Ltd. and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec Consulting Ltd.'s present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec Consulting Ltd. is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec Consulting Ltd. at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec Consulting Ltd. must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec Consulting Ltd. will not be responsible to any party for damages incurred as a result of failing to notify Stantec Consulting Ltd. that differing site or sub-surface conditions are present upon becoming aware of such conditions.

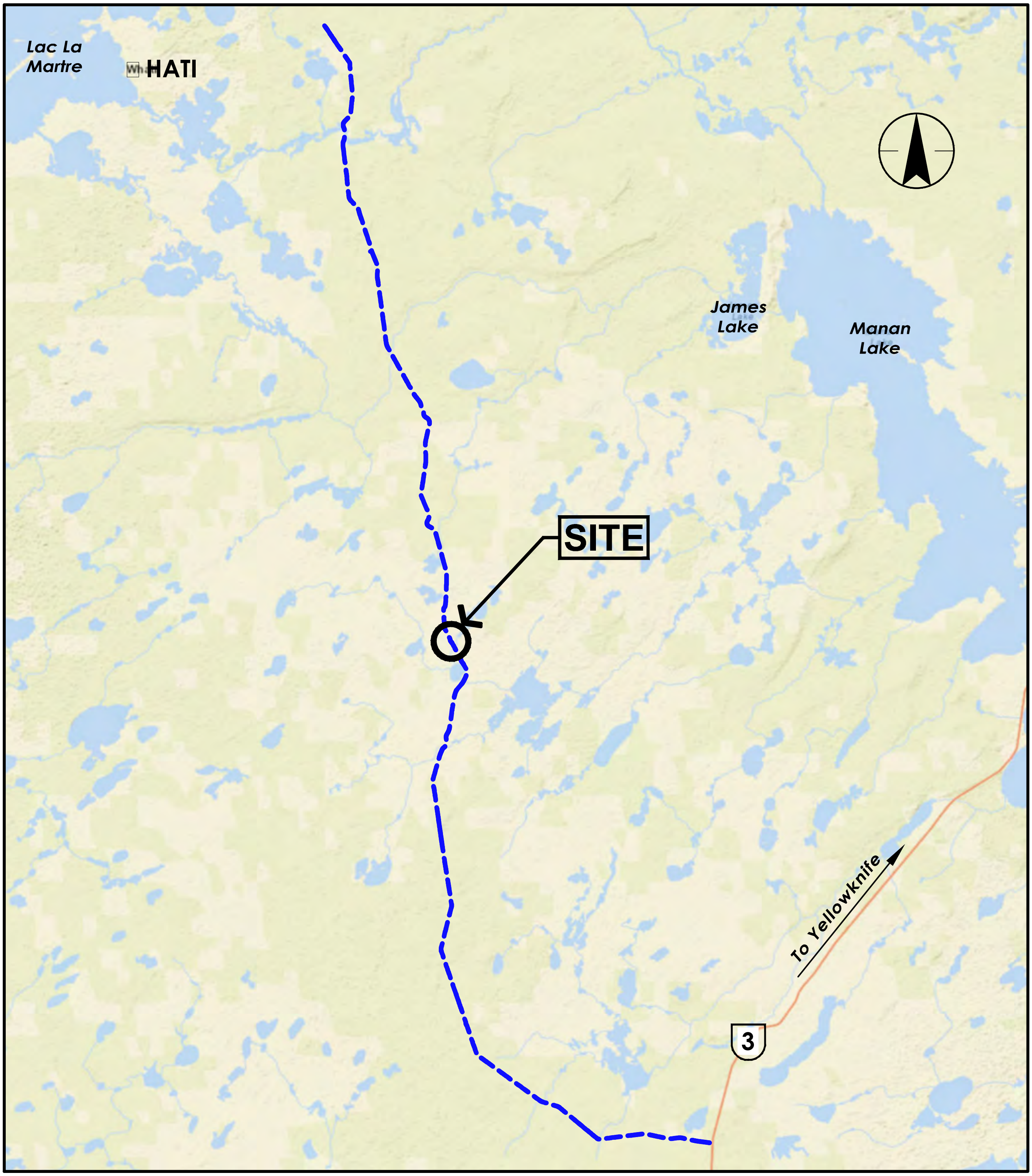
PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec Consulting Ltd., sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec Consulting Ltd. cannot be responsible for site work carried out without being present.

APPENDIX B

Drawing No. 1 – Key Plan

Drawing No. 2 – General Layout and Borehole Location Plan

Site Photos



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2017/05/23 1:10 PM By: Pinnell, Brian

APRIL 2017
Pro□□□No. 144902448

Stantec

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LEGEND

PROPOSED ALIGNMENT

NOTES

IMAGERY□ESRI ©2017.

Client/Project

TLICHO ENGINEERING & ENVIRONMENTAL SERVICES LTD.

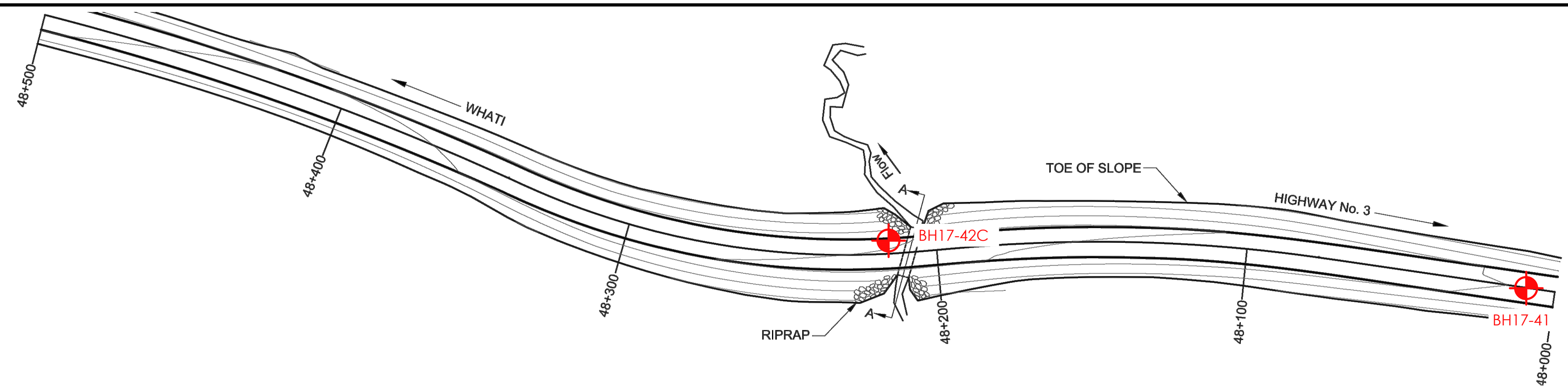
GEOTECHNICAL INVESTIGATION
BRIDGE CROSSING #10□, NWT

Drawing No.

1

Title

□EY PLAN



SITE PLAN
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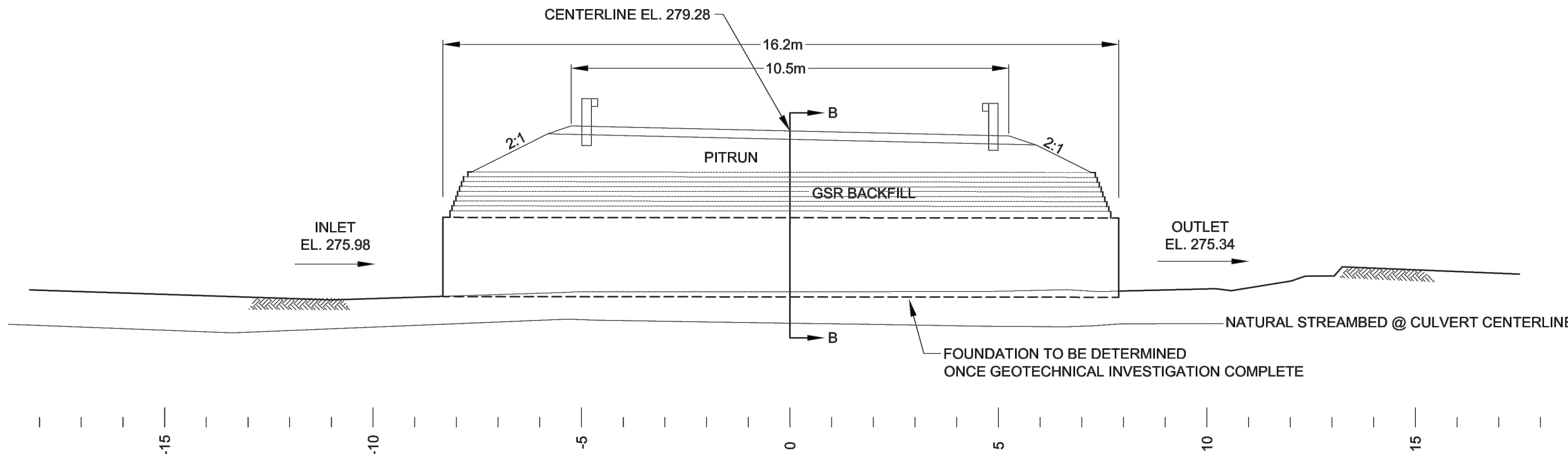
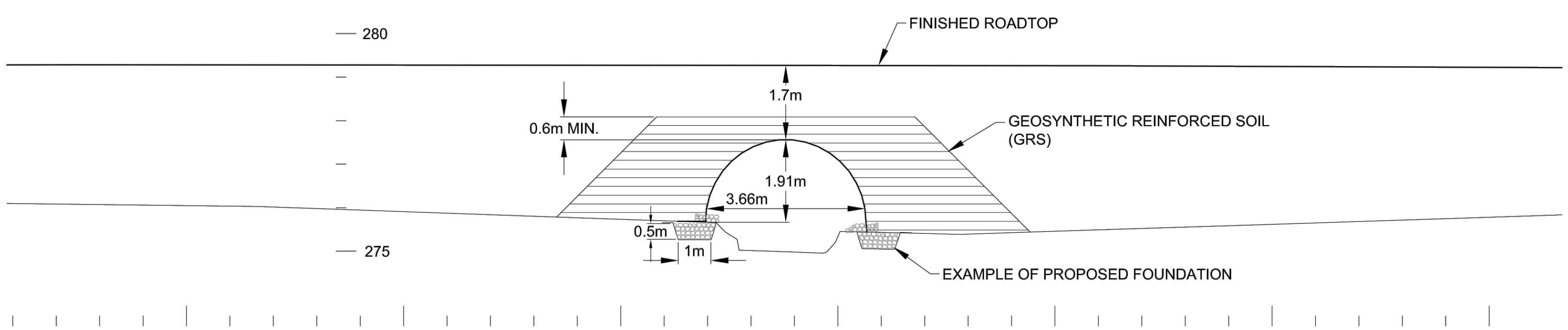
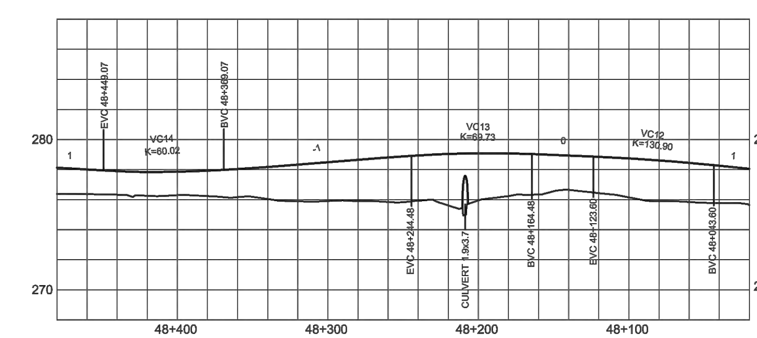


CULVERT PROFILE A-A @ 48+208.8
1:150



SECTION B-B
1:150

PLAN
1:10,000



ROADWAY PROFILE
H 1:5,000 V 1:500

T:\1449XXX\144902448 Ontario\From Ontario\Crossing 10a\144902448_C10a_General Layout.dwg
2017/05/23 1:32 PM By: Pinnell, Brian

APRIL 2017
PROJECT No. 144902448

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LEGEND

APPROXIMATE BOREHOLE LOCATION

NOTES

1. DRAWING PROVIDED BY DOT TECHNICAL SERVICES (TASR-04-16 (CROSSING#10□).

Client/Project

TLICHO ENGINEERING & ENVIRONMENTAL SERVICES LTD.

GEOTECHNICAL INVESTIGATION
CROSSING #10□ CULVERT, NWT

Drawing No.

2

Title

GENERAL LAYOUT AND BOREHOLE LOCATION PLAN

Photo No. 1: BH17-41 Looking Roadside

Photo No. 2: BH17-41 Looking Along Road

Photo No. 3: BH17-41 Looking Roadside

Photo No. 4: BH17-41 Looking Along Road

Photo No. 5: BH17-42C Looking Toward Borehole

Photo No. 6: BH17-42C Closer View of Thermistor Cables and PVC Pipe

Photo No. 7: BH17-42C Looking Roadside

Photo No. 8: BH17-42C Looking Roadside

v:\01216\active\other_pc_projects\144902448\05_report_deliv\draft_doc\crossing 10a\appendices\appendix b\photos\144902448_crossing_10a_photo_pages.docx

APPENDIX C

Symbols and Terms Used on Borehole Records

Stantec Borehole Records

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

Rootmat	- vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
Topsoil	- mixture of soil and humus capable of supporting vegetative growth
Peat	- mixture of visible and invisible fragments of decayed organic matter
Till	- unstratified glacial deposit which may range from clay to boulders
Fill	- material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

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

Terminology describing soil types:
The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4th Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):
Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

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

Terminology describing compactness of cohesionless soils:
The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. A relationship between compactness condition and N-Value is shown in the following table.

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

Terminology describing consistency of cohesive soils:
The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	Undrained Shear Strength		Approximate SPT N-Value
	kips/sq.ft.	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25 - 0.5	12.5 - 25	2-4
Firm	0.5 - 1.0	25 - 50	4-8
Stiff	1.0 - 2.0	50 – 100	8-15
Very Stiff	2.0 - 4.0	100 - 200	15-30
Hard	>4.0	>200	>30

ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Terminology describing rock quality:

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

Alternate (Colloquial) Rock Mass Quality	
Very Severely Fractured	*Crushed*
Severely Fractured	*Shattered or Very Blocky*
Fractured	*Blocky*
Moderately Jointed	*Sound*
Intact	*Very Sound*

RQD (Rock Quality Designation) denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 in.) long are summed and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

SCR (Solid Core Recovery) denotes the percentage of solid core (cylindrical) retrieved from a borehole of any orientation. All pieces of solid (cylindrical) core are summed and divided by the total length of the core run (It excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

Fracture Index (FI) is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

Terminology describing rock with respect to discontinuity and bedding spacing:

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

Terminology describing rock strength:

Strength Classification	Grade	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	<1
Very Weak	R1	1 – 5
Weak	R2	5 – 25
Medium Strong	R3	25 – 50
Strong	R4	50 – 100
Very Strong	R5	100 – 250
Extremely Strong	R6	>250

Terminology describing rock weathering:

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

STRATA PLOT

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

Boulders Cobbles Gravel	Sand	Silt	Clay	Organics	Asphalt	Concrete	Fill	Igneous Bedrock	Meta-morphic Bedrock	Sedi-mentary Bedrock

SAMPLE TYPE

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

WATER LEVEL MEASUREMENT

▼ measured in standpipe, piezometer, or well

▽ inferred

RECOVERY

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

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to ‘A’ size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

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

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

BOREHOLE RECORD

BH17-41

CLIENT: Tlicho E&E Services Ltd.
BOREHOLE No.: BH17-41
LOCATION: Northwest Territories, Canada
PROJECT No.: 144902448
DATES: BORING: March 11, 2017
WATER LEVEL: N/A
DATUM: Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0		75 mm ROOTMAT						
		Brown, frozen, silty SAND (SM) with gravel - Occasional cobbles - Approx. sample temperature: AS1: -1.4 to -1.9°C AS3: +17.0 to +19.5°C			AS	1		
1					SS	2	0	>50
					AS	3		
1.5		End of Borehole - Refusal at depth of 1.5m - Refusal at depth of 1.2m, 2.5m north of the first BH location, large amount of cobbles to ground surface upon refusal - Refusal at depth of 1.0m depth, 2m north of the second BH location						

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS: W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

Depth scale: 0 1 2 3 4 5 6 7 8

▽ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

▣ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ________
Date ________

BOREHOLE RECORD

N: 6 962 702 E: 508 613

BH17-42C

CLIENT Tlicho E&E Services Ltd. BOREHOLE No. BH17-42C

LOCATION Northwest Territories, Canada PROJECT No. 144902448

DATES: BORING March 13, 2017 WATER LEVEL N/A DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	276,52					
	276,4	100 mm ROOTMAT				
		Brown, frozen, PEAT (OL-OH)	AS	1		
	275,7	- Approx. sample temperature: AS1: -1.0 to -2.9°C SS2: -2.8 to -3.6°C - Frozen soil description: Vx - Vc	SS	2	230	>50
		Very dense, brown to grey, frozen, silty, clayey SAND (SC-SM) with gravel - occasional cobbles	AS	3		
		- Approx. sample temperature: SS2: -2.8 to -3.6°C AS3: 1.6 to 1.8°C SS4: 0.5 to 0.9°C AS5: 0.2 to 0.7°C	SS	4	150	>50
			AS	5		
	272,6	- Auger sample AS7 was taken within SS6 sample interval	SS	6	0	>50
4		End of Borehole - Auger refusal at depth of 3.96m - Auger refusal at depth of 3.48m, 5m north of the first BH location - Auger refusal at depth of 2.44m, 3m north of the second BH location - Thermistor installed at depth of 3.96m in the first BH, 2.44m in the second BH, and 1.37m in the third BH				

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

245,25

Depth (m): 0 1 2 3 4 5 6 7 8

STRATA PLOT | WATER LEVEL

Inferred Groundwater Level

Groundwater Level Measured in Standpipe

Field Vane Test, kPa

Remoulded Vane Test, kPa

Pocket Penetrometer Test, kPa

App'd

Date

APPENDIX D

Laboratory Test Results

Stantec

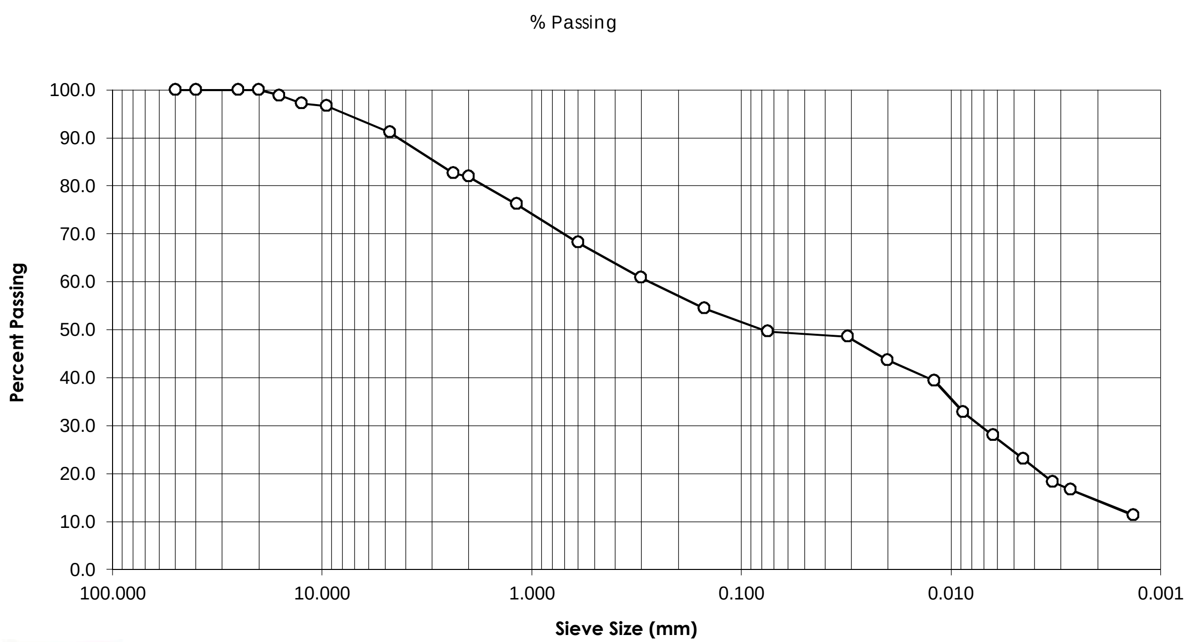
Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho All Season Road
Project No: 144902448

OFFICE	LABORATORY
10160 - 112 ST	10575 106 ST
Edmonton, Alberta	Edmonton, Alberta
Canada T5K 2L6	Canada T5H 2X5
Tel: (780) 917-7000	Tel: (780) 917-7463

SAMPLE No.: AS3
SOURCE: BH17-41
TESTED BY: JA

DATE TESTED: April 19, 2017
DATE RECEIVED: April 4, 2017
SAMPLE DESCRIPTION: Silty Sand (SM)



CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0063	28.0
40.0	100.0	0.0045	23.1
25.0	100.0	0.0033	18.3
20.0	100.0	0.0027	16.7
16.0	98.9	0.0013	11.3
12.5	97.2		
9.5	96.7		
4.75	91.1		
2.36	82.7		
2.00	82.0		
1.18	76.2		
0.600	68.2		
0.300	60.8		
0.150	54.4		
0.075	49.6		
0.0311	48.6		
0.0201	43.7		
0.0120	39.3		
0.0088	32.9		

Gravel:	8.9%	D_{10}:	-
Sand:	41.5%	D_{30}:	0.0074
Silt:	35.2%	D_{60}:	0.2814
Clay:	14.4%	C_u:	-
		C_c:	-

Comments:

Figure No. 1

Reviewed by:

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

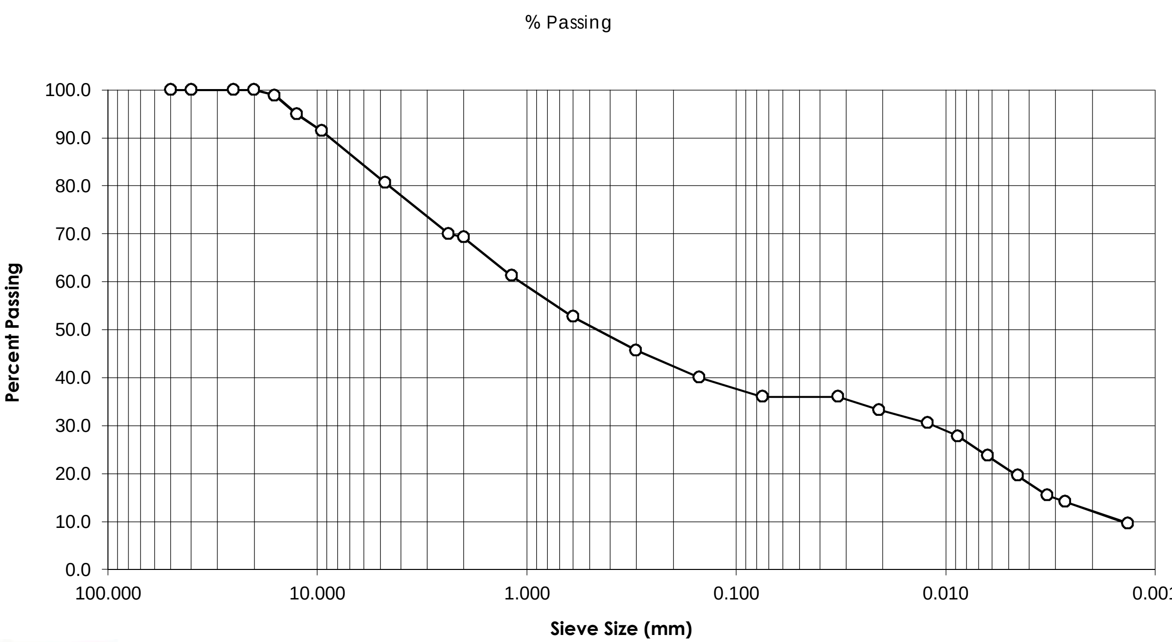
Client: Tli Cho Engineering&Environmental Services
Project Name: TliCho All Season Road
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: AS5
SOURCE: BH17-42C
TESTED BY: JA

DATE TESTED: April 20, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Silty Sand with some clay & gravel (SM-SC)



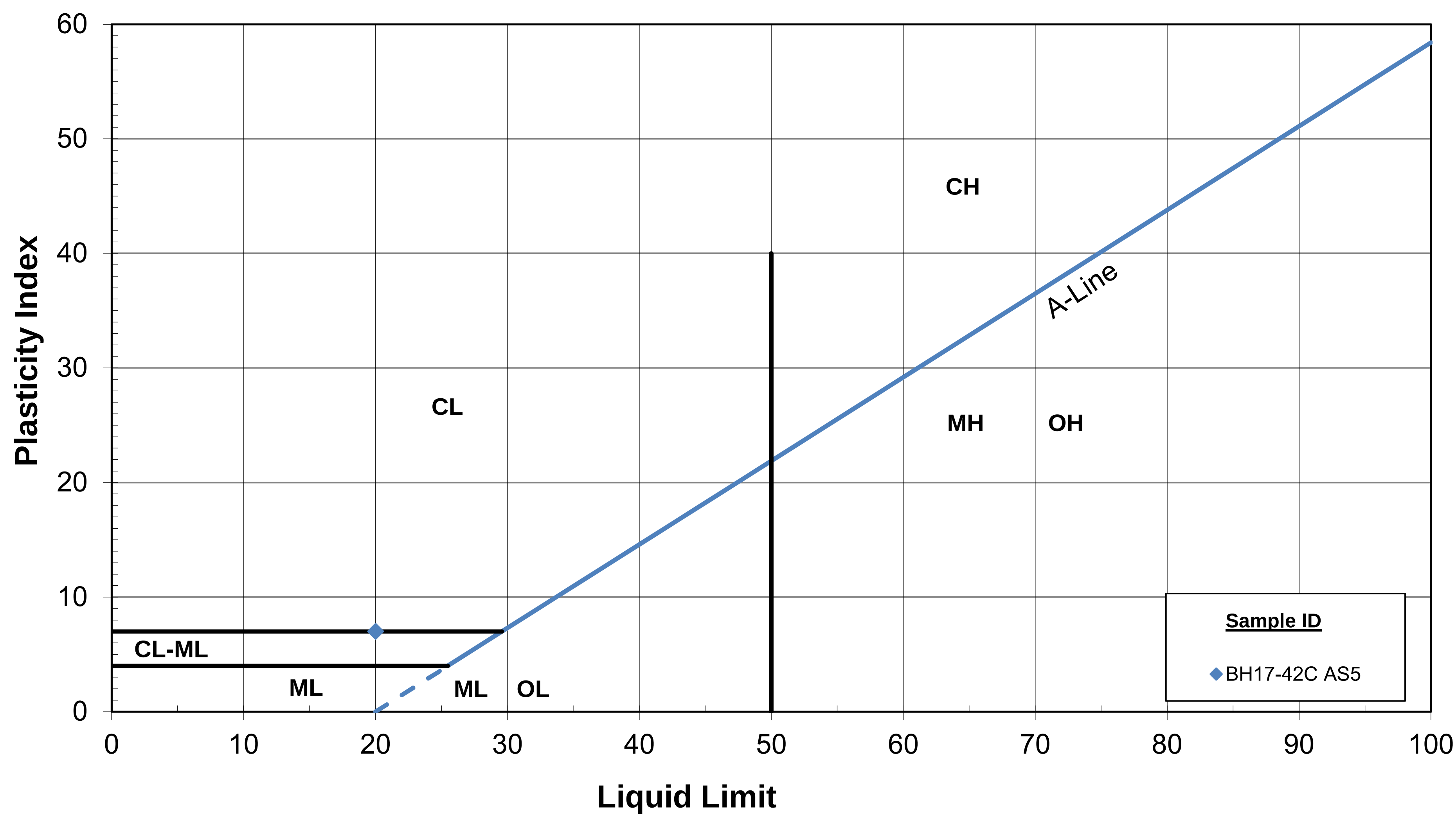
Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0063	23.7
40.0	100.0	0.0045	19.6
25.0	100.0	0.0033	15.5
20.0	100.0	0.0027	14.1
16.0	98.8	0.0013	9.6
12.5	94.9		
9.5	91.4		
4.75	80.7		
2.36	70.0		
2.00	69.3		
1.18	61.3		
0.600	52.7		
0.300	45.7		
0.150	40.0		
0.075	36.1		
0.0325	36.0		
0.0208	33.3		
0.0122	30.6		
0.0088	27.8		

Gravel:	19.3%	D_{10}:	0.0015
Sand:	44.6%	D_{30}:	0.0115
Silt:	23.9%	D_{60}:	1.0996
Clay:	12.2%	C_u:	736.66
		C_c:	0.08

Comments:

Figure No. 2

Reviewed by:



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Tlicho Engineering & Environmental Services

Tlicho All Season Road

PLASTICITY CHART

Figure No. 3

Project No. 144902448

APPENDIX E

Thermistor Resistance Versus Temperature Relationship

Thermistor Readings

Resistance versus Temperature Relationship 3000 Ohm NTC Thermistors

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	30	525.4	70	153.2	110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.99K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-35	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	282.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	56.92	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965	53	250.9	93	83.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	3000	25	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

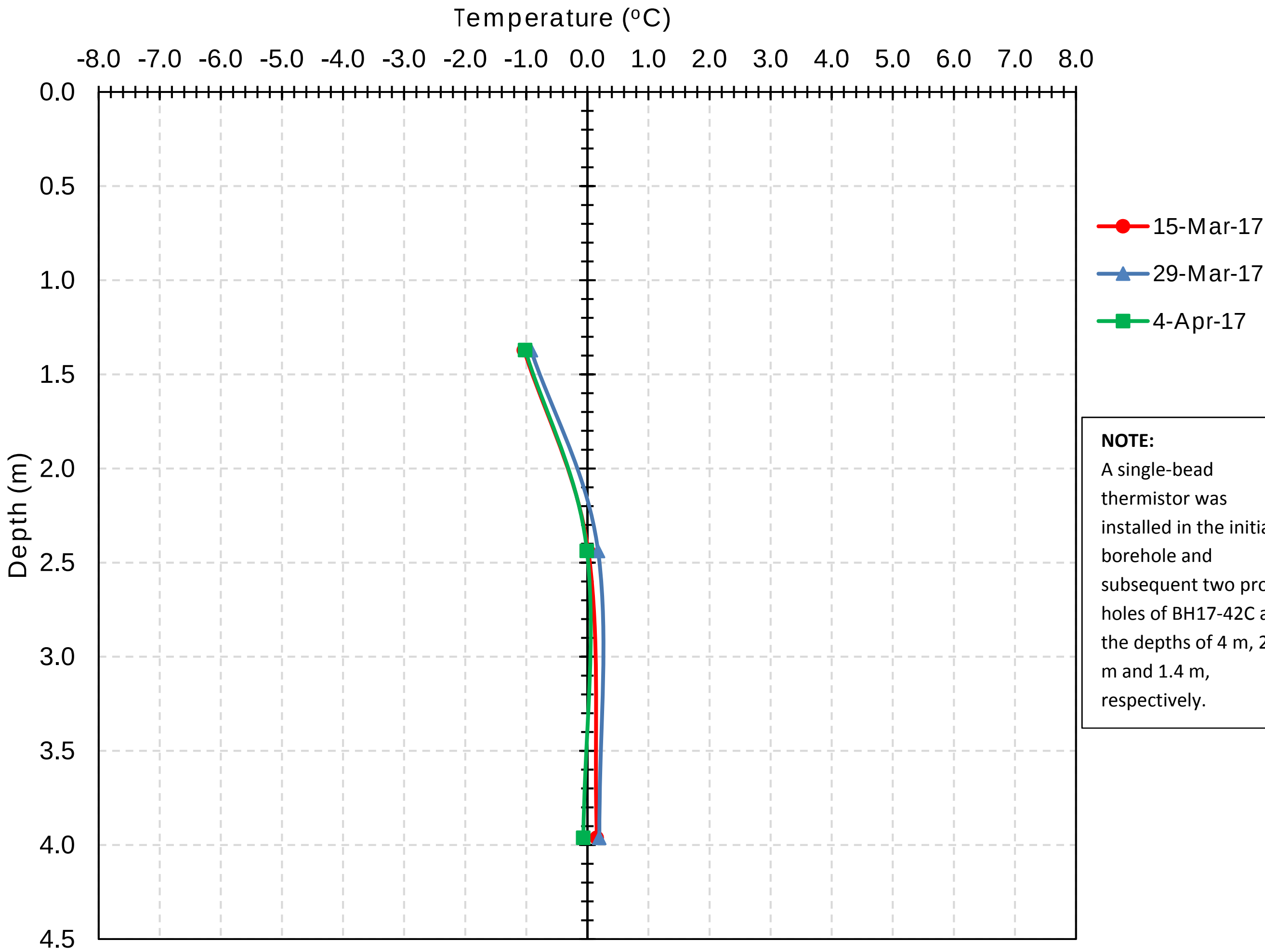
Temperature calculated using:

Steinhart-Hart Linearization

$$T_C = \frac{1}{C_0 + C_1(\ln R) + C_3(\ln R)^3} - 273.15$$

3000 Ohm @ 25C NTC Thermistor

C_0= 0.0014051
C_1= 0.0002369
C_3= 0.0000001019
lnR= Natural Log of Resistance
T_c= Temperature in °C



NOTE:
A single-bead thermistor was installed in the initial borehole and subsequent two probe holes of BH17-42C at the depths of 4 m, 2.4 m and 1.4 m, respectively.

Borehole	**BH17-42C**					
Drilled:	13-Mar-17		Drilled Depth:		3.96	m
Installed:	13-Mar-17					
Reading			**Bead**	TS4350	TS4369	TS4352
Date		**Days**	**Depth (m)**	1.37	2.44	3.96
Post-Install	13-Mar-17	0	R (ohms)	16.40	18.40	14.00
			T (°C)	-9.8	-11.9	-6.9
2	15-Mar-17	2	R (ohms)	10.32	9.78	9.71
			T (°C)	-1.0	0.0	0.2
3	29-Mar-17	16	R (ohms)	10.26	9.7	9.69
			T (°C)	-0.9	0.2	0.2
4	4-Apr-17	22	R (ohms)	10.31	9.79	9.82
			T (°C)	-1.0	0.0	-0.1

Stantec

Thermistor Readings BH17-42C

Figure No. 4

Project No. 144902448

Geotechnical Data Report
Proposed Bridge Crossing #14
Station 69+666

Geotechnical Investigation,
Proposed Tlicho All-Season Road,
Northwest Territories

Stantec

Prepared for:
Tlicho Engineering and
Environmental Services Ltd.

Prepared by:
Stantec Consulting Ltd.
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Project No. 144902448

June 2017

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1.0 INTRODUCTION

Acting at the authorization of Tlicho Engineering and Environmental Services Ltd. (Tlicho), Stantec Consulting Ltd. (Stantec) carried out a geotechnical investigation in support of the proposed bridge planned at Crossing #14 along the proposed Tlicho All Season Access Road (TASR). The purpose of the investigation was to characterize subsurface conditions and provide geotechnical comments and recommendations to assist with proposed bridge design and site development.

The investigation was carried out in general accordance with Stantec's proposal dated January 12, 2017, as part of an overall geotechnical program by Tlicho for the Government of the Northwest Territories (GNWT) along the proposed 94 km TASR alignment extending from the Yellowknife Highway (Highway 3) to the Settlement of Whatì on the south shore of Lac La Martre (RFP Event ID: EV000000001132). The scope of work outlined in the GNWT Request for Proposal includes the geotechnical investigation and design of the 94 km long TASR corridor, four bridges and three structural culverts. Tlicho was responsible for management and execution of the overall project and team as the Prime Contractor, with Stantec acting as sub-consultant providing geotechnical engineering and technical services to the project, including:

- Provision of geotechnical field personnel to log subsurface conditions during drilling operations at eighty-one (81) geotechnical boreholes in accordance with the RFP:
  - Thirteen (13) boreholes at the four (4) proposed major bridge crossings:
    - Crossing #8, Station 40+400 - Duport River Crossing
    - Crossing #9, Station 45+175 - (unnamed)
    - Crossing #14, Station 69+666 - James River Crossing
    - Crossing #15, Station 85+397 - La Martre River
  - Three (3) boreholes at the three (3) proposed major bridge culvert crossings:
    - Crossing #5, Station 16+532
    - Crossing #6, Station 19+427
    - Crossing #10a, Station 48+208
  - Sixty-five (65) boreholes to observe the subsurface conditions along the road alignment;
- Installation and reading of thermistors;
- Borehole layout and as-drilled survey;
- Completion of a laboratory testing program on the recovered borehole samples as specified in the RFP; and
- Geotechnical engineering assessment and reporting on the field and laboratory findings in two reports (Geotechnical Data Report and Geotechnical Recommendations Report) for each crossing location and for the overall roadway alignment.
  - These documents should be read in conjunction with the Statement of General Conditions, Appendix A.

This Geotechnical Data Report contains the factual findings from the geotechnical investigation undertaken at the Crossing #14 site by Stantec including: a summary of the field and laboratory

procedures; Borehole Records; laboratory test results; and a discussion of the factual findings. The Geotechnical Recommendation Report for Crossing #14, presenting the results of our geotechnical analysis with discussion and recommendations for design purposes is provided under separate cover.

2.0 SITE DESCRIPTION AND GEOLOGY AND CLIMATE

2.1 SITE DESCRIPTION

The Crossing #14 bridge is proposed at the James River located at approximately the 68.7 km station mark along the TASR corridor as shown on Drawing No. 1 – Site Location Plan, provided in Appendix B. At this location, the proposed road center line and bridge is aligned with the original Lac La Martre winter road.

Based on a previous hydrologic study (Stantec, 2015), it is understood that the watercourse is a braided, meandering channel. The well-defined meandering channel is approximately 10 m wide and 2.5 to 3.0 m deep. The floodplain is approximately 80 m wide. At the time of the investigation, the watercourse channel(s) were not visible during the walk around inspection of the bridge location due to snow and ice cover. The vegetation in the floodplain is primarily comprised of shrubs (65%) however there is also approximately 15% conifer trees and 20% grasses covering the area. Snow cover depths of approximately 50 to 55 cm was measured in surrounding areas. Photographs showing the general site conditions at the proposed bridge crossing are provided in Appendix B.

It is understood that the original Lac La Martre overland winter road was established by the military in the 1950s, and used as a public winter road for the northern Tlicho communities up until the late 1980s. More recently it has been used by the local communities for travel using all-terrain vehicles including snowmobiles, dog sleds, ATVs, and trucks (GNWT DOT, 2016). Previous site development for the road at this location appears to be limited. The roadbed is approximately level with the surrounding undisturbed vegetated areas with no significant historic ground disturbance (regrading cut/fill) apparent.

2.2 PHYSIOGRAPHY AND GEOLOGY

The site is located within the Great Slave Plain High Boreal Ecoregion (ECG, 2009 and GNWT DOT, 2016). In this section of the TASR corridor (GNWT DOT, 2016), regional topography is generally subdued with plains and gently rolling hills. Drainage ranges from ‘well’ to ‘moderately well’ with occasional seasonal tributaries. Vegetation includes regenerating jack pine forest, ephemeral stream crossing/swampland, dwarf shrub and mixed stands. The general area was subjected to forest fires in the last decade.

Based on available surficial geology mapping conducted by the Geological Survey of Canada, and previous project terrain mapping (Kavik AXYS Inc, 2008 and GNWT DOT, 2016), natural overburden material in the area has been mapped as till, coarse beach glaciolacustrine and fine glaciolacustrine material associated with glacial Lake McConnell, and occasional veneers of organic or fluvial materials overlying bedrock. Within stream channels and floodplains, recent fluvial deposits are expected. Based on geological mapping published by the Geological Survey of Canada (Okulitch, A.V, 2006), the site is mapped within the Interior Platform geologic province, situated over Paleozoic aged sedimentary rocks of the Lonely Bay Formation consisting of brown limestone and minor dolostone.

2.3 CLIMATE & PERMAFROST

2.3.1 Climate

Based on a review of historic climate data completed using the Yellowknife Airport (Climate Reference ID: 2204100), Whatì meteorological station (Lac la Martre, Climate Reference ID: 2202678) and other sources (GNWT, 2016), it is understood that the TASR area has a subarctic climate (Dfc according to the Köppen climate classification system) characterized by generally relatively cold winters followed by short summers. It is noted that the Whatì station is located approximately 13 km west of the northern limit of the TASR and the Yellowknife station is located approximately 100 km east of the southern limit of the TASR.

Average annual daily mean temperatures are about -4.3 °C (Yellowknife Station) to -4.7 °C (Whatì Station), with the lowest average daily winter temperatures generally occurring in January, while the warmest month (based on the average temperature) occurs in July. The average annual precipitation is estimated on the order of 289 mm, with an average annual rainfall of 170.7 mm generally occurring throughout June through September, and an average annual snowfall of 157.6 cm generally occurring from September through May (Yellowknife Station).

The average freezing and thawing indices between 1981 and 2010 have been 3343.1°C days and 1813.3°C days, respectively (Yellowknife Station). A 2009 study completed by Holubec, et. al., using data from 1978 to 2008 in their model, was adapted by CSA (2010). The CSA study suggests a warming trend of 0.58°C per decade within the Central Arctic region (including the TASR site). As per Table 5.2 in CSA (2010), seasonal mean temperature change under moderate (A1B) green-house gas scenarios, the mean annual temperatures for the Arctic Sector C1 are projected to be 1.3°C (2011-2040), 2.7°C (2041-2070), and 3.7°C (2071 – 2100), respectively. It is noted that the TASR site is located near the margins of the C1 and W1 sectors, therefore the temperatures will likely be some combination of the two sector predictions. This report references the temperatures for Arctic Sector C1, which are warmer temperatures compared to Arctic Sector W1.

2.3.2 Permafrost

Canada permafrost mapping from the National Atlas of Canada (Heginbottom et al. 1995) shows the TASR site lies within the zone of extensive discontinuous permafrost, with an estimated 50% and 90% of the landscape covered. It is understood that no public thermistor or intrusive investigation records exist for the immediate vicinity of the TASR. Previous reconnaissance trips by earlier terrain mapping crews and GNWT personnel did not encounter any apparent permafrost landforms or thermokarst zones within the corridor, however a zone affected by thermokarst processes was noted between Whatì, Behchoko, and the area north of Slemon Lake (Kavik AXYS Inc, 2008 and GNWT DOT, 2016).

Based on regional studies completed in surrounding areas (GNWT, 2016), permafrost is anticipated to be relatively warm and correlated with forest cover type areas underlain by finer-textured glacial and post-glacial sediments such as glaciolacustrine and lacustrine deposits, as well as peatlands where organic material contribute to the forming and preservation of permafrost. Ground ice content, if present in these finer grained deposits in the upper 10 to 20 m is anticipated to be less than 10% to 20% ice by volume (Heginbottom et al. 1995). Ground ice is generally expected to be less common in areas of exposed bedrock and where the underlying sediments are coarse and vegetation cover is thin.

Permafrost near Yellowknife is reported to be generally warm (>-2°C), less than 50 m thick with active layer thickness less than1 to up to 3 m (Wolfe, 1998). Permafrost conditions along the nearby Highway 3 have been reported as typically warmer than -1°C, with an active layer thickness varying from less than 0.7 m to 1.5 m. Permafrost degradation has been noted along the Highway in recent years with settlements in soil-covered areas generally attributed to the degradation of the ice-rich permafrost subgrade particularly where it was constructed adjacent to a water body and where the road crossed over the old alignment (BGC, 2011; and Wolfe et al, 2015;). Permafrost, where present, will be susceptible to degradation due to ground disturbance, such as removal of trees and surface vegetation or earthworks.

Recent studies commissioned by GNWT reported that climate change trends have negatively impacted infrastructure supported on permafrost and are projected to continue to negatively impact permafrost conditions in the region (Dillon 2007; BGC, 2011). Continued warming, changes in freeze-thaw patterns, and ultimately degradation of permafrost in the region are anticipated due to increasing temperatures and amounts of precipitation, and decreases in snow and ice cover.

3.0 INVESTIGATION PROCEDURES

3.1 FIELD INVESTIGATION

The geotechnical field investigation for the bridge, conducted as part of the overall TASR alignment geotechnical program between March 17 and March 22, 2017, consisted of four geotechnical holes as shown on the General Layout and Borehole Location Plan, Drawing No. 2 in Appendix B. It is to be noted that the layout is conceptual and the final design details will be determined at a later date. Two boreholes were advanced at the approximate locations of the proposed bridge abutments (BH17-57B and BH17-60B) and two boreholes (BH17-58B and BH17-59B) were advanced at the approximate locations of the proposed pier locations within the floodplain. Borehole locations were selected by GNWT and were established in the field by Stantec using a Trimble Geo XH GPS unit. Some boreholes were relocated up to 5 m from the original location to minimize interference with traffic on the existing winter road; the final locations of the boreholes were recorded using the GPS unit.

Boreholes were completed using a skid mounted drill rig capable of auger and diamond drilling. The drill rig was operated by Northtech Drilling Ltd. Boreholes were to be advanced to a target depth of 30 m below existing ground surface using solid stem augers and NW casing with regular sampling using conventional 50 mm split spoon samplers during the performance of the Standard Penetration Test (SPT), or 3 m into bedrock, whichever came first. Between 3.8 m and 6.1 m of rock was cored using a NQ core bit. The drilling depth was increased to allow for additional sampling based on the quality of the rock obtained at site.

The field work was conducted under the part-time monitoring of a GNWT field representative and full-time supervision of Jacques Duguay B.Eng., Justin Matthew, B.Eng., and Jim Oswell, PhD., P.Eng. (Stantec) who maintained detailed logs and obtained samples from the various strata encountered. Subsurface conditions were classified in general accordance with the procedures outlined in the attached explanatory key: Symbol and Terms Used on Borehole and Test Pit Records with soil descriptions prepared in accordance with ASTM D2487 and D2488. Temperatures of soils samples were measured by a handheld infrared thermometer on recovery at surface. Our observations of the temperature readings suggest the drilling process altered the temperature of the soil samples and that these measurements should not be considered representative of in situ conditions. For example, soil samples collected from the augers within the seasonal frost layer (denoted as AS) had temperature readings greater than 0° C. Frozen soils were classified in accordance with ASTM D4083 and D7099. Rock was classified in accordance to the symbols and terms, Appendix C. Groundwater levels were estimated in the open boreholes at the time of drilling with water level tape and/or the moisture condition of the recovered samples.

On completion of drilling, thermistor strings were installed in all four boreholes and backfilled with cuttings and sand. Frozen sand was broken up mechanically so that the material could be placed in contact with the instrument without larger frozen fragments damaging the thermistor beads.

3.2 LOCATION AND ELEVATION SURVEY

Final borehole locations and geodetic elevations were surveyed in the field by Stantec personnel using a Trimble Geo XH GPS with decimeter accuracy capability. The accuracy of the Trimble unit may be affected by satellite coverage at the time of the survey. Table 3.1 summarizes the borehole information.

Table 3.1: Borehole Summary

	Boreholes			
	BH17-57B	BH17-58B	BH17-59B	BH17-60B
NAD83 / UTM Zone 11N Coordinates Northing Easting	6982652 504480	6982666 504474	6982702 504455	6982723 504449
Ground Surface Elevation, m	248.8	248.2	248.2	249.1
Total Depth Drilled, m	22.0	21.9	20.9	23.5
End of Borehole Elevation, m	226.8	226.3	227.3	225.6
Number of Soil Samples	15	16	16	19
Number of Rock Core Samples	3	3	3	4

3.3 LABORATORY TESTING

All samples were taken to the Stantec Edmonton or Calgary laboratories for detailed classification and testing. Sample preservation and handling of frozen samples was in general accordance with industry standard practices (ASTM WK24243, ASTM Special Technical Publication, no 599:88-112).

Selected soil samples underwent gradation analysis, Atterberg limits, and moisture content testing. Unconfined compression testing was also carried out on select bedrock core samples. The laboratory testing summary is shown in Table 3.2 below.

Table 3.2: Laboratory Testing for Crossing #14

Laboratory Testing	Moisture Content	Gradation Analysis	Atterberg Limits	Compression
Number of Tests	44	13	10	4

To assess the potential for corrosion of buried steel elements and potential for sulphate attack on buried concrete elements, three samples of the native overburden material were tested at Maxxam Analytics for pH, water soluble sulphate and chloride concentrations, and resistivity. The results are reported in Section 4.4.

Samples remaining after testing will be placed in storage for a period of one year after issuance of the final report. After the storage period, the samples will be discarded unless we are directed otherwise by Tlicho Engineering and Environmental Services Ltd.

4.0 SUBSURFACE CONDITIONS

4.1 SUBSURFACE PROFILE

The subsurface conditions observed in the boreholes are presented in detail on the Borehole Records provided in Appendix C with further discussion below on the individual soil units encountered. An explanation of the symbols and terms used to describe the Borehole Records is provided in Appendix C.

It should be noted that the SPT blow counts and relative density/consistency descriptions of frozen soils in the Appendix C should be used with caution. It is highly likely, particularly for cohesive soils, that the strengths implied by the blow counts will be significantly reduced by thawing.

In general, the subsurface stratigraphy at the bridge location consisted of a deposit of clay or silt with variable amounts of sand over, glacial till predominantly consisting of clay with variable amounts of sand and silt overlying, bedrock. Frequent cobbles and boulders were observed in the glacial till layer. The overburden soils were frozen to a depth of approximately 1 m at boreholes BH 17-57B and BH17-60B (proposed abutment locations) and a depth less than 0.6 m at boreholes BH17-58B and BH17-59B (proposed pier locations). The stratigraphic profile of the site is shown on Drawing No. 3 in Appendix B.

4.1.1 Organic Soil

A surficial layer of frozen rootmat was encountered at all boreholes with exception of BH17-57B. The organic soils were typically 50 mm and 100 mm in thickness, however the sites were grubbed prior to the start of work therefore it is possible that the surficial organic layer is thicker than indicated on the borehole logs.

4.1.2 Sandy Lean Clay to Silt with Sand

<u>BH17-57B</u>

Frozen grey silty clay with sand to silt with sand was encountered at ground surface and extended to a depth of approximately 1.5 m. The temperature of a soil sample obtained from the infrared thermometer was 1.5°C at a depth of about 3.3 m. The frozen soil description of the uppermost 1.5 m was N_{bn}.

The SPT N-value of the silt with sand was 9 blows for 0.3 m; in unfrozen soil this corresponds to a relative density of loose, however it is likely that this soil will be even less dense after thawing. Pocket penetrometer tests on a sample of clay indicated an undrained shear strength of 50 kPa.

Grain size distribution and moisture content tests carried out on a representative sample of the material yielded the following results:

Gravel:	0%
Sand:	17 to 27%
Fines (silt and clay):	73 to 83%
Silt size:	60 to 61%
Clay size:	13 to 22%
Moisture content:	15 to 20%

An Atterberg limits test carried out on one representative sample from this layer indicated a liquid limit of 21 and plasticity index of 6. The grain size distribution curve is provided in Figure 1 and 2, and the corresponding plasticity charts are given in Figure 14 of Appendix D. The Unified Soil Classification System (USCS) group symbol for this layer is CL-ML (silty clay with sand) to ML (silt with sand).

<u>BH17-58B</u>

Dark brown to grey silty clay with sand was encountered below the frozen rootmat and extended to a depth of 2.4 m. Temperatures of the soil samples obtained from the infrared thermometer ranged from 0.0 to +5.2°C.

The SPT N-value of the silty sand was 3 blows for 0.3 m; in unfrozen soil this corresponds to a very loose relative density. Pocket penetrometer tests on a sample of clay indicated an undrained shear strength of 122 kPa, which corresponds to a very stiff consistency.

Soil gradation testing was not completed on a sample of this material due to poor sample recovery, therefore classification is based on visual observations.

<u>BH17-59B</u>

Dark grey silt with sand to sandy lean clay was encountered below the surficial rootmat and extended to a depth of 4.9 m. Temperatures of the soil samples obtained from the infrared thermometer ranged from 0.0 to +7.6°C.

The SPT N-value of the silt with sand to sandy lean clay ranged between 3 and 5 blows for 0.3 m, which corresponds to a very loose relative density. Pocket penetrometer tests on samples of clay indicated the undrained shear strength ranged from 20 kPa to 35 kPa, which corresponds to a soft to firm consistency.

Grain size distribution and moisture content tests carried out on a representative sample of the material yielded the following results:

Gravel:	0%
Sand:	22 to 30%
Fines (silt and clay):	70 to 78%
Silt size:	58 to 67%
Clay size:	11 to 12%
Moisture content:	25 to 42%

Atterberg limits tests carried out on two representative samples from this layer indicated liquid limits of 31 and 45 and a plasticity index of 13. The USCS group symbol for this layer is ML (silt with sand) and CL (sandy lean clay). Representative grain size distribution plots for this layer are given in Figures 3 and 4 and the corresponding plasticity charts are given in Figure 14 of Appendix D.

<u>BH17-60B</u>

Grey to light brown sandy silty clay to silt with sand was encountered below the rootmat and extended to a depth of 4.4 m. Temperatures of the soil samples obtained from the infrared thermometer ranged from +6.7 to +7.5°C. Some organics were observed in samples obtained within the upper 3 m.

The SPT N-values of the sandy silty clay to silt with sand ranged between 3 and 5 blows for 0.3 m, which corresponds to a soft consistency. Pocket Penetrometer tests on samples of clay indicated the undrained shear strength ranged from 15 kPa to 25 kPa, which corresponds to a soft to firm consistency.

Grain size distribution and moisture content tests carried out on representative samples of the material yielded the following results:

Gravel:	0 to 1%
Sand:	16 to 35%
Fines (silt and clay):	65 to 83%
Silt size:	54 to 61%
Clay size:	11 to 22%
Moisture content:	21 to 37%

Atterberg limits tests carried out on two representative samples from this layer indicated a liquid limit of 26 and plasticity indices of 4 and 5. The grain size distribution curve is provided in Figures 5 and 6, and the corresponding plasticity charts are given in Figure 14 of Appendix D. The USCS group symbol for this layer is CL-ML (sandy silty clay) and ML (silt with sand).

4.1.3 Sandy Silt to Silty Sand

BH17-58B

Brown sandy silt to silty sand was encountered below the silty clay with sand and extended to a depth of 3.0 m.

The SPT N-value of the sandy silt to silty sand was 93 blows for 75 mm of penetration. The high blow count is attributed to the presence of cobbles and boulders in the underlying till and is not considered representative of the soil stratum.

Soil gradation testing was not completed on a sample of this material due to poor sample recovery, therefore classification is based on visual observations.

4.1.4 Peat

A 150 mm thick layer of peat was encountered below the alluvial soils (sandy silty clay to silt with sand) in BH17-60B at a depth of 4.4 m. The organic soil was underlain by glacial till.

4.1.5 Glacial TILL

Glacial till was observed in the boreholes overlying bedrock. Glacial till deposits are heterogeneous, unstratified deposits of gravel, sand, and silt and clay sized particles deposited directly by glaciers. The mineralogy and lithology of till is dependent on the source of the materials, therefore may vary widely (Holtz et. al., 2011).

BH17-57B

Gravelly lean clay with sand to sandy clay till was encountered between 3.5 m and 17.7 m below ground surface. Frequent cobbles and boulders were observed in the till. Temperatures of the soil samples obtained using the infrared thermometer were in the order of +5.0°C.

Pocket penetrometer tests on samples of clay indicated the undrained shear strength of approximately 200 kPa, which corresponds to a very stiff to hard consistency. Due to the presence of cobbles and boulders the till was cored using a NQ bit. Intermittent SPT samples were obtained for sampling and to measure blow counts. SPT N-values of 28 and 40 blows per 0.3 m were measured in the till which correspond to very stiff to hard consistency.

Grain size distribution and moisture content carried out on representative samples of the till yielded the following results:

Gravel:	9 to 29%
Sand:	19 to 26%
Fines (silt and clay):	52 to 65%

Silt size:	28 to 33%
Clay size:	24 to 32%
Moisture Content:	9 to 22%

Atterberg limits test carried out on representative samples from this layer indicated liquid limits of 27 and 29 and plasticity index of 15 and 13, respectively. The USCS group symbol for this layer is CL (gravelly lean clay with sand and sandy lean clay). Representative grain size distribution plots for this layer are given in Figures 7 and 8 and the corresponding plasticity charts are given in Figure15 of Appendix D.

<u>BH17-58B</u>

Sandy lean clay till was encountered between 3.0 m and 16.8 m below ground surface. Auger refusal occurred at a depth of 3.2 m, the borehole was relocated 0.9 m to the north of the initial location and advanced to a depth of 3.3 m and sampling resumed. The refusal was attributed to the presence of a cobble or boulder at the surface of the till. Frequent cobbles and boulders were observed in the till. Temperatures of the soil samples obtained using the infrared thermometer ranged from +4.8 to +5.4°C.

Pocket penetrometer tests on samples of clay indicated the undrained shear strength ranged from 75 kPa to greater than 200 kPa, which corresponds to a stiff to hard consistency. Due to the presence of cobbles and boulders the till was cored using a NQ bit. Intermittent SPT samples were obtained for sampling and to measure blow counts. A SPT N-value of 29 blows per 0.3 m was measured in the till which corresponds to a very stiff consistency.

Grain size distribution and moisture content tests carried out on representative samples of the till yielded the following results:

Gravel:	12%
Sand:	22%
Fines (silt and clay):	66%
Silt size:	35%
Clay size:	31%
Moisture Content:	14 to 15%

Atterberg limits test carried out on one representative sample from this layer indicated a liquid limit of 29 and plasticity index of 14. The USCS group symbol for this layer is CL (sandy lean clay). The representative grain size distribution plot for this layer is given in Figure 9 and the corresponding plasticity charts are given in Figure 15 of Appendix D.

BH17-59B

Lean clay with sand till was encountered between 4.9 m and 16.9 m below ground surface. Frequent cobbles and boulders were observed in the till. The temperature of a soil sample obtained using the infrared thermometer was +7.2°C.

Pocket penetrometer tests on samples of clay indicated the undrained shear strength ranged from 200 kPa to 300 kPa, which corresponds to a hard consistency. Due to the presence of cobbles and boulders the till was cored using a NQ bit. A SPT N-value of 31 blows per 0.3 m was measured in the till which corresponds to a hard consistency.

Grain size distribution and moisture content tests carried out on representative samples of the till yielded the following results:

Gravel:	2 to 5%
Sand:	22 to 23%
Fines (silt and clay):	73 to 76%
Silt size:	40 to 43%
Clay size:	32 to 33%
Moisture Content:	6 to 21%

Atterberg limits test carried out on two representative samples from this layer indicated liquid limits of 30 and 31 and plasticity indices of 19 and 17, respectively. The USCS group symbol for this layer is CL (lean clay with sand). Representative grain size distribution plots for this layer are given in Figures 10 and 11 and the corresponding plasticity charts are given in Figure 15 of Appendix D.

BH17-60B

Silty sand to sandy lean clay till was encountered between depths of 4.5 m and 17.4 m. Frequent cobbles and boulders were observed in the till. Temperatures of the soil samples obtained using the infrared thermometer ranged from +5.1 to +7.1°C.

Pocket penetrometer tests on samples of clay indicated the undrained shear strength ranged from 300 kPa to 400 kPa, which corresponds to a hard consistency. Due to the presence of cobbles and boulders the till was cored using a NQ bit. Intermittent SPT samples were obtained for sampling and to measure blow counts. SPT N-values of 27 and 82 blows per 0.3 m were measured in the till, which correspond to a very stiff to hard consistency.

Grain size distribution and moisture content tests carried out on representative samples of the till yielded the following results:

Gravel:	0 to 14%
Sand:	21 to 52%
Fines (silt and clay):	48 to 65%

Silt size: 34 to 35%
Clay size: 14 to 31%
Moisture Content: 13 to 17%

Atterberg limits tests carried out on two representative samples from this layer indicated liquid limits of 17 and 29 and plasticity indices of 4 and 15, respectively. The USCS group symbol for this layer is SM (silty sand) and CL (sandy lean clay). Representative grain size distribution plots for this layer are given in Figures 12 and 13 and the corresponding plasticity charts are given in Figure 15 of Appendix D.

4.1.6 Bedrock

Bedrock was encountered in all four borings. The bedrock surface was encountered at an elevation of approximately 231 m, or depths of 16.8 to 17.7 m below ground surface at the boring locations. The bedrock consisted predominantly of grey and white dolomite. A detailed description of the rock core is provided in the Field Bedrock Core Logs in Appendix C. Rock core photographs are also provided in Appendix C.

Rock Quality Designation (RQD) values measured on the retrieved bedrock core ranged between 0% and 100%, indicating a very poor to excellent rock mass quality. The Total Core Recovery (TCR) of the bedrock ranged from 50% to 100%. Weathering of the bedrock was described as fresh, with no visible signs of weathering. Four bedrock samples obtained from boreholes BH17-57B and BH17-58B at depths between 17.9 m and 20.3 m were moderately reactive in response to hydrochloric acid tests.

Unconfined compressive strength tests were carried out on four bedrock samples. The results of these tests are summarized in Table 4.1. The unconfined compressive strength tests results ranged between 61 MPa and 145 MPa, which indicates the bedrock is strong to very strong.

Table 4.1: Results of Unconfined Compressive Strength of Rock Cores

Borehole No	Depth (m)	Test Elevation (m)	Unconfined Compressive Strength (MPa)
BH17-57B	20.5 to 20.6	228.2	116
BH17-58B	19.1 to 19.2	229.1	145
BH17-59B	20.6 to 20.7	227.5	152
BH17-60B	18.8 to 18.9	230.3	61

4.2 PERMAFROST CONDITIONS

Infrared thermometer readings were taken of samples throughout the drilling. The readings ranged between +7.6 to less than 0°C, as indicated on the borehole logs (Appendix C).

Based on the visual examination and infrared thermometer readings of the recovered auger and split spoon samples, frozen soil conditions were inferred to depths of 0.6 m to 1 m below ground surface. The infrared thermometer was used during sampling when the soils have been heated by friction generated by the action of the drill. It was also observed during the field work the sample temperatures taken when exposed to very cold air temperatures also displayed erratic values. Therefore, the reported infrared temperature readings should be used with caution.

Thermistor readings are considered to be a more reliable indication of the temperature of the soils compared to the infrared thermometer readings. Thermistors were installed in each of the four borings (BH17-57B to BH17-60B) between March 20 and 23, 2017. The resistance versus temperature table for the thermistors is included in Appendix E. Several readings were taken between the installation date and April 4, 2017 and are plotted in Figures 16 to 19 in Appendix E. The drilling process likely altered the temperature of soil surrounding the borehole; the initial thermistor readings appear to behave erratically, however, with time the thermistor responses have become more representative of the subsurface temperatures.

Available thermistor temperature measurements suggest the ground was seasonally frozen between 0.5 m and 1.5 m depth. The April 4, 2017 thermistor readings from BH17-57B indicate that the soil temperature ranges from +1.0 to +2.2°C and is unfrozen to a depth of approximately 21 m (see Figure 16, Appendix E). The thermistor readings from BH17-58B indicate that the temperatures range between +1.5 and +2.3°C and is unfrozen to a depth of approximately 21 m (see Figure 17, Appendix E). The thermistor readings obtained from BH17-59B (see Figure 18, Appendix E) indicate that the temperatures are between +0.1°C near ground surface and +2.6°C and is unfrozen to a depth of approximately 19.0 m. The thermistor readings obtained at BH17-60B (Figure 19, Appendix E) indicate that the soils are frozen near surface (0°C) but quickly increase to 2.0°C and is unfrozen to a depth of approximately 22.0 m.

The results suggest that permafrost conditions are likely not present at the proposed location of Crossing #14 at the James River, due to the warming influence of the river. It is likely that the warmer than typical ground temperatures at depth are the result of thermal warming due to the long-term presence of the river with year-round flowing water at temperatures above freezing. These “positive” temperatures, over time, created a large warm bulb below the river channel and within the floodplain where the river channel has migrated over the millennium.

4.3 GROUNDWATER

Groundwater was encountered in borehole BH17-58B at a depth of 2.3 m below the ground surface at the time of drilling. Groundwater was not observed at the remaining three boreholes within the drilling depths. The groundwater depths observed during the drilling are summarized in Table 4.2.

The groundwater levels were recorded in winter conditions and will likely vary seasonally. Changes in the groundwater, and the water levels of the James River, due to seasonal fluctuations in response to precipitation events, should be anticipated.

Table 4.2: Summary of Groundwater Levels

Borehole No.	Observation/Measurement Date	Groundwater Depth (m)	Ground Surface Elevation (m)	Groundwater Elevation (m)
BH17-57B	March 20, 2017	Not observed	248.8	n/a
BH17-58B	March 17, 2017	2.3	248.2	245.9
BH17-59B	March 21, 2017	Not observed	248.2	n/a
BH17-60B	March 22, 2017	Not observed	249.1	n/a

4.4 CHEMICAL TEST RESULTS

Three samples of the native overburden material from Boreholes BH17-57B, BH17-59B, and BH17-60B were tested for pH, water soluble sulphate and chloride concentrations, and resistivity at Maxxam Analytics. The analysis results are provided in Table 4.3 and in Appendix D.

Table 4.3: Results of Chemical Analysis

Borehole No	Sample No.	Depth (m)	pH	Chloride (%)	Sulphate (%)	Resistivity (Ohm-m)
BH17-57B	SS10	12.2 to 12.8	8.0	0.0011	0.13	3.5
BH17-59B	AS2	1.0 to 1.5	7.5	0.0031	0.023	12
BH17-60B	AS4	3.0 to 3.5	7.5	0.0030	0.036	57

5.0 CLOSURE

Use of this report is subject to the Statement of General Conditions provided in Appendix A. It is the responsibility of Tlicho Engineering and Environmental Services Ltd., who is identified as “the Client” within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec Consulting Ltd. should any of these not be satisfied. The Statement of General Conditions addresses the following:

- Use of the report
- Basis of the report
- Standard of care
- Interpretation of site conditions
- Varying or unexpected site conditions
- Planning, design or construction

This report was written by Sylvia Dooley, M.ScE. and reviewed by Christopher McGrath, P.Eng. and Jim Oswell, P.Eng. Mr. McGrath and Dr. Oswell are registered members of the Northwest Territories and Nunavut Association of Professional Engineers and Geoscientists. We trust that the information contained in this report is adequate for your present purposes. If you have any questions about the contents of the report or if we can be of any other assistance, please contact us at your convenience.

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6.0 REFERENCES

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2009a. Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) (ASTM D2488). ASTM International, West Conshohocken, PA.

ASTM . 2009b. DRAFT New Practice for Handling, Transportation, and Storage of Frozen Soil and Rock Samples (ASTM WK24243). ASTM International, West Conshohocken, PA.

ASTM. 2010. Standard Terminology Relating to Frozen Soil and Rock (ASTM D7099). ASTM International, West Conshohocken, PA.

ASTM. 2011. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

ASTM. 2016. Standard Practice for Description of Frozen Soils (Visual-Manual Procedure) (ASTM D4083). ASTM International, West Conshohocken, PA.

BGC Engineering Inc. 2011. Highway 3 – Climate Change Vulnerability Assessment – Final Report.

Canadian Standards Association (CSA). 2010. Technical Guide Infrastructure in permafrost: A guideline for climate change adaptation. Canadian Standards Association, Mississauga, ON, Canada.

Dillon Consulting Ltd. 2007. Climate Change and Transportation in the NWT. March 2007.

Environment Canada. Warming Trends °C/Decade, Based on homogenized temperature data – the most recent 30 yr record (1981 – 2010); Environment Canada.

Environment Canada. (2016, September 1) Canadian Climate Normals 1981–2010. Yellowknife Station. Retrieved from http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProv&lstProvince=NT&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=1706&dispBack=0

GNWT, 2009. Ecosystem Classification Group (ECG) 2009. Ecological Regions of the Northwest Territories: Taiga Shield. Department of Environment and Natural Resources, GNWT. Yellowknife, NT.

GNWT DOT, 2016. Proposed Tlicho All-season Road, Project Description Report. March 2016

Heginbottom, J.A., Dubreuil, M.A., and P.A. Harker. 1995. Canada-Permafrost; National Atlas of Canada, 5th edition, Plate 2.1. Geomatics Canada, National Atlas Information Service and Geological Survey of Canada (MCR 4177).

Kavik AXYS Inc. 2008a. Multi-Level Mapping and Route Analysis – Tlicho Transportation Corridor. Route Identification and Evaluation. Yellowknife, NT. January 2008.Project No. Project No. 144902005.

Okulitch, A.V. 2004. Geological compilation of Phanerozic Bedrock Geology (Map NP-11/12-G), Slave River District of MacKenzie, Northwest Territories. Geological Survey of Canada, Open File 5281.

Stantec, 2015.Tli Cho Road Alignment, Hydrologic and Hydraulic Study. Project No. 144902005.

Wolfe, 1998. Living with frozen ground : a field guide to permafrost in Yellowknife, Northwest Territories, edited by Stephen A. Wolfe ; contributions by Stephen A. Wolfe

S.A. Wolfe, P.D. Morse, T.E. Hoeve, W.E Sladen, S.V. Kokelj, L.U. Arenson, 2015. Disequilibrium permafrost conditions on NWT Highway 3

7.0 BIBLIOGRAPHY

Andersland, O.B., and Ladanyi, B. 1994. An Introduction to Frozen Ground Engineering. Chapman & Hall Inc., New York, NY, USA.

Canadian Foundation Engineering Manual (CFEM). 2006. Fourth Edition. Canadian Geotechnical Society, 488 p.

CHBDC. 2014. Canadian Highway Bridge Design Code. Canadian Standards Association, Mississauga, Ontario.

GSC, 1965. Glacial Lake McConnell and the surficial geology of parts of Slave River and Redstone River map areas, District of Mackenzie; Craig, B G. Geological Survey of Canada, Bulletin 122, 1965,; 44 pages, doi:10.4095/100639. Natural Resources Canada. 1995: Canada Permafrost; The National Atlas of Canada 5th Edition, scale 1:7 500 000.

GSC, 1989. Glacial Features Around the Keewatin Ice Divide, Northwest Territories; Aylsworth, J M; Shilts, W. Geological Survey of Canada, Preliminary Map 24-1987, 1989, ; 2 sheets, doi:10.4095/126992.

Kerr and Wilson, 2000. 2000-C3. Preliminary surficial geology studies and mineral exploration considerations in the Yellowknife area, Northwest Territories. D.E. Kerr and P. Wilson.

APPENDIX A

Statement of General Conditions

STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec Consulting Ltd. and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec Consulting Ltd.'s present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec Consulting Ltd. is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec Consulting Ltd. at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec Consulting Ltd. must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec Consulting Ltd. will not be responsible to any party for damages incurred as a result of failing to notify Stantec Consulting Ltd. that differing site or sub-surface conditions are present upon becoming aware of such conditions.

PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec Consulting Ltd., sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec Consulting Ltd. cannot be responsible for site work carried out without being present.

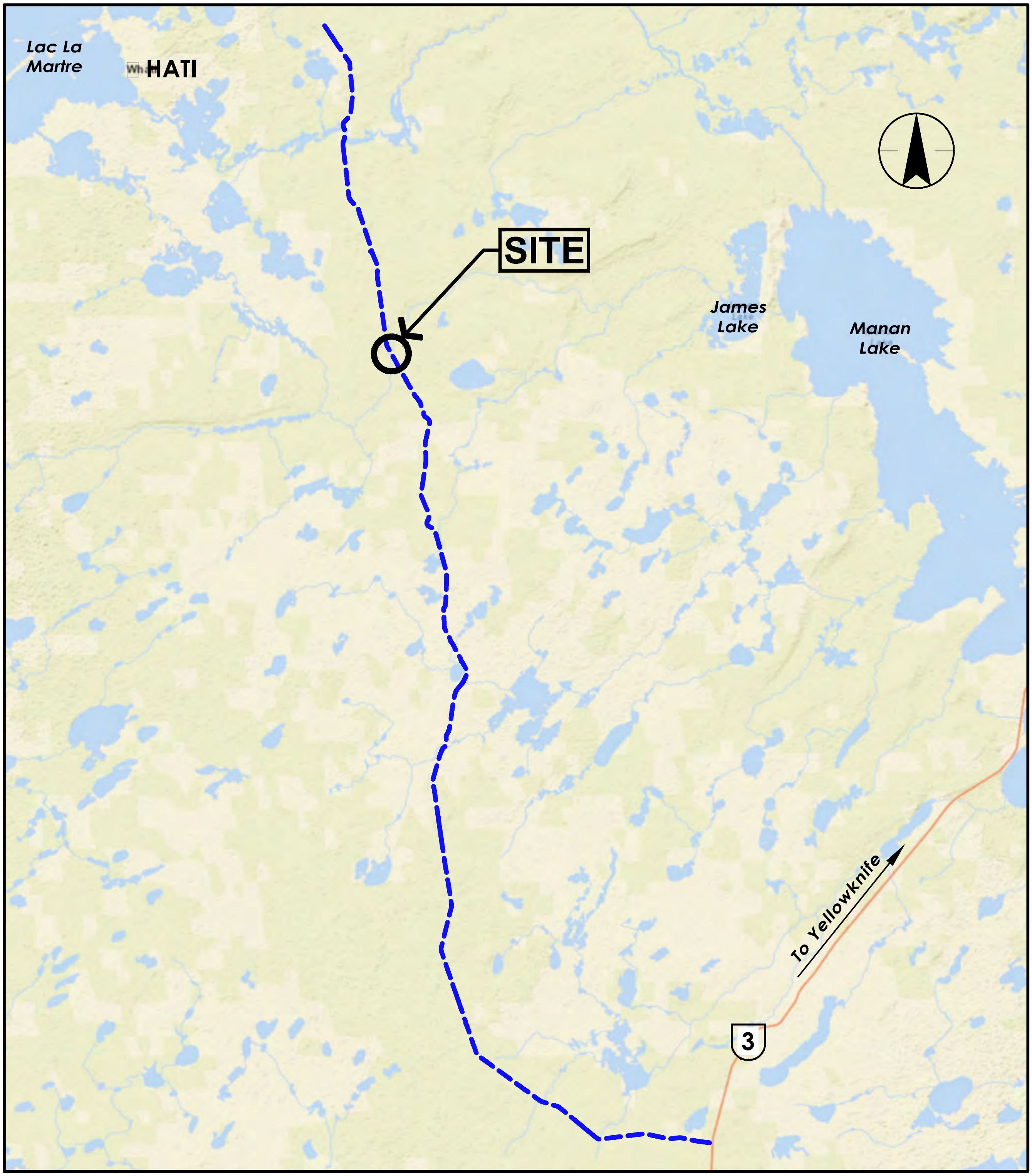
APPENDIX B

Drawing No. 1 – Site Location Plan

Drawing No. 2 - Borehole Location Plan

Drawing No. 3 – Subsurface Profile

Site Photos



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LEGEND

PROPOSED ALIGNMENT

NOTES

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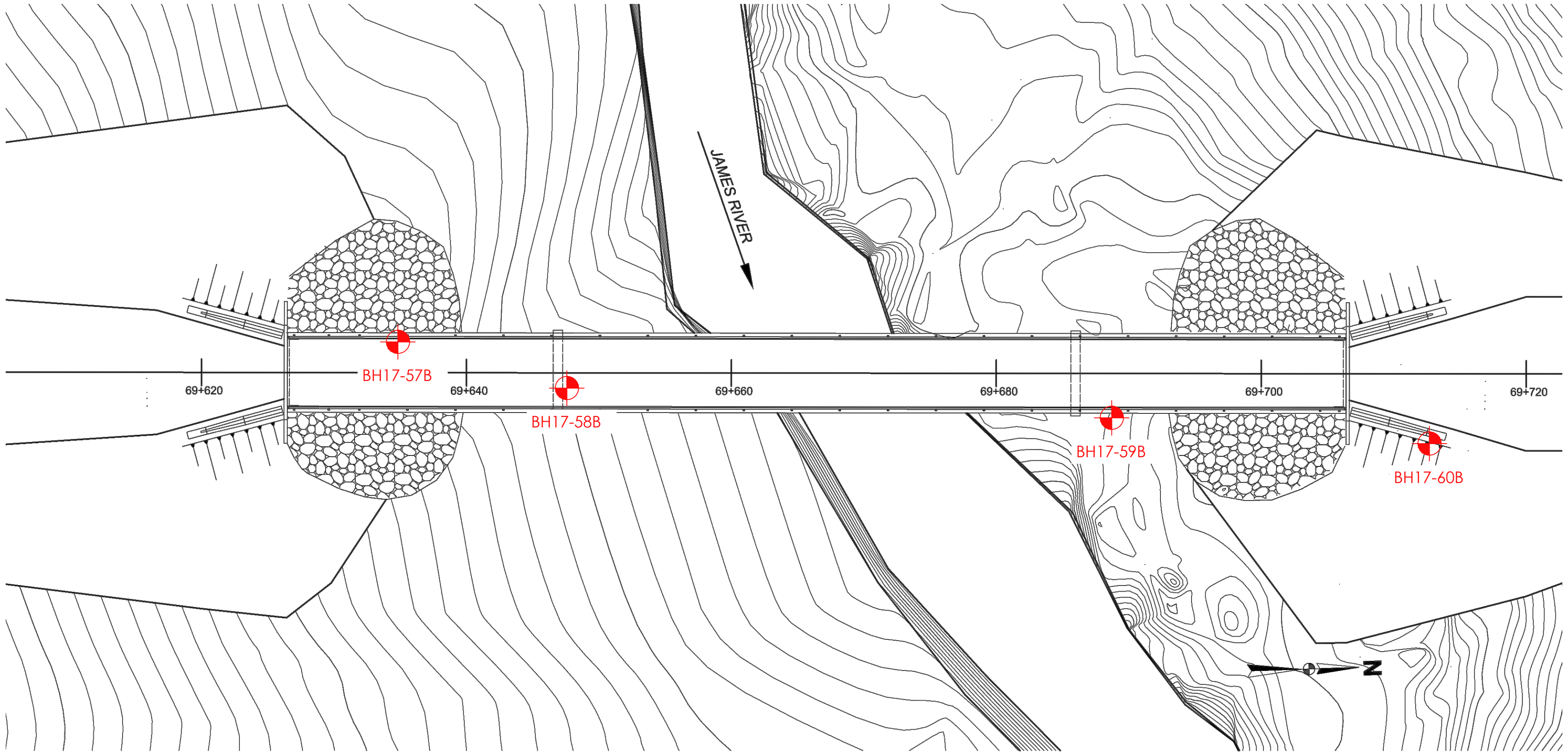
CROSSING #14 JAMES RIVER, NWT

Drawing No.

1

Title

□EY PLAN



SITE PLAN
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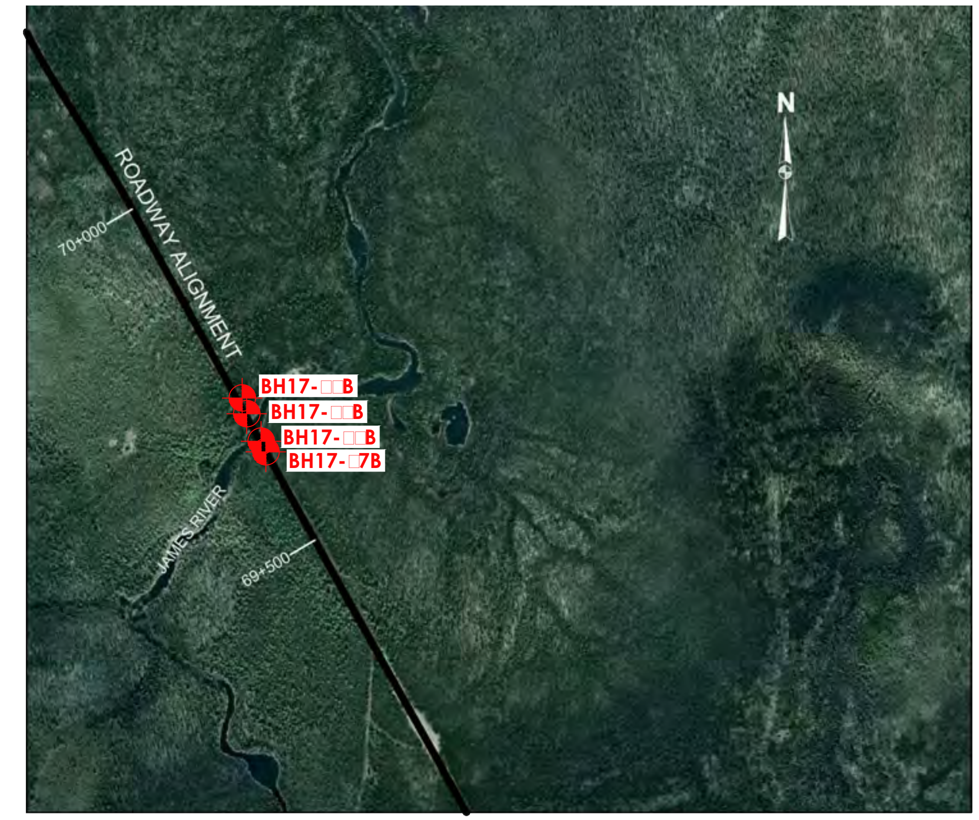
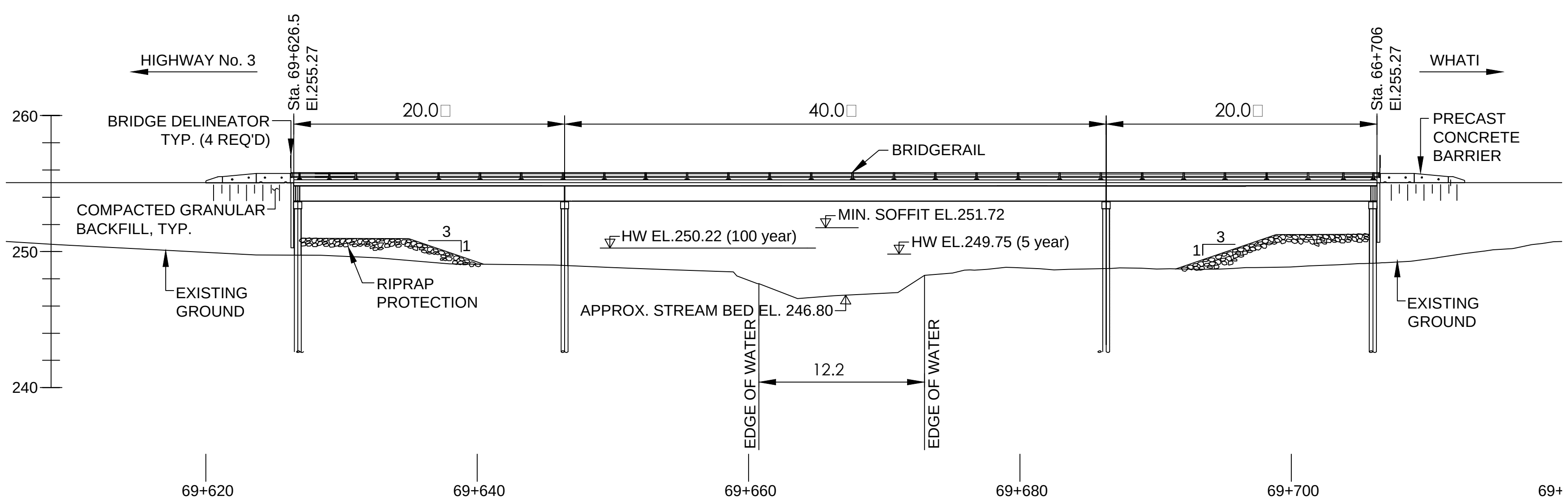
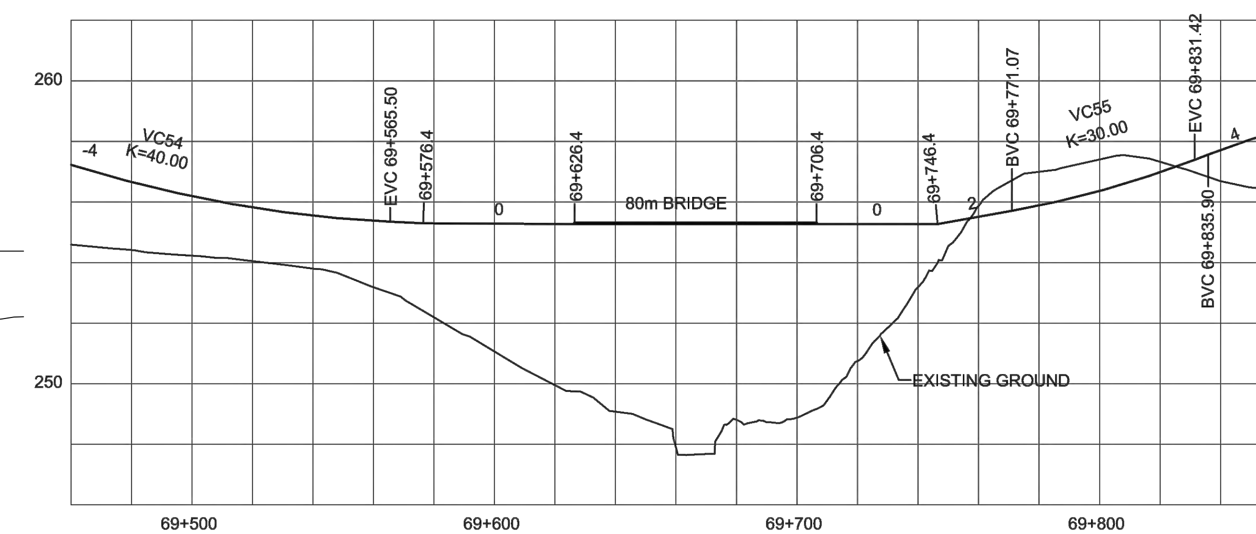


PLAN
1:5,000



ELEVATION
H 1:500 V 1:500



ROADWAY PROFILE
H 1:2,500 V 1:250

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LEGEND

APPROXIMATE BOREHOLE LOCATION

NOTES

1. DRAWING PROVIDED BY DOT TECHNICAL SERVICES (TASR-07-16 (CROSSING#14).

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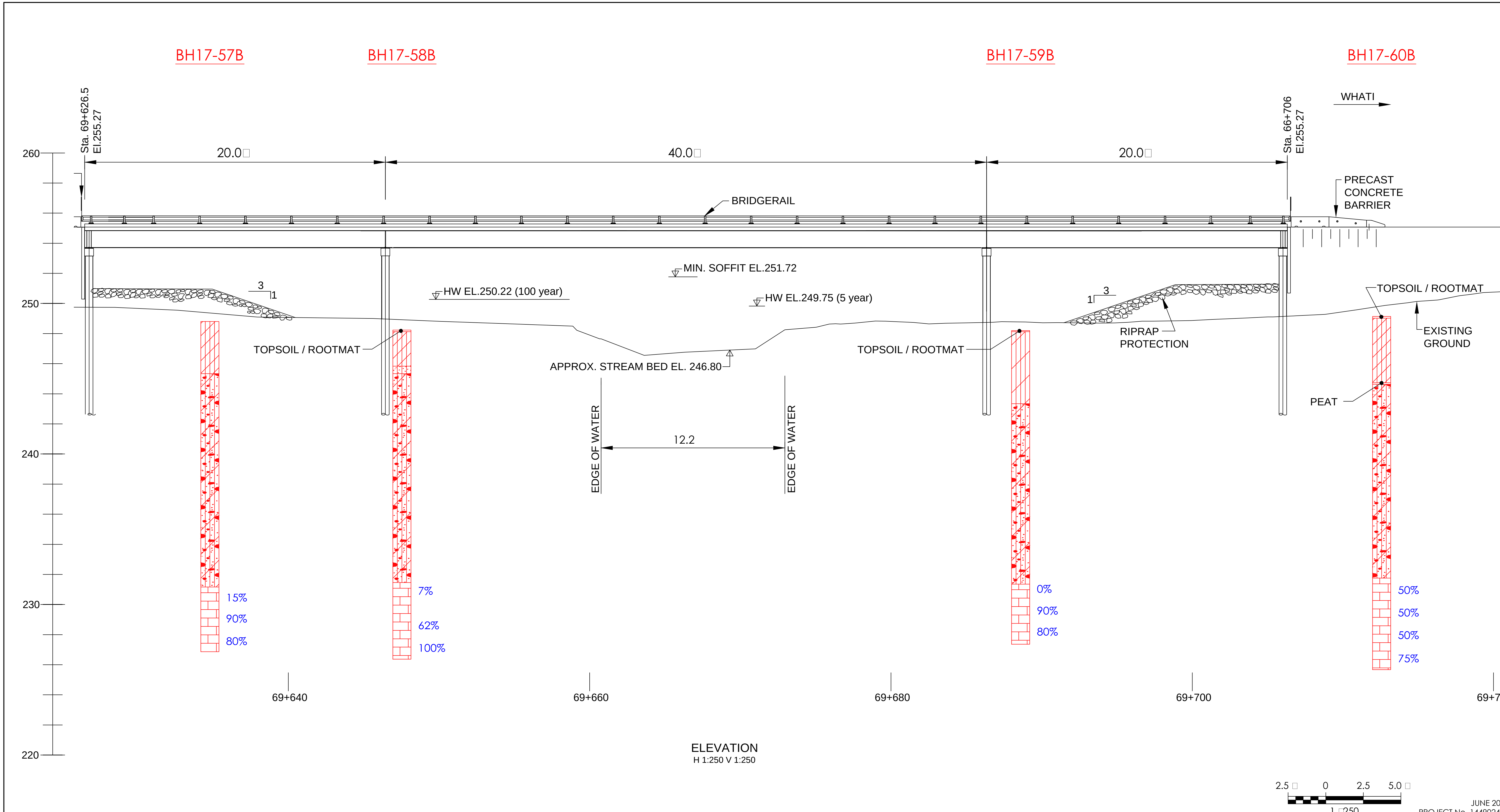
CROSSING #14 JAMES RIVER, NWT

Drawing No.
2

Title

GENERAL LAYOUT AND BOREHOLE LOCATION PLAN



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LEGEND

- 90 — RQD (ROCK QUALITY DESIGNATION)
- TOPSOIL / ROOTMAT
- PEAT
- SILTY SAND (SM) TO SANDY SILT (ML)
- SILTY CLAY (CL-ML) WITH SAND, SILT (ML) WITH SAND, SANDY LEAN CLAY (CL)
- TILL: SANDY LEAN CLAY (CL), GRAVELLY LEAN CLAY WITH SAND (CL), SILTY SAND (SM). FREQUENT COBBLES AND BOULDERS WITHIN TILL LAYER.
- DOLOMITE

NOTES

1. DRAWING PROVIDED BY DOT TECHNICAL SERVICES (TASR-07-16 (CROSSING#14).

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Drawing No.

Title
SUBSURFACE PROFILE

Photo No. 1: Borehole Location BH17-57B

Photo No. 2: Borehole Location BH17-57B

Photo No. 3: Borehole Location BH17-58B

Photo No. 4: Borehole Location BH17-59B

Photo No. 5: Borehole Location BH17-59B in foreground

Photo No. 6: Borehole Location BH17-60B

APPENDIX C

Symbols and Terms Used on Borehole Records

Stantec Borehole Records

Field Bedrock Core Logs

Bedrock Core Photos

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

Rootmat	- vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
Topsoil	- mixture of soil and humus capable of supporting vegetative growth
Peat	- mixture of visible and invisible fragments of decayed organic matter
Till	- unstratified glacial deposit which may range from clay to boulders
Fill	- material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

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

Terminology describing soil types:
The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4th Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):
Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

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

Terminology describing compactness of cohesionless soils:
The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. A relationship between compactness condition and N-Value is shown in the following table.

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

Terminology describing consistency of cohesive soils:
The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	Undrained Shear Strength		Approximate SPT N-Value
	kips/sq.ft.	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25 - 0.5	12.5 - 25	2-4
Firm	0.5 - 1.0	25 - 50	4-8
Stiff	1.0 - 2.0	50 – 100	8-15
Very Stiff	2.0 - 4.0	100 - 200	15-30
Hard	>4.0	>200	>30

ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Terminology describing rock quality:

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

Alternate (Colloquial) Rock Mass Quality	
Very Severely Fractured	*Crushed*
Severely Fractured	*Shattered or Very Blocky*
Fractured	*Blocky*
Moderately Jointed	*Sound*
Intact	*Very Sound*

RQD (Rock Quality Designation) denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 in.) long are summed and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

SCR (Solid Core Recovery) denotes the percentage of solid core (cylindrical) retrieved from a borehole of any orientation. All pieces of solid (cylindrical) core are summed and divided by the total length of the core run (It excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

Fracture Index (FI) is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

Terminology describing rock with respect to discontinuity and bedding spacing:

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

Terminology describing rock strength:

Strength Classification	Grade	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	<1
Very Weak	R1	1 – 5
Weak	R2	5 – 25
Medium Strong	R3	25 – 50
Strong	R4	50 – 100
Very Strong	R5	100 – 250
Extremely Strong	R6	>250

Terminology describing rock weathering:

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

STRATA PLOT

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

Boulders Cobbles Gravel	Sand	Silt	Clay	Organics	Asphalt	Concrete	Fill	Igneous Bedrock	Meta-morphic Bedrock	Sedi-mentary Bedrock

SAMPLE TYPE

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

WATER LEVEL MEASUREMENT

▼ measured in standpipe, piezometer, or well

▽ inferred

RECOVERY

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

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to 'A' size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

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

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

BOREHOLE RECORD

N: 6 982 652 E: 504 480

BH17-57B

CLIENT: Tlicho Engineering and Environmental Services Ltd.
LOCATION: Northwest Territories, Canada
DATES: BORING March 20, 2017 WATER LEVEL N/A
BOREHOLE No. BH17-57B
PROJECT No. 144902448
DATUM Geodetic

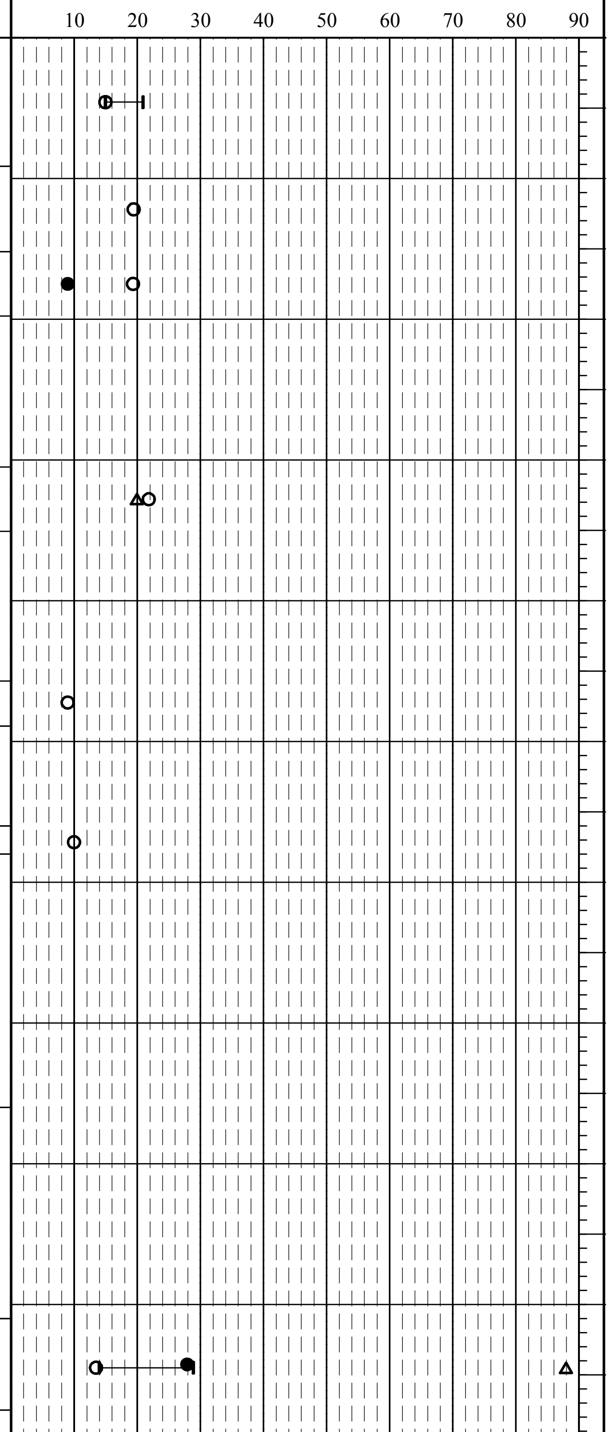
DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION
0	248.78	Grey, frozen silty CLAY (CL-ML) with sand to SILT (ML) with sand - trace organic material throughout - PP SS3 < 50kPa - Soil unfrozen below 1.5 m depth - SPT refusal at 3.05 m - Approx. sample temperature: 1.5°C at 3.5 m
3.5	245.3	Very stiff to hard grey, gravelly lean CLAY (CL) with sand to sandy lean CLAY (CL) TILL - Frequent cobbles and boulders inferred by auger grinding at 3.7 m

SAMPLES

TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
AS	1	-	-
AS	2	-	-
SS	3	305	9
ST	4	457	-
ST	5	-	
		-	-
SS	6	-	-
NQ	7	27%	-
NQ	8	17%	-
SS	9	381	28

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●



∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ______
Date ______

Stantec

BOREHOLE RECORD

N: 6 982 652 E: 504 480

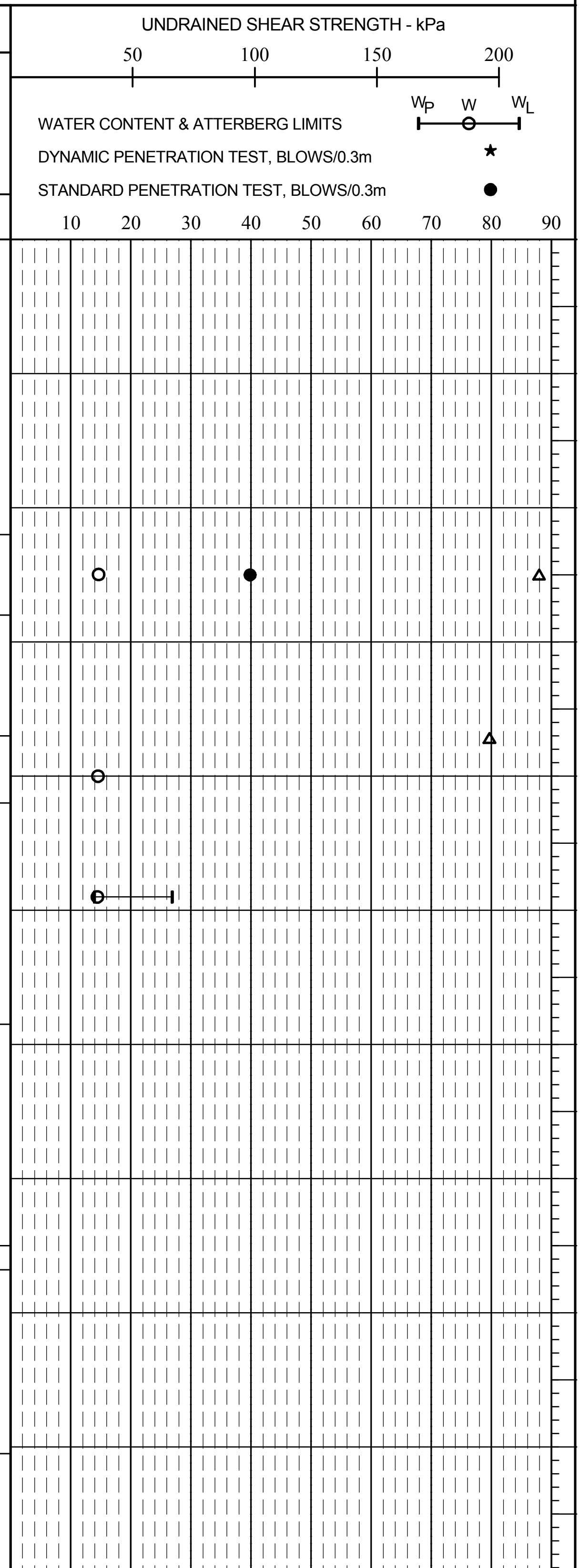
BH17-57B

CLIENT Tlicho Engineering and Environmental Services Ltd.
BOREHOLE No. BH17-57B

LOCATION Northwest Territories, Canada
PROJECT No. 144902448

DATES: BORING March 20, 2017 WATER LEVEL N/A
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
10–12		- Approx. sample temperature: SS9: 4.9°C NQ 12: 5.0°C	NQ	10	17%	-
12–13		PP SS11 = >200kPa PP SS13 = 200 kPa	SS	11	533	40
13			NQ	12	10%	-
14			SS	13	-	-
15			NQ	14	-	-
16–17			NQ	15	100%	-
17.6	231.1		NQ	16	72%	-
18		Very poor to good quality, light grey DOLOMITE - Horizontal fractures - See Field Bedrock Core Logs for details	NQ	17	52%	15%
19–20			NQ	18	82%	90%



Inferred Groundwater Level
Groundwater Level Measured in Standpipe

Field Vane Test, kPa
Remoulded Vane Test, kPa
Pocket Penetrometer Test, kPa

App'd
Date

Stantec

BOREHOLE RECORD

N: 6 982 652 E: 504 480

BH17-57B

CLIENT Tlicho Engineering and Environmental Services Ltd.

LOCATION Northwest Territories, Canada

DATES: BORING March 20, 2017 WATER LEVEL N/A

BOREHOLE No. BH17-57B

PROJECT No. 144902448

DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
20–22					NQ	19	93%	80%
22	226.8	End of Borehole Note: - Temperature measurements are based on infrared thermometer measurements and may not be representative of in situ geothermal regime - Site was grubbed prior to start of drilling therefore organic surificial layer may be thicker than indicated.						

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

Depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

Inferred Groundwater Level

Groundwater Level Measured in Standpipe

Field Vane Test, kPa

Remoulded Vane Test, kPa

Pocket Penetrometer Test, kPa

App'd

Date

Stantec

BOREHOLE RECORD

N: 6 982 666 E: 504 474

BH17-58B

CLIENT Tlicho Engineering and Environmental Services Ltd. BOREHOLE No. BH17-58B
LOCATION Northwest Territories, Canada PROJECT No. 144902448
DATES: BORING March 17, 2017 WATER LEVEL 2.3 m (Mar 20) DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	WATER LEVEL	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	248.20						
	248.1	50 mm FROZEN ROOTMAT					
		Stiff, dark brown to grey, silty CLAY (CL) with sand - Organics observed throughout, particularly uppermost 0.8 m - Approx. sample temperature: AS1: <0°C SS2: +4.7 to +5.2°C		AS	1	-	-
1				SS	2	356	3
2				AS	3	-	-
	245.8		∇ (2.3 m)				
		Very dense, brown, sandy SILT (ML) to silty SAND (SM)		SS	4	89	93/75 mm
3	245.3	Very stiff, grey, sandy lean clay (CL) TILL - Frequent cobbles and boulders throughout - Note: Due to the presence of a boulder borehole was relocated 0.9 m North of original BH 17-58B location after initial refusal, advanced to 3.3 m, and sampling was resumed.		AS	5	-	
4				NQ	6	-	-
5–6				NQ	7	50%	-
7				NQ	8	13%	-
8				NQ	9	0%	0%

∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ________
Date ________

Stantec

BOREHOLE RECORD

N: 6 982 666 E: 504 474

BH17-58B

CLIENT: Tlicho Engineering and Environmental Services Ltd.
BOREHOLE No.: BH17-58B
LOCATION: Northwest Territories, Canada
PROJECT No.: 144902448
DATES: BORING: March 17, 2017
WATER LEVEL: 2.3 m (Mar 20)
DATUM: Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
8						
			NQ	10	17%	0%
9						
			NQ	11	19%	-
10						
11			NQ	12	10%	-
12		- Approx. sample temperature: SS13: 4.8 to 5.4°C	SS	13	-	29
13			NQ	14	-	
14						
			NQ	15	-	-
15						
			SS	16	-	-
16						

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ________
Date ________

Stantec

BOREHOLE RECORD

N: 6 982 666 E: 504 474

BH17-58B

CLIENT Tlicho Engineering and Environmental Services Ltd.

LOCATION Northwest Territories, Canada

DATES: BORING March 17, 2017 WATER LEVEL 2.3 m (Mar 20)

BOREHOLE No. BH17-58B

PROJECT No. 144902448

DATUM Geodetic

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
16								
	231.4	Very poor to excellent quality light grey DOLOMITE - Horizontal fractures - See Field Bedrock Core Logs for details						
17					NQ	17	50%	7%
18								
19					NQ	18	100%	62%
20								
21					NQ	19	100%	100%
22	226.3	End of Borehole Note: - Temperature measurements are based on infrared thermometer measurements and may not be representative of in situ geothermal regime. - Difficulties with drilling equipment caused blow counts to						
23								
24								

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

BOREHOLE RECORD

N: 6 982 666 E: 504 474

BH17-58B

CLIENT Tlicho Engineering and Environmental Services Ltd.
LOCATION Northwest Territories, Canada
DATES: BORING March 17, 2017 WATER LEVEL 2.3 m (Mar 20)

BOREHOLE No. BH17-58B
PROJECT No. 144902448
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
24		be inconsistent and unreliable. - Site was grubbed prior to start of drilling therefore organic surificial layer may be thicker than indicated.						
25								
26								
27								
28								
29								
30								
31								
32								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

Inferred Groundwater Level
Groundwater Level Measured in Standpipe

Field Vane Test, kPa
Remoulded Vane Test, kPa
Pocket Penetrometer Test, kPa

App'd ________
Date ________

STN13-STAN-GEO 144902448 TLICHO ALL SEASON ROAD INVESTIGATION.GPJ SMART.GDT 5/30/17

Stantec

BOREHOLE RECORD

N: 6 982 702 E: 504 455

BH17-59B

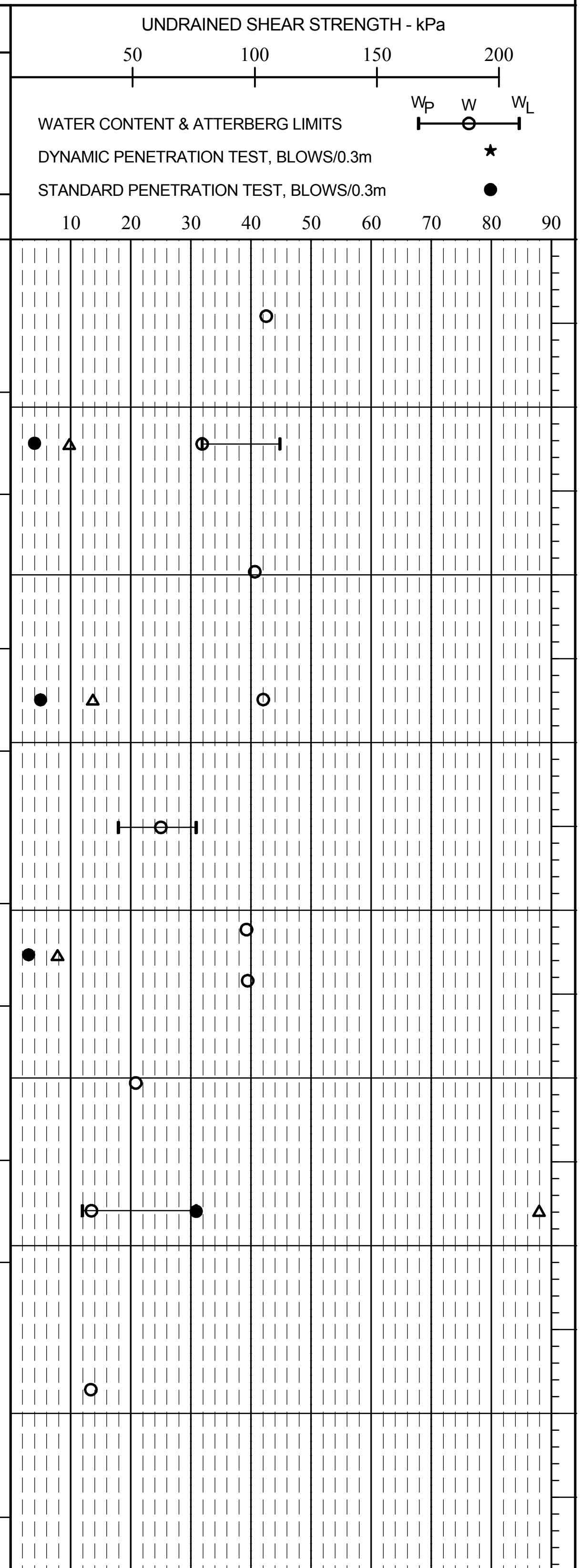
CLIENT: Tlicho Engineering and Environmental Services Ltd. — BOREHOLE No.: BH17-59B

LOCATION: Northwest Territories, Canada — PROJECT No.: 144902448

DATES: BORING: March 21, 2017 — WATER LEVEL: N/A — DATUM: Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	248.17					
	248.1	100 mm ROOTMAT				
		Firm, dark grey SILT (ML) to sandy lean CLAY (CL) - Organics noted throughout. - Approx. sample temperature: SS2: 7.6°C SS4: 7.0°C SS6: 5.1°C - Samples observed to be in a thawed state when obtained during drilling.	AS	1	-	
			SS	2	559	4
			AS	3	-	
			SS	4	584	5
			AS	5	-	
			SS	6	508	3
	243.3	Very stiff to hard, grey lean clay (CL) with sand TILL - Trace gravel - Frequent cobbles and boulders - Approx. sample temperature: SS8: 7.2°C - NQ12: PP > 200 kPa - NQ15: PP > 300 kPa	AS	7	-	
			SS	8	533	31
			NQ	9	15%	
8						

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8



▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Stantec

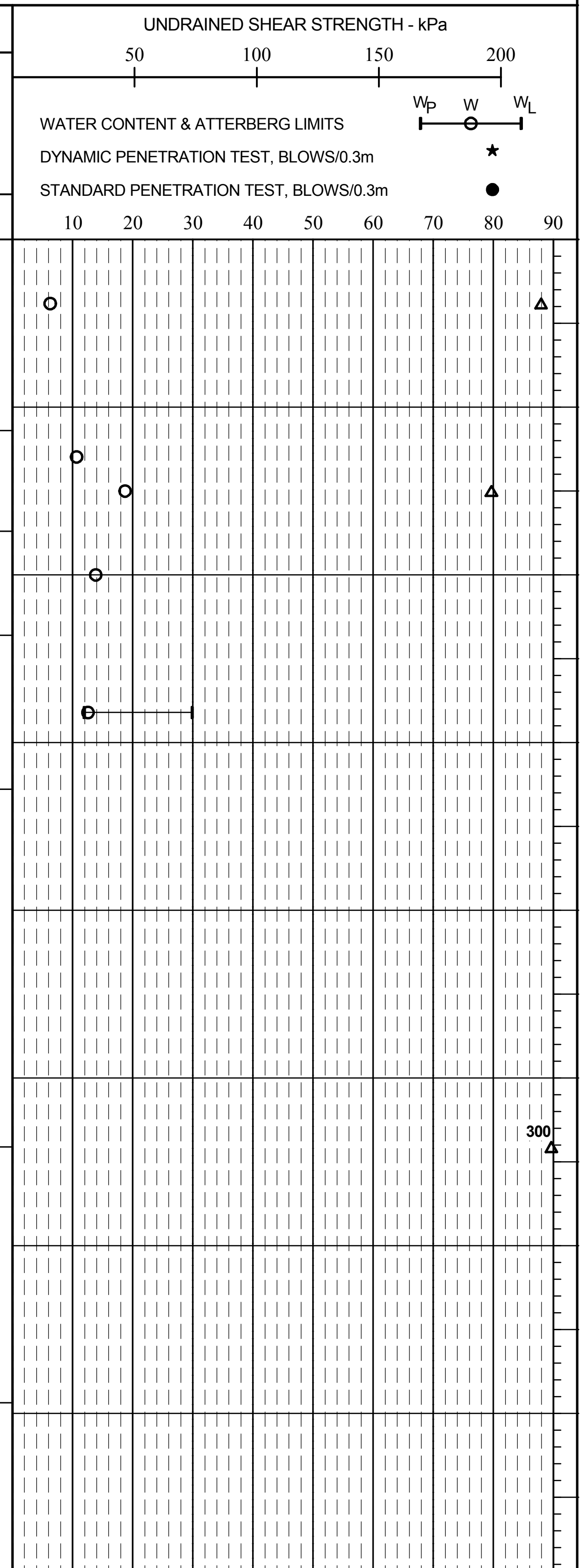
BOREHOLE RECORD

N: 6 982 702 E: 504 455

BH17-59B

CLIENT: Tlicho Engineering and Environmental Services Ltd.	BOREHOLE No.: BH17-59B
LOCATION: Northwest Territories, Canada	PROJECT No.: 144902448
DATES: BORING: March 21, 2017 WATER LEVEL: N/A	DATUM: Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
8					NQ	10	55%	
9					SS	11	50%	
10					NQ	12	33%	
					NQ	13	92%	
11–13					NQ	14	10%	
14					NQ	15	100%	
15–16					NQ	16	60%	



Inferred Groundwater Level

Groundwater Level Measured in Standpipe

Field Vane Test, kPa

Remoulded Vane Test, kPa

Pocket Penetrometer Test, kPa

App'd ________

Date ________

Stantec

BOREHOLE RECORD

N: 6 982 702 E: 504 455

BH17-59B

CLIENT Tlicho Engineering and Environmental Services Ltd.
BOREHOLE No. BH17-59B
LOCATION Northwest Territories, Canada
PROJECT No. 144902448
DATES: BORING March 21, 2017 WATER LEVEL N/A
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
16								
17	231.3	Very poor to good quality, grey DOLOMITE - Horizontal fractures - See Field Bedrock Core Logs for details			NQ	17	80%	0%
18					NQ	18	100%	90%
19								
20					NQ	19	100%	80%
21	227.3	End of Borehole Note: - Temperature measurements are based on infrared thermometer measurements and may not be representative of in situ geothermal regime - Site was grubbed prior to start of drilling therefore organic surificial layer may be thicker than indicated.						
22								
23								
24								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ________

Date ________

Stantec

BOREHOLE RECORD

N: 6 982 723 E: 504 449

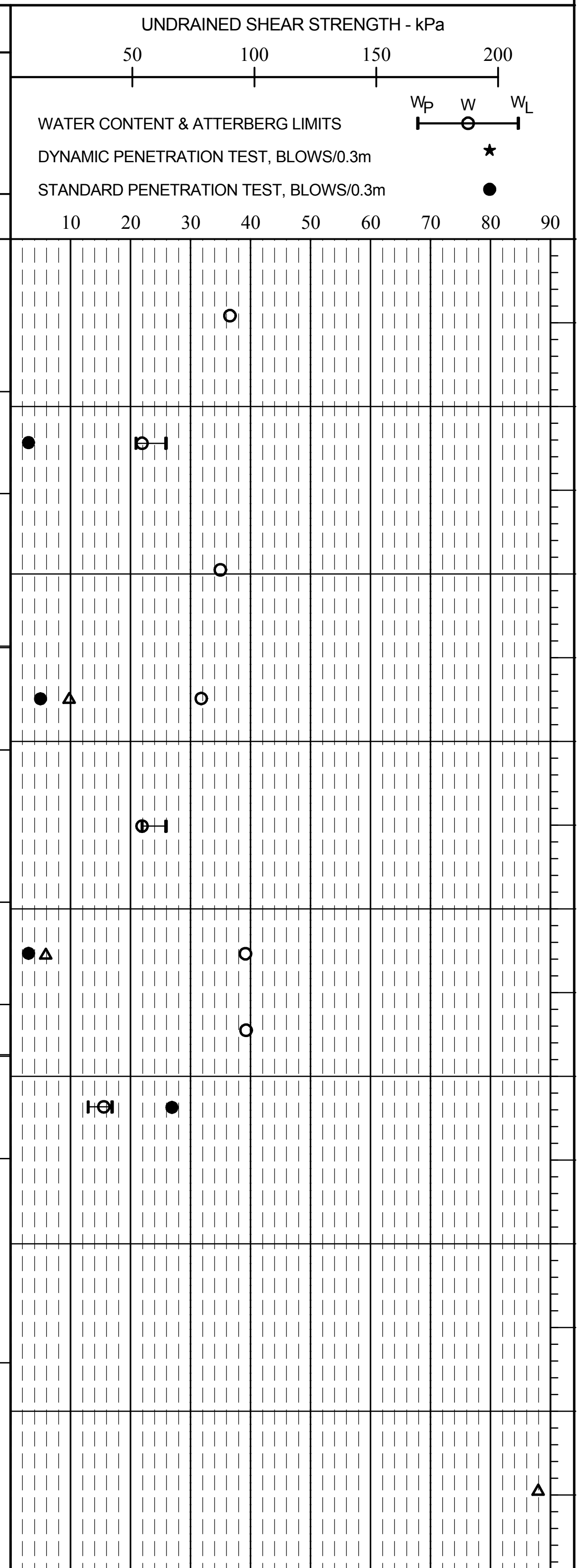
BH17-60B

CLIENT Tlicho Engineering and Environmental Services Ltd. — BOREHOLE No. BH17-60B

LOCATION Northwest Territories, Canada — PROJECT No. 144902448

DATES: BORING March 22, 2017 — WATER LEVEL N/A — DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	249.11							
	249.0	100 mm FROZEN ROOTMAT						
		Firm grey to light brown sandy SILTY CLAY (CL-ML) to SILT (ML) with sand			AS	1	-	-
1		- organics noted in SS2 and SS4			SS	2	406	3
		- Approx. sample temperature: SS2: 7.5°C SS4: 6.7°C						
2		- SS4 PP 25 kPa			AS	3	-	-
		- increased sand content in SS4			SS	4	559	5
3					AS	5	-	-
4		- becoming sandy at 4 m			SS	6	330	3
	244.7	Peat, 150 mm thick						
	244.6	Very stiff to hard, grey silty sand (SM) to sandy lean clay (CL) TILL			AS	7	-	-
5		- Approx. sample temperature: SS6: 7.1°C SS8: 5.1°C			SS	8	279	27
6		- Frequent cobbles and boulders			NQ	9	25%	-
7					NQ	10	38%	-
8								



Inferred Groundwater Level

Groundwater Level Measured in Standpipe

Field Vane Test, kPa

Remoulded Vane Test, kPa

Pocket Penetrometer Test, kPa

App'd ________

Date ________

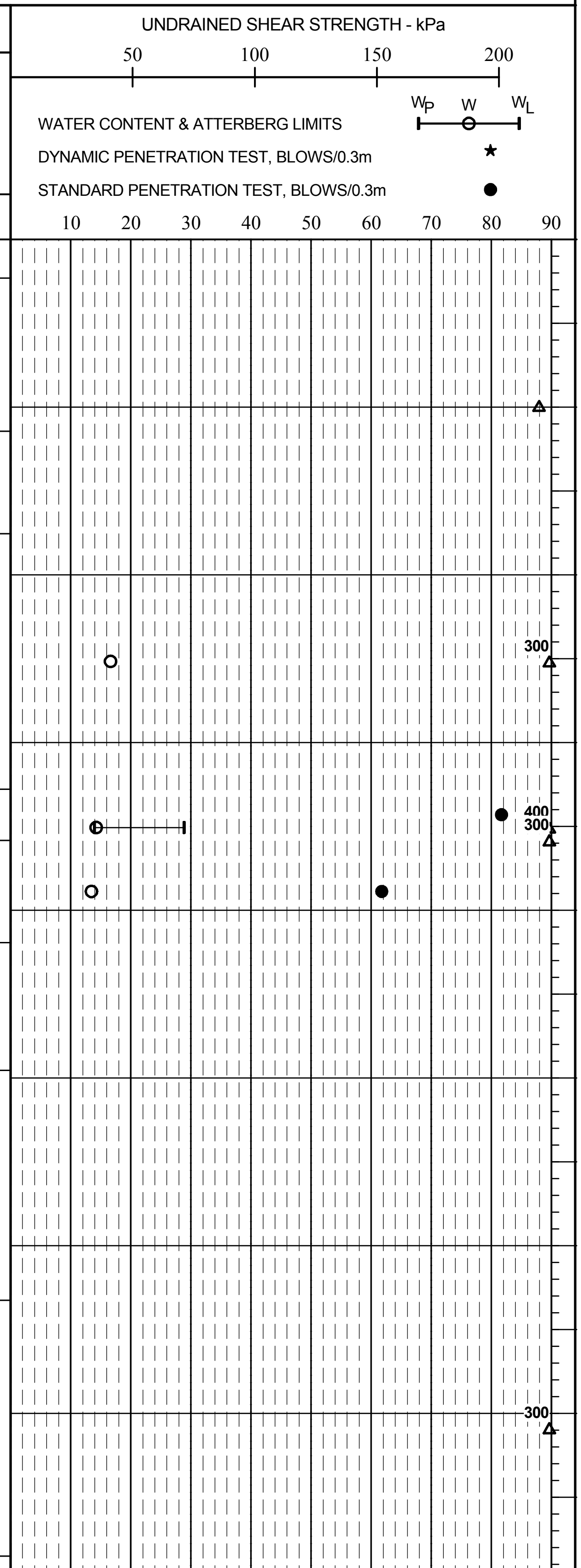
BOREHOLE RECORD

N: 6 982 723 E: 504 449

BH17-60B

CLIENT: Tlicho Engineering and Environmental Services Ltd.
BOREHOLE No.: BH17-60B
LOCATION: Northwest Territories, Canada
PROJECT No.: 144902448
DATES: BORING: March 22, 2017
WATER LEVEL: N/A
DATUM: Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
8			NQ	11	38%	-
9		- NQ16: PP>300 kPa - NQ17: PP>400 kPa - NQ18: PP>300 kPa - NQ19: PP>300kPa	SS	12	152	-
10			NQ	13	20%	-
11			SS	14	54%	82
			SS	15	54%	62
12			NQ	16	31%	-
13			NQ	17	22%	-
14–15			NQ	18	20%	-
16						



Inferred Groundwater Level
Groundwater Level Measured in Standpipe

Field Vane Test, kPa
Remoulded Vane Test, kPa
Pocket Penetrometer Test, kPa

App'd ________
Date ________

Stantec

BOREHOLE RECORD

N: 6 982 723 E: 504 449

BH17-60B

CLIENT Tlicho Engineering and Environmental Services Ltd.
BOREHOLE No. BH17-60B
LOCATION Northwest Territories, Canada
PROJECT No. 144902448
DATES: BORING March 22, 2017 WATER LEVEL N/A
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
16					NQ	19	13%	-
17	231.7	Fair quality, grey DOLOMITE - Horizontal factures - See Field Bedrock Core Logs for details			NQ	20	88%	50%
18								
19					NQ	21	100%	50%
20								
21					NQ	22	100%	50%
22								
23					NQ	23	100%	75%
	225.6	End of Borehole Note:						
24								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ________
Date ________

Stantec

BOREHOLE RECORD

N: 6 982 723 E: 504 449

BH17-60B

CLIENT	Tlicho Engineering and Environmental Services Ltd.	BOREHOLE No.	BH17-60B
LOCATION	Northwest Territories, Canada	PROJECT No.	144902448
DATES: BORING	March 22, 2017 WATER LEVEL N/A	DATUM	Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD	UNDRAINED SHEAR STRENGTH - kPa
24		- Temperature measurements are based on infrared thermometer measurements and may not be representative of in situ geothermal regime. - Site was grubbed prior to start of drilling therefore organic surificial layer may be thicker than indicated.							
25									
26									
27									
28									
29									
30									
31									
32									

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P W W_L)

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

Inferred Groundwater Level

Groundwater Level Measured in Standpipe

Field Vane Test, kPa

Remoulded Vane Test, kPa

Pocket Penetrometer Test, kPa

App'd ________

Date ________

Field Bedrock Core Log

Stantec

Client:	Tlicho E&E Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	20-Mar-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-57B
		Logger:	JMO/JGM/SR

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
17.7	NQ 17	52	15	19.1	Very poor quality, light grey dolomite	R4	W1	1	JN	F	C	RU	G	none	moderately reactive to hydrchloric acid	
19.1	NQ 18	82	90	20.4	Good quality, light grey dolomite	R5	W1	1	JN	F	C-M	RU	G	none		
20.4	NQ 19	93	80	21.9	Good quality, grey dolomite	R5	W1	2	JN	F/V	C	RU	G	none	moderately reactive to hydrchloric acid	

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

JOINT APERTURE

C = Closed = < 0.5 mm
G = Gapped = 0.5 to 10 mm
O = Open = > 10 mm

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
3	RU = Rough, Irregular, Undulating
1.5	SU = Smooth, Undulating
1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

Stantec

Field Bedrock Core Log

Client:	Tlicho E&E Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	20-Apr-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-58B
		Logger:	JMO/JGM/SR

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
16.8	NQ 17	50	7	18.9	Very poor quality, grey dolomite	R4	W1	1	JN	F	C	RU	G	None	Moderately reactive to hydrchloric acid	
18.9	NQ 18	100	62	20.4	Fair quality, grey, dolomite	R5	W1	1	JN	F	C	RU	G	None	Moderately reactive to hydrchloric acid	
20.4	NQ 19	100	100	21.9	Excellent quality, grey, dolomite	R5	W1	2	JN	F-D	C	RU	G	None		

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

JOINT APERTURE

C = Closed = < 0.5 mm
G = Gapped = 0.5 to 10 mm
O = Open = > 10 mm

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
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1.5	SU = Smooth, Undulating
1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

Stantec

Field Bedrock Core Log

Client:	Tlicho E&E Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	17-May-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-59B
		Logger:	JMO/JGM/SR

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
16.9	NQ 17	80	0	18.0	Very poor quality, grey dolomite	R4	W1	1	JN	F	C	RU	G	None		
18	NQ 18	100	90	19.4	Excellent quality, grey, dolomite	R5	W1	1	JN	F	C	RU	G	None		
19.4	NQ 19	100	80	20.9	Good quality, grey, dolomite	R5	W1	1	JN	F	C	RU	G	None		

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

JOINT APERTURE

C = Closed = < 0.5 mm
G = Gapped = 0.5 to 10 mm
O = Open = > 10 mm

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
3	RU = Rough, Irregular, Undulating
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1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

Field Bedrock Core Log

Client:	Tlicho E&E Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	17-May-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-60B
		Logger:	JMO/JGM/SR

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES							OCCASIONAL FEATURES	DRILLING OBSERVATIONS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING		
17.3	NQ 20	88	50	19.0	Fair quality, grey, dolomite	R4	W1	1	JN	F	C	RU	G	none		
19.0	NQ 21	100	50	20.4	Fair quality, grey, dolomite	R4	W1	1	JN	F	C	RU	G	none		
20.4	NQ 22	100	50	21.9	Excellent quality, grey, dolomite	R5	W1	2	JN	F/V	C	RU	G	none		
21.9	NQ 23	100	75	23.5	Excellent quality, grey, dolomite	R5	W1	1	JN	F	C	RU	G	none		

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

JOINT APERTURE

C = Closed = < 0.5 mm
G = Gapped = 0.5 to 10 mm
O = Open = > 10 mm

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
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1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

Stantec	**Project No.: 144902448**	**Rock Core Photographs**
	Project Name: Tlicho All Season Road – Crossing #14	

Rock Core Photo No.:	**1**	**Borehole:**	**BH 17-57B**	**Depth:**	**6.1 m to 15.2 m**

Rock Core Photo No.:	**2**	**Borehole:**	**BH 17-57B**	**Depth:**	**15.2 to 20.0 m**

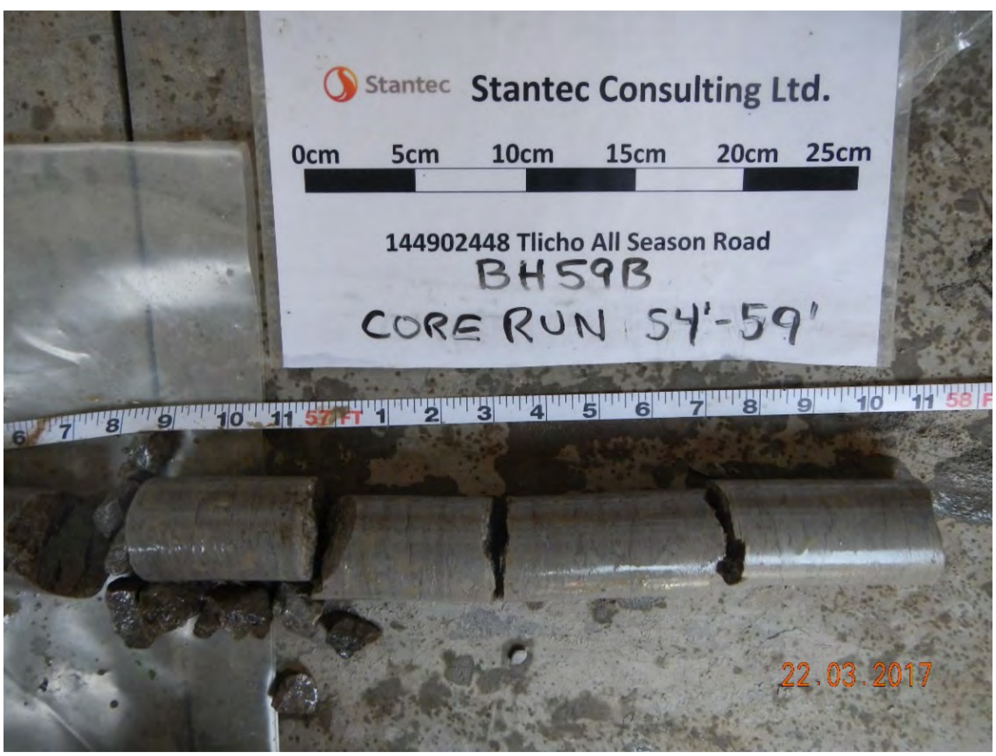
Stantec	**Project No.: 144902448**	**Rock Core Photographs**
	Project Name: Tlicho All Season Road – Crossing #14	

Rock Core Photo No.:	**3**	**Borehole:**	**BH 17-57B**	**Depth:**	**20.0 to 21.9 m**

Rock Core Photo No.:	**4**	**Borehole:**	**BH 17-58B**	**Depth:**	**3.7 to 18.5 m**

Stantec	**Project No.: 144902448**	**Rock Core Photographs**
	Project Name: Tlicho All Season Road – Crossing #14	

Rock Core Photo No.:	**5**	**Borehole:**	**BH 17-58B**	**Depth:**	**18.3 to 21.9 m**



Rock Core Photo No.:	**6**	**Borehole:**	**BH 17-59B**	**Depth:**	**16.5 to 18.0 m**

Stantec	**Project No.: 144902448**	**Rock Core Photographs**
	Project Name: Tlicho All Season Road – Crossing #14	

Rock Core Photo No.:	**7**	**Borehole:**	**BH 17-59B**	**Depth:**	**18.0 to 19.4 m**

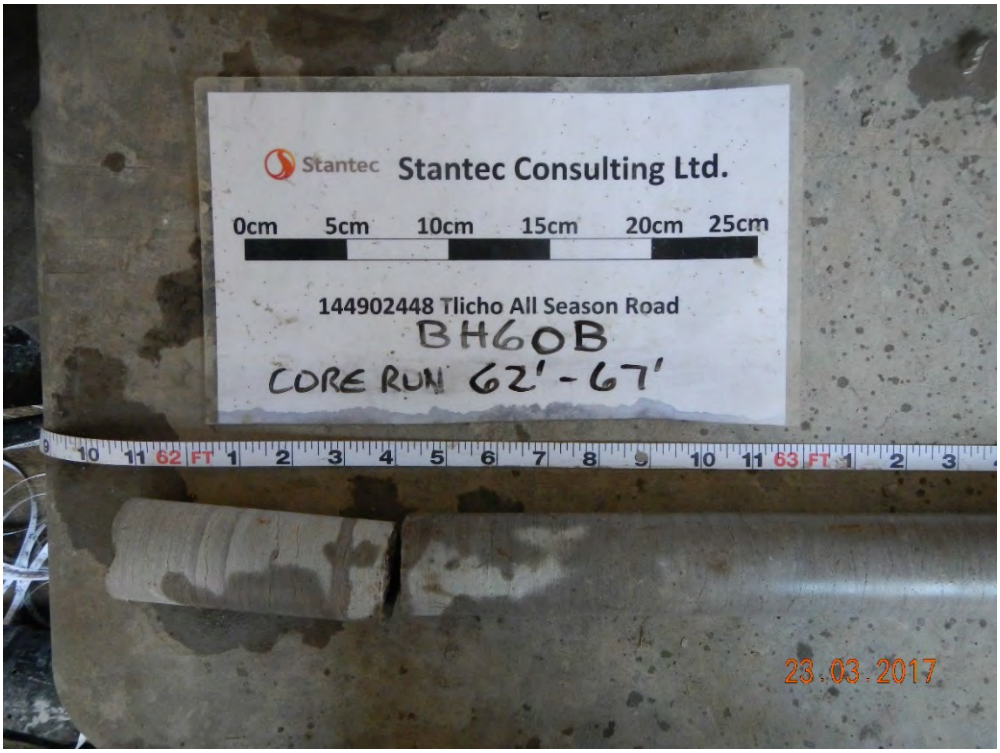
Rock Core Photo No.:	**8**	**Borehole:**	**BH 17-59B**	**Depth:**	**19.5 to 20.9 m**

Stantec	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #14	

Rock Core Photo No.:	**9**	**Borehole:**	**BH 17-60B**	**Depth:**	**15.8 to 17.4 m**

Rock Core Photo No.:	**10**	**Borehole:**	**BH 17-60B**	**Depth:**	**17.4 to 18.9 m**

Stantec	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #14	



Rock Core Photo No.:	11	Borehole:	BH 17-60B	Depth:	18.9 to 20.4 m

Rock Core Photo No.:	12	Borehole:	BH 17-60B	Depth:	18.9 to 20.4 m

Stantec	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #14	

Rock Core Photo No.: 13	Borehole: BH 17-60B	Depth: 20.4 to 21.9 m

Rock Core Photo No.: 14	Borehole: BH 17-60B	Depth: 21.9 to 23.5 m

APPENDIX D

Laboratory Test Results

Stantec

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10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

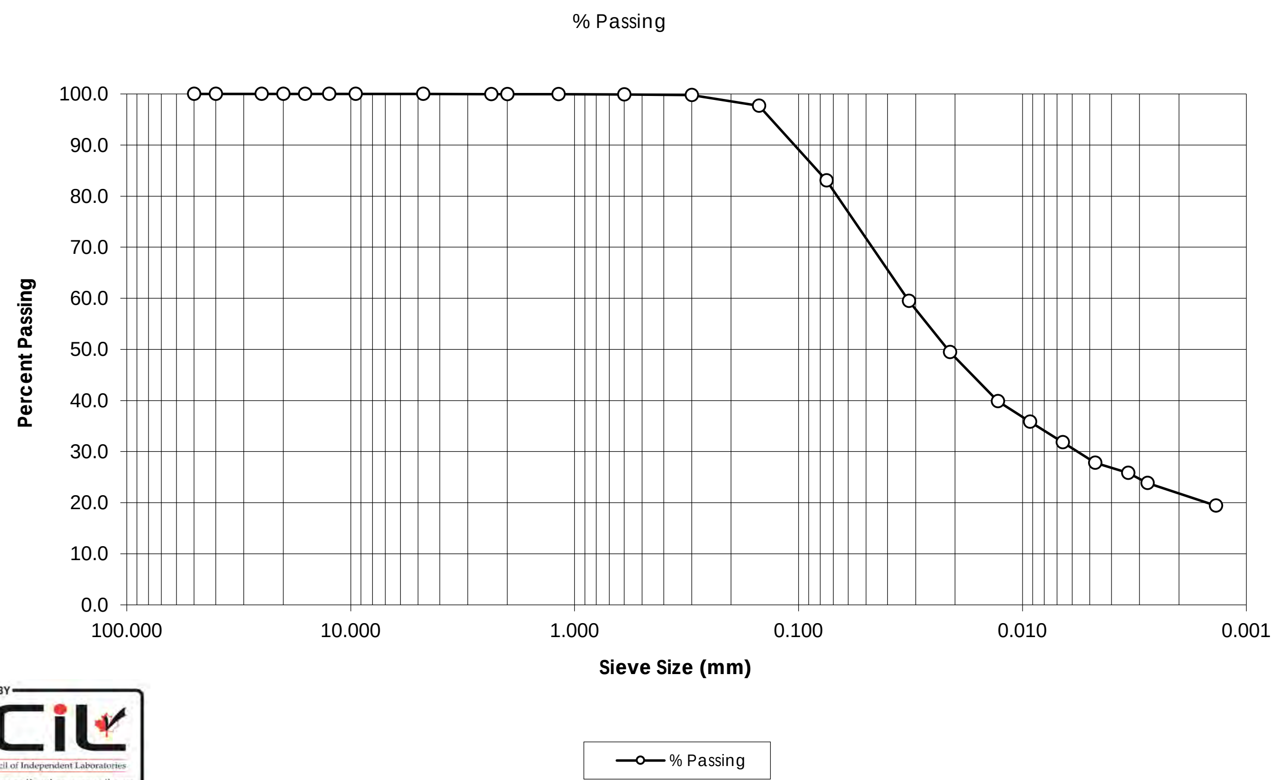
LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

Client: TliCho Engineering & Environmental Services
Project Name: TliCho All Season Rd. Investig.
Project No: 144902448

SAMPLE No.: AS1
SOURCE: BH17-57B
TESTED BY: JA

DATE TESTED: April 16, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Silty clay with sand (CL-ML)



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0066	31.8
40.0	100.0	0.0047	27.8
25.0	100.0	0.0034	25.8
20.0	100.0	0.0028	23.8
16.0	100.0	0.0014	19.4
12.5	100.0		
9.5	100.0		
4.75	100.0		
2.36	100.0		
2.00	100.0		
1.18	100.0		
0.600	99.9		
0.300	99.8		
0.150	97.7		
0.075	83.1		
0.0322	59.5		
0.0211	49.5		
0.0129	39.8		
0.0092	35.8		

Gravel:	0.0%	D_{10}:	-
Sand:	16.9%	D_{30}:	0.0058
Silt:	61.3%	D_{60}:	0.0333
Clay:	21.8%	C_u:	-
		C_c:	-

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Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Comments:

Figure 1

Reviewed by:

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

Client: TliCho Engineering & Environmental Services
Project Name: TliCho All Season Rd. Investig.
Project No: 144902448

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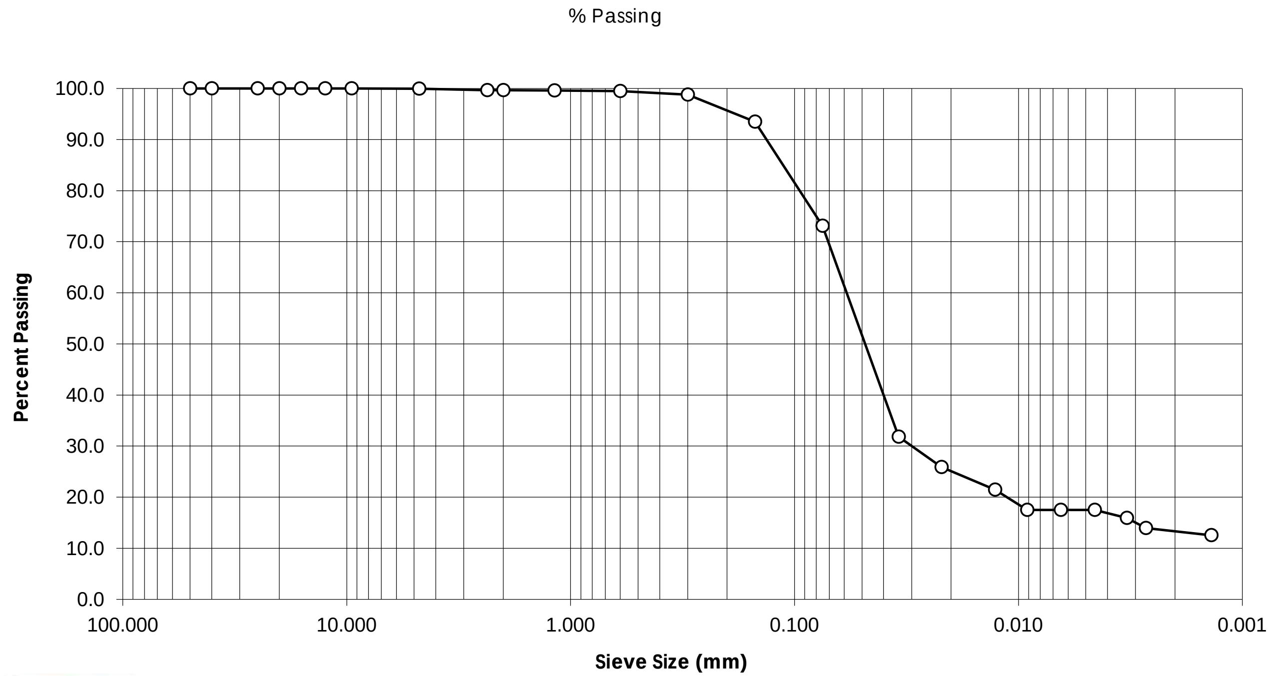
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: ST1
SOURCE: BH17-57B
TESTED BY: JA

DATE TESTED: April 18, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Silt with sand (ML)



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0065	17.5
40.0	100.0	0.0046	17.5
25.0	100.0	0.0033	15.9
20.0	100.0	0.0027	13.9
16.0	100.0	0.0014	12.5
12.5	100.0		
9.5	100.0		
4.75	100.0		
2.36	99.6		
2.00	99.6		
1.18	99.6		
0.600	99.5		
0.300	98.8		
0.150	93.5		
0.075	73.1		
0.0343	31.8		
0.0221	25.9		
0.0127	21.5		
0.0091	17.5		

Gravel:	0.0%	D_{10}:	-
Sand:	26.8%	D_{30}:	0.0308
Silt:	59.8%	D_{60}:	0.0653
Clay:	13.4%	C_u:	-
		C_c:	-

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Comments:

Figure 2

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Tel: (780) 917-7463

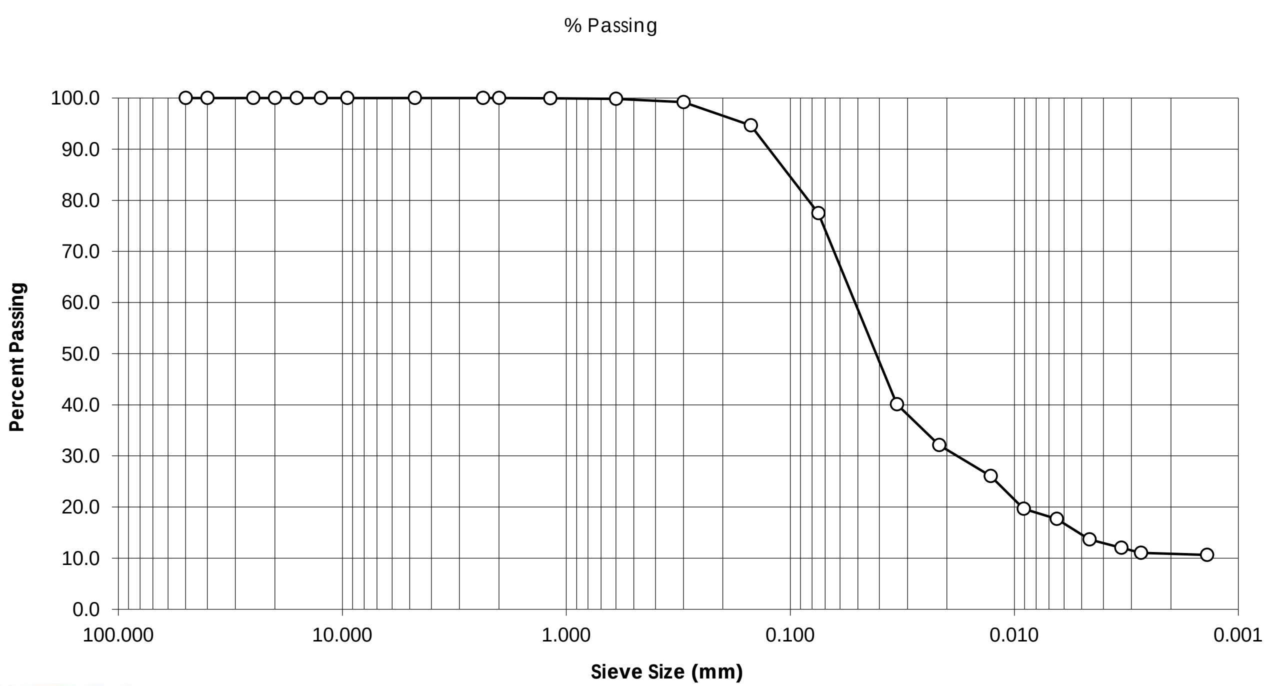
Stantec

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

Client: TliCho Engineering & Environmental Services
Project Name: TliCho All Season Rd. Investig.
Project No: 144902448

SAMPLE No.: SS1
SOURCE: BH17-59B
TESTED BY: JA

DATE TESTED: April 18, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Silt with sand (ML)



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0065	17.7
40.0	100.0	0.0046	13.6
25.0	100.0	0.0033	12.0
20.0	100.0	0.0027	11.0
16.0	100.0	0.0014	10.6
12.5	100.0		
9.5	100.0		
4.75	100.0		
2.36	100.0		
2.00	100.0		
1.18	100.0		
0.600	99.9		
0.300	99.2		
0.150	94.6		
0.075	77.5		
0.0335	40.1		
0.0217	32.1		
0.0128	26.1		
0.0091	19.7		

Gravel:	0.0%	D_{10}:	-
Sand:	22.5%	D_{30}:	0.0188
Silt:	66.6%	D_{60}:	0.0589
Clay:	10.9%	C_u:	-
		C_c:	-

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For specific tests as listed on www.ccil.com

Comments:

Figure 3

Reviewed by:

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

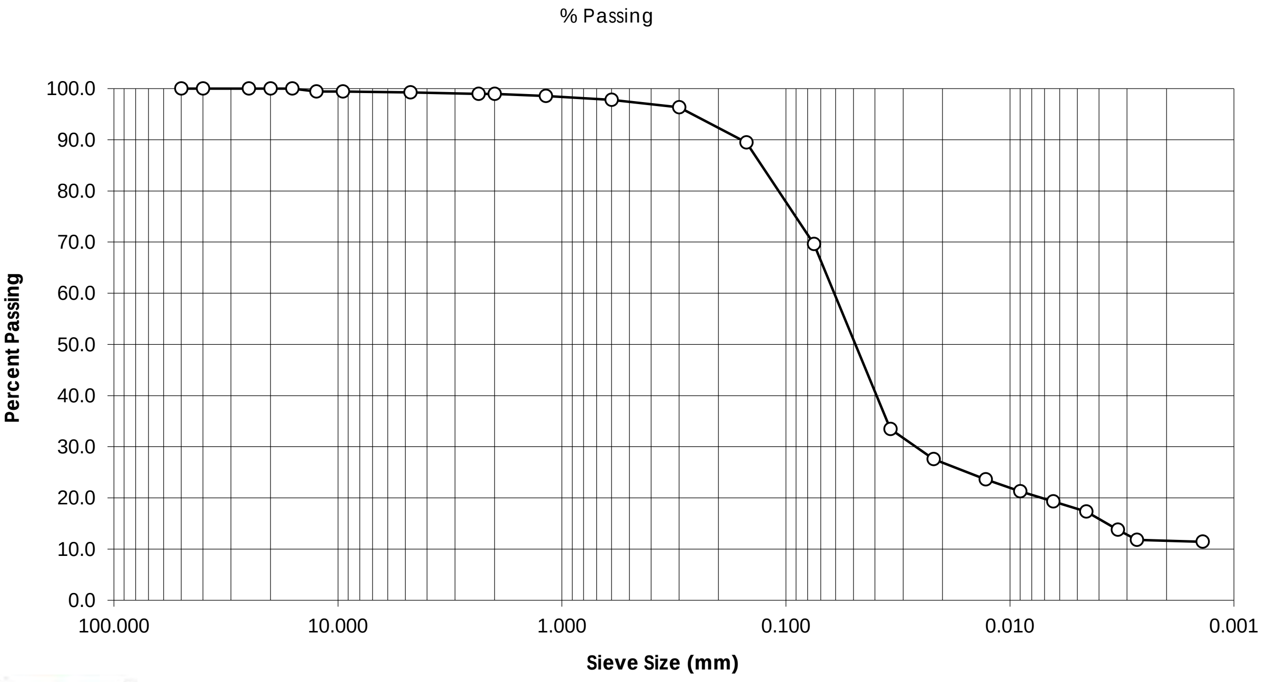
Client: TliCho Engineering & Environmental Services
Project Name: TliCho All Season Rd. Investig.
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: AS3
SOURCE: BH17-59B
TESTED BY: JA

DATE TESTED: April 18, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy lean clay (CL)



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0064	19.3
40.0	100.0	0.0046	17.3
25.0	100.0	0.0033	13.8
20.0	100.0	0.0027	11.8
16.0	100.0	0.0014	11.4
12.5	99.4		
9.5	99.4		
4.75	99.2		
2.36	99.0		
2.00	99.0		
1.18	98.6		
0.600	97.8		
0.300	96.4		
0.150	89.5		
0.075	69.6		
0.0341	33.5		
0.0219	27.6		
0.0128	23.6		
0.0090	21.3		

Gravel:	0.8%	D_{10}:	-
Sand:	29.6%	D_{30}:	0.0273
Silt:	58.0%	D_{60}:	0.0667
Clay:	11.6%	C_u:	-
		C_c:	-

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Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Comments:

Figure 4

Reviewed by:

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

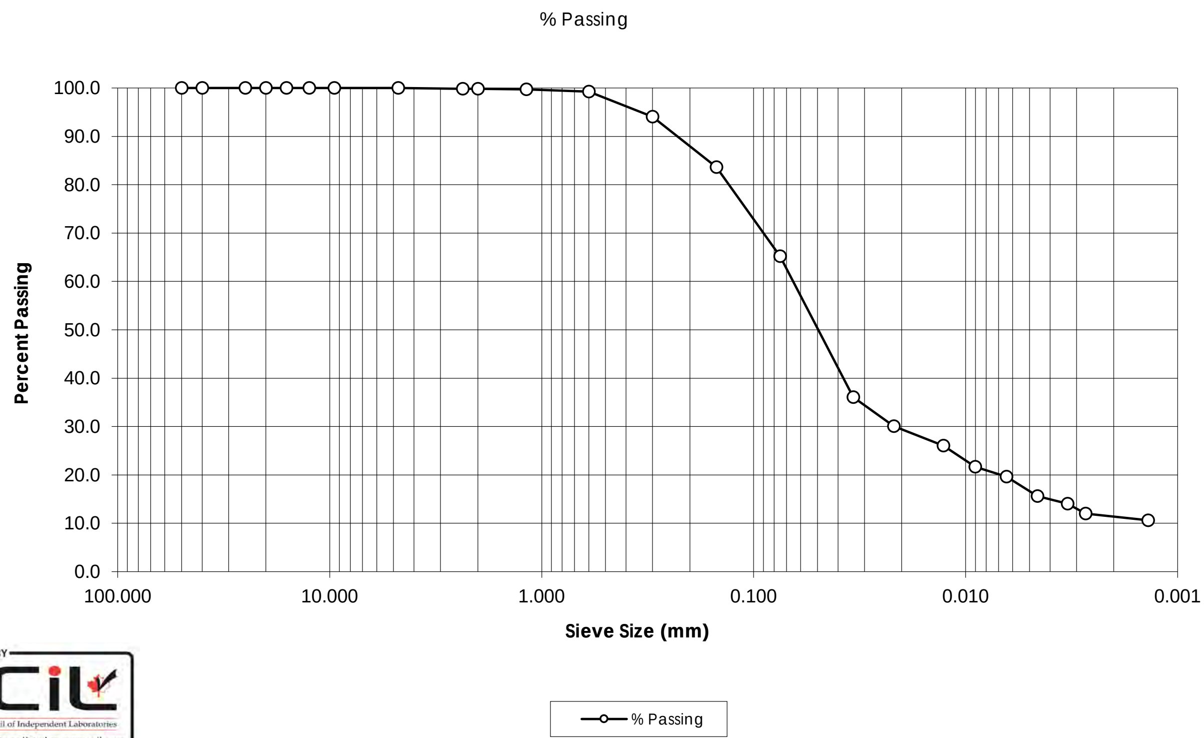
Client: TliCho Engineering & Environmental Services
Project Name: TliCho All Season Rd. Investig.
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: SS1
SOURCE: BH17-60B
TESTED BY: JA

DATE TESTED: April 18, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy silty clay (CI-ML)



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	**100.0**	**0.0064**	**19.7**
40.0	**100.0**	**0.0046**	**15.6**
25.0	**100.0**	**0.0033**	**14.0**
20.0	**100.0**	**0.0027**	**12.0**
16.0	**100.0**	**0.0014**	**10.6**
12.5	**100.0**		
9.5	**100.0**		
4.75	**100.0**		
2.36	**99.8**		
2.00	**99.8**		
1.18	**99.7**		
0.600	**99.2**		
0.300	**94.1**		
0.150	**83.6**		
0.075	**65.2**		
0.0339	**36.1**		
0.0218	**30.1**		
0.0128	**26.1**		
0.0090	**21.7**		

Gravel:	0.0%	D_{10}:	-
Sand:	34.8%	D_{30}:	0.0217
Silt:	53.8%	D_{60}:	0.0692
Clay:	11.4%	C_u:	-
		C_c:	-

Comments:

Figure 5

Reviewed by:

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

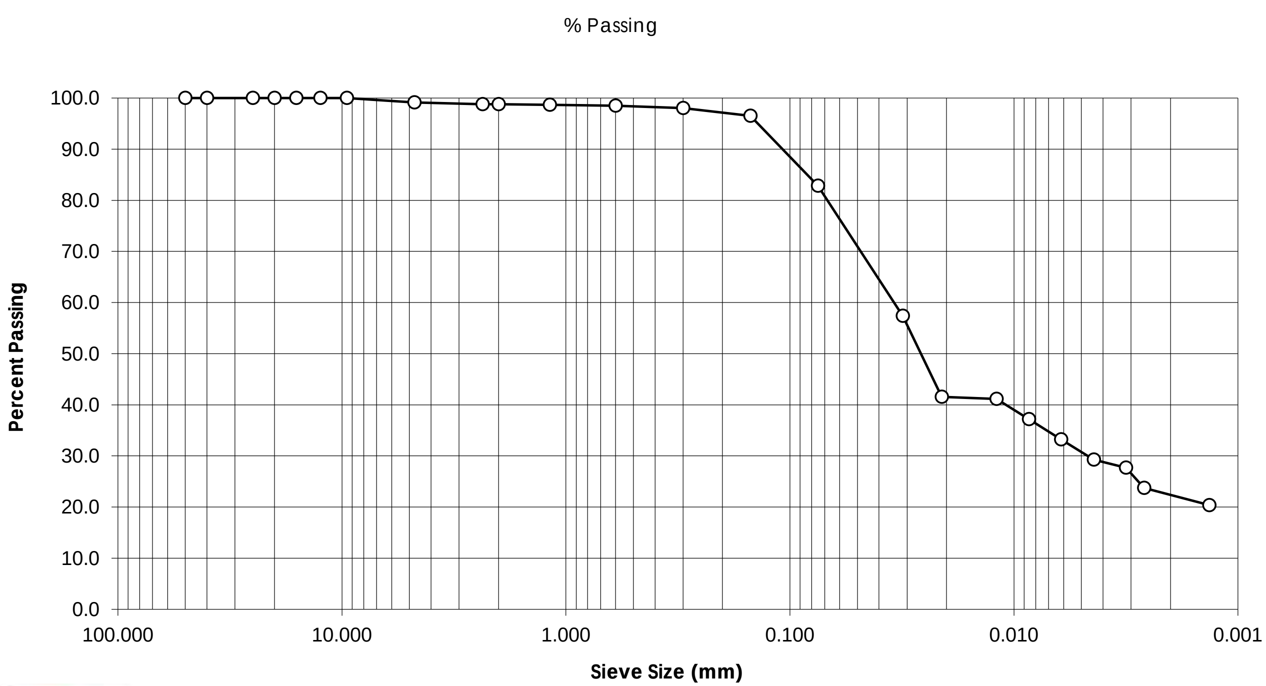
Client: TliCho Engineering & Environmental Services
Project Name: TliCho All Season Rd. Investig.
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: AS3
SOURCE: BH17-60B
TESTED BY: JA

DATE TESTED: April 18, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Silt with sand (ML)



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0062	33.2
40.0	100.0	0.0044	29.3
25.0	100.0	0.0032	27.7
20.0	100.0	0.0026	23.7
16.0	100.0	0.0013	20.4
12.5	100.0		
9.5	100.0		
4.75	99.2		
2.36	98.8		
2.00	98.8		
1.18	98.7		
0.600	98.5		
0.300	98.1		
0.150	96.5		
0.075	82.9		
0.0314	57.4		
0.0210	41.6		
0.0120	41.2		
0.0086	37.2		

Gravel:	0.8%	D_{10}:	-
Sand:	16.3%	D_{30}:	0.0047
Silt:	60.5%	D_{60}:	0.0367
Clay:	22.4%	C_u:	-
		C_c:	-

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Comments:

Figure 6

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Grain Size Analysis

Hydrometer Report

ASTM D422

CANFEM

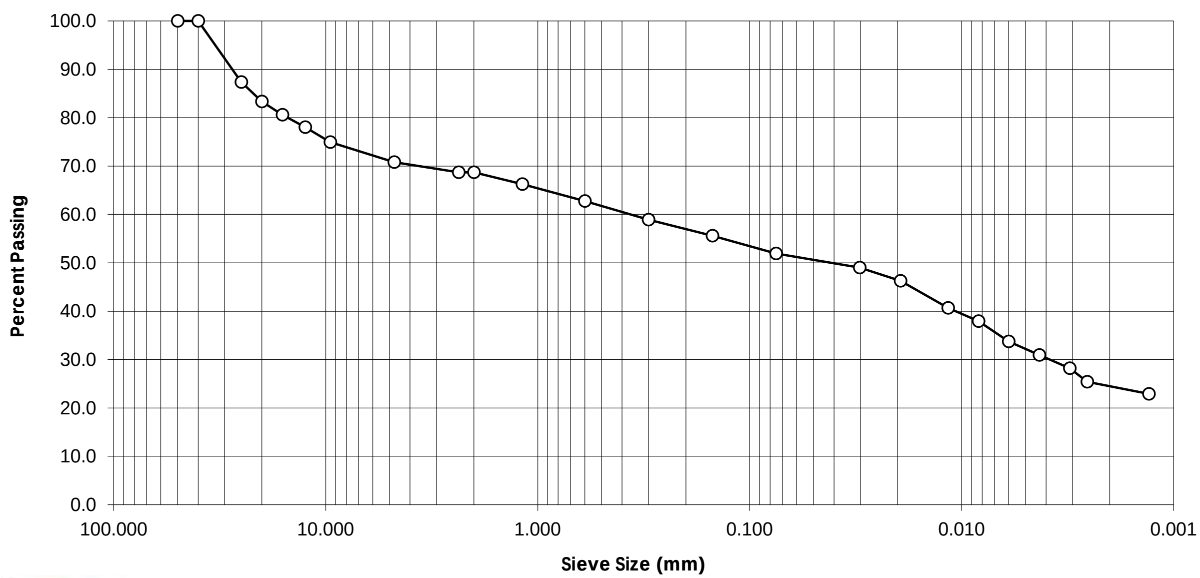
Client: TliCho Engineering & Environmental Services

Project Name: TliCho AllSeason Rd. Investig.

Project No: 144902448

SAMPLE No.: SS10
SOURCE: BH17-57B
TESTED BY: JA

DATE TESTED: April 17, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Gravelly lean clay with sand (CL)



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	**100.0**	**0.0060**	**33.7**
40.0	**100.0**	**0.0043**	**31.0**
25.0	**87.3**	**0.0031**	**28.2**
20.0	**83.3**	**0.0026**	**25.4**
16.0	**80.6**	**0.0013**	**22.9**
12.5	**78.0**		
9.5	**74.9**		
4.75	**70.8**		
2.36	**68.7**		
2.00	**68.7**		
1.18	**66.3**		
0.600	**62.8**		
0.300	**58.9**		
0.150	**55.6**		
0.075	**52.0**		
0.0303	**49.0**		
0.0194	**46.2**		
0.0116	**40.7**		
0.0083	**37.9**		

Gravel:	29.2%	D_{10}:	-
Sand:	18.8%	D_{30}:	0.0039
Silt:	27.5%	D_{60}:	0.3867
Clay:	24.5%	C_u:	-
		C_c:	-

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Comments:

Figure 7

Reviewed by:

Grain Size Analysis

Hydrometer Report
ASTM D422
CANFEM

Client: Tli Cho Engineering&Environmental Services Ltd
Project Name: TliCho AllSeason Rd.Investig.
Project No: 144902448

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Edmonton, Alberta
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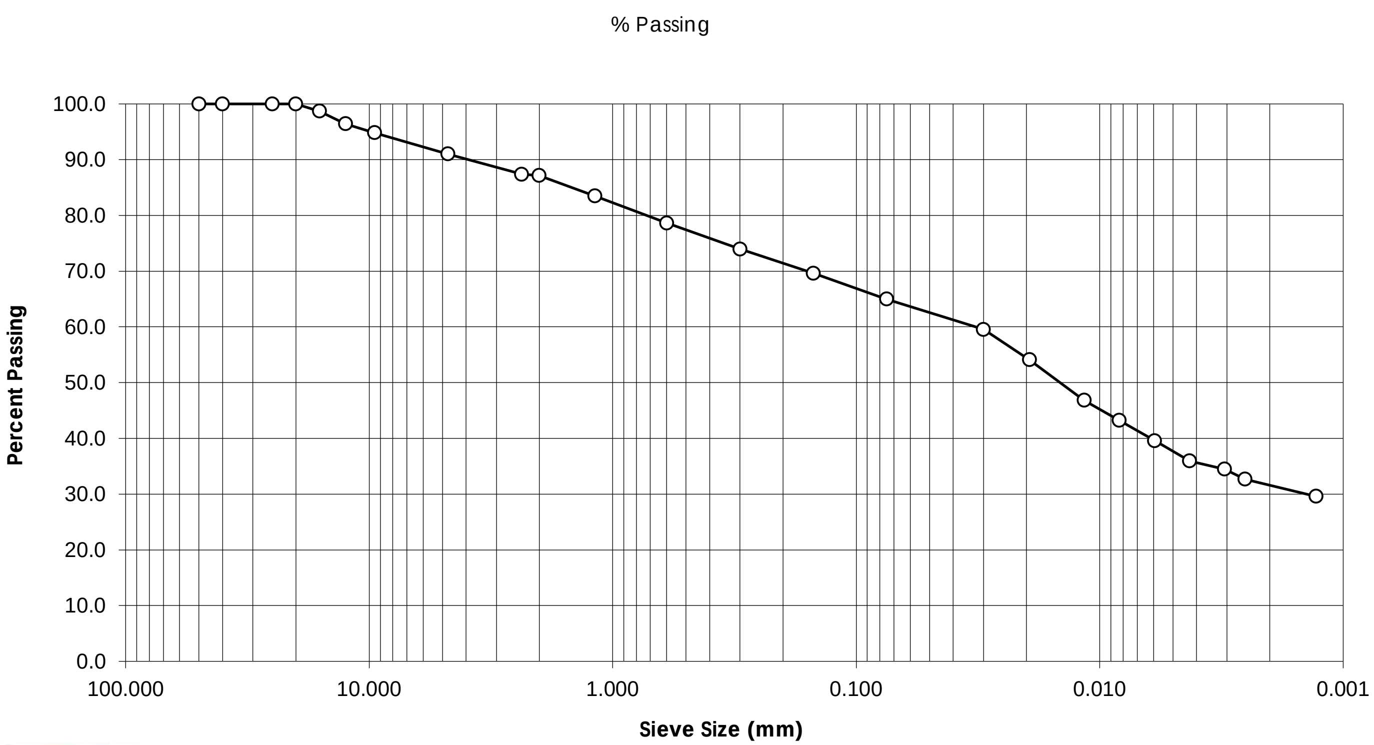
Tel: (780) 917-7463

SAMPLE No.: 14.63 m - 15.24 m
SOURCE: BH17-57B
TESTED BY: JA

DATE TESTED: April 14, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy lean clay (CL)



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0059	39.6
40.0	100.0	0.0043	35.9
25.0	100.0	0.0031	34.5
20.0	100.0	0.0025	32.7
16.0	98.7	0.0013	29.6
12.5	96.4		
9.5	94.8		
4.75	91.0		
2.36	87.4		
2.00	87.2		
1.18	83.5		
0.600	78.6		
0.300	74.0		
0.150	69.6		
0.075	65.0		
0.0300	59.5		
0.0194	54.1		
0.0116	46.8		
0.0083	43.2		

Gravel:	9.0%	D_{10}:	-
Sand:	26.0%	D_{30}:	0.0015
Silt:	33.4%	D_{60}:	0.0340
Clay:	31.6%	C_u:	-
		C_c:	-

Comments:

Figure 8

Reviewed by:

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

Client: TliCho Engineering & Environmental Services
Project Name: TliCho All Season Rd. Investig.
Project No: 144902448

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LABORATORY
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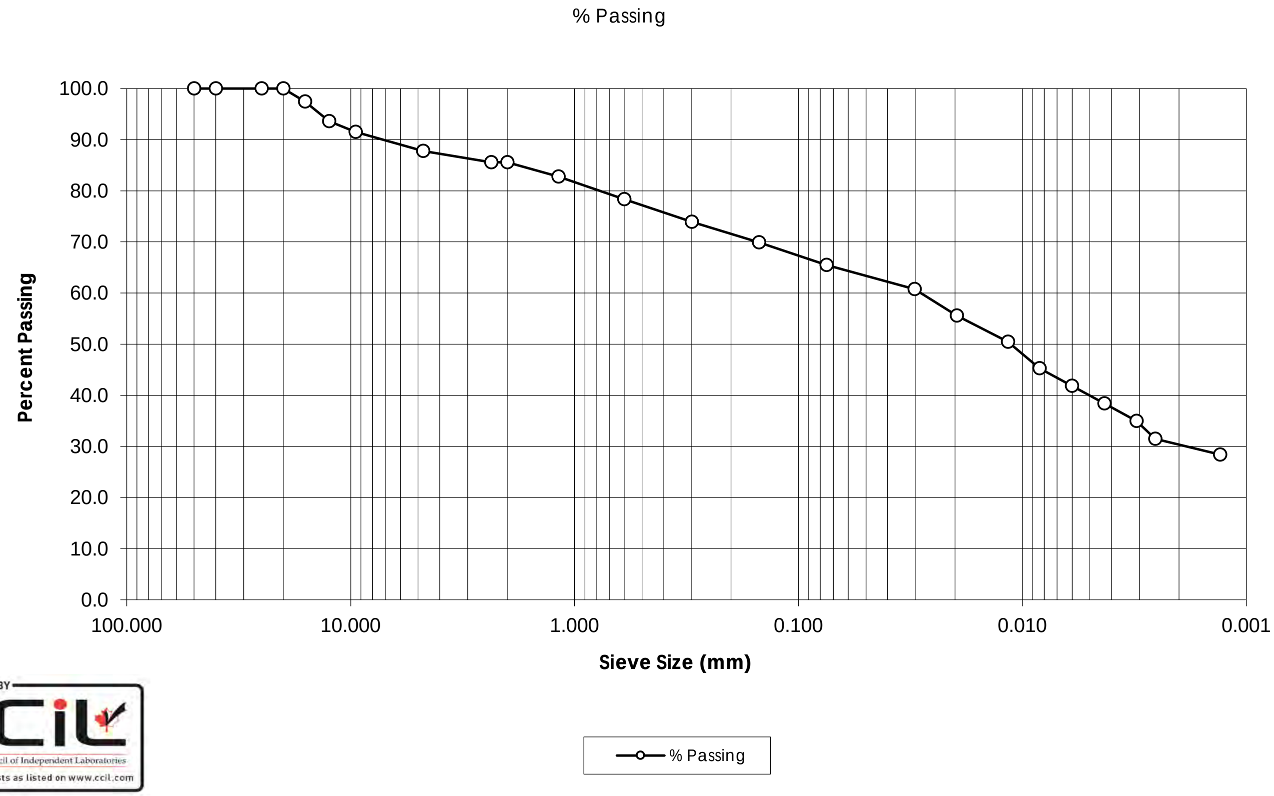
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: SS13
SOURCE: BH17-58B
TESTED BY: JA

DATE TESTED: April 17, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy lean clay (CL)



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0060	41.8
40.0	100.0	0.0043	38.4
25.0	100.0	0.0031	34.9
20.0	100.0	0.0026	31.5
16.0	97.5	0.0013	28.4
12.5	93.6		
9.5	91.5		
4.75	87.8		
2.36	85.6		
2.00	85.6		
1.18	82.8		
0.600	78.3		
0.300	74.0		
0.150	69.9		
0.075	65.5		
0.0303	60.8		
0.0196	55.6		
0.0116	50.4		
0.0084	45.3		

Gravel:	12.2%	D_{10}:	-
Sand:	22.3%	D_{30}:	0.0020
Silt:	35.1%	D_{60}:	0.0288
Clay:	30.4%	C_u:	-
		C_c:	-

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Comments:

Figure 9

Reviewed by:

Grain Size Analysis

Hydrometer Report
ASTM D422
CANFEM

Client: Tli Cho Engineering&Environmental Services Ltd
Project Name: TliCho All Season Rd. Investig.
Project No: 144902448

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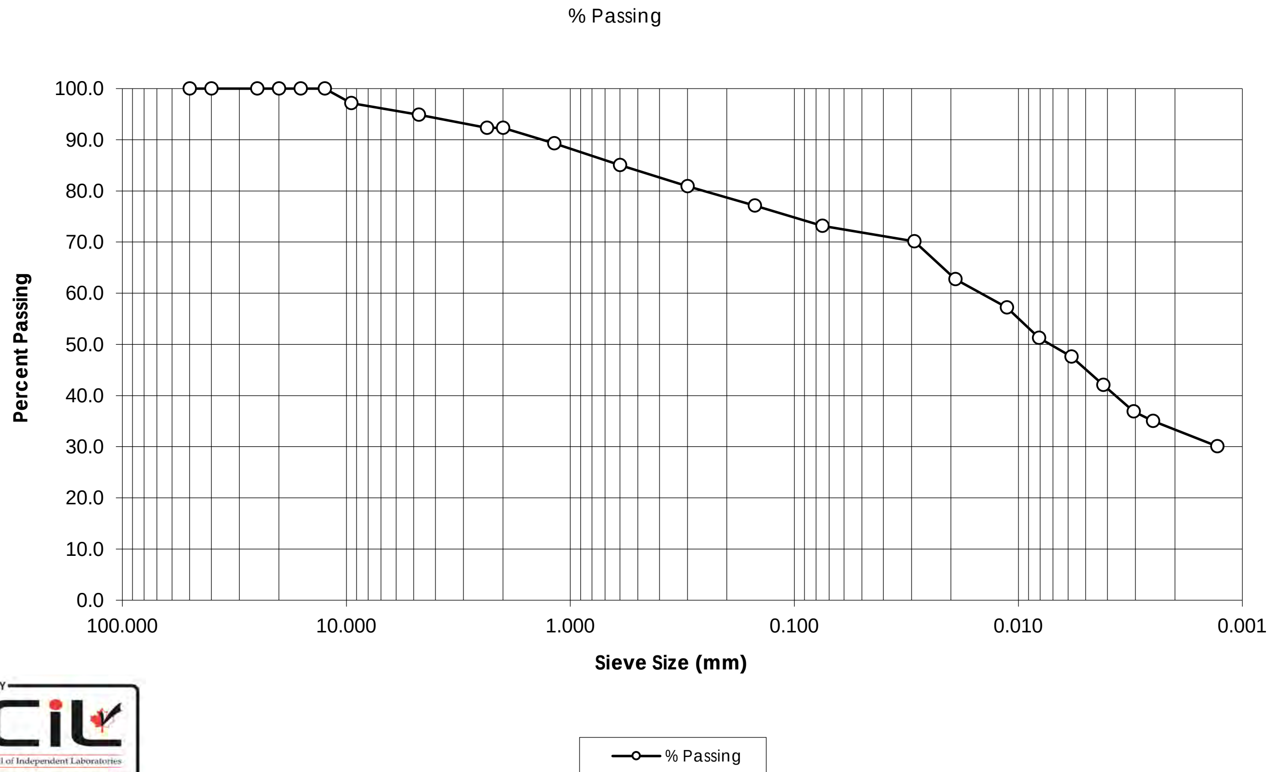
Tel: (780) 917-7463

SAMPLE No.: SS8
SOURCE: BH17-59B
TESTED BY: JA

DATE TESTED: April 18, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Lean clay with sand (CL)



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0058	47.6
40.0	100.0	0.0042	42.1
25.0	100.0	0.0031	36.9
20.0	100.0	0.0025	35.1
16.0	100.0	0.0013	30.1
12.5	100.0		
9.5	97.1		
4.75	94.9		
2.36	92.3		
2.00	92.3		
1.18	89.3		
0.600	85.1		
0.300	80.9		
0.150	77.1		
0.075	73.2		
0.0291	70.1		
0.0191	62.7		
0.0112	57.2		
0.0081	51.3		

Gravel:	5.1%	D_{10}:	-
Sand:	21.7%	D_{30}:	-
Silt:	39.8%	D_{60}:	0.0153
Clay:	33.4%	C_u:	-
		C_c:	-

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Comments:

Figure 10

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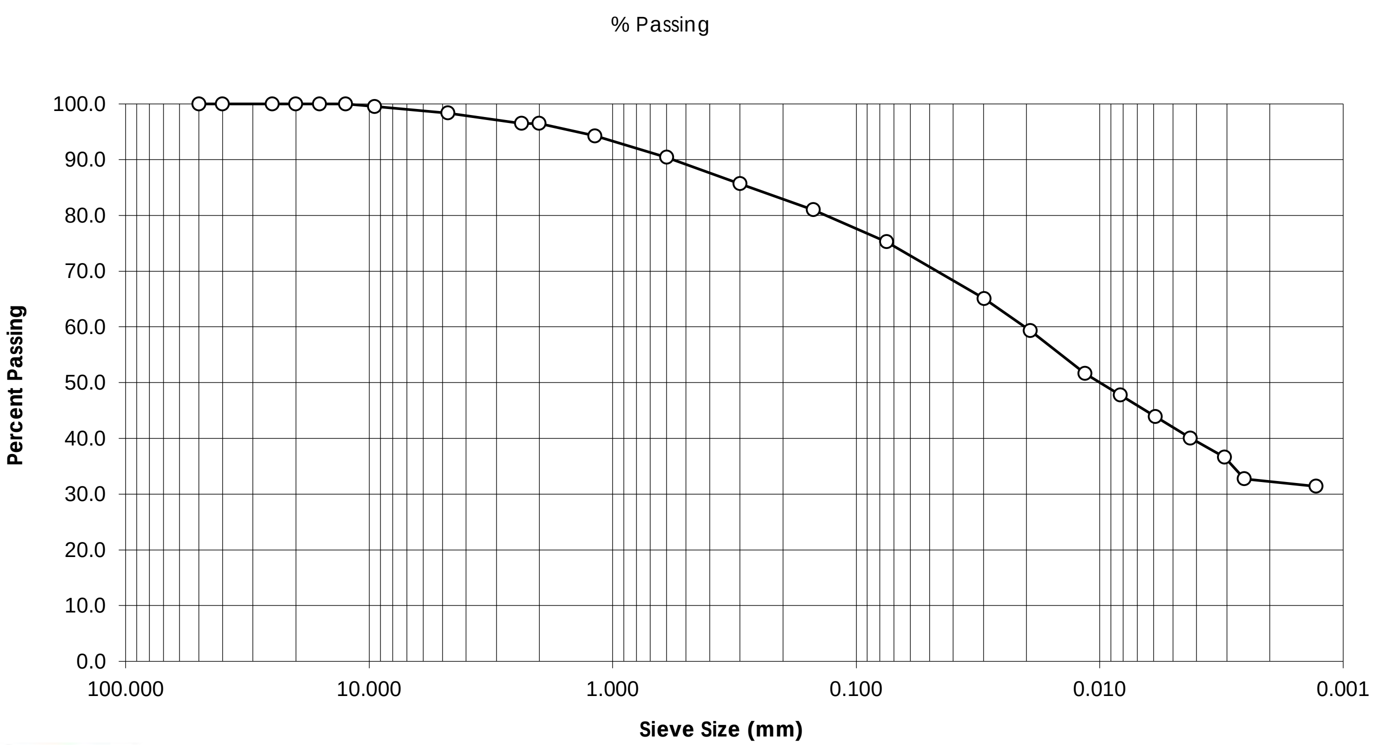
Grain Size Analysis

Hydrometer Report
ASTM D422
CANFEM

Client: Tli Cho Engineering&Environmental Services Ltd
Project Name: TliCho AllSeason Rd.Investig.
Project No: 144902448

SAMPLE No.: 10.36 m - 11.28 m
SOURCE: BH17-59B
TESTED BY: JA

DATE TESTED: April 18, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Lean clay with sand



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Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0059	43.9
40.0	100.0	0.0042	40.1
25.0	100.0	0.0031	36.6
20.0	100.0	0.0025	32.7
16.0	100.0	0.0013	31.4
12.5	100.0		
9.5	99.5		
4.75	98.4		
2.36	96.5		
2.00	96.5		
1.18	94.3		
0.600	90.4		
0.300	85.7		
0.150	81.0		
0.075	75.3		
0.0298	65.1		
0.0192	59.3		
0.0115	51.6		
0.0082	47.8		

Gravel:	1.6%	D_{10}:	-
Sand:	23.1%	D_{30}:	-
Silt:	43.0%	D_{60}:	0.0206
Clay:	32.3%	C_u:	-
		C_c:	-

Comments:

Figure 11

Reviewed by:

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

Client: TliCho Engineering & Environmental Services
Project Name: TliCho All Season Rd. Investig.
Project No: 144902448

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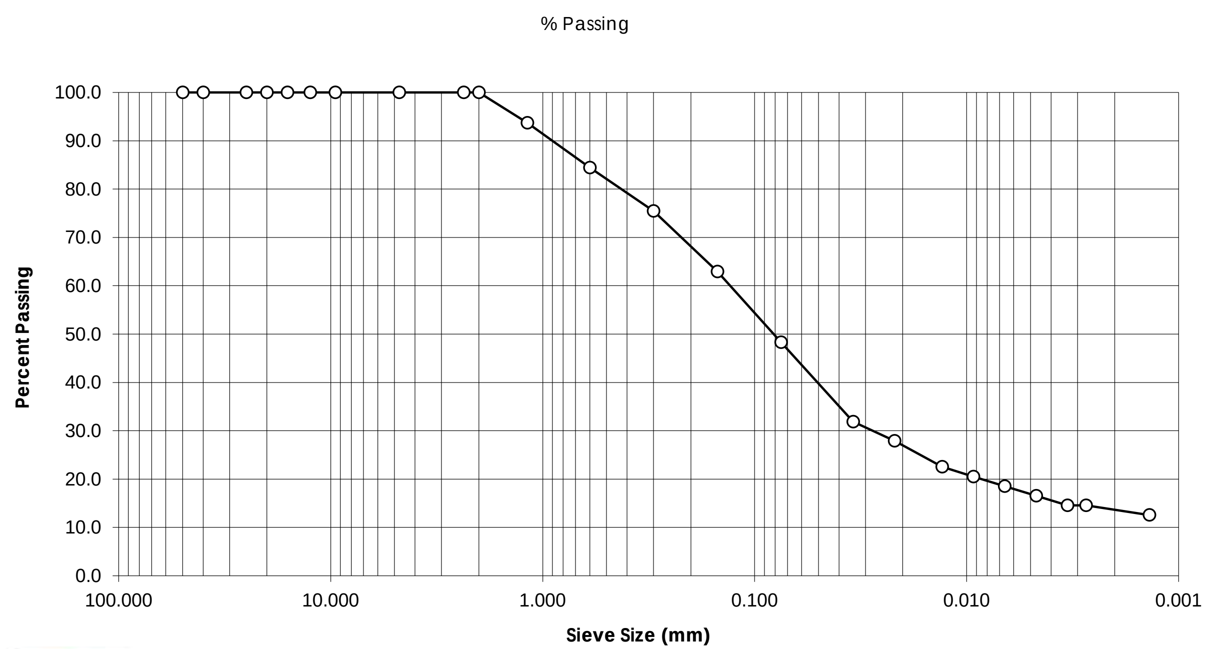
SAMPLE No.: SS4
SOURCE: BH17-60B
TESTED BY: JA

DATE TESTED: April 19, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Silty sand (SM)



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0066	18.5
40.0	100.0	0.0047	16.5
25.0	100.0	0.0033	14.6
20.0	100.0	0.0027	14.6
16.0	100.0	0.0014	12.6
12.5	100.0		
9.5	100.0		
4.75	100.0		
2.36	100.0		
2.00	100.0		
1.18	93.7		
0.600	84.5		
0.300	75.5		
0.150	62.9		
0.075	48.3		
0.0343	31.9		
0.0219	27.9		
0.0131	22.5		
0.0093	20.5		

Gravel:	0.0%	D_{10}:	-
Sand:	51.7%	D_{30}:	0.0286
Silt:	34.6%	D_{60}:	0.1365
Clay:	13.7%	C_u:	-
		C_c:	-

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Comments:

Figure 12

Reviewed by:

Grain Size Analysis
Hydrometer Report
ASTM D422
CANFEM

Client: Tli Cho Engineering&Environmental Services Ltd
Project Name: TliCho AllSeason Rd.Investig.
Project No: 144902448

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LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: 11.28 m - 11.89 m
SOURCE: BH17-60B
TESTED BY: JA

DATE TESTED: April 18, 2017
DATE RECEIVED: February 27, 2017
SAMPLE DESCRIPTION: Sandy lean clay

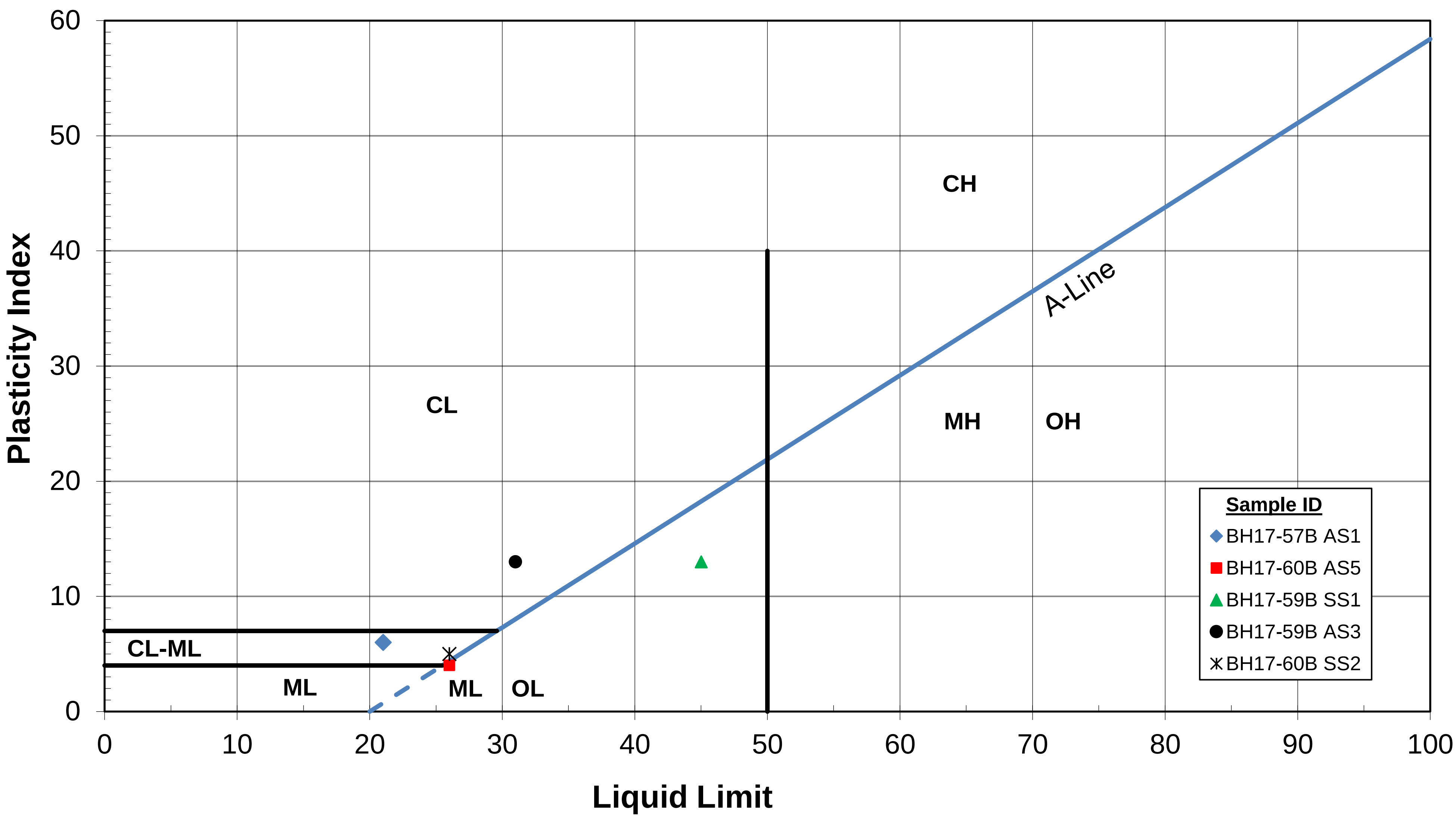
Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0058	41.3
40.0	100.0	0.0042	38.0
25.0	100.0	0.0030	35.0
20.0	100.0	0.0025	31.6
16.0	95.3	0.0013	28.8
12.5	93.9		
9.5	88.6		
4.75	85.8		
2.36	83.5		
2.00	83.5		
1.18	80.8		
0.600	77.0		
0.300	73.2		
0.150	69.4		
0.075	65.0		
0.0302	56.6		
0.0194	53.3		
0.0113	48.0		
0.0081	44.6		

Gravel:	14.2%	D_{10}:	-
Sand:	20.8%	D_{30}:	0.0018
Silt:	34.3%	D_{60}:	0.0490
Clay:	30.7%	C_u:	-
		C_c:	-

Comments:

Figure 13

Reviewed by:



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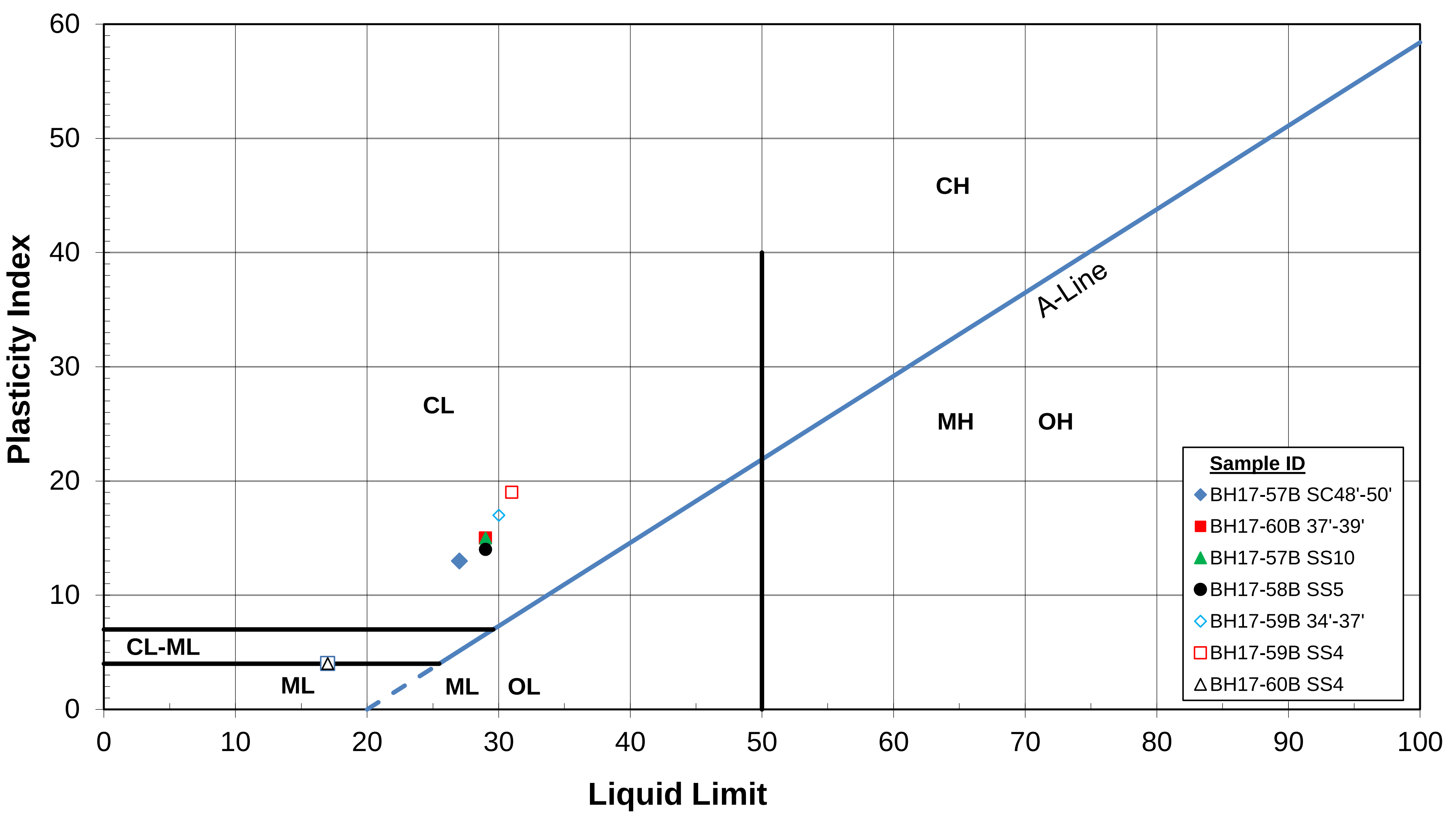
Tlicho Engineering & Environmental Services

Tlicho All Season Road

PLASTICITY CHART

Figure No. 14

Project No. 144902448



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Tlicho All Season Road

PLASTICITY CHART

Figure No. 15

Project No. 144902448

APPENDIX E

Thermistor Resistance versus Temperature Table

Thermistor Readings

Resistance versus Temperature Relationship 3000 Ohm NTC Thermistors

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	30	525.4	70	153.2	110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.99K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-35	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	282.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	56.92	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965	53	250.9	93	83.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	3000	25	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

Temperature calculated using:

Steinhart-Hart Linearization

$$T_C = \frac{1}{C_0 + C_1(\ln R) + C_3(\ln R)^3} - 273.15$$

3000 Ohm @ 25C NTC Thermistor

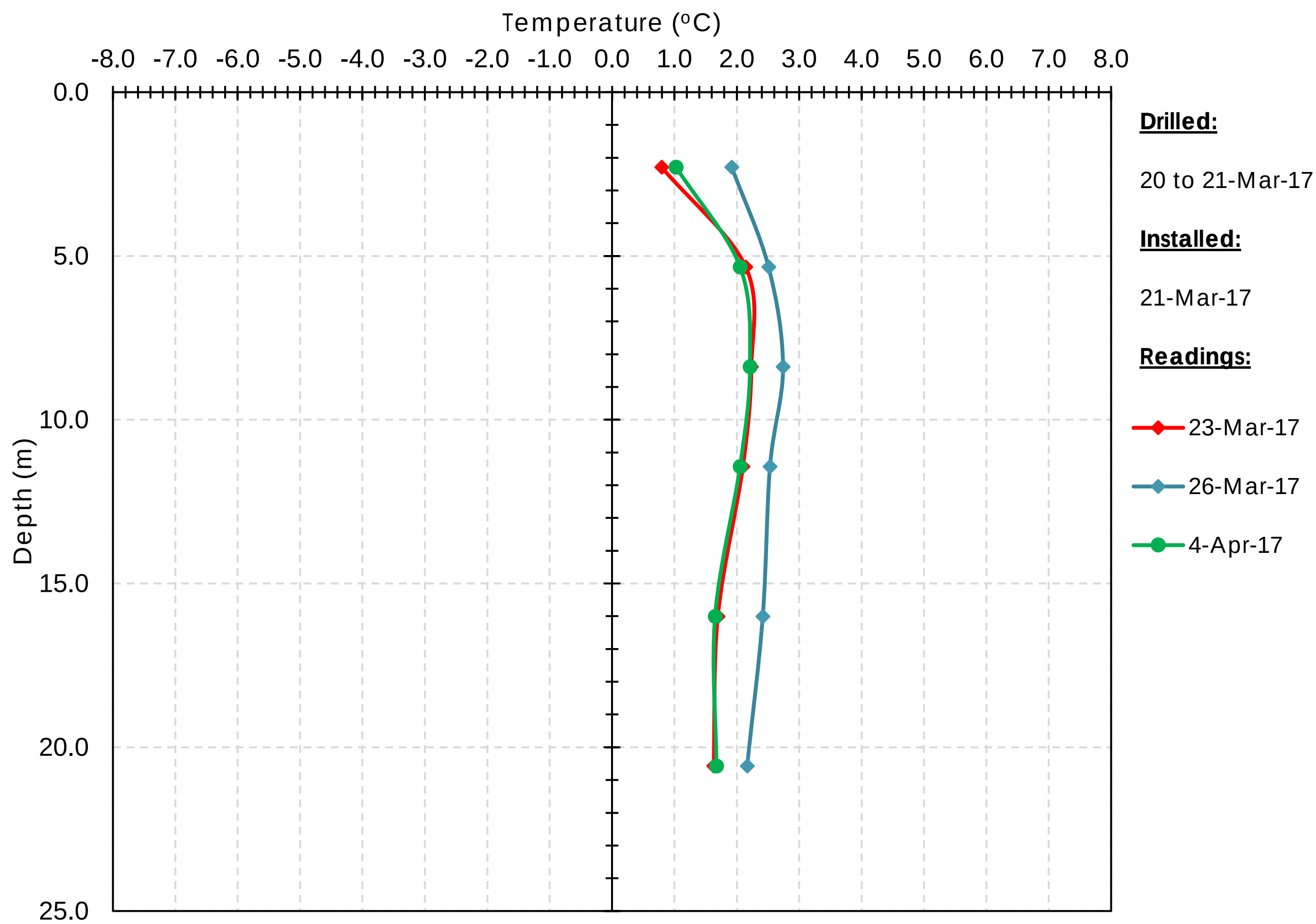
C_0= 0.0014051

C_1= 0.0002369

C_3= 0.0000001019

lnR= Natural Log of Resistance

T_C= Temperature in °C



Borehole	BH-57B								
Drilled:	20 to 21-Mar-17				Drilled Depth:			21.95	m
Installed:	21-Mar-17								
Reading			**Bead**	TS4325	TS4327	TS4389	TS4420	TS4418	TS4436
Date		**Days**	**Depth (m)**	2.29	5.33	8.38	11.43	16.00	20.57
Post-Install	23-Mar-17	2	**R (Kilo Ω)**	9.40	8.78	8.74	8.80	8.98	9.01
			T (°C)	0.8	2.1	2.2	2.1	1.7	1.6
2	24-Mar-17	3	**R (Kilo Ω)**	8.75	8.76	8.28	8.08	8.40	8.39
			T (°C)	2.2	2.2	3.3	3.8	3.0	3.0
3	4-Apr-17	14	**R (Kilo Ω)**	9.29	8.82	8.75	8.82	9	8.99
			T (°C)	1.0	2.1	2.2	2.1	1.7	1.7

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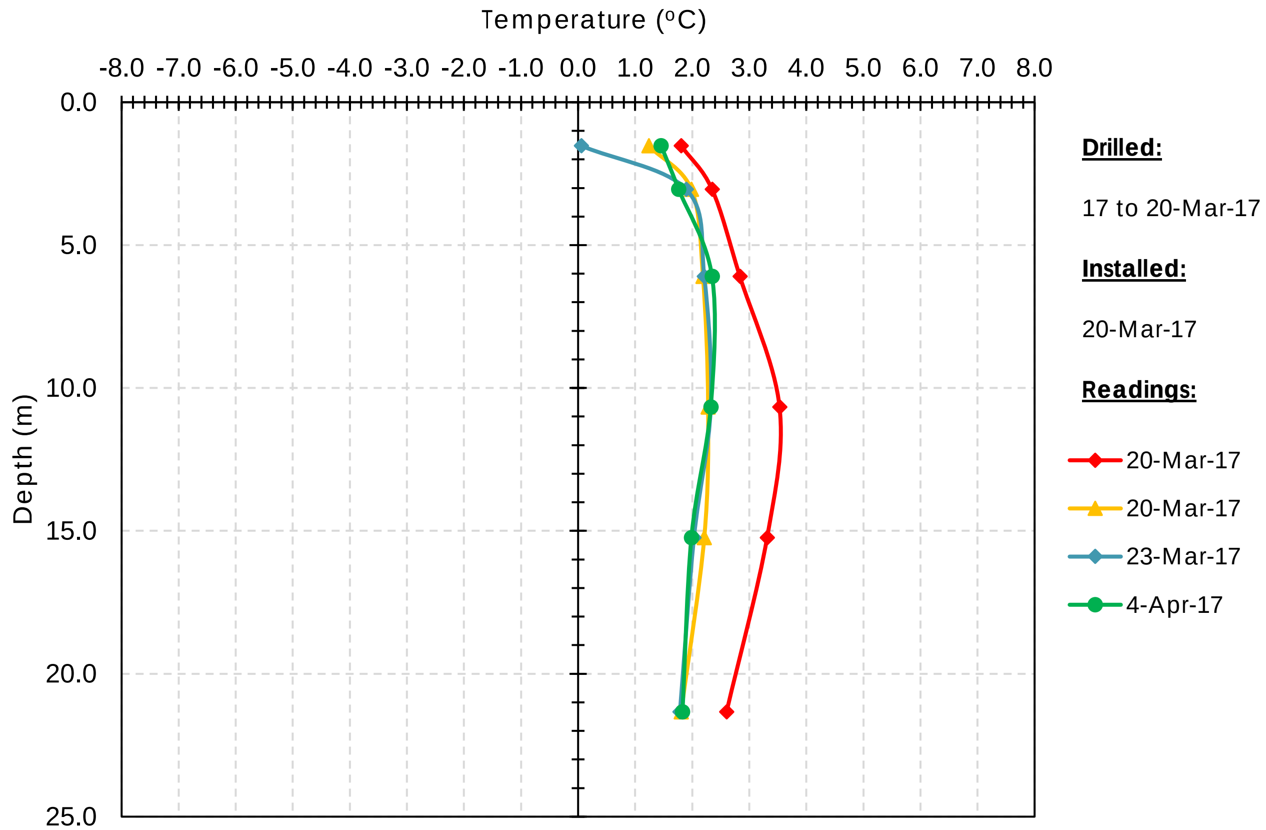
Thermistor Readings
BH17-57B

Figure No. 16

Project No. 144902448



Borehole **BH-58B**

Drilled: 17 to 20-Mar-17 Drilled Depth: 21.95 m

Installed: 20-Mar-17

Reading			**Bead**	TS4421	TS4417	TS4438	TS4439	TS4448	TS4437
Date		**Days**	**Depth (m)**	1.52	3.05	6.10	10.67	15.24	21.34
Post-Install	20-Mar-17	0	**R (Kilo Ω)**	8.93	8.69	8.48	8.19	8.28	8.58
			T (°C)	1.8	2.3	2.8	3.5	3.3	2.6
Post-Install	20-Mar-17	0	**R (Kilo Ω)**	9.19	8.85	8.76	8.72	8.75	8.93
			T (°C)	1.2	2.0	2.2	2.3	2.2	1.8
2	23-Mar-17	3	**R (Kilo Ω)**	9.76	8.89	8.75	8.7	8.83	8.94
			T (°C)	0.1	1.9	2.2	2.3	2.0	1.8
3	24-Mar-17	4	**R (Kilo Ω)**	8.78	8.9	8.77	8.42	8.85	8.94
			T (°C)	2.1	1.9	2.2	3.0	2.0	1.8
4	4-Apr-17	15	**R (Kilo Ω)**	9.09	8.95	8.69	8.7	8.85	8.92
			T (°C)	1.5	1.8	2.3	2.3	2.0	1.8

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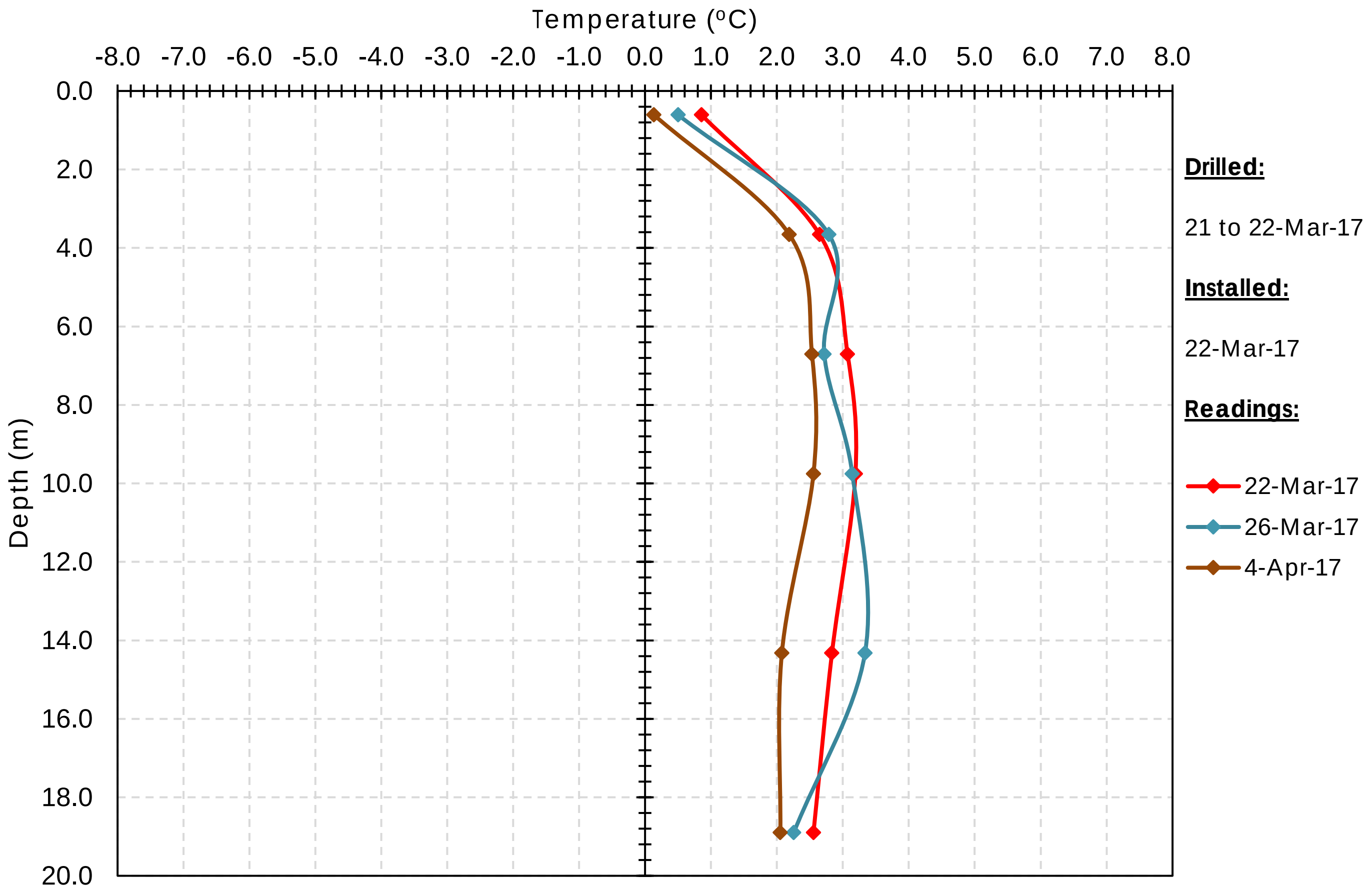
Thermistor Readings BH17-58B

Figure No. 17

Project No. 144902448



Borehole	BH-59B								
Drilled:	21 to 22-Mar-17				Drilled Depth:			20.88	m
Installed:	22-Mar-17								
Reading			**Bead**	TS4390	TS4391	TS4404	TS4408	TS4442	TS4443
Date		**Days**	**Depth (m)**	0.61	3.66	6.71	9.75	14.33	18.90
Post-Install	22-Mar-17	0	**R (Kilo Ω)**	9.37	8.56	8.38	8.33	8.48	8.60
			T (°C)	0.9	2.6	3.1	3.2	2.8	2.6
2	26-Mar-17	4	**R (Kilo Ω)**	9.54	8.5	8.53	8.35	8.27	8.73
			T (°C)	0.5	2.8	2.7	3.1	3.3	2.3
3	4-Apr-17	13	**R (Kilo Ω)**	9.72	8.76	8.61	8.6	8.81	8.82
			T (°C)	0.1	2.2	2.5	2.6	2.1	2.1

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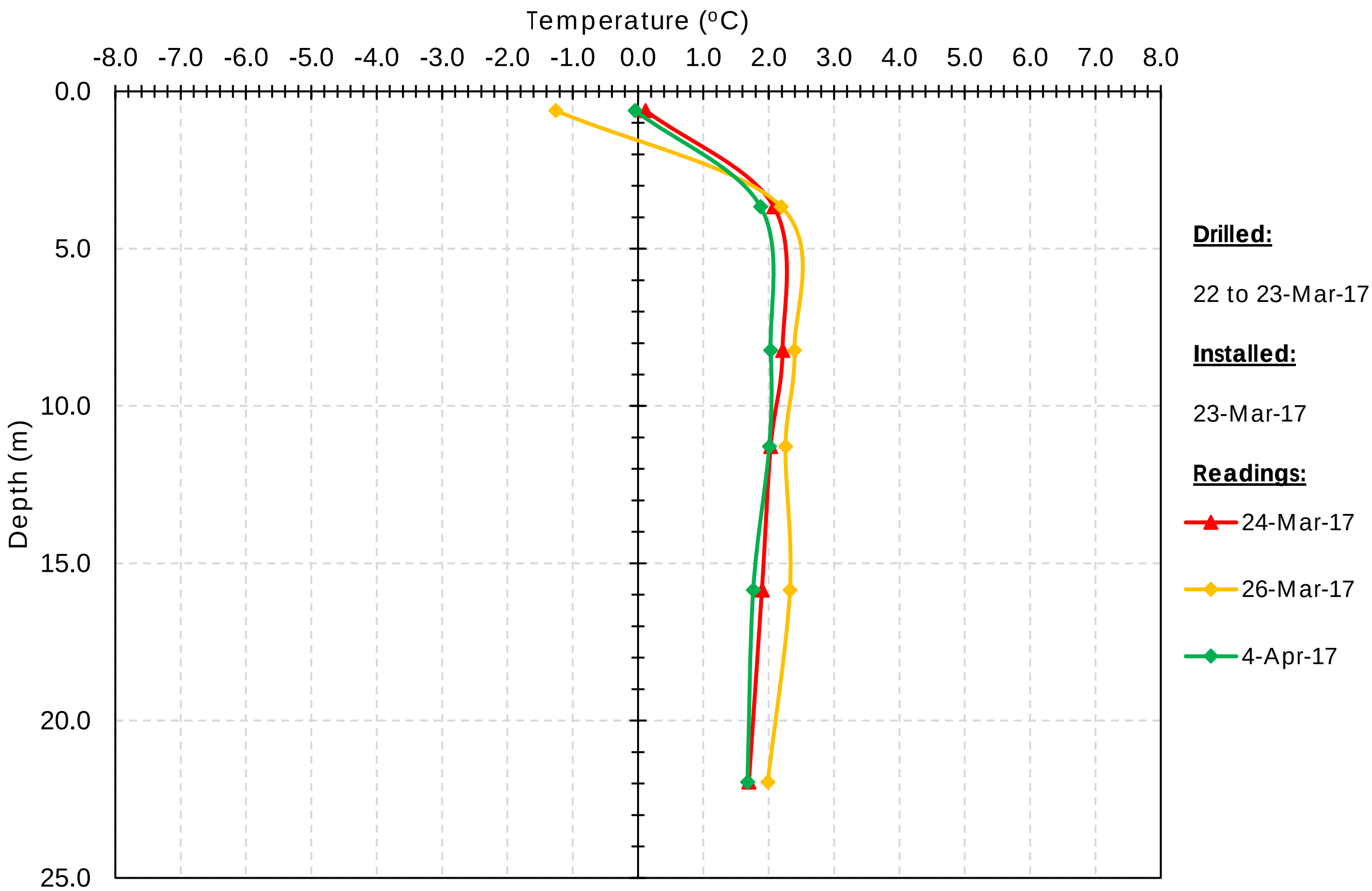
Thermistor Readings
BH17-59B

Figure No. 18

Project No. 144902448



Borehole	**BH-60B**								
Drilled:	22 to 23-Mar-17				Drilled Depth:			23.47	m
Installed:	23-Mar-17								
Reading			**Bead**	TS4384	TS4388	TS4419	TS4422	TS4426	TS4431
Date		**Days**	**Depth (m)**	0.61	3.66	8.23	11.28	15.85	21.95
Post-Install	23-Mar-17	0	**R (Kilo Ω)**	7.15	6.63	8.14	6.68	8.08	7.55
			T (°C)	6.3	7.8	3.7	7.7	3.8	5.2
2	24-Mar-17	1	**R (Kilo Ω)**	9.73	8.81	8.75	8.83	8.89	8.98
			T (°C)	0.1	2.1	2.2	2.0	1.9	1.7
3	26-Mar-17	3	**R (Kilo Ω)**	10.44	8.76	8.67	8.73	8.7	8.85
			T (°C)	-1.3	2.2	2.4	2.3	2.3	2.0
4	4-Apr-17	12	**R (Kilo Ω)**	9.81	8.9	8.83	8.84	8.95	8.99
			T (°C)	0.0	1.9	2.0	2.0	1.8	1.7

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Thermistor Readings BH17-60B

Figure No. 19

Project No. 144902448

Draft Geotechnical Data Report
Proposed Bridge Crossing #15
Station 85+397

Geotechnical Investigation,
Proposed Tlicho All-Season Road,
Northwest Territories

Prepared for:
Tlicho Engineering and
Environmental Services Ltd.

Prepared by:
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Project No. 144902448

June 2017

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1.0 INTRODUCTION

Acting at the authorization of Tlicho Engineering and Environmental Services Ltd. (Tlicho), Stantec Consulting Ltd. (Stantec) carried out a geotechnical investigation in support of the proposed bridge planned at Crossing #15 along the proposed Tlicho All Season Access Road (TASR). The purpose of the investigation was to characterize subsurface conditions and provide geotechnical comments and recommendations to assist with proposed bridge design and site development.

The investigation was carried out in general accordance with Stantec's proposal dated January 12, 2017, as part of an overall geotechnical program by Tlicho for the Government of the Northwest Territories (GNWT) along the proposed 94 km TASR alignment extending from the Yellowknife Highway (Highway 3) to the Settlement of Whatì on the south shore of Lac La Martre (RFP Event ID: EV000000001132). The scope of work outlined in the GNWT Request for Proposal includes the geotechnical investigation and design of the 94 km long TASR corridor, four bridges and three structural culverts. Tlicho was responsible for management and execution of the overall project and team as the Prime Contractor, with Stantec acting as sub-consultant providing geotechnical engineering and technical services to the project, including:

- Provision of geotechnical field personnel to log subsurface conditions during drilling operations at eighty-one (81) geotechnical boreholes in accordance with the RFP:
  - Thirteen (13) boreholes at the four (4) proposed major bridge crossings:
    - Crossing #8, Station 40+400 - Duport River Crossing
    - Crossing #9, Station 45+175 - (unnamed)
    - Crossing #14, Station 69+666 - James River Crossing
    - Crossing #15, Station 85+397 - La Martre River
  - Three (3) boreholes at the three (3) proposed major bridge culvert crossings:
    - Crossing #5, Station 16+532
    - Crossing #6, Station 19+427
    - Crossing #10a, Station 48+208
  - Sixty-five (65) boreholes to observe the subsurface conditions along the road alignment;
- Installation and reading of thermistors;
- Borehole layout and as-drilled survey;
- Completion of a laboratory testing program on the recovered borehole samples as specified in the RFP; and
- Geotechnical engineering assessment and reporting on the field and laboratory findings in two reports (Geotechnical Data Report and Geotechnical Recommendations Report) for each crossing location and for the overall roadway alignment.
  - These documents should be read in conjunction with the Statement of General Conditions, Appendix A.

This Geotechnical Data Report contains the factual findings from the geotechnical investigation undertaken at the Crossing #15 site by Stantec including: a summary of the field and laboratory

procedures; Borehole Records; laboratory test results; and a discussion of the factual findings. The Geotechnical Recommendation Report for Crossing #15, presenting the results of our geotechnical analysis with discussion and recommendations for design purposes is provided under separate cover.

2.0 SITE DESCRIPTION AND GEOLOGY AND CLIMATE

2.1 SITE DESCRIPTION

The Crossing #15 bridge is proposed at the La Martre River located at approximately the 85.4 km station mark along the TASR corridor as shown on Drawing No. 1 – Site Location Plan, provided in Appendix B. At this location, the proposed road center line and bridge is aligned with the original Lac La Martre winter road.

Based on a previous hydrologic study (Stantec, 2015), it is understood that the river is approximately 27 m wide and 3.0 to 4.0 m deep in the vicinity of the proposed bridge location. Based on aerial photos the floodplain is estimated to be approximately 85 m wide and consists of marshy terrain with tall grasses immediately adjacent to thick forest. At the time of the investigation, the watercourse channel was not visible during the walk around inspection of the bridge location due to snow and ice cover. Snow cover depths of approximately 50 to 55 cm was measured in surrounding areas. Photographs showing the general site conditions at the proposed bridge crossing are provided in Appendix B.

It is understood that the original Lac La Martre overland winter road was established by the military in the 1950s, and used as a public winter road for the northern Tlicho communities up until the late 1980s. More recently it has been used by the local communities for travel using all-terrain vehicles including snowmobiles, dog sleds, ATVs, and trucks (GNWT DOT, 2016). Previous site development for the road at this location appears to be limited. The roadbed is approximately level with the surrounding undisturbed vegetated areas with no significant historic ground disturbance (regrading cut/fill) apparent.

2.2 PHYSIOGRAPHY AND GEOLOGY

The site is located within the Great Slave Plain High Boreal Ecoregion (ECG, 2009 and GNWT DOT, 2016). In this section of the TASR corridor (GNWT DOT, 2016), regional topography is generally subdued with plains and gently rolling hills. Drainage ranges from 'well' to 'moderately well' with occasional seasonal tributaries. Vegetation includes regenerating jack pine forest, ephemeral stream crossing/swampland, dwarf shrub and mixed stands. The general area was subjected to forest fires in the last decade.

Based on available surficial geology mapping conducted by the Geological Survey of Canada, and previous project terrain mapping (Kavik AXYS Inc, 2008 and GNWT DOT, 2016), natural overburden material in the area has been mapped as till, coarse beach glaciolacustrine and fine glaciolacustrine material associated with glacial Lake McConnell, and occasional veneers of organic or fluvial materials overlying bedrock. Within stream channels and floodplains, recent fluvial deposits are expected. Based on geological mapping published by the Geological Survey of Canada (Okulitch, A.V, 2006), the site is mapped within the Interior Platform geologic province, situated over Paleozoic aged sedimentary rocks of the Chedabucto Lake Formation consisting of brown fine grained dolostone to cherty, sandy dolostone.

2.3 CLIMATE & PERMAFROST

2.3.1 Climate

Based on a review of historic climate data completed using the Yellowknife Airport (Climate Reference ID: 2204100), Whatì meteorological station (Lac la Martre, Climate Reference ID: 2202678) and other sources (GNWT, 2016), it is understood that the TASR area has a subarctic climate (Dfc according to the Köppen climate classification system) characterized by generally relatively cold winters followed by short summers. It is noted that the Whatì station is located approximately 13 km west of the northern limit of the TASR and the Yellowknife station is located approximately 100 km east of the southern limit of the TASR.

Average annual daily mean temperatures are about -4.3 °C (Yellowknife Station) to -4.7 °C (Whatì Station), with the lowest average daily winter temperatures generally occurring in January, while the warmest month (based on the average temperature) occurs in July. The average annual precipitation is estimated on the order of 289 mm, with an average annual rainfall of 170.7 mm generally occurring throughout June through September, and an average annual snowfall of 157.6 cm generally occurring from September through May (Yellowknife Station).

The average freezing and thawing indices between 1981 and 2010 have been 3343.1°C days and 1813.3°C days, respectively (Yellowknife Station). A study completed in 2009 by Holubec, et. al., using data from 1978 to 2008 in their model was adapted by CSA (2010). The CSA study suggests a warming trend of 0.58°C per decade within the Central Arctic region (including the TASR site). As per Table 5.2 in CSA (2010), increases under moderate (A1B) green-house gas scenarios, the mean annual temperatures for the Arctic Sector C1 are projected to be 1.3°C (2011-2040), 2.7°C (2041-2070), and 3.7°C (2071 – 2100), respectively. It is noted that the TASR site is located near the margins of the C1 and W1 sectors, therefore the temperatures will likely be some combination of the two sector predictions. This report references the temperatures for Arctic Sector C1, which are warmer temperatures compared to Arctic Sector W1, and hence, more conservative

2.3.2 Permafrost

Canada permafrost mapping from the National Atlas of Canada (Heginbottom et al. 1995) shows the TASR site lies within the zone of extensive discontinuous permafrost, with an estimated 50% and 90% of the landscape covered. It is understood that no public thermistor or intrusive investigation records exist for the immediate vicinity of the TASR. Previous reconnaissance trips by earlier terrain mapping crews and GNWT personnel did not encounter any apparent permafrost landforms or thermokarst zones within the corridor, however a zone affected by thermokarst processes was noted between Whatì, Behchoko, and the area north of Slemon Lake (Kavik AXYS Inc, 2008 and GNWT DOT, 2016).

Based on regional studies completed in surrounding areas (GNWT, 2016), permafrost is anticipated to be relatively warm and correlated with forest cover type areas underlain by finer-textured glacial and post-glacial sediments such as glaciolacustrine and lacustrine deposits, as well as peatlands where organic material contribute to the forming and preservation of permafrost. Ground ice content, if present in these finer grained deposits in the upper 10 to 20 m is anticipated to be less than 10% to 20% ice by volume (Heginbottom et al. 1995). Ground ice is generally expected to be less common in areas of exposed bedrock and where the underlying sediments are coarse and vegetation cover is thin.

Permafrost near Yellowknife is reported to be generally warm (>-2°C), less than 50 m thick with active layer thickness less than1 to up to 3 m (Wolfe, 1998). Permafrost conditions along the nearby Highway 3 have been reported as typically warmer than -1°C, with an active layer thickness varying from less than 0.7 m to 1.5 m. Permafrost degradation has been noted along the Highway in recent years with settlements in soil-covered areas generally attributed to the degradation of the ice-rich permafrost subgrade particularly where it was constructed adjacent to a water body and where the road crossed over the old alignment (BGC, 2011; and Wolfe et al, 2015;). Permafrost, where present, will be susceptible to degradation due to ground disturbance, such as removal of trees and surface vegetation or earthworks.

Recent studies commissioned by GNWT reported that climate change trends have negatively impacted infrastructure supported on permafrost and are projected to continue to negatively impact permafrost conditions in the region (Dillon 2007; and BGC, 2011). Continued warming, changes in freeze-thaw patterns, and ultimately degradation of permafrost in the region are anticipated due to increasing temperatures and amounts of precipitation, and decreases in snow and ice cover.

3.0 INVESTIGATION PROCEDURES

3.1 FIELD INVESTIGATION

The geotechnical field investigation for the bridge, conducted as part of the overall TASR alignment geotechnical program between March 26 and March 28, 2017, consisted of four geotechnical holes as shown on the General Layout and Borehole Location Plan, Drawing No. 2 in Appendix B. It is noted that the layout is conceptual and the final design details will be determined at a later date. Two boreholes were advanced at the approximate locations of the proposed bridge abutments (BH17-71B and BH17-74B) and two boreholes (BH17-72B and BH17-73B) were advanced at the approximate locations of the proposed piers, within the floodplain. Borehole locations were selected by GNWT and were established in the field by Stantec using a Trimble Geo XH GPS unit. Some boreholes were relocated up to 5 m from the original location to set up the drill on more even ground and to avoid having to remove large trees; the final locations of the boreholes were recorded using the GPS unit.

Boreholes were completed using a skid mounted drill rig capable of auger and diamond drilling. The drill rig was operated by Northtech Drilling Ltd. Boreholes were to be advanced to a target depth of 30 m below existing ground surface using solid stem augers and NW casing with regular sampling using conventional 50 mm split spoon samplers during the performance of the Standard Penetration Test (SPT), or 3 m into bedrock, whichever came first. Between 3.0 m and 5.0 m of rock was cored using a NQ core bit. The drilling depth was increased to allow for additional sampling based on the quality of rock obtained at site.

The field work was conducted under the part-time monitoring of a GNWT field representative and full-time supervision of Jacques Duguay, P.Eng.(Ontario) and Jim Oswell, PhD., P.Eng. (Stantec) who maintained detailed logs and obtained samples from the various strata encountered. Subsurface conditions were classified in general accordance with the procedures outlined in the attached explanatory key: Symbol and Terms Used on Borehole and Test Pit Records with soil descriptions prepared in accordance with ASTM D2487 and D2488. Temperatures of soils samples were measured by a handheld infrared thermometer on recovery at surface. Our observations of the temperature readings suggest the drilling process altered the temperature of the soil samples and that these measurements should not be considered representative of in situ conditions. For example, soil samples collected from the augers (denoted as AS) within the seasonal frost layer had temperature readings greater than 0° C. Frozen soils were classified in accordance with ASTM D4083 and D7099. Groundwater levels were estimated in the open boreholes at the time of drilling with water level tape and/or the moisture condition of the recovered samples.

On completion of drilling, thermistor strings were installed in all four boreholes and backfilled with cuttings and sand. Frozen sand was broken up by hand so that the material could be placed in contact with the instrument without larger frozen fragments damaging the thermistor beads.

3.2 LOCATION AND ELEVATION SURVEY

Final borehole locations and geodetic elevations were surveyed in the field by Stantec personnel using a Trimble Geo XH GPS with decimeter accuracy capability. The accuracy of the Trimble unit may be affected by satellite coverage at the time of the survey. Table 3.1 summarizes the borehole information.

Table 3.1: Borehole Summary

	Boreholes			
	BH17-71B	**BH17-72B**	**BH17-73B**	**BH17-74B**
NAD83 / UTM Zone 11N Coordinates Northing Easting	 6997742 501212	 6997771 501216	 6997811 501212	 6997837 501217
Ground Surface Elevation, m	262.0	261.3	261.5	262.1
Total Depth Drilled, m	9.8	11.3	12.9	11.3
End of Borehole Elevation, m	252.2	250.0	248.6	250.8
Number of Soil Samples	9	9	5	7
Number of Rock Core Samples	2	4	3	2

3.3 LABORATORY TESTING

All samples were taken to the Stantec Edmonton or Calgary laboratories for detailed classification and testing. Sample preservation and handling of frozen samples was in general accordance with industry standard practices (ASTM WK24243, ASTM Special Technical Publication, no 599:88-112).

Selected soil samples underwent gradation analysis testing. It should be noted that there was very poor recovery during the advance of split spoons and coring caused the majority of the finer-grained particles to be washed out of recovered soil core samples. Therefore, the lab testing was limited due to the limited number of samples obtained during the investigation. Unconfined compression testing was also carried out on select bedrock core samples. The laboratory testing summary is shown in Table 3.2 below.

Table 3.2: Laboratory Testing for Crossing #15

Laboratory Testing	Moisture Content	Gradation Analysis	Atterberg Limits	Compression
Number of Tests	0	2	0	4

To assess the potential for corrosion of buried steel elements and potential for sulphate attack on buried concrete elements, one sample of the native overburden material was tested at Maxxam Analytics for pH, water soluble sulphate and chloride concentrations, and resistivity. The results are reported in Section 4.4.

Samples remaining after testing will be placed in storage for a period of one year after issuance of the final report. After the storage period, the samples will be discarded unless we are directed otherwise by Tlicho Engineering and Environmental Services Ltd.

4.0 SUBSURFACE CONDITIONS

4.1 SUBSURFACE PROFILE

The subsurface conditions observed in the boreholes are presented in detail on the Borehole Records provided in Appendix C with further discussion below on the individual soil units encountered. An explanation of the symbols and terms used to describe the Borehole Records is provided in Appendix C.

It should be noted that the SPT blow counts and relative density/consistency descriptions of frozen soils in the Appendix C should be used with caution. It is highly likely, particularly for cohesive soils, that the strengths implied by the blow counts will be significantly reduced by thawing.

In general, the subsurface stratigraphy at the bridge location consisted of a veneer of organic rich silty soil overlying a fluvial deposit predominantly consisting of gravel with variable amounts of sand, overlying bedrock. Frequent cobbles and boulders were observed in the fluvial layer. The overburden soils were frozen to a depth of approximately 1.2 m at boreholes BH 17-72B, 0.5 m at BH17-73B (proposed pier locations) and a depth of 3.0 m and 0.6 m at boreholes BH17-71B and BH17-74B (proposed abutment locations), respectively. The stratigraphic profile of the site is shown on Drawing No. 3 in Appendix B.

4.1.1 Organic Soil

A surficial layer of frozen organic silt was encountered at BH17-71B and BH17-74B. The organic soils were typically 200 mm to 600 mm in thickness. The organic soil was underlain by coarse-grained fluvial deposits.

4.1.2 Sandy Silt

A 150 to 200 mm thick layer of frozen sandy silt was encountered immediately under a surficial layer of ice at boreholes BH17-72B and BH17-73B. The sandy silt was underlain by coarse-grained fluvial deposits. Site observations suggest the sandy silt is a low-plastic material.

A grain size distribution test carried out on a representative sample of the sandy silt yielded the following results:

Gravel:	6%
Sand:	37%
Fines (silt and clay):	57%

The Unified Soil Classification System (USCS) group symbol for this layer is ML (sandy silt). The representative grain size distribution plot for this layer is given in Figure 1 of Appendix D.

4.1.3 Fluvial Deposits

Fluvial soils were observed in all of the boreholes overlying bedrock. Fluvial deposits are typically coarse-grained soils deposited by flowing water. At this site they are deposits of gravel, sand, and silt and clay sized particles. The size of the particles is a function of the energy of the stream at the time of deposition. High energy streams (or flows) will deposit coarser grained soils while low energy streams (or flows) will deposit finer grained soils.

BH17-71B

Well graded gravel with sand (GW) was encountered between 0.2 m and 6.2 m below ground surface. Due to the difficulty advancing the split spoon sampler and augers it has been inferred that there are frequent cobbles and boulders. The temperatures of a soil sample obtained using the infrared thermometer was measured to be +4.5°C at a depth of approximately 2.6 m.

Due to the presence of cobbles and boulders the soil was cored using a NQ bit. Intermittent SPT samples were obtained for sampling and to measure blow counts. Very high SPT N-values (>50 blows per 0.1 m) measured in the soil are considered to be a result of the frequent cobbles and boulders and may not be representative of the relative density of the gravel and sand. Due to the difficult augering conditions observed, and requirement for coring of the soil, the relatively density is inferred to be dense to very dense.

A grain size distribution carried out on a representative sample of the soil yielded the following results:

Gravel:	66%
Sand:	30%
Fines (silt and clay):	4%

The USCS group symbol for this layer is GW (well graded gravel with sand). The representative grain size distribution plot for this layer is given in Figure 2 of Appendix D.

BH17-72B

Well graded gravel with sand (GW) was encountered between 0.5 m and 6.2 m below ground surface. Due to the difficulty advancing the split spoon sampler and augers it has been inferred that there are frequent cobbles and boulders. The temperature of a soil sample obtained using the infrared thermometer was +3.1°C at a depth of approximately 0.6 m.

Due to the presence of cobbles and boulders the soil was cored using a NQ bit. Intermittent SPT samples were obtained for sampling and to measure blow counts. Very high SPT N-values (>50 blows per 0.1 m) measured in the soil are considered to be a result of the frequent cobbles and boulders and may not be representative of the relative density of the gravel and sand. Due to the difficult augering conditions observed, and requirement for coring of the soil, the relatively density is inferred to be dense to very dense.

Representative samples suitable for laboratory testing were not obtained within this borehole, therefore characterization of the soil is based on visual observations.

BH17-73B

Well graded gravel with sand (GW) was encountered between 0.2 m and 8.2 m below ground surface. Due to the difficulty advancing the split spoon sampler and augers it has been inferred that there are frequent cobbles and boulders.

Due to the presence of cobbles and boulders the soil was cored using a NQ bit. Intermittent SPT samples were obtained for sampling and to measure blow counts. Very high SPT N-values (>100 blows per 0.1 m) measured in the soil are considered to be a result of the frequent cobbles and boulders and may not be representative of the relative density of the gravel and sand. Due to the difficult augering conditions observed, and requirement for coring of the soil, the relatively density is inferred to be dense to very dense.

Representative samples suitable for laboratory testing were not obtained within this borehole, therefore characterization of the soil is based on visual observations.

BH17-74B

Well graded gravel with sand (GW) was encountered between 0.6 m and 7.9 m below ground surface. Due to the difficulty advancing the split spoon sampler and augers it has been inferred that there are frequent cobbles and boulders.

Due to the presence of cobbles and boulders the soil was cored using a NQ bit. Intermittent SPT samples were obtained for sampling and to measure blow counts. Very high SPT N-values (>50 blows per 0.01 m) measured in the soil are considered to be a result of the frequent cobbles and boulders and may not be representative of the relative density of the gravel and sand. Due to the difficult augering conditions observed, and requirement for coring of the soil, the relatively density is inferred to be dense to very dense.

Representative samples suitable for laboratory testing were not obtained within this borehole, therefore characterization of the soil is based on visual observations.

4.1.4 Bedrock

Bedrock was encountered in all four borings. The bedrock surface was encountered at an elevation of approximately 254 m to 255 m, or depths of 6.3 to 8.2 m below ground surface at the boring locations. The bedrock consisted predominantly of grey and white dolostone.
A detailed description of the rock core is provided in the Field Bedrock Core Logs in Appendix C. Rock core photographs are also provided in Appendix C.

Rock Quality Designation (RQD) values measured on the retrieved bedrock core ranged between 60% and 100%, indicating a poor to excellent rock mass quality. The Total Core Recovery (TCR) of the bedrock ranged from 85% to 100%. Weathering of the bedrock was described as fresh, no visible signs of weathering.

Unconfined compressive strength tests were carried out on four bedrock samples. The results of these tests are summarized in Table 4.1. The unconfined compressive strength tests results ranged between 92 MPa and 189 MPa, which indicates the bedrock is strong to very strong.

Table 4.1: Results of Unconfined Compressive Strength of Rock Cores

Borehole No	Depth (m)	Test Elevation (m)	Unconfined Compressive Strength (MPa)
BH17-71B	6.9 to 7.0	255.0	189
BH17-72B	10.5 to 10.6	250.7	114
BH17-73B	10.2 to 10.6	251.2	92
BH17-74B	9.6 to 9.7	254.6	127

4.2 PERMAFROST CONDITIONS

Infrared thermometer readings were taken of samples throughout the drilling. The readings ranged between +3.1 to +4.5°C, as indicated on the borehole logs (Appendix C).

Based on the visual examination and infrared thermometer readings of the recovered auger and split spoon samples, frozen soil conditions were inferred to depths of 0.5 m to 3.0 m below ground surface. The infrared thermometer was used during sampling when the soils have been heated by friction generated by the action of the drill. It was also observed during the field work the sample temperatures taken when exposed to very cold air temperatures also displayed erratic values. Therefore, the reported infrared temperature readings should be used with caution.

Thermistor readings are considered to be a more reliable indication of the temperature of the soils compared to the infrared thermometer readings. Thermistors were installed in each of the four borings (BH17-71B to BH17-74B) between March 26 and 28, 2017. The resistance versus temperature table for the thermistors is included in Appendix E. Several readings were taken between the installation date and April 2, 2017 and are plotted in Figures 3 to 6 in Appendix E.

The April 2, 2017 thermistor readings from BH17-71B indicate that the soil temperature ranges from +0.5 to -1.9°C and is frozen to a depth of approximately 4.5 m (see Figure 3, Appendix E). The thermistor readings from BH17-72B indicate that the temperatures range between +0.8 and +4.0°C and is unfrozen to a depth of approximately 8 m (see Figure 4, Appendix E). The thermistor readings obtained from BH17-73B (see Figure 5, Appendix E) indicate that the temperatures are between +0.4°C and +3.8°C and the soil/bedrock is unfrozen to a depth of approximately 11.3 m. The thermistor readings obtained at BH17-74B (Figure 6, Appendix E) indicate that the soils are just above 0°C near surface but increase to1.5°C and is unfrozen to a depth of approximately 7.3 m. Given the proximity of the boreholes to the active river channel (particularly boreholes BH17-72B and BH17-73B) unfrozen conditions are expected.

The results suggest that permafrost conditions are likely not present at the proposed location of the piers at Crossing #15 at the La Martre River, due to the warming influence of the river. It is likely that the warmer than typical ground temperatures at depth are the result of thermal warming due to the long-term presence of the river with year-round flowing water at temperatures above freezing. These “positive” temperatures, over time, created a large warm bulb below the river channel and within the floodplain where the river channel has migrated over the millennium. Permafrost is likely present at the south abutment (BH17-71B) but not present at the north abutment (BH17-74B). It is likely that the thermal regime at the borehole locations had not reached equilibrium between the installation and reading dates, therefore additional readings are recommended to confirm permafrost occurrence.

4.3 GROUNDWATER

Groundwater was encountered at a depth of 3.0 m and 0.6 m below the ground surface at the time of drilling in boreholes BH17-71B and BH17-74B, respectively. Groundwater was not observed at the remaining two boreholes within the drilling depths. The groundwater depths observed during the drilling are summarized in Table 4.2.

The groundwater levels were recorded in winter conditions and will likely vary seasonally. Changes in the groundwater, and the water levels of the La Martre River, due to seasonal fluctuations in response to precipitation events should be anticipated. In permafrost terrain, groundwater will be confined to the seasonal active layer or immediately below the permafrost.

Table 4.2: Summary of Groundwater Levels

Borehole No.	Observation/Measurement Date	Groundwater Depth (m)	Ground Surface Elevation (m)	Groundwater Elevation (m)
BH17-71B	March 26, 2017	3.05	262.0	258.95
BH17-72B	March 27, 2017	Not observed	261.3	n/a
BH17-73B	March 28, 2017	Not observed	261.5	n/a
BH17-74B	March 27, 2017	0.6	262.1	261.5

4.4 CHEMICAL TEST RESULTS

One sample of the native overburden material from Borehole BH17-74B were tested for pH, water soluble sulphate and chloride concentrations, and resistivity at Maxxam Analytics. The analysis results are provided in Table 4.3 and in Appendix D.

Table 4.3: Results of Chemical Analysis

Borehole No	Sample No.	Depth (m)	pH	Chloride (%)	Sulphate (%)	Resistivity (Ohm-m)
BH17-74B	AS1	0.0 to 2.6	7.3	0.0027	0.0049	24

5.0 CLOSURE

Use of this report is subject to the Statement of General Conditions provided in Appendix A. It is the responsibility of Tlicho Engineering and Environmental Services Ltd., who is identified as "the Client" within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec Consulting Ltd. should any of these not be satisfied. The Statement of General Conditions addresses the following:

- Use of the report
- Basis of the report
- Standard of care
- Interpretation of site conditions
- Varying or unexpected site conditions
- Planning, design or construction

This report was written by Sylvia Dooley, M.ScE. and reviewed by Christopher McGrath, P.Eng. and Jim Oswell, P.Eng. Mr. McGrath and Dr. Oswell are registered members of the Northwest Territories and Nunavut Association of Professional Engineers and Geoscientists. We trust that the information contained in this report is adequate for your present purposes. If you have any questions about the contents of the report or if we can be of any other assistance, please contact us at your convenience.

STANTEC CONSULTING LTD.

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6.0 REFERENCES

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2009a. Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) (ASTM D2488). ASTM International, West Conshohocken, PA.

ASTM . 2009b. DRAFT New Practice for Handling, Transportation, and Storage of Frozen Soil and Rock Samples (ASTM WK24243). ASTM International, West Conshohocken, PA.

ASTM. 2010. Standard Terminology Relating to Frozen Soil and Rock (ASTM D7099). ASTM International, West Conshohocken, PA.

ASTM. 2011. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

ASTM. 2016. Standard Practice for Description of Frozen Soils (Visual-Manual Procedure) (ASTM D4083). ASTM International, West Conshohocken, PA.

BGC Engineering Inc. 2011. Highway 3 – Climate Change Vulnerability Assessment – Final Report.

Canadian Standards Association (CSA). 2010. Technical Guide Infrastructure in permafrost: A guideline for climate change adaptation. Canadian Standards Association, Mississauga, ON, Canada.

Dillon Consulting Ltd. 2007. Climate Change and Transportation in the NWT. March 2007.

Environment Canada. Warming Trends °C/Decade, Based on homogenized temperature data – the most recent 30 yr record (1981 – 2010); Environment Canada.

Environment Canada. (2016, September 1) Canadian Climate Normals 1981–2010. Yellowknife Station. Retrieved from http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProv&lstProvince=NT&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=1706&dispBack=0

GNWT, 2009. Ecosystem Classification Group (ECG) 2009. Ecological Regions of the Northwest Territories: Taiga Shield. Department of Environment and Natural Resources, GNWT. Yellowknife, NT.

GNWT DOT, 2016. Proposed Tlicho All-season Road, Project Description Report. March 2016

Heginbottom, J.A., Dubreuil, M.A., and P.A. Harker. 1995. Canada-Permafrost; National Atlas of Canada, 5th edition, Plate 2.1. Geomatics Canada, National Atlas Information Service and Geological Survey of Canada (MCR 4177).

Kavik AXYS Inc. 2008a. Multi-Level Mapping and Route Analysis – Tlicho Transportation Corridor. Route Identification and Evaluation. Yellowknife, NT. January 2008.Project No. Project No. 144902005.

Okulitch, A.V. 2004. Geological compilation of Phanerozic Bedrock Geology (Map NP-11/12-G), Slave River District of MacKenzie, Northwest Territories. Geological Survey of Canada, Open File 5281.

Stantec, 2015.Tli Cho Road Alignment, Hydrologic and Hydraulic Study. Project No. 144902005.

Wolfe, 1998. Living with frozen ground : a field guide to permafrost in Yellowknife, Northwest Territories, edited by Stephen A. Wolfe ; contributions by Stephen A. Wolfe

S.A. Wolfe, P.D. Morse, T.E. Hoeve, W.E Sladen, S.V. Kokelj, L.U. Arenson, 2015. Disequilibrium permafrost conditions on NWT Highway 3

7.0 BIBLIOGRAPHY

Andersland, O.B., and Ladanyi, B. 1994. An Introduction to Frozen Ground Engineering. Chapman & Hall Inc., New York, NY, USA.

Canadian Foundation Engineering Manual (CFEM). 2006. Fourth Edition. Canadian Geotechnical Society, 488 p.

CHBDC. 2014. Canadian Highway Bridge Design Code. Canadian Standards Association, Mississauga, Ontario.

GSC, 1965. Glacial Lake McConnell and the surficial geology of parts of Slave River and Redstone River map areas, District of Mackenzie; Craig, B G. Geological Survey of Canada, Bulletin 122, 1965,; 44 pages, doi:10.4095/100639. Natural Resources Canada. 1995: Canada Permafrost; The National Atlas of Canada 5th Edition, scale 1:7 500 000.

GSC, 1989. Glacial Features Around the Keewatin Ice Divide, Northwest Territories; Aylsworth, J M; Shilts, W. Geological Survey of Canada, Preliminary Map 24-1987, 1989, ; 2 sheets, doi:10.4095/126992.

Kerr and Wilson, 2000. 2000-C3. Preliminary surficial geology studies and mineral exploration considerations in the Yellowknife area, Northwest Territories. D.E. Kerr and P. Wilson.

APPENDIX A

Statement of General Conditions

STATEMENT OF GENERAL CONDITIONS

<u>USE OF THIS REPORT</u>: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec Consulting Ltd. and the Client. Any use which a third party makes of this report is the responsibility of such third party.

<u>BASIS OF THE REPORT</u>: The information, opinions, and/or recommendations made in this report are in accordance with Stantec Consulting Ltd.'s present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec Consulting Ltd. is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

<u>STANDARD OF CARE</u>: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

<u>INTERPRETATION OF SITE CONDITIONS</u>: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec Consulting Ltd. at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

<u>VARYING OR UNEXPECTED CONDITIONS</u>: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec Consulting Ltd. must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec Consulting Ltd. will not be responsible to any party for damages incurred as a result of failing to notify Stantec Consulting Ltd. that differing site or sub-surface conditions are present upon becoming aware of such conditions.

<u>PLANNING, DESIGN, OR CONSTRUCTION</u>: Development or design plans and specifications should be reviewed by Stantec Consulting Ltd., sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec Consulting Ltd. cannot be responsible for site work carried out without being present.

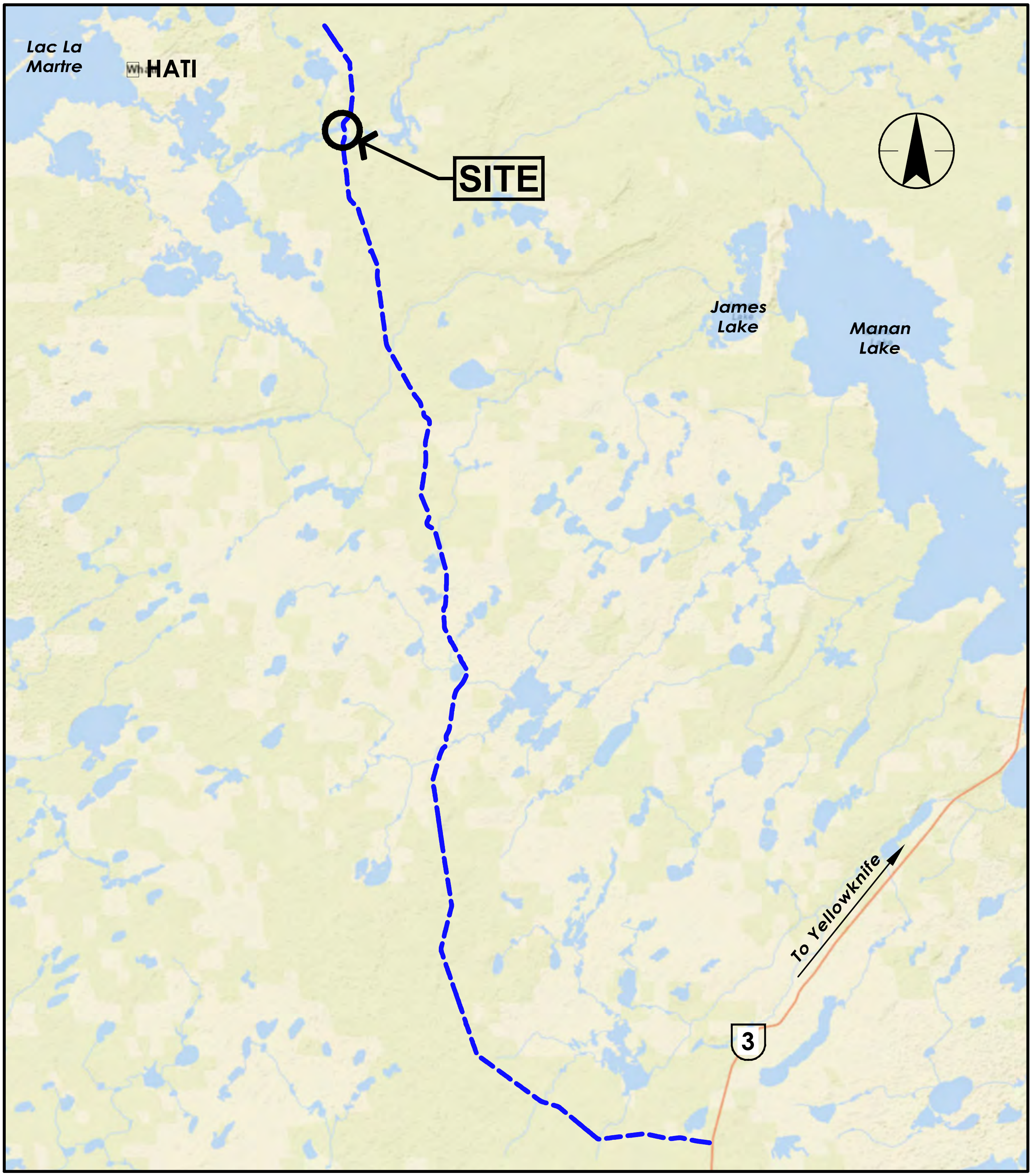
APPENDIX B

Drawing No. 1 – Site Location Plan

Drawing No. 2 - Borehole Location Plan

Drawing No. 3 – Subsurface Profile

Site Photos



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CROSSING #15 LA MARTRE RIVER, NWT

Drawing No.

1

Title

□EY PLAN

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LEGEND

PROPOSED ALIGNMENT

NOTES

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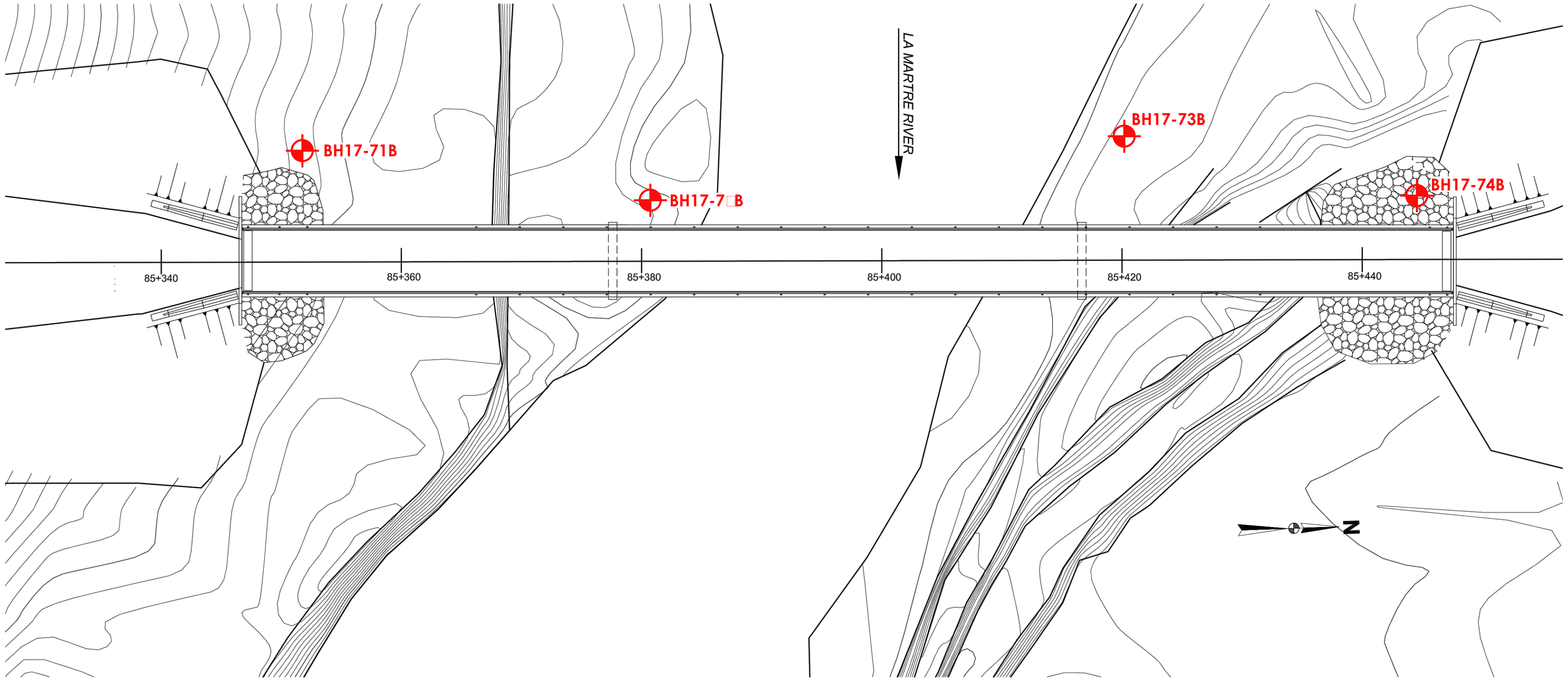

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PLAN
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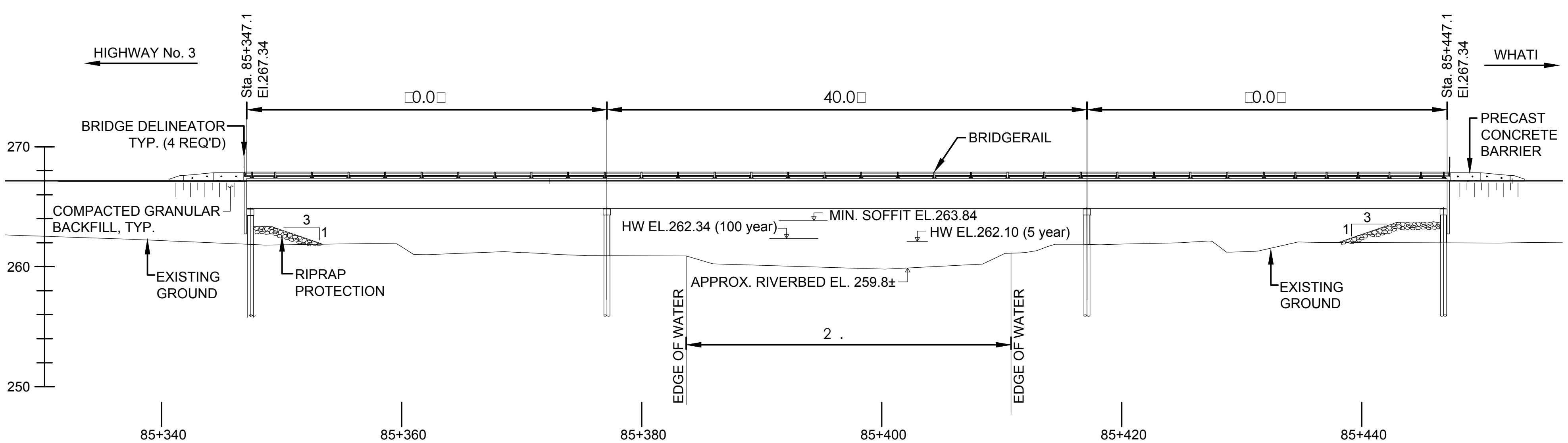

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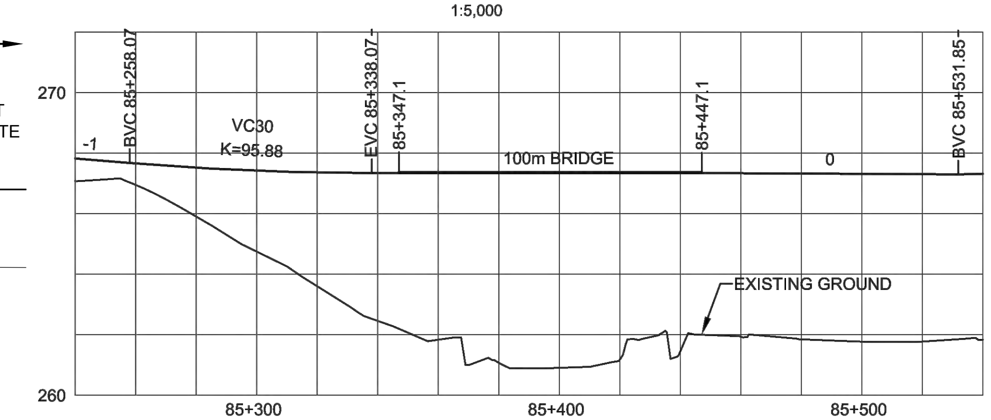

ROADWAY PROFILE
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PROJECT No. 144902448

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LEGEND

APPROXIMATE BOREHOLE LOCATION

NOTES

1. DRAWING PROVIDED BY DOT TECHNICAL SERVICES (TASR-08-16 CROSSING#15).

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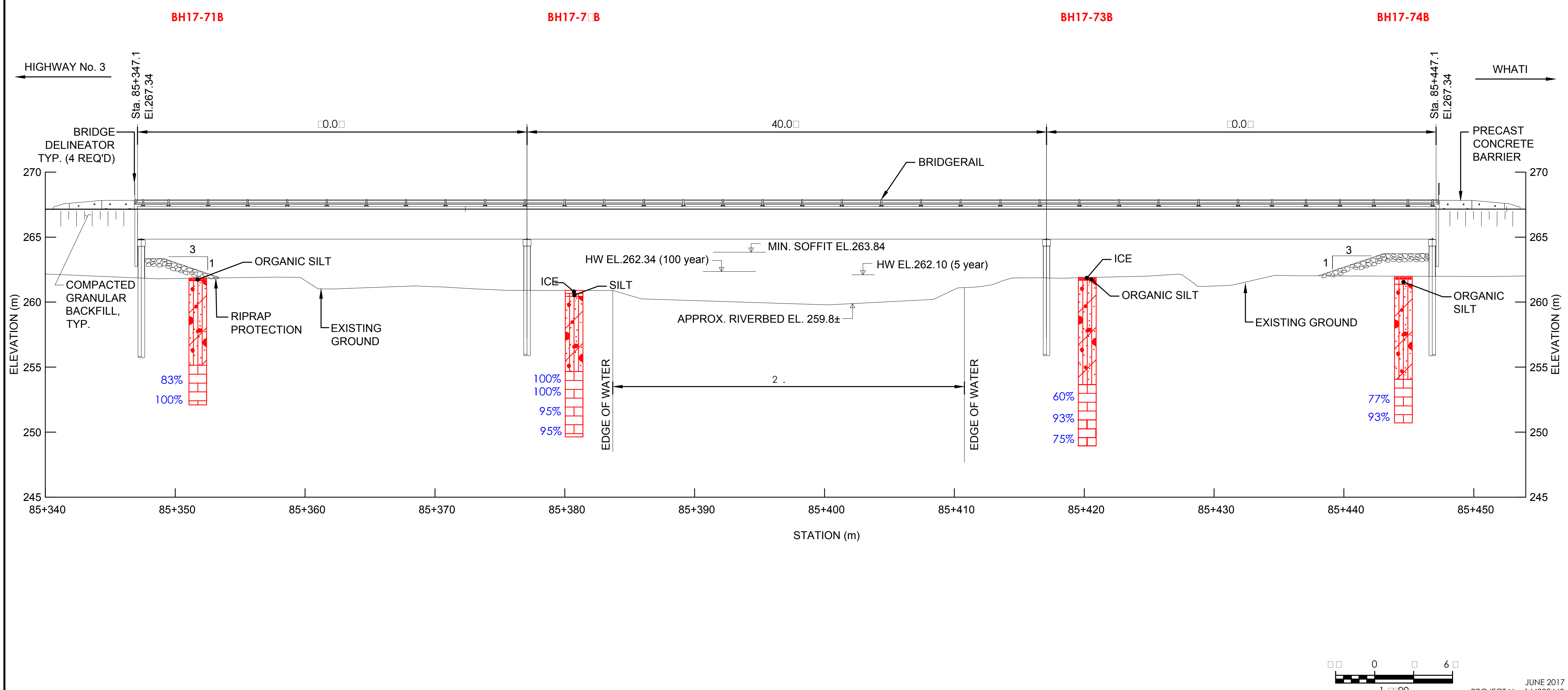
BRIDGE CROSSING #15, LA MARTRE RIVER, NWT

Drawing No.

2

Title

GENERAL LAYOUT AND BOREHOLE LOCATION PLAN



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LEGEND

- □9□ R□D (ROC□ □UALITY DESIGNATION)
- SANDY SILT (ML)
- □LUVIAL □GRAVEL WITH SAND (GW). □RE□UENT COBBLES AND BOULDERS
- DOLOSTONE

NOTES

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Drawing No.
□

Title

SUBSUR□ACE PRO□ILE

Photo No. 1: Borehole Location BH17-71B

Photo No. 2: Borehole Location BH17-71B

Photo No. 3: Borehole Location BH17-72B

Photo No. 4: Borehole Location BH17-72B

Photo No. 5: Borehole Location BH17-73

Photo No. 6: Borehole Location BH17-74B

Photo No. 5: Borehole Location BH17-74B, facing NW

APPENDIX C

Symbols and Terms Used on Borehole Records

Stantec Borehole Records

Field Bedrock Core Logs

Bedrock Core Photos

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

Rootmat	- vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
Topsoil	- mixture of soil and humus capable of supporting vegetative growth
Peat	- mixture of visible and invisible fragments of decayed organic matter
Till	- unstratified glacial deposit which may range from clay to boulders
Fill	- material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

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

Terminology describing soil types:
The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4th Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):
Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

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

Terminology describing compactness of cohesionless soils:
The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. A relationship between compactness condition and N-Value is shown in the following table.

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

Terminology describing consistency of cohesive soils:
The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	Undrained Shear Strength		Approximate SPT N-Value
	kips/sq.ft.	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25 - 0.5	12.5 - 25	2-4
Firm	0.5 - 1.0	25 - 50	4-8
Stiff	1.0 - 2.0	50 – 100	8-15
Very Stiff	2.0 - 4.0	100 - 200	15-30
Hard	>4.0	>200	>30

ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Terminology describing rock quality:

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

Alternate (Colloquial) Rock Mass Quality	
Very Severely Fractured	*Crushed*
Severely Fractured	*Shattered or Very Blocky*
Fractured	*Blocky*
Moderately Jointed	*Sound*
Intact	*Very Sound*

RQD (Rock Quality Designation) denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 in.) long are summed and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

SCR (Solid Core Recovery) denotes the percentage of solid core (cylindrical) retrieved from a borehole of any orientation. All pieces of solid (cylindrical) core are summed and divided by the total length of the core run (It excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

Fracture Index (FI) is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

Terminology describing rock with respect to discontinuity and bedding spacing:

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

Terminology describing rock strength:

Strength Classification	Grade	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	<1
Very Weak	R1	1 – 5
Weak	R2	5 – 25
Medium Strong	R3	25 – 50
Strong	R4	50 – 100
Very Strong	R5	100 – 250
Extremely Strong	R6	>250

Terminology describing rock weathering:

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

STRATA PLOT

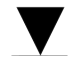
Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.

Boulders Cobbles Gravel	Sand	Silt	Clay	Organics	Asphalt	Concrete	Fill	Igneous Bedrock	Meta-morphic Bedrock	Sedi-mentary Bedrock

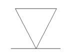
SAMPLE TYPE

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

WATER LEVEL MEASUREMENT



measured in standpipe, piezometer, or well



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RECOVERY

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

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to ‘A’ size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

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

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

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BOREHOLE RECORD

N: 6 997 742 E: 501 212

BH17-71B

CLIENT Tlicho Engineering and Environmental Services Ltd. BOREHOLE No. BH17-71B

LOCATION Northwest Territories, Canada PROJECT No. 144902448

DATES: BORING March 26, 2017 WATER LEVEL March 26, 2017 DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	262.00							
	261.8	Frozen, organic SILT (OL)						
		Dense to very dense, grey, well graded GRAVEL with sand (GW) - Frequent cobbles and boulders - Ground ice description: Vr (to 3.0 m) - Approx. sample temperature: SS2: +4.5°C			AS	1		
					SS	2	50	100/75mm
3				∇	NQ	3	40%	
					NQ	4	0%	
4					SS	5	178	50/100mm
					NQ	6	75%	
5					NQ	7	64%	
6					NQ	8	79%	
					NQ	9	100%	
	255.3	Good to excellent quality, light grey DOLOSTONE - See Field Bedrock Core Logs for details			NQ	10	100%	83%
9					NQ	11	100%	100%
	252.2	End of Borehole						
10								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

▣ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd

Date

Stantec

BOREHOLE RECORD

N: 6 997 771 E: 501 216

BH17-72B

CLIENT Tlicho Engineering and Environmental Services Ltd. BOREHOLE No. BH17-72B

LOCATION Northwest Territories, Canada PROJECT No. 144902448

DATES: BORING March 27, 2017 WATER LEVEL N/A DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	261.30							
	261.1	240 mm ICE			AS	1	-	
	260.9	Frozen, brown, sandy SILT (ML)			SS	2	100%	100/64mm
1		Dense to very dense, grey to black, well graded GRAVEL with sand (GW) - Frequent cobbles and boulders			AS	3		
2		- Ground ice description: Vr (to 1.2 m)						
		- Approx. sample temperature: SS2: +3.1°C			SS	4	127	140/127mm
3					NQ	5	78%	
					NQ	6	83%	
4					NQ	7	30%	
5		- firm, grey, clay matrix observed at approximately 4.0 m			NQ	8	22%	
6	255.1				NQ	9	67%	
		Good to excellent quality, light grey DOLOSTONE			NQ	10	89%	100%
7		- See Field Bedrock Core Logs for details			NQ	11	100%	100%
8								
9					NQ	12	100%	95%
10								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

Inferred Groundwater Level

Groundwater Level Measured in Standpipe

Field Vane Test, kPa

Remoulded Vane Test, kPa

Pocket Penetrometer Test, kPa

App'd ________

Date ________

BOREHOLE RECORD

N: 6 997 771 E: 501 216

BH17-72B

CLIENT Tlicho Engineering and Environmental Services Ltd.
BOREHOLE No. BH17-72B

LOCATION Northwest Territories, Canada
PROJECT No. 144902448

DATES: BORING March 27, 2017 WATER LEVEL N/A
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD	UNDRAINED SHEAR STRENGTH - kPa
10					NQ	13	100%	95%	
11	250.0								
		End of Borehole							
12									
13									
14									
15									
16									
17									
18									
19									
20									

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS: W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

▣ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ________

Date ________

Stantec

BOREHOLE RECORD

N: 6 997 811 E: 501 212

BH17-73B

CLIENT Tlicho Engineering and Environmental Services Ltd. BOREHOLE No. BH17-73B

LOCATION Northwest Territories, Canada PROJECT No. 144902448

DATES: BORING March 28, 2017 WATER LEVEL N/A DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	**261.53**							
	261.4	80 mm ICE			AS	1		
	261.3	Frozen SILT (ML) - auger refusal at 0.2 m						
1–8		Dense to very dense, grey, well graded GRAVEL with sand (GW) - Frequent cobbles and boulders - Advance casing to 2.6 m - Ground ice description: Vr (to 0.5 m)						
					SS	2	50	100/150mm
					NQ	3	13%	
					NQ	4	20%	
					NQ	5	20%	
					NQ	6	50%	
8	253.3	Fair to excellent quality, light grey DOLOSTONE - See Field Bedrock Core Logs for details			NQ	7	88%	60%
10								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

▣ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Stantec

BOREHOLE RECORD

N: 6 997 811 E: 501 212

BH17-73B

CLIENT Tlicho Engineering and Environmental Services Ltd.
BOREHOLE No. BH17-73B
LOCATION Northwest Territories, Canada
PROJECT No. 144902448
DATES: BORING March 28, 2017 WATER LEVEL N/A
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
10					NQ	8	100%	93%
11								
12					NQ	9	100%	75%
13	248.6	End of Borehole						
14								
15								
16								
17								
18								
19								
20								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS: W_P, W, W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

Inferred Groundwater Level

Groundwater Level Measured in Standpipe

Field Vane Test, kPa

Remoulded Vane Test, kPa

Pocket Penetrometer Test, kPa

App'd

Date

Stantec

BOREHOLE RECORD

N: 6 997 837 E: 501 217

BH17-74B

CLIENT: Tlicho Engineering and Environmental Services Ltd.
BOREHOLE No.: BH17-74B
LOCATION: Northwest Territories, Canada
PROJECT No.: 144902448
DATES: BORING: March 27, 2017 WATER LEVEL: March 27, 2017
DATUM: Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	WATER LEVEL	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	262.08	Frozen, dark brown, organic SILT (OL)		AS	1		
	261.5	Dense to very dense, grey, well graded GRAVEL with sand (GW) - Frequent cobbles and boulders - split spoon refusal at 0.64 m - auger refusal at 0.64 m, advance casing to 2.1 m	∇	~~SS~~	~~2~~		~~50/25mm~~
				NQ	3	42%	
		- attempted split spoon at 3.66 m, 50 blows/0 mm, no sample obtained		NQ	4	30%	
				NQ	5	63%	
				NQ	6	46%	
				NQ	7	58%	27%
	254.2	Poor to excellent quality, light grey DOLOSTONE - No sample obtained between 8.2 and 8.5 m - See Field Bedrock Core Logs for details		NQ	8	85%	77%
10							

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ______
Date ______

Stantec

BOREHOLE RECORD

N: 6 997 837 E: 501 217

BH17-74B

CLIENT Tlicho Engineering and Environmental Services Ltd.

BOREHOLE No. BH17-74B

LOCATION Northwest Territories, Canada

PROJECT No. 144902448

DATES: BORING March 27, 2017 WATER LEVEL March 27, 2017

DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY (mm)	SAMPLES: N-VALUE OR RQD
10					NQ	9	100%	93%
11	250.8	End of Borehole						
12								
13								
14								
15								
16								
17								
18								
19								
20								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

▣ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ________

Date ________

Field Bedrock Core Log

Stantec

Client: Tlicho E&E Services Ltd.
Project: Tlicho All Season Road
Contractor: Northtech Drilling Ltd.

Project No.: 144902448
Date: 26-Mar-17
Borehole No.: BH17-71B
Logger: JMO/JRD

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
6.7	NQ 10	100	83	8.2	Good quality, light grey dolostone	R5	W1	1	JN	F	C	RU	G	none		
8.2	NQ 11	100	100	9.8	Excellent quality, light grey dolostone	R5	W1	1	JN	F	C-M	RU	G	none		

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

JOINT APERTURE

C = Closed = < 0.5 mm
G = Gapped = 0.5 to 10 mm
O = Open = > 10 mm

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
3	RU = Rough, Irregular, Undulating
1.5	SU = Smooth, Undulating
1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

Stantec

Field Bedrock Core Log

Client:	Tlicho E&E Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	27-Mar-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-72B
		Logger:	JMO/JRD

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
6.2	NQ 10	89	100	6.7	Excellent quality, grey dolostone	R5	W1	1	JN	F	C	RU	G	None		
6.7	NQ 11	100	95	8.2	Excellent quality, grey, dolostone	R5	W1	1	JN	F	C	RU	G	None		
8.2	NQ 12	100	95	9.8	Excellent quality, grey, dolostone	R5	W1	1	JN	F	C	RU	G	None		
9.8	NQ 13	100	80	11.3	Good quality, grey, dolostone	R5	W1	1	JN	F	G	RU	G	None		

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

JOINT APERTURE

C = Closed = < 0.5 mm
G = Gapped = 0.5 to 10 mm
O = Open = > 10 mm

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
3	RU = Rough, Irregular, Undulating
1.5	SU = Smooth, Undulating
1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

Field Bedrock Core Log

Client:	Tlicho E&E Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	28-Mar-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-73B
		Logger:	JMO/JRD

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
8.2	NQ 7	88	60	9.8	Fair quality, grey dolostone	R4	W1	1	JN	F	C	RU	G	None		
9.8	NQ 8	100	93	11.3	Excellent quality, grey, dolostone	R4	W1	1	JN	F	C	RU	G	None		
11.3	NQ 9	100	75	12.8	Good quality, grey, dolostone	R4	W1	1	JN	F	C	RU	G	None		

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

JOINT APERTURE

C = Closed = < 0.5 mm
G = Gapped = 0.5 to 10 mm
O = Open = > 10 mm

FILLING

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

WEATHERING

Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
3	RU = Rough, Irregular, Undulating
1.5	SU = Smooth, Undulating
1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar

Stantec

Field Bedrock Core Log

Client:	Tlicho E&E Services Ltd.	**Project No.:**	144902448
Project:	Tlicho All Season Road	**Date:**	28-Mar-17
Contractor:	Northtech Drilling Ltd.	**Borehole No.:**	BH17-74B
		Logger:	JMO/JRD

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
7.5	NQ 7	n/a	n/a	8.5	Grey dolostone	n/a	n/a	n/a	JN	F	C	RU	G	none		
8.5	NQ 8	85	77	9.8	Excellent quality, grey, dolostone	R5	W1	1	JN	F	C	RU	G	none		
9.8	NQ 9	100	93	11.3	Excellent quality, grey, dolostone	R5	W1	1	JN	F	C	RU	G	none		

STRENGTH (MPa)

Grade/Classification	Est. Strength (MPa)
R0 Extremely Week	0.25 - 1.0
R1 Very Weak	1.0 - 5.0
R2 Weak	5.0 - 25.0
R3 Medium Strong	25.0 - 50.0
R4 Strong	50.0 - 100.0
R5 Very Strong	100.0 - 250.0
R6 Extremely Strong	>250.0

JOINT TYPE

BD = Bedding
JN = Joint
FOL = Foliation
CON = Contact
FLT = Fault
VN = Vein

ORIENTATION

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

JOINT APERTURE

C = Closed = < 0.5 mm
G = Gapped = 0.5 to 10 mm
O = Open = > 10 mm

FILLING

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

WEATHERING

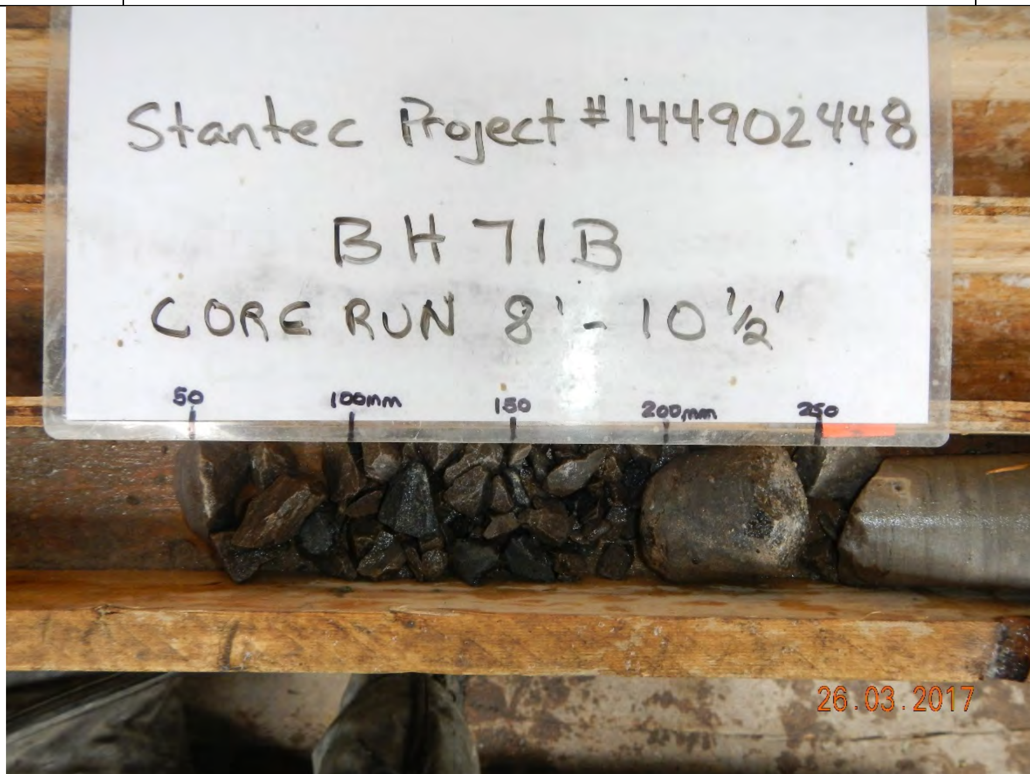
Grade/Classification	Description
W1 Fresh	No Visible Signs of Weathering
W2 Slightly	Discoloration, Weathering on Discontinuities
W3 Moderately	<50% of Rock Material is Decomposed, Fresh Core Stones
W4 Highly	>50% Decomposed to soil: Fresh Core Stones
W5 Completely	100% Decomposed to Soil: Original Structure Intact
W6 Residual Soil	All Rock Converted to Soil, Structure and Fabric Destroyed

DISCONTINUITY SPACING

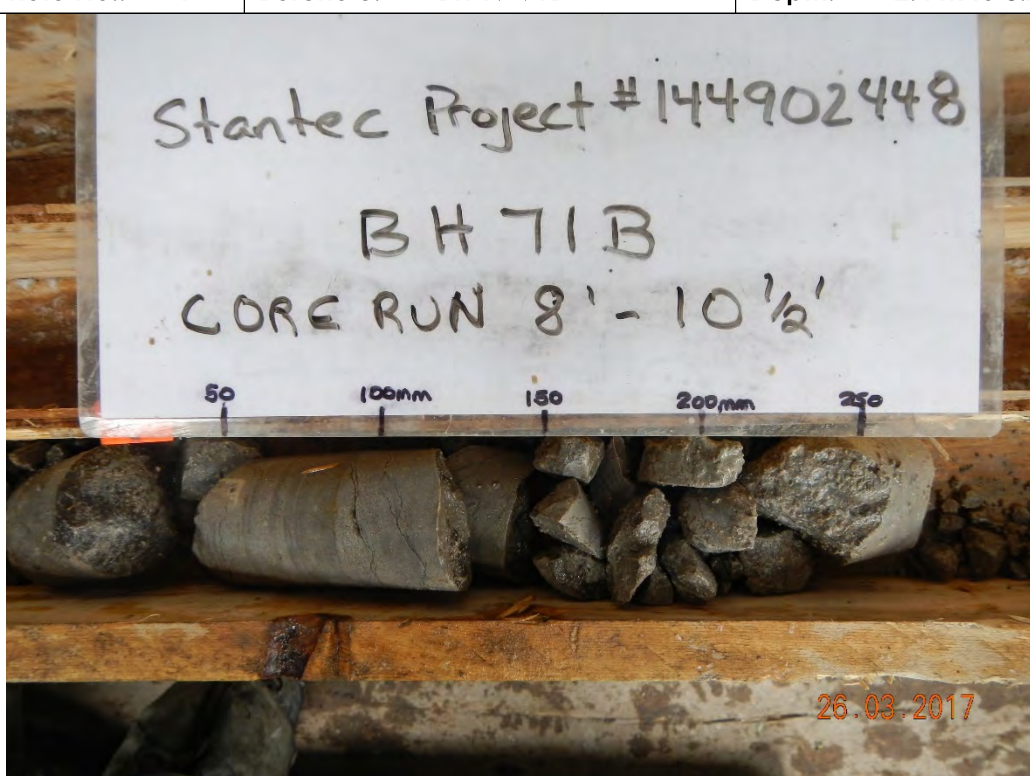
Spacing (mm)	
EW = >6000	Extremely Wide
VW = 2000 - 6000	Very Wide
W = 600 - 2000	Wide
M = 200 - 600	Moderate
C = 60 - 200	Close
VC = 20 - 60	Very Close
EC = <20	Extremely Close

JOINT ROUGHNESS

Jr	Description
4	DJ = Discontinuous Joints
3	RU = Rough, Irregular, Undulating
1.5	SU = Smooth, Undulating
1.5	LU = Slickensided, Undulating
1.0	RP = Rough or Irregular, Planar
0.5	SP = Smooth, Planar
2	LP = Slickensided, Planar



Rock Core Photo No.: 1	Borehole: BH 17-71B	Depth: 2.4 m to 3.2 m



Rock Core Photo No.: 2	Borehole: BH 17-71B	Depth: 2.4 m to 3.2 m

Stantec	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #15	

Rock Core Photo No.: 3	Borehole: BH 17-71B	Depth: 4.3 m to 4.9 m

Rock Core Photo No.: 4	Borehole: BH 17-71B	Depth: 5.8 m to 6.4 m

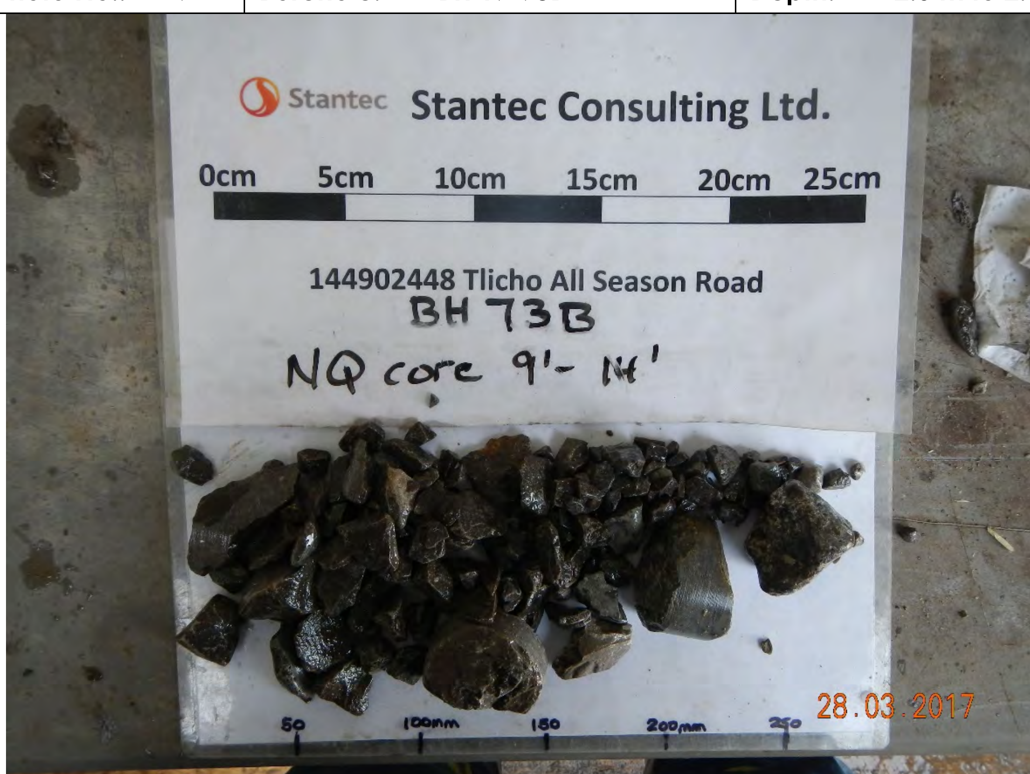
Stantec	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #15	

Rock Core Photo No.: 5	Borehole: BH 17-71B	Depth: 6.4 m to 9.8 m

Rock Core Photo No.: 6	Borehole: BH 17-72B	Depth: 6.2 to 10.6 m

Stantec	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #15	

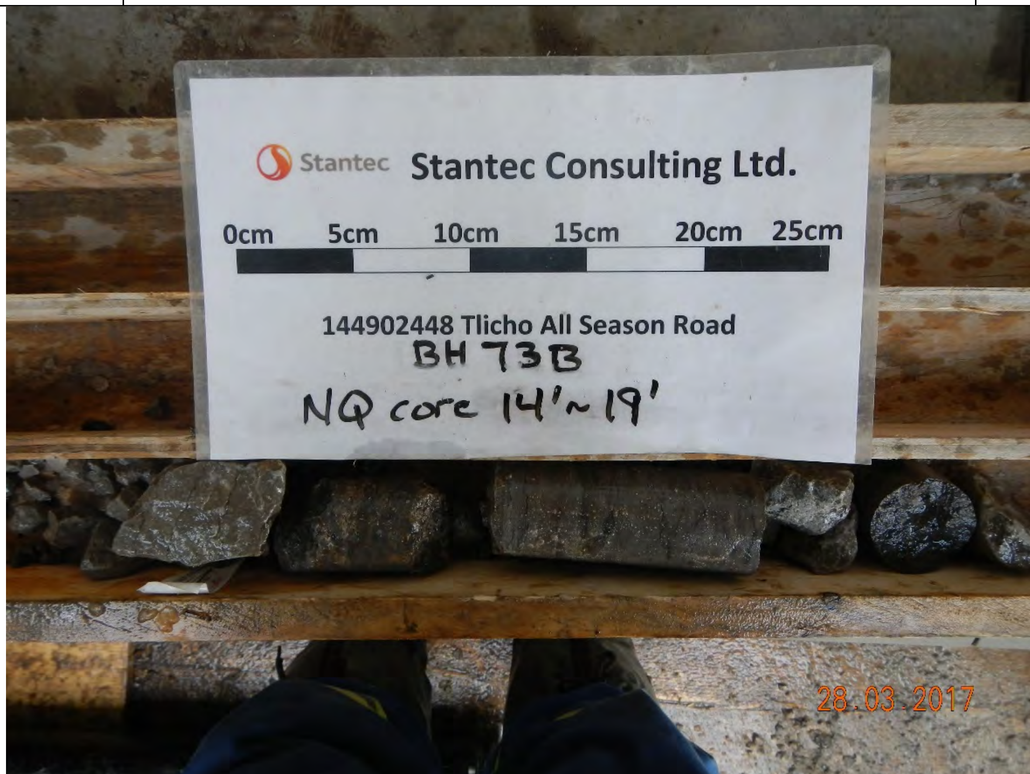
Rock Core Photo No.: 7	Borehole: BH 17-73B	Depth: 2.6 m to 2.7 m



Rock Core Photo No.: 8	Borehole: BH 17-73B	Depth: 2.7 m to 4.3 m

V:\01216\active\other_pc_projects\144902448\05_report_deliv\draft_doc\Crossing 15 La Martre River\Data Report\Appendices\Appendix C\3_crossing_15_rock_core_photo_pages.docx

	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #15	



Rock Core Photo No.: 9	Borehole: BH 17-73B	Depth: 4.3 m to 5.8 m

Rock Core Photo No.: 10	Borehole: BH 17-73B	Depth: 5.8 m to 7.3 m

	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #15	

Rock Core Photo No.:	11	Borehole:	BH 17-73B	Depth:	7.3 m to 7.9 m

Rock Core Photo No.:	12	Borehole:	BH 17-73B	Depth:	Approx. 7.9 m

Rock Core Photo No.:	13	Borehole:	BH 17-73B	Depth:	Approx. 7.9 m

Rock Core Photo No.:	14	Borehole:	BH 17-73B	Depth:	8.2 to 9.8 m

Stantec	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #15	

Rock Core Photo No.: 15	Borehole: BH 17-74B	Depth: 2.1 m to 3.7 m

Rock Core Photo No.: 16	Borehole: BH 17-74B	Depth: 3.7 m to 5.2 m

Stantec	Project No.: 144902448	Rock Core Photographs
	Project Name: Tlicho All Season Road – Crossing #15	

Rock Core Photo No.:	17	Borehole:	BH 17-74B	Depth:	5.2 m to 6.4 m

Rock Core Photo No.:	18	Borehole:	BH 17-74B	Depth:	6.4 to 11.3 m

APPENDIX D

Laboratory Test Results

Grain Size Analysis

ASTM C136, ASTM C117

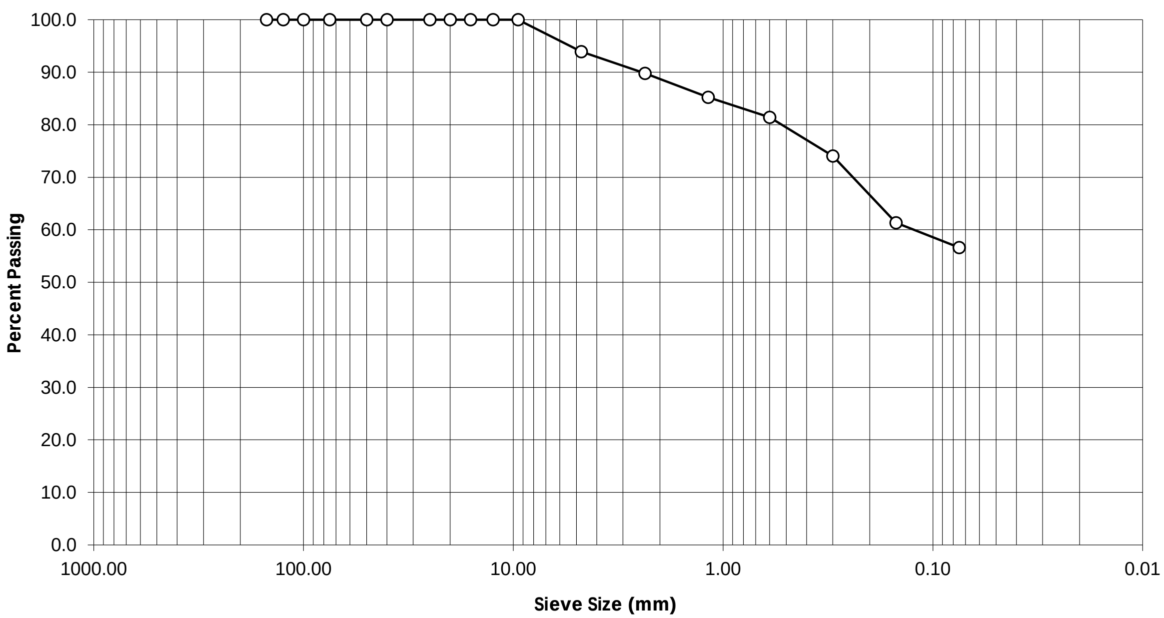
Client: Tlicho Engineering & Environmental Services
Project Name: Tlicho AllSeason Rd. Investig.
Project No: 144902448

OFFICE
10160 - 112 ST
Edmonton, Alberta
Canada T5K 2L6
Tel: (780) 917-7000

LABORATORY
10575 106 ST
Edmonton, Alberta
Canada T5H 2X5
Tel: (780) 917-7463

SAMPLE No.: 0.3 - 0.46 m
SOURCE: BH17-72B
TESTED BY: NN

DATE RECEIVED: March 27, 2017
DATE TESTED: April 14, 2017
SAMPLE DESCRIPTION: Sandy silt (ML)



Sieve (mm)	Sample % Passing	Specifications Lower	Specifications Upper
150.0	100.0	-	-
125.0	100.0	-	-
100.0	100.0	-	-
75.0	100.0	-	-
50.0	100.0	-	-
40.0	100.0	-	-
25.0	100.0	-	-
20.0	100.0	-	-
16.0	100.0	-	-
12.5	100.0	-	-
9.5	100.0	-	-
4.75	93.9	-	-
2.36	89.8	-	-
1.18	85.2	-	-
0.600	81.4	-	-
0.300	74.1	-	-
0.150	61.4	-	-
0.075	56.6	-	-

Cobble:	0.0%	D_{10}:	-
Gravel:	6.1%	D_{30}:	-
Sand:	37.3%	D_{60}:	0.1290
Fines:	56.6%	C_u:	-
		C_c:	-

Comments:

Figure 1

Reviewed by:

Grain Size Analysis

ASTM C136, ASTM C117

Client: Tlicho Engineering & Environmental Services

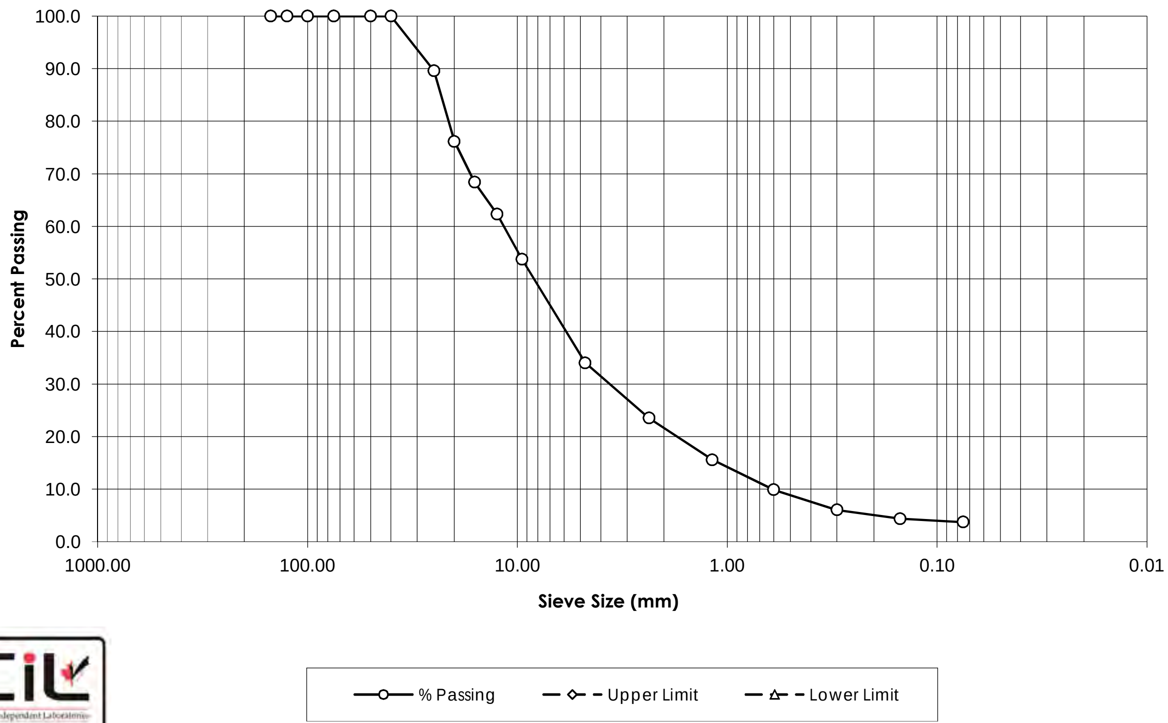
Project Name: Tlicho AllSeason Rd.Investig.

Project No: 144902448

OFFICE	LABORATORY
10160 - 112 ST	10575 106 ST
Edmonton, Alberta	Edmonton, Alberta
Canada T5K 2L6	Canada T5H 2X5
Tel: (780) 917-7000	Tel: (780) 917-7463

SAMPLE No.: SS5
SOURCE: BH17-71B
TESTED BY: RP

DATE RECEIVED: March 27, 2017
DATE TESTED: April 14, 2017
SAMPLE DESCRIPTION: Well graded gravel with sand (GW)



Sieve (mm)	Sample % Passing	Specifications Lower	Specifications Upper
150.0	100.0	-	-
125.0	100.0	-	-
100.0	100.0	-	-
75.0	100.0	-	-
50.0	100.0	-	-
40.0	100.0	-	-
25.0	89.6	-	-
20.0	76.2	-	-
16.0	68.4	-	-
12.5	62.3	-	-
9.5	53.7	-	-
4.75	34.0	-	-
2.36	23.5	-	-
1.18	15.6	-	-
0.600	9.9	-	-
0.300	6.1	-	-
0.150	4.4	-	-
0.075	3.7	-	-

Cobble:	0.0%	D_{10}:	0.6161
Gravel:	66.0%	D_{30}:	3.9331
Sand:	30.3%	D_{60}:	11.7339
Fines:	3.7%	C_u:	19.05
		C_c:	2.14

CERTIFIED BY CCIL Canadian Council of Independent Laboratories For specific tests as listed on www.ccil.com

Comments:

Figure 2

Reviewed by:

Maxxam
A Bureau Veritas Group Company

Success Through Science®

Your Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Your C.O.C. #: A174619

Attention:RYLEY PROZNIK

STANTEC CONSULTING LTD
10160-112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2017/04/20
Report #: R2371968
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B728026
Received: 2017/04/17, 14:30

Sample Matrix: Soil
Samples Received: 12

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Chloride (Soluble)	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00020	SM 22 4500-Cl G m
Resistivity	9	N/A	2017/04/18	AB WI-00065	Auto Calc
Conductivity @25C (Soluble)	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00004	SM 22 2510 B m
Total Organic Carbon by Combustion-Sub (1)	3	2017/04/20	2017/04/20		
pH @25C (Soluble)	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00006	SM 22 4500 H+B m
Soluble Ions	9	2017/04/18	2017/04/18	AB SOP-00033 / AB SOP-00042	EPA 200.7 CFR 2012 m
Soluble Paste	9	2017/04/18	2017/04/18	AB SOP-00033	Carter 2nd ed 15.2m
Soluble Ions Calculation	9	N/A	2017/04/18	AB WI-00065	Auto Calc

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
(1) This test was performed by Maxxam Ontario (From Edmonton)

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Maxxam
A Bureau Veritas Group Company

Success Through Science®

Your Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Your C.O.C. #: A174619

Attention:RYLEY PROZNIK

STANTEC CONSULTING LTD
10160-112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2017/04/20
Report #: R2371968
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B728026
Received: 2017/04/17, 14:30

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Wendy Sears, Project manager
Email: WSears@maxxam.ca
Phone# (403)735-2277
==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		QW8655	QW8656		QW8657		QW8658		
Sampling Date		2017/02/24	2017/03/12		2017/03/24		2017/03/22		
COC Number		A174619	A174619		A174619		A174619		
	UNITS	**BH17-16C AS1-A**	**BH17-33B 10'-11.5'**	**RDL**	**BH17-74B AS1**	**RDL**	**BH17-60B AS4**	**RDL**	**QC Batch**
CONVENTIONALS									
Total Organic Carbon (C)	mg/kg	ATTACHED	N/A	500	N/A	500	N/A	500	8608469
Calculated Parameters									
Resistivity @ 25 °C	ohm-m	N/A	3.9	0.050	24	0.050	7.9	0.050	8605241
Calculated Chloride (Cl)	%	N/A	0.018	0.00044	0.0027	0.0010	0.0030	0.00026	8604932
Calculated Sulphate (SO4)	%	N/A	0.16	0.00044	0.0049	0.0010	0.036	0.00026	8604932
Soluble Parameters									
Soluble Chloride (Cl)	mg/L	N/A	210	5.0	13	5.0	57	5.0	8605786
Soluble Conductivity	dS/m	N/A	2.5	0.020	0.41	0.020	1.3	0.020	8605626
Soluble pH	pH	N/A	7.57	N/A	7.28	N/A	7.47	N/A	8605629
Saturation %	%	N/A	88	N/A	210	N/A	52	N/A	8605356
Soluble Sulphate (SO4)	mg/L	N/A	1900	5.0	24	5.0	700	5.0	8605816

RDL = Reportable Detection Limit
N/A = Not Applicable

Maxxam ID		QW8659		QW8660		QW8661	QW8661		
Sampling Date		2017/03/20		2017/03/09		2017/03/21	2017/03/21		
COC Number		A174619		A174619		A174619	A174619		
	UNITS	**BH17-57B 40'-42'**	**RDL**	**BH17-31B 5'-6.5'**	**RDL**	**BH17-59B AS2**	**BH17-59B AS2 Lab-Dup**	**RDL**	**QC Batch**
Calculated Parameters									
Resistivity @ 25 °C	ohm-m	3.5	0.050	4.4	0.050	12	N/A	0.050	8605241
Calculated Chloride (Cl)	%	0.0011	0.00033	0.0015	0.00045	0.0031	N/A	0.00027	8604932
Calculated Sulphate (SO4)	%	0.13	0.00033	0.13	0.00045	0.023	N/A	0.00027	8604932
Soluble Parameters									
Soluble Chloride (Cl)	mg/L	17	5.0	17	5.0	57	52	5.0	8605786
Soluble Conductivity	dS/m	2.9	0.020	2.3	0.020	0.83	0.91	0.020	8605626
Soluble pH	pH	7.95	N/A	7.56	N/A	7.51	7.52	N/A	8605629
Saturation %	%	65	N/A	91	N/A	55	54	N/A	8605356
Soluble Sulphate (SO4)	mg/L	2000	5.0	1400	5.0	430	N/A	5.0	8605816

RDL = Reportable Detection Limit
Lab-Dup = Laboratory Initiated Duplicate
N/A = Not Applicable

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Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		QW8662		QW8663		QW8664	QW8665		
Sampling Date		2017/03/05		2017/03/17		2017/02/24	2017/02/27		
COC Number		A174619		A174619		A174619	A174619		
	UNITS	**BH17-32B AS3**	**RDL**	**BH17-38B AS1**	**RDL**	**BH17-16C AS3**	**BH17-25 GS1**	**RDL**	**QC Batch**
CONVENTIONALS									
Total Organic Carbon (C)	mg/kg	N/A	500	N/A	500	N/A	ATTACHED	500	8608469
Calculated Parameters									
Resistivity @ 25 °C	ohm-m	3.9	0.050	16	0.050	28	N/A	0.050	8605241
Calculated Chloride (Cl)	%	0.012	0.00032	0.00080	0.00034	<0.00023	N/A	0.00023	8604932
Calculated Sulphate (SO4)	%	0.11	0.00032	0.0027	0.00034	0.0028	N/A	0.00023	8604932
Soluble Parameters									
Soluble Chloride (Cl)	mg/L	190	5.0	12	5.0	<5.0	N/A	5.0	8605786
Soluble Conductivity	dS/m	2.5	0.020	0.62	0.020	0.35	N/A	0.020	8605626
Soluble pH	pH	7.81	N/A	7.70	N/A	7.93	N/A	N/A	8605629
Saturation %	%	65	N/A	68	N/A	46	N/A	N/A	8605356
Soluble Sulphate (SO4)	mg/L	1800	5.0	39	5.0	61	N/A	5.0	8605816

RDL = Reportable Detection Limit
N/A = Not Applicable

Maxxam ID		QW8666		
Sampling Date		2017/02/17		
COC Number		A174619		
	UNITS	**BH17-12 AS1**	**RDL**	**QC Batch**
CONVENTIONALS				
Total Organic Carbon (C)	mg/kg	ATTACHED	500	8608469

RDL = Reportable Detection Limit

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Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	18.3°C

TOC by Combustion results are attached to this report file. The reference number from Maxxam Campobello for these results is B777170

Results relate only to the items tested.

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Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

QUALITY ASSURANCE REPORT

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
8605356	LX	QC Standard	Saturation %	2017/04/18		101	%	89 - 111
8605356	LX	RPD	Saturation %	2017/04/18	0.93		%	12
8605356	LX	RPD [QW8661-01]	Saturation %	2017/04/18	0.65		%	12
8605626	ACZ	QC Standard	Soluble Conductivity	2017/04/18		93	%	75 - 125
8605626	ACZ	Spiked Blank	Soluble Conductivity	2017/04/18		99	%	90 - 110
8605626	ACZ	Method Blank	Soluble Conductivity	2017/04/18	<0.020		dS/m	
8605626	ACZ	RPD [QW8661-01]	Soluble Conductivity	2017/04/18	9.0		%	20
8605629	BJO	QC Standard	Soluble pH	2017/04/18		99	%	97 - 103
8605629	BJO	Spiked Blank	Soluble pH	2017/04/18		100	%	97 - 103
8605629	BJO	RPD [QW8661-01]	Soluble pH	2017/04/18	0.13		%	N/A
8605786	CH7	Matrix Spike [QW8661-01]	Soluble Chloride (Cl)	2017/04/18		107	%	75 - 125
8605786	CH7	QC Standard	Soluble Chloride (Cl)	2017/04/18		100	%	75 - 125
8605786	CH7	Spiked Blank	Soluble Chloride (Cl)	2017/04/18		106	%	80 - 120
8605786	CH7	Method Blank	Soluble Chloride (Cl)	2017/04/18	<5.0		mg/L	
8605786	CH7	RPD [QW8661-01]	Soluble Chloride (Cl)	2017/04/18	7.9		%	30
8605816	CJ5	QC Standard	Soluble Sulphate (SO4)	2017/04/18		89	%	75 - 125
8605816	CJ5	Method Blank	Soluble Sulphate (SO4)	2017/04/18	<5.0		mg/L	

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

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Maxxam Job #: B728026
Report Date: 2017/04/20

STANTEC CONSULTING LTD
Client Project #: 144902448
Site Location: NORTHWEST TERRITORIES
Sampler Initials: JM, KP

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Micheline Piche, Project Manager

Suwan Fock, B.Sc., QP, Inorganics Senior Analyst

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Maxxam

Calgary: 4000 19st St. NE, T2E 6P8. Ph: (403) 291-3077, Fax: (403) 735-2240, Toll free: (800) 386-7247
Edmonton: 9331 - 48 Street, T6B 2R4. Ph: (780) 577-7100, Fax: (780) 450-4187, Toll free: (877) 465-8889
www.maxxamanalytics.com

Chain of Custody A174619

Page: ____ of ____

475

Company:	Invoice To: C/O Report Address ☐	Report To: Same as Invoice ☑	Report Distribution (E-Mail):
	STANTEC CONSULTING LTD.		RYLEY.PROZNIK@STANTEC.COM
Contact:	RYLEY PROZNIK		
Address:	Prov: AB PC: 1233	Prov: PC:	
Contact #s:	Ph: 780-239-1498 Cell:	Ph: Cell:	

REGULATORY GUIDELINES:
- ☐ AT1
- ☐ CCME
- ☐ Regulated Drinking Water
- ☐ Other:

All samples are held for 60 calendar days after sample receipt, unless specified otherwise.

PO #: 144902448
Project # / Name: 144902448 / TLICHO ALL SEASON ROAD
Site Location: NORTHWEST TERRITORIES
Quote #:
Sampled By: JM / KP

SERVICE REQUESTED: ☐ RUSH (Contact lab to reserve) Date Required: ☐ REGULAR (5 to 7 Days)

See reverse for package specifics

	Sample ID	Depth (unit)	Matrix GW / SW Soil	Date/Time Sampled YY/MM/DD 24:00	SOIL: BTEX F1-F4	Sieve (75 micron)	Regulated Metals (CCME / AT1)	Salinity 4	Assessment ICP Metals	Basic Class II Landfill	Resistivity	pH	Sulphates & Chlorides	WATER: ☐BTEX F1 ☐VOCs	☐BTEX F1-F2 ☐BTEX F1-F4	☐ Routine Water ☐ Turb ☐ F	☐ TOC ☐ DOC	Regulated Metals (CCME / AT1) Total	Dissolved	Mercury ☐ Total ☐ Dissolved	Other Analysis: ORGANIC CONTENT	HOLD - Do not Analyze	# of Containers Submitted
1	BH17-16C AS1-A																				✓		
2	BH17-33B 10'-11.5'										✓	✓	✓										
3	BH17-74B AS1										✓	✓	✓										
4	BH17-60B AS4										✓	✓	✓										
5	BH17-57B 40'-42'										✓	✓	✓										
6	BH17-31B 5'-6.5'										✓	✓	✓										
7	BH17-59B AS2										✓	✓	✓										
8	BH17-32B AS3										✓	✓	✓										
9	BH17-38B AS1										✓	✓	✓										
10	BH17-16C AS3										✓	✓	✓										
11	BH17-25 GS1																				✓		
12	BH17-12 AS1																				✓		

Please indicate Filtered, Preserved or Both (F, P, F/P) → F/P

Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):
/NIKO NAVAL	17/04/07	
Relinquished By (Signature/Print): /Ryley Proznik	17/04/17	14:30

Special Instructions:

# of Jars Used & Not Submitted

LAB USE ONLY			
Received By: David Tidman	Date: 20170417	Time: 1430	Maxxam Job #: B728026 D-T
Lab Comments:	Custody Seal: No	Temperature: Bags 18, 19, 18	Ice: No

AB FCD-00331 Rev3 2010/05

Maxxam Analytics International Corporation o/a Maxxam Analytics

APPENDIX E

Thermistor Resistance versus Temperature Table

Thermistor Readings

Resistance versus Temperature Relationship 3000 Ohm NTC Thermistors

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	30	525.4	70	153.2	110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.99K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-35	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	282.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	56.92	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965	53	250.9	93	83.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	3000	25	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

Temperature calculated using:

Steinhart-Hart Linearization

$$T_C = \frac{1}{C_0 + C_1(\ln R) + C_3(\ln R)^3} - 273.15$$

3000 Ohm @ 25C NTC Thermistor

C_0= 0.0014051

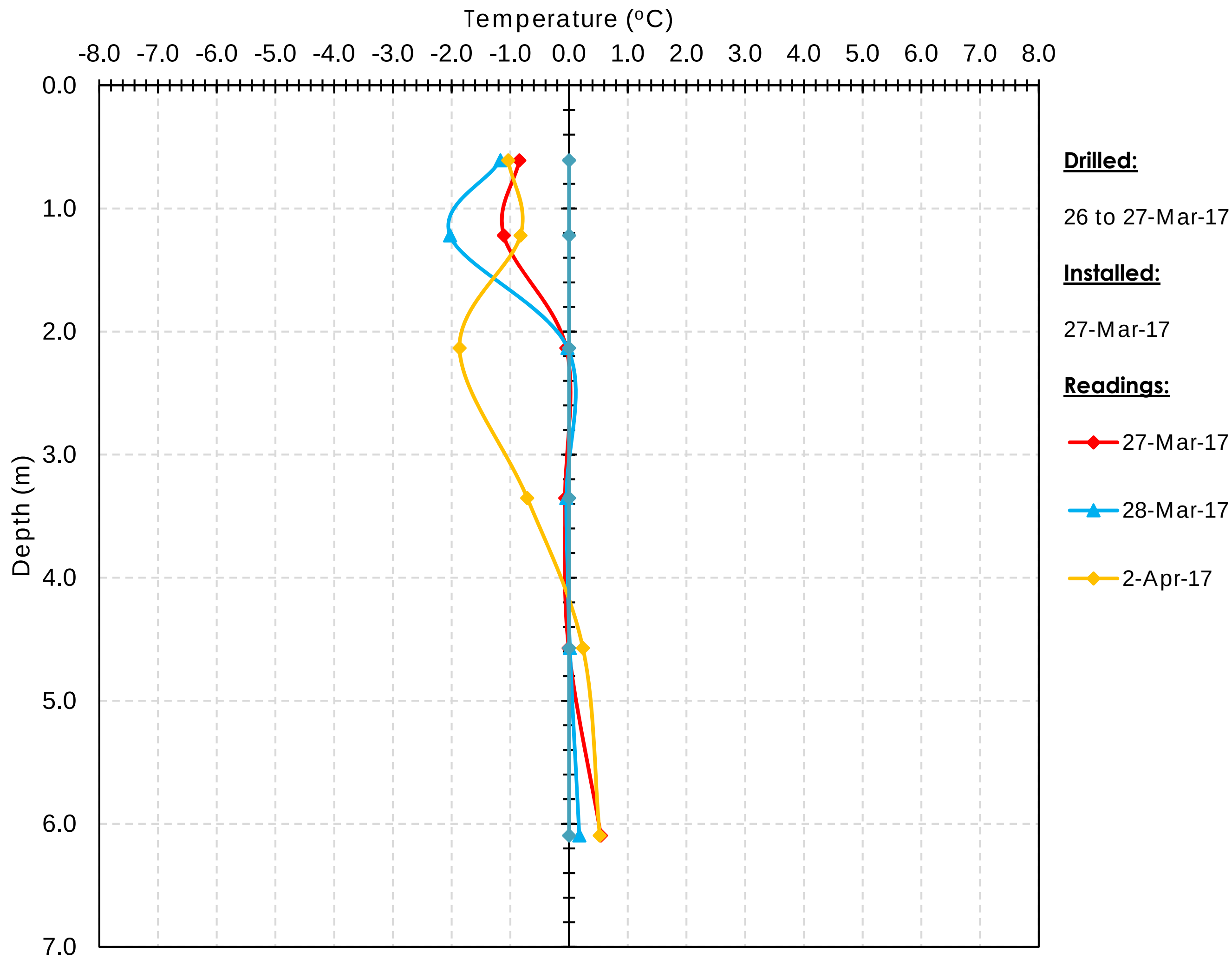
C_1= 0.0002369

C_3= 0.0000001019

lnR= Natural Log of Resistance

T_C= Temperature in °C

Document THL0006A



Borehole	**BH17-71B**								
Drilled:	26 to 27-Mar-17				Drilled Depth:			9.75	m
Installed:	27-Mar-17								
Reading			**Bead**	#6	#5	#4	#3	#2	#1
				TS4412	TS4405	TS4406	TS4416	TS4410	TS4434
Date		**Days**	**Depth (m)**	0.61	1.22	2.13	3.35	4.57	6.10
Post-Install	27-Mar-17	0	**R (Kilo Ω)**	10.22	10.36	9.81	9.82	9.79	9.52
			T (°C)	-0.8	-1.1	0.0	-0.1	0.0	0.5
2	28-Mar-17	1	**R (Kilo Ω)**	10.39	10.86	9.8	9.81	9.78	9.7
			T (°C)	-1.2	-2.0	0.0	0.0	0.0	0.2
3	2-Apr-17	6	**R (Kilo Ω)**	10.32	10.21	10.77	10.15	9.67	9.53
			T (°C)	-1.0	-0.8	-1.9	-0.7	0.2	0.5

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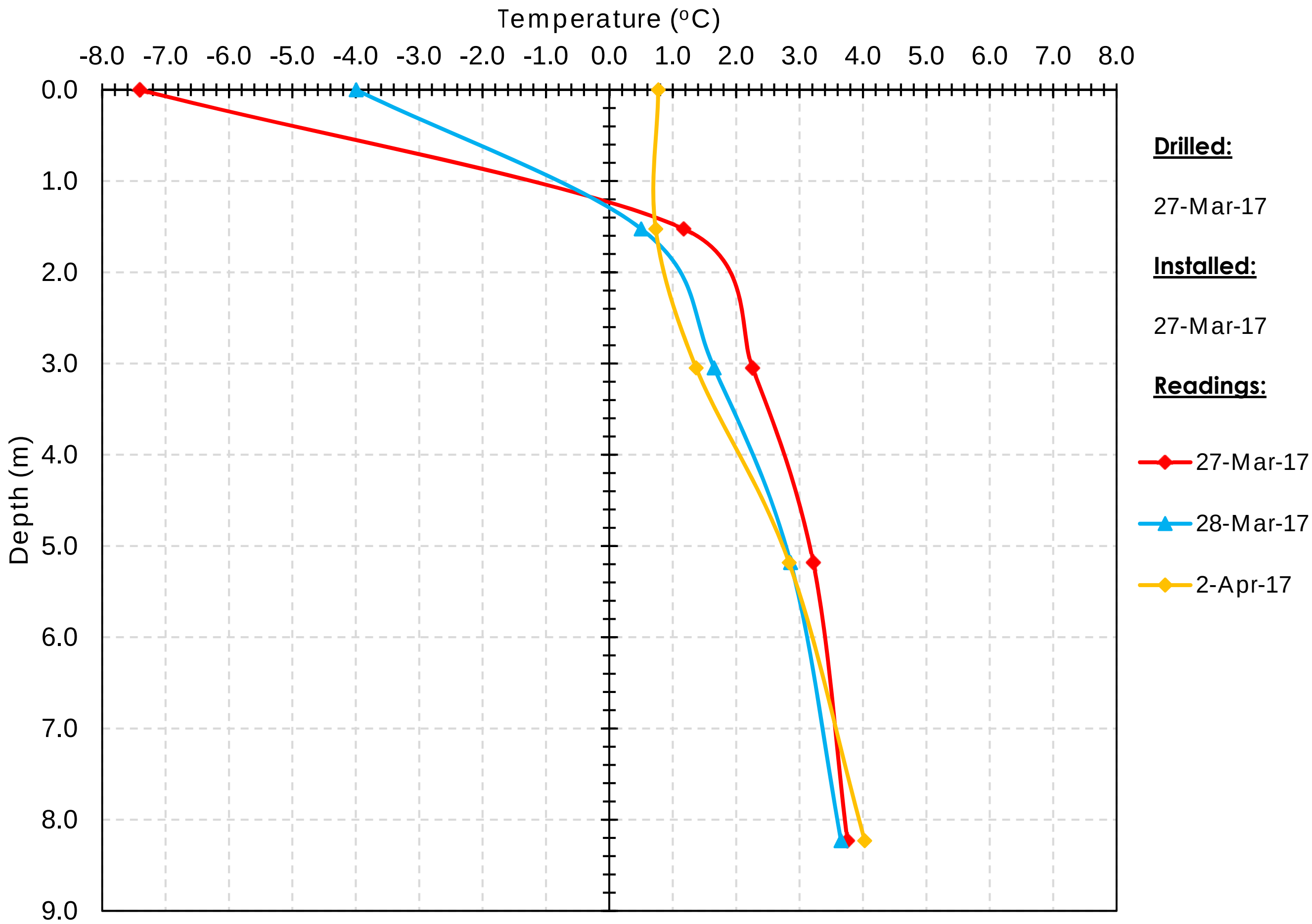
Thermistor Readings
BH17-71B

Figure No. 3

Project No. 144902448



Borehole	BH17-72B							
Drilled:	27-Mar-17				Drilled Depth:		11.28	m
Installed:	27-Mar-17							
Reading			Bead	TS4376	TS4374	TS4415	TS4428	TS4429
Date		Days	Depth (m)	0.00	1.52	3.05	5.18	8.23
Post-Install	27-Mar-17	0	R (Kilo Ω)	14.41	9.22	8.73	8.32	8.10
			T (°C)	-7.4	1.2	2.3	3.2	3.8
2	28-Mar-17	1	R (Kilo Ω)	12.03	9.54	9.00	8.47	8.14
			T (°C)	-4.0	0.5	1.7	2.9	3.7
3	2-Apr-17	6	R (Kilo Ω)	9.41	9.43	9.13	8.48	7.99
			T (°C)	0.8	0.7	1.4	2.8	4.0

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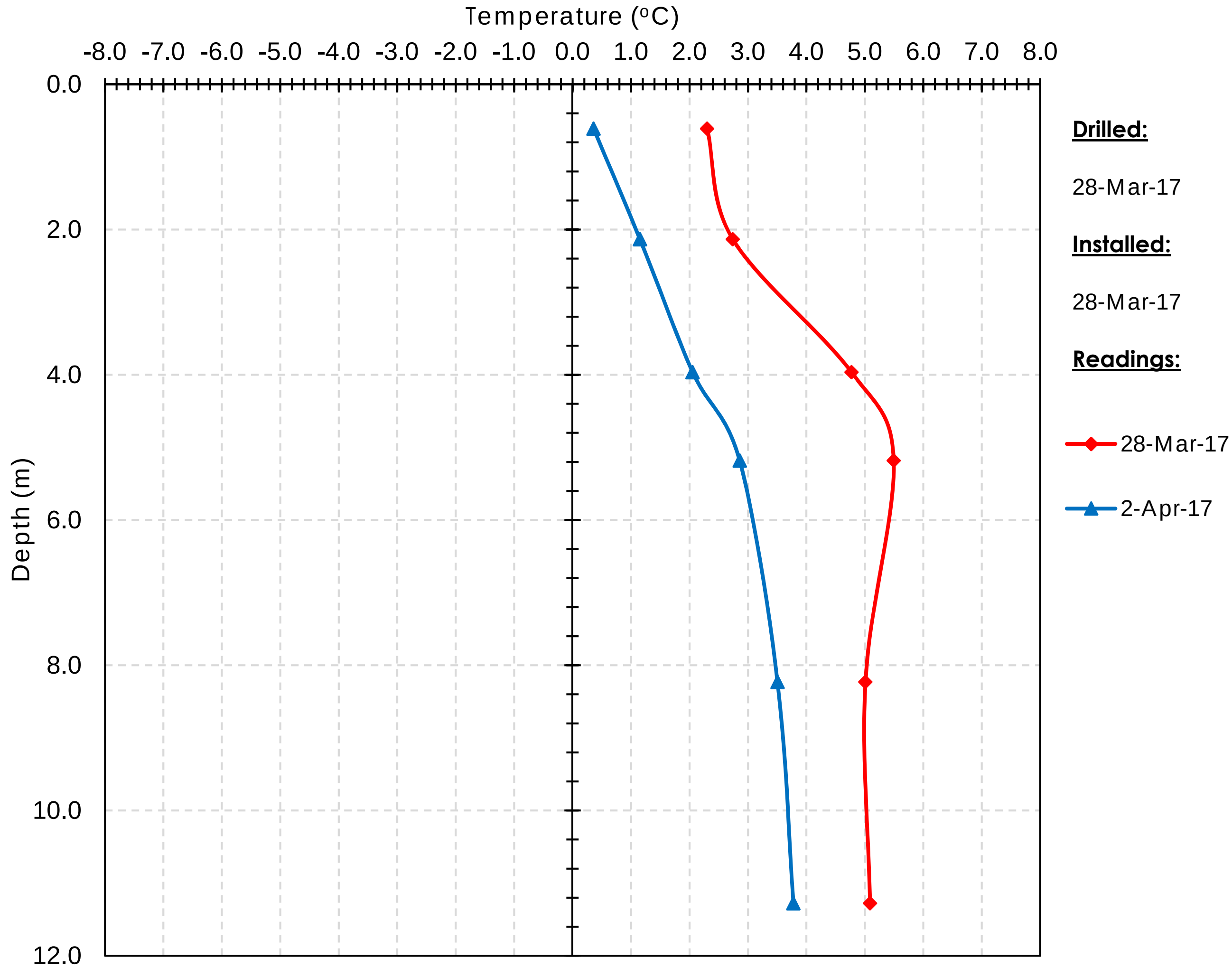
Thermistor Readings
BH17-72B

Figure No. 4

Project No. 144902448



Borehole	**BH-73B**								
Drilled:	28-Mar-17				Drilled Depth:		12.80	m	
Installed:	28-Mar-17								
Reading			**Bead**	#6	#5	#4	#3	#2	#1
				TS4445	TS4430	TS4447	TS4446	TS4432	TS4433
Date		**Days**	**Depth (m)**	0.61	2.13	3.96	5.18	8.23	11.28
Post-Install	28-Mar-17	0	**R (Kilo Ω)**	8.71	8.52	7.70	7.43	7.61	7.58
			T (°C)	2.3	2.7	4.8	5.5	5.0	5.1
2	2-Apr-17	5	**R (Kilo Ω)**	9.61	9.23	8.82	8.47	8.2	8.09
			T (°C)	0.4	1.2	2.1	2.9	3.5	3.8

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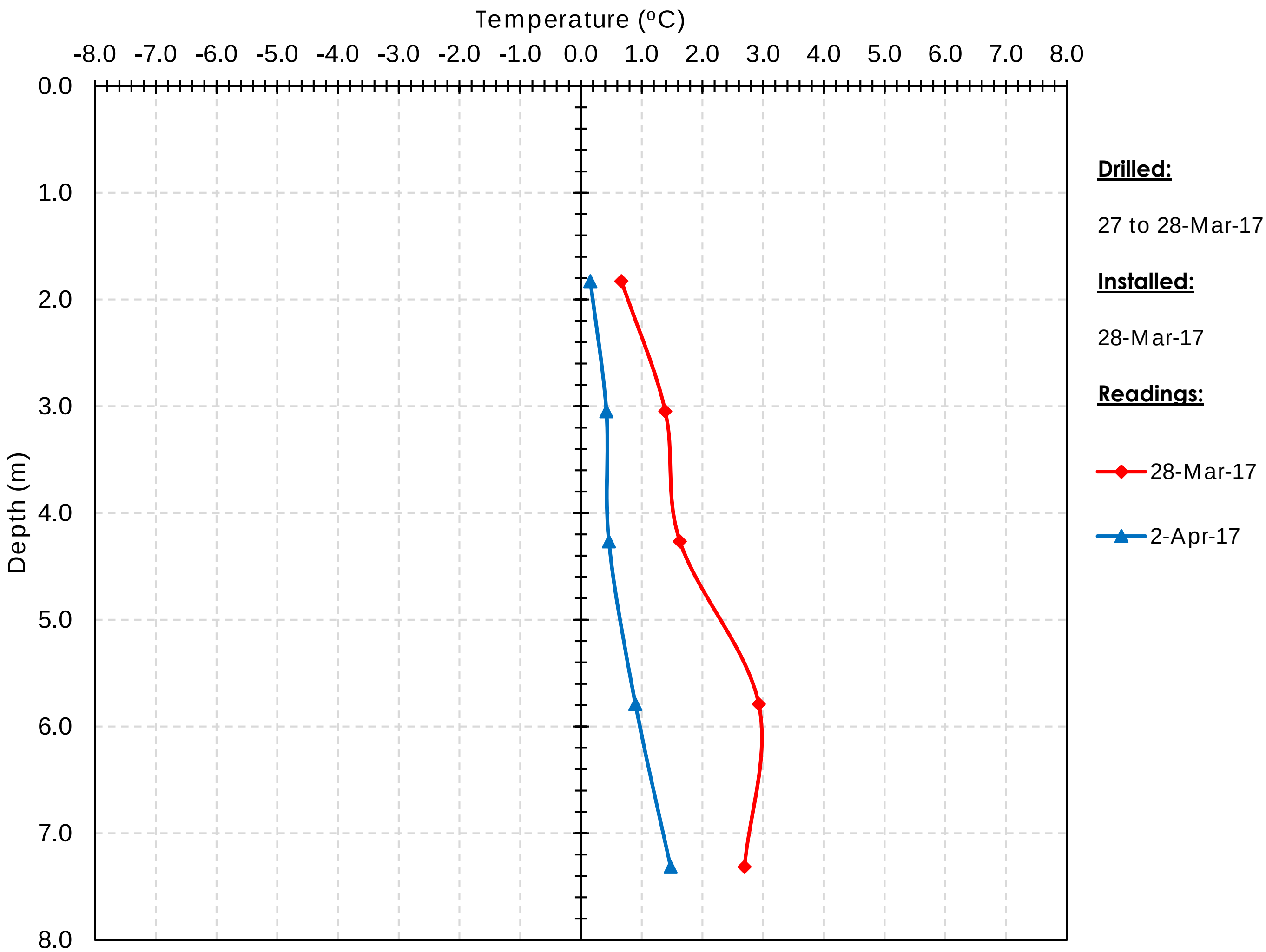
Thermistor Readings
BH17-73B

Figure No. 5

Project No. 144902448



Borehole	BH17-74B								
Drilled:	27 to 28-Mar-17				Drilled Depth:		11.28	m	
Installed:	28-Mar-17								
Reading			Bead	#6 TS4342	#5 TS4356	#4 TS4343	#3 TS4423	#2 TS4411	#1 TS4409
Date		Days	Depth (m)	0.61	1.83	3.05	4.27	5.79	7.32
Post-Install	28-Mar-17	0	R (Kilo Ω)	-	9.46	9.12	9.01	8.44	8.54
			T (°C)	-	0.7	1.4	1.6	2.9	2.7
2	2-Apr-17	5	R (Kilo Ω)	-	9.71	9.58	9.56	9.35	9.08
			T (°C)	-	0.2	0.4	0.5	0.9	1.5

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Thermistor Readings BH17-74B

Figure No. 6

Project No. 144902448