Lake Louise Campground
Geotechnical Investigation

Prepared for:
Parks Canada Agency

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Project No.: 113678159

March 22, 2018

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1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by Parks Canada Agency (Parks Canada) to conduct a geotechnical investigation for a proposed new operations center at the Lake Louise Campground. The geotechnical investigation was carried out in general accordance with our proposal dated September 18, 2017. Authorization to proceed was received on September 19, 2017. The purpose of the investigation was to obtain subsurface soil and groundwater information, and provide geotechnical recommendations for the design and construction of the proposed new development.

The scope of work for this investigation included the following:

- Conduct a field drilling program to identify existing subsurface soil and groundwater conditions within the proposed development footprint.
- Prepare a report presenting the findings of the field and laboratory testing programs, and provide recommendations pertaining to the geotechnical engineering aspects of project design and construction.

1.1 SITE AND GEOLOGY

The proposed development is located within the Lake Louise Campground, Alberta in the NW¼ (LSD 14) of 22-28-16 W5M (see Figure 1 in **Appendix B**). At the time of the field investigation, the development footprint consisted of a moderately treed area with some stumps and shrubs. The proposed development is bounded by an existing trailer dumping area to the south, RV campgrounds to the west, and a railway to the east. Existing asphalt surfaced roads surround the development and provide access to both the campgrounds and the proposed new operations center. The topography was generally noted to be relatively flat with minor elevation changes and depressions along the ground surface.

Based on published surficial geology information[1], the native subsurface soils at the site were expected to include a fluvial deposit consisting of poorly to well sorted sand and gravel.

[1] Fenton, M./M., et al. (2013), Surficial Geology of Alberta; Energy Resources Conservation Board

1.2 PROPOSED DEVELOPMENT

It is understood that the proposed development will consist of a new one story high operations center building not exceeding 30 m by 30 m in footprint size. It is understood that no underground structures are currently being considered for the development and that shallow footings are the preferred foundation option. The building will include a garage for equipment storage; shop and work area; supplies storage; offices; lunch room; and washroom facilities. At the time of preparing this report, no additional information regarding the proposed development such as proposed foundation loads, grading plans, or drawings were available for review and consideration. We have assumed that there are no significant (>1 m) grade raises planned as part of the development.

2.0 METHOD OF INVESTIGATION

2.1 FIELD INVESTIGATION

Prior to the start of the field investigation, Stantec personnel made arrangements to verify the locations of underground utilities at and near the proposed borehole location. One (1) borehole was advanced within the development footprint to a depth of 9.2 m below existing ground surface. The investigation was carried out on October 25, 2017 using a track-mounted, Overburden Drilling with Eccentric Drilling (ODEX) rig owned and operated by All Service Drilling Inc. of Airdrie, Alberta. The approximate borehole location is shown in Figure 2.0 in **Appendix B** and was recorded using a handheld GPS. The borehole location was selected by Stantec personnel based on drill rig accessibility and in consideration of the anticipated building footprint location.

The subsurface stratigraphy encountered in the borehole was recorded by Stantec personnel as the borehole was advanced. All soil descriptions and identifications during drilling were made in accordance with the Unified Soil Classification System (USCS). Representative samples of each stratum encountered were collected at close intervals and the soils' relative consistency was assessed during the performance of Standard Penetration Tests (SPTs).

The measured groundwater level upon completion is shown on the Borehole Record in **Appendix C**.

2.2 LABORATORY TESTING

All samples recovered from the field program were stored in moisture tight containers and were returned to our Calgary laboratory for detailed classification and testing. Laboratory testing was performed on selected samples, including:

- natural moisture content determinations
- water soluble sulphates testing
- grain size analysis

The results of the laboratory testing are discussed within this report and are included on the Borehole Records in **Appendix C**, provided in **Appendix D**, or are discussed within the text of this report**.** Samples remaining after testing will be stored for a period of three (3) months after issuance of the final report. Samples will then be discarded after this period unless otherwise directed.

3.0 RESULTS OF THE INVESTIGATION

3.1 GENERAL

The subsurface soil and groundwater conditions encountered in the borehole is described in detail on the Borehole Record, with additional and supplementary information provided in this section. The Borehole Record, along with an explanation of the symbols and terms used in the descriptions, are in **Appendix C**.

In general, the subsurface conditions encountered consisted of a surficial layer of rootmat (measuring approximately 100 mm thick) overlying silty sand, overlying gravel. A summary of the subsurface conditions observed at the borehole location is described in detail in the following sections.

3.2 SILTY SAND (SM)

Brown silty sand was encountered beneath the rootmat, and measured approximately 1.4 m thick. The silty sand contained trace gravel, and was generally noted to be brown in color and dry to moist.

Moisture content testing completed on a sample of the silty sand indicated a natural moisture content of approximately 5%.

One SPT conducted in the silty sand stratum indicated an N-value of 37. In terms of relative compactness, based on the SPT test result the sandy silt may be described as dense.

3.3 GRAVEL (GP-GM)

Brown gravel was encountered below the silty sand at an approximate depth of 1.4 m. The gravel was poorly-graded and contained varying silt and sand content. It was noted as brown in color and dry to wet. The granular sized particles were generally noted to be angular to sub-rounded in the retrieved samples. Seepage was noted within this gravel layer at an approximate depth of 4.6 m.

Results of moisture content testing on the gravel samples indicated natural moisture contents between 2% and 8%, with an average of 4%. Results of a grain size analysis performed on a gravel sample (BH1 - SS4) indicated 72% gravel, 21% sand, and 7% fines (silt and clay sized particles). Based on the laboratory test results and the USCS, the gravel may be described as poorly-graded gravel (GP-GM) with silt and sand.

Results of SPTs conducted within the gravel indicated N-values between 19 and 31, and averaged 24. In terms of relative consistency, based on SPT N-values, the gravel may be described as compact to dense.

3.4 GROUNDWATER

No standpipe piezometers were installed for this investigation. Groundwater within the borehole was measured following completion of drilling. Based on field observations groundwater was present within the gravel at a depth of 4.6 m. The observed groundwater level at the time of the investigation is shown in the Borehole Record in **Appendix C**.

Groundwater levels vary from year to year and from season to season, and depend on many factors including surface and subsurface drainage, precipitation, and the hydrogeology of the area. Fluctuations in the groundwater levels should be anticipated. Groundwater levels in Alberta can typically experience fluctuation in the order of about 1 m with the peak groundwater levels generally occurring in June or July.

4.0 DISCUSSION AND RECOMMENDATIONS

4.1 GEOTECHNICAL CONSIDERATIONS

Based on the information obtained from the geotechnical investigation, the site soil and groundwater conditions encountered are suitable for the proposed development from the geotechnical engineering perspective, provided that the recommendations outlined within this report are adhered to.

A layer of silty sand was encountered at the surface and extended to an approximate depth of 1.4 m. Our experience with this material is that it will require increased moisture conditioning and effort for reuse as Engineered Fill. Silty sands have a narrow moisture range in which they can be properly compacted, they tend to dry quickly and are easily disturbed and loosened when in a dry state. Silty sands are also highly erodible and highly frost susceptible. The silty sand layer generally extended to shallow depths, so it is recommended that this material be over-excavated where encountered at the foundation level. Foundations placed within the local gravel will minimize future issues with frost heaving and improve subgrade strength. The silty sand may be relocated for use within parking areas, landscaping or other non-loaded areas.

4.2 SITE GRADING AND PREPARATION

All organic soil, uncontrolled fill, loose, soft or any other deleterious materials must be removed from beneath the outline of proposed foundation footprints. The subgrade should consist of the native gravel or Engineered Fill (as outlined in **Section 4.4**) within foundation areas. Within roadways and parking areas, the subgrade may consist of either native gravel, native silty sand, or Engineered Fill.

Following stripping, the exposed subgrade surfaces within pavement and slab-on-grade areas should be scarified to a depth of 200 mm and moisture conditioned within the range of ±3% of optimum in the native gravel (optimum to be determined in accordance with ASTM D698), and ±2% of optimum for the native silty sand. Before any subsequent fill placement, the exposed subgrade should be compacted to 98% of Standard Proctor Maximum Dry Density (SPMDD).

Following preparation, exposed subgrade surfaces should be proof-rolled using heavy equipment such as a loaded tandem dump truck. All soft areas should be sub excavated to competent material and replaced with approved Engineered Fill. To promote subgrade uniformity, soft area repair should be carried out using soil of a similar nature to the in-situ subgrade soils. Soft area repairs using gravel should be carried out with due consideration given to proper drainage of the repaired area.

Where construction is carried out during winter conditions, subgrade surfaces should be protected from freezing. In addition, the subgrade should be protected from wetting or drying, both before and after the placement of granular base material and concrete. Subgrade surfaces that are allowed to dry or become wet should be scarified, moisture conditioned, and re-compacted as required.

The final subgrade surface within building areas should be carefully graded to prevent ponding and to direct water away toward adequate drainage systems whenever possible (as outlined in **Section 4.6**).

To reduce the risk of differential settlement from differential fill thickness, the subgrade should be graded with a slope flatter than five horizontal to one vertical (5H:1V) prior to receiving fill material.

4.3 FOUNDATIONS

4.3.1 Strip and Square Footings

Shallow strip and square footings are feasible foundation options for the proposed structure, provided that the footings are placed on the native gravel or on Engineered Fill. Shallow foundations embeded a minimum of 0.5 m into the native gravel or Engineered Fill may be designed based on a factored bearing capacity of 250 kPa at Ultimate Limit States (ULS). This bearing capacity is applicable for square footing sizes between 0.6 m x 0.6 m to 2.5 m x 2.5 m; and for strip footings between 0.45 m to 1.2 m wide. A geotechnical resistance factor of 0.5 has been used in obtaining the ULS value, and is considered applicable for downward (compressive) static loads. Settlement for Serviceability Limit States (SLS) can be checked once further design details (such as proposed loading and footing configuration) are provided. For preliminary consideration, if footings are designed and constructed as recommended in this report, settlement can be assumed to be less than 25 mm for footings placed on the native gravel or Engineered Fill.

Footings should be placed a minimum of 2.4 m below finished ground surface for unheated structures, and a minimum of 1.9 m for heated structures. Footings founded above the specified minimum depths should be protected against frost action by means of insulation. Insulation requirements are discussed in **Section 4.7**.

The subgrade surfaces beneath footing foundations must be free from frozen, loose or soft materials. The base of all footings must be inspected by qualified geotechnical personnel prior to placing concrete to confirm the above design pressures and to ensure there are no disturbances or deleterious materials at the bearing surface.

4.3.2 Slab-on-Grade

A conventional slab-on-grade unit will be suitable for the proposed building, provided that the recommendations outlined within this report are adhered to. A layer of approved granular material (such as Alberta Transportation Specifications Designation 2 - Class 20 or approved equivalent) of at least 150 mm in thickness should be placed immediately beneath the floor slab for leveling and support purposes and to act as a capillary break. This material should be compacted to a minimum of 98% SPMDD at water content within ±3% of optimum. It is important that subgrade surfaces be protected from moisture changes and freezing temperatures both during and after construction to minimize the potential for frost heave/thaw action on the subgrade soils. The final subgrade surface within building areas should be carefully graded to prevent ponding and to direct water away from the floor slab area.

Elastic response of subgrade is commonly evaluated using a modulus of subgrade reaction. Typical values of the modulus of vertical subgrade reaction for a 1 ft2 plate (300 mm by 300 mm), kv1, are about 60 MPa/m for subgrades consisting of the native gravel or Engineered Fill of a similar nature to the gravel. The modulus of subgrade reaction is not an intrinsic property. The values of modulus of subgrade reaction provided above are estimates based on the current geotechnical data and are meant to cover average conditions for the site. Actual modulus values change with rigidity and contact area of the slab. If requested, Stantec can determine representative modulus values during detailed design based on predicted settlement for specific foundation rigidity, loading conditions and contact area.

For unheated or exterior slabs founded above the predicted frost depth, they will be exposed to frost action and should therefore be protected in accordance with the recommendations in **Section 4.7.** Perimeter drainage with a positive outlet should be provided where floor slabs are below exterior finished grades.

Slabs-on-grade should float independently of all load-bearing walls and columns to minimize the potential for damage from small differential settlement between these elements.

4.4 FILL MATERIALS AND COMPACTION REQUIREMENTS

The existing gravel at the site is considered suitable for reuse as Structural Engineered Fill with proper moisture conditioning. The existing silty sand and sandy silt is not considered suitable for use as Structural Engineered Fill within foundation areas. The silty sand may be reused as General Engineered Fill outside of structurally loaded areas. As previously noted, the silty sand is easily disturbed and has a narrow range over which it can achieve proper compaction. Increased moisture conditioning and compactive effort should be anticipated when working with the silty sand.

Drying or wetting of the site soils will be required during periods of heavy rain, hot weather, or if excavated material is allowed to dry excessively prior to reuse. Alternatively, mixing of dry and wet soils to reach the optimum moisture content may be considered, provided that qualified geotechnical personnel approve the mixed soil prior to use.

Structural Engineered Fill is defined as fill placed within structurally loaded areas, and as such will be subject to foundation loads. Structural Engineered Fill should consist of the native gravel. Alternatively, import granular fill conforming to Alberta Transportation specifications (such as Designation 6 Class 80) may also be used. Structural Engineered Fill should be moisture conditioned to within ±3% of optimum moisture content and compacted to a minimum of 100% SPMDD. General Engineered Fill is defined as fill placed within non-structurally loaded areas such as landscaping, light traffic roadways, and parking areas. General Engineered Fill may consist of the native silty sand, native gravel or imported granular fill. Silty sand should be moisture conditioned to within ±2% of optimum moisture content. The gravel should be moisture conditioned to within ±3% of optimum. General Engineered Fill should be compacted to a minimum of 98% SPMDD within access roads and parking areas; and 95% of SPMDD within non-structural and landscaped areas.

All fill materials must be free of organics, debris, and other deleterious materials. Fill materials should be placed in lifts having a thickness such that the compaction equipment can achieve the required density, but not exceed 300 mm.

All imported fill materials should be tested and approved by a geotechnical engineer prior to delivery to the Site.

4.5 EXCAVATION AND DEWATERING

Temporary excavations for foundation construction, conducted above the groundwater table should be supported or be flattened at side slopes no steeper than 1H:1V. In areas where discharge or groundwater seepage is occurring, sidewalls may need to be flattened. Some sloughing should be expected and periodic cleaning at the slope base may be required. Excavations should be inspected regularly for signs of instability and flattened as required. All excavations and shoring should be in accordance with the applicable Alberta Occupational Health and Safety regulations.

Based on the results of the field investigation groundwater is expected at an approximate depth of 4.5 m; however, dewatering requirements at the site will be dependent upon the seasonal variation of the groundwater elevation, precipitation during construction, and the depth of excavation below groundwater. If groundwater is encountered in excavations, it is expected that a dewatering system using sump pumps with shallow trenches to direct water away from the work areas will be the most feasible dewatering system in these conditions. The location of trenches and sumps are best determined during construction based on the location of any channels encountered. Pumping requirements will vary as the excavation proceeds deeper below groundwater elevation and in response to seasonal fluctuations and weather at the time of construction.

4.6 SITE DRAINAGE

The prepared subgrade surface should be shaped to prevent ponding of water on the site as recommended in **Section 4.2**. Excess water should not be allowed to pond and should be drained or pumped from the site as quickly as possible both during and after construction.

The finished grades should provide surface drainage away from all structures. Positive surface drainage should be established to prevent ponding of water. A minimum gradient of 2% should be used wherever possible. Roof and other drains should discharge well clear of any buildings or equipment. Surrounding landscaping should be designed such that runoff water is prevented from ponding.

4.7 FROST PROTECTION

Foundation elements for unheated structures should have a minimum frost protection equivalent to a soil cover of at least 2.4 m. Perimeter foundations of heated buildings should be designed with a minimum soil cover of 1.9 m, provided that the foundation is not insulated in a manner that will reduce heat flow to the soil beneath the footings. Extruded polystyrene rigid insulation may be considered to provide an equivalent soil cover. Stantec can provide further recommendations for the type and thickness of rigid insulation during detailed design, if required.

4.8 SEISMIC CONSIDERATIONS

Seismic design for "normal structures", such as warehouses, low-rise commercial buildings, and high-rise office towers, is based on the 2015 National Building Code of Canada (NBCC). The primary objective of the NBCC earthquake resistant design requirements for "normal structures" is to protect the life and safety of the building occupants as the building responds to strong ground shaking. Structures designed in conformance with the NBCC provisions may undergo extensive structural damage during strong ground shaking but should not collapse. Collapse is defined to be a state where occupants can no longer exit the building because of structural failure. This implies that supporting foundations necessary to ensure the building's post-earthquake stability must be protected against excessive movement under strong ground shaking.

The 2015 NBCC seismic design procedures are based on ground motion parameters (e.g., peak ground acceleration (PGA) and spectral acceleration, Sa values) having a 2% probability of exceedance in 50 years; i.e., the 2,475 year return period earthquake event.

Based on the results of the Stantec field investigation, it is appropriate to classify the ground conditions at the subject site as a **Class D** Site, in accordance with the 2015 NBCC (Table 4.1.8.4.A).

4.9 CONCRETE

One (1) test was conducted on a select soil sample (BH1 - SS6) to determine the water soluble sulphate content of site soils. The sulphate concentration in the sample was below 0.05%. Based on the one value, the degree of exposure may be considered negligible (based on CSA A23.1-14, Table 3). Therefore, type GU cement may be used for concrete in contact with site soils.

Air entrainment to the requirements of CSA A23.1-14 should be specified for all concrete in contact with freezing temperatures. Slabs that will receive a surface hardener should not be air entrained. Stricter specifications may be required for structural requirements, other exposure conditions, or other considerations.

5.0 CLOSURE

This report has been prepared for the sole benefit of Parks Canada Agency and its agents, and may not be used by any third party without the express written consent of Stantec Consulting Ltd. and Parks Canada Agency.

Any use, which a third party makes of this report, is the responsibility of such third party. Use of this report is subject to the Statement of General Conditions provided in **Appendix A**. It is the responsibility of Parks Canada Agency, who is identified as "the Client" within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec 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 above information meets with your present requirements. Should you have any questions or require further information, please contact us. This report has been prepared by Katie Chuey, EIT., and by Gary Liu, P.Eng., and reviewed by Kyle Noble, P.Eng.

Yours truly,

STANTEC CONSULTING LTD.

PROFESSIONAL ENGINEER GARY LIU ALBERTA

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APPENDIX A
STATEMENT OF GENERAL CONDITIONS

Stantec

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 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'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 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.

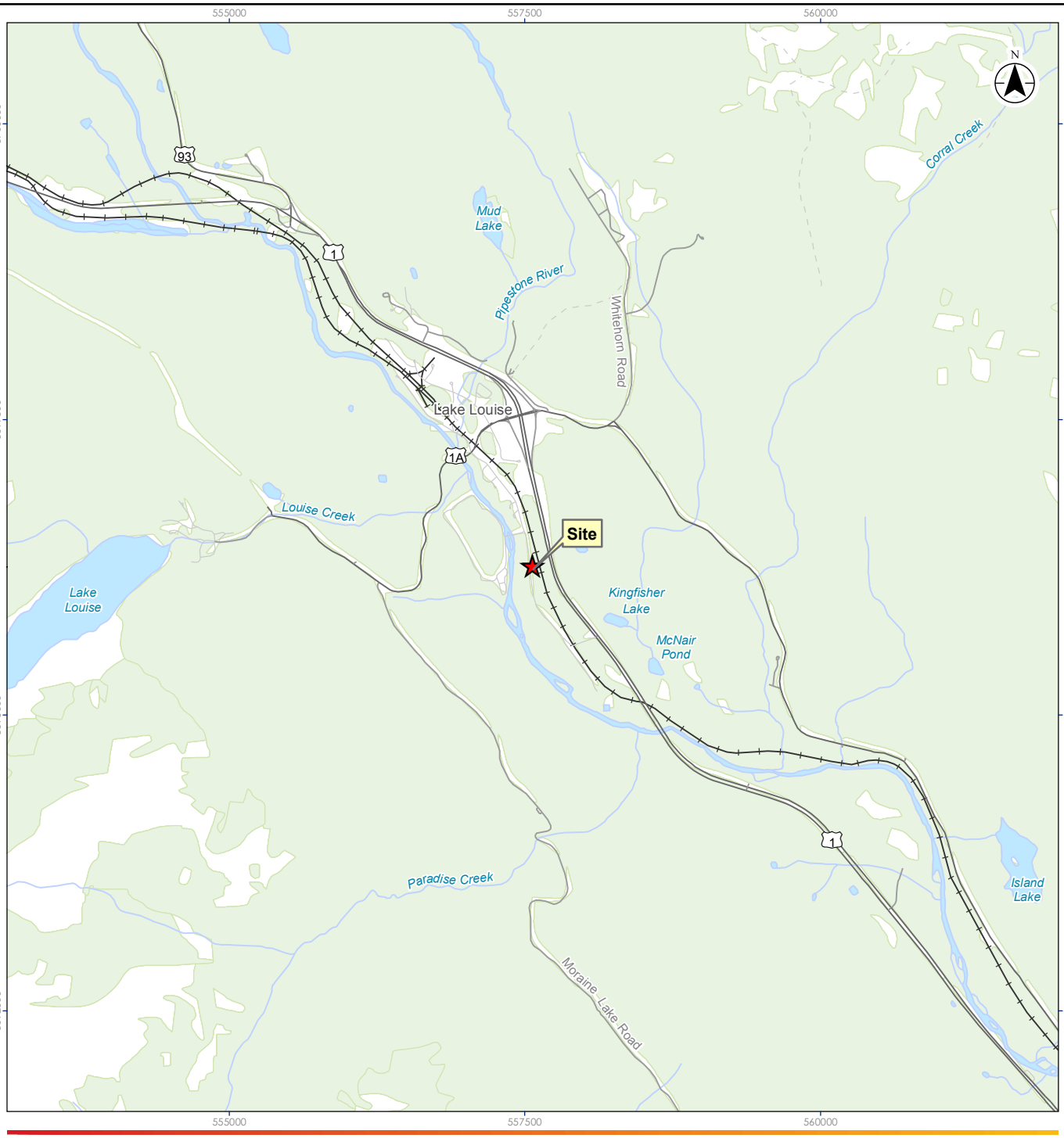
STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

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 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 behaviour. 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 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 will not be responsible to any party for damages incurred as a result of failing to notify Stantec 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, 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 cannot be responsible for site work carried out without being present.

APPENDIX B
FIGURES



Highway
Major Road
Local Street
Resource Road
Railway
Watercourse
Waterbody
Wooded Area

0 0.5 1 1.5 2 km

1:50,000 (at original document size of 8.5x11)

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Source: DataBC, Government of British Columbia; Natural Resources Canada
3. This document is provided for use by the intended recipient only. This information is confidential and proprietary and is not to be provided to any other recipient without written consent of.

Stantec

Project Location
Lake Louise
Alberta

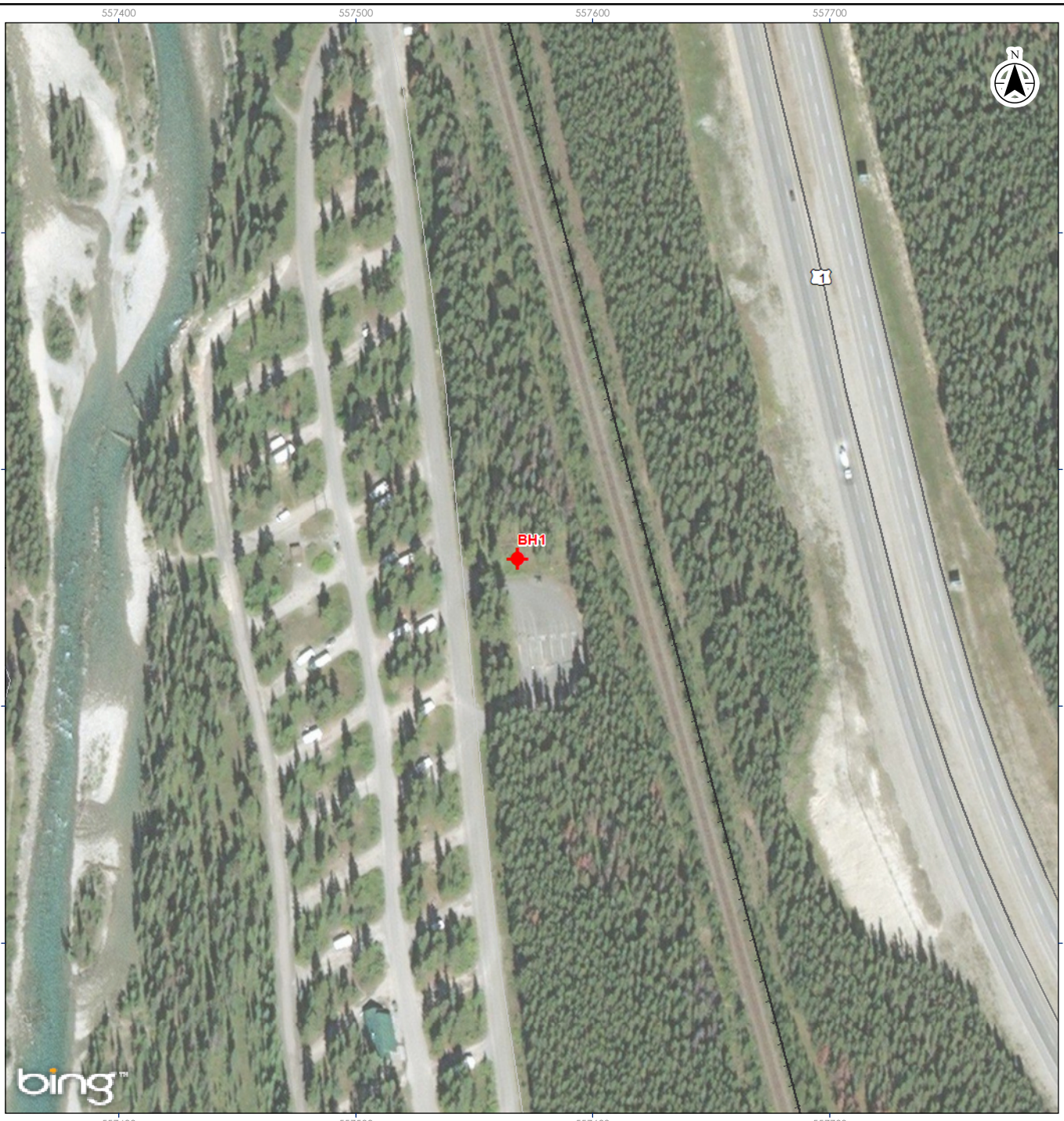
Project Number 113678159
Prepared by SSUN 20171024
Discipline Review by KCHUEY 20171024

Client/Project
Parks Canada Agency
Lake Louise Campground

Figure No.
1

Title
Site Location Plan

\\Cd1183-f03\workgroup\1232\projects\113678159\figures\discipline\Geotechnical\fig_113678159_02_borehole_location_plan.mxd Revised: 2017-12-08 By: ssun



Highway
Local Street
Railway
Borehole Location

0 20 40 60 80 100 m
1:2,500 (at original document size of 8.5x11)

Stantec

Project Location
Lake Louise
Alberta

Project Number 113678159
Prepared by SSUN 20171024
Discipline Review by KCHUEY 20171024

Client/Project
Parks Canada Agency
Lake Louise Campground

Figure No.
2

Title
Borehole Location Plan

Notes
1. Coordinate System: NAD 1983 UTM Zone 11N
2. Data Source: DataBC, Government of British Columbia; Natural Resources Canada
3. This document is provided for use by the intended recipient only. This information is confidential and proprietary and is not to be provided to any other recipient without written consent of.

APPENDIX C
BOREHOLE RECORDS

Stantec

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

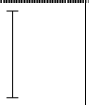
Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals 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

BH1

CLIENT _____ PROJECT No. **113678159**

LOCATION **Lake Louise Campground Rehabilitation** BH SIZE **140 mm**

DATES (mm/dd/yy): BORING **10/25/17** WATER LEVEL **4.6 m (10/25/17)** DATUM **N/A**

DEPTH(m)	ELEVATION(m)	SOIL DESCRIPTION	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY mm	SAMPLES N-VALUE OR RQD %	MONITOR WELL/ PIEZOMETER
0		ROOTMAT						
		Dense brown silty SAND (SM) - trace gravel, roots and rootlets, dry to moist		BS	1			
1				SS	2	360	37	
				BS	3			
		Compact brown poorly graded GRAVEL (GP-GM) with silt and sand - angular to sub rounded, dry to moist - trace rootlets to 1.5 m		SS	4	270	31	
2				BS	5			
3				SS	6	280	23	
				BS	7			
4								
		- water below 4.6 m		SS	8	220	19	
5				BS	9			
		- inferred boulder from 5.5 m to 6.4 m		BS	10			
6		- SPT on SS11 at 6.1 m: 50 for 0 mm		SS	11	0	Refusal	
		- inferred boulder from 6.8 m to 7.0 m						
7		- trace silt below 7.0 m		BS	12			
				BS	13			
8								
9								
		End of Borehole (9.2 m) - borehole slough to 4.6 m upon removal of casing - water at 4.6 m - backfilled with bentonite from 0.3 m to 1.2 m and sand from 1.2 m to 4.6 m						
10								
11								

Cu (from pocket penetrometer) ★
Cu (from laboratory testing) ▲
UNDRAINED SHEAR STRENGTH, Cu (kPa)
50 100 150 200
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10 20 30 40 50 60 70 80 90

App'd_____ Dec 8 2017 11:17:38

APPENDIX D
LABORATORY TEST RESULTS

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Moisture Content of Soil or Aggregate
CSA A23.2-11A
ASTM D2216

OFFICE
325 - 25th Street SE
Suite 200
Calgary, Alberta
Canada T2A 7H8
Tel: (403) 716-8000

LABORATORY
10830 - 46th Street SE
Calgary, Alberta
Canada T2C 1G4
Tel: (403) 253-7876

Client: Parks Canada
Project: Lake Louise Campground
Project No.: 113678159

Date Tested: 1-Nov-17
Tested By: B.Pelkey

Moisture Content Worksheet

Borehole / Test Pit No.	BH1	BH1	BH1	BH1	BH1		
Sample	SS2	SS4	SS6	BS7	SS8		
Tare No.							
Mass Tare Container	1.48	1.51	1.53	1.37	1.37		
Mass Sample (Wet+Tare) (g)	37.78	31.43	52.12	33.72	45.94		
Mass Sample (Dry+Tare) (g)	36.13	30.9	50.92	32.16	42.57		
Mass of Water (g)	1.65	0.53	1.20	1.56	3.37		
Mass Dry Sample (g)	34.65	29.39	49.39	30.79	41.20		
Moisture Content (%)	4.8%	1.8%	2.4%	5.1%	8.2%		
Comments							
Borehole / Test Pit No.							
Sample							
Tare No.							
Mass Tare Container							
Mass Sample (Wet+Tare) (g)							
Mass Sample (Dry+Tare) (g)							
Mass of Water (g)							
Mass Dry Sample (g)							
Moisture Content (%)							
Comments							
Borehole / Test Pit No.							
Sample							
Tare No.							
Mass Tare Container							
Mass Sample (Wet+Tare) (g)							
Mass Sample (Dry+Tare) (g)							
Mass of Water (g)							
Mass Dry Sample (g)							
Moisture Content (%)							
Comments							
Borehole / Test Pit No.							
Sample							
Tare No.							
Mass Tare Container							
Mass Sample (Wet+Tare) (g)							
Mass Sample (Dry+Tare) (g)							
Mass of Water (g)							
Mass Dry Sample (g)							
Moisture Content (%)							
Comments							

Reviewed By: [signature]

Stantec

Grain Size Analysis
Hydrometer Report
ASTM D7928 / D6913
CANFEM

Client: Parks Canada
Project Name: Lake Louise Campground
-
Project No: 113678159.600

OFFICE
325 - 25th Street SE
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LABORATORY
10830 - 46th Street SE
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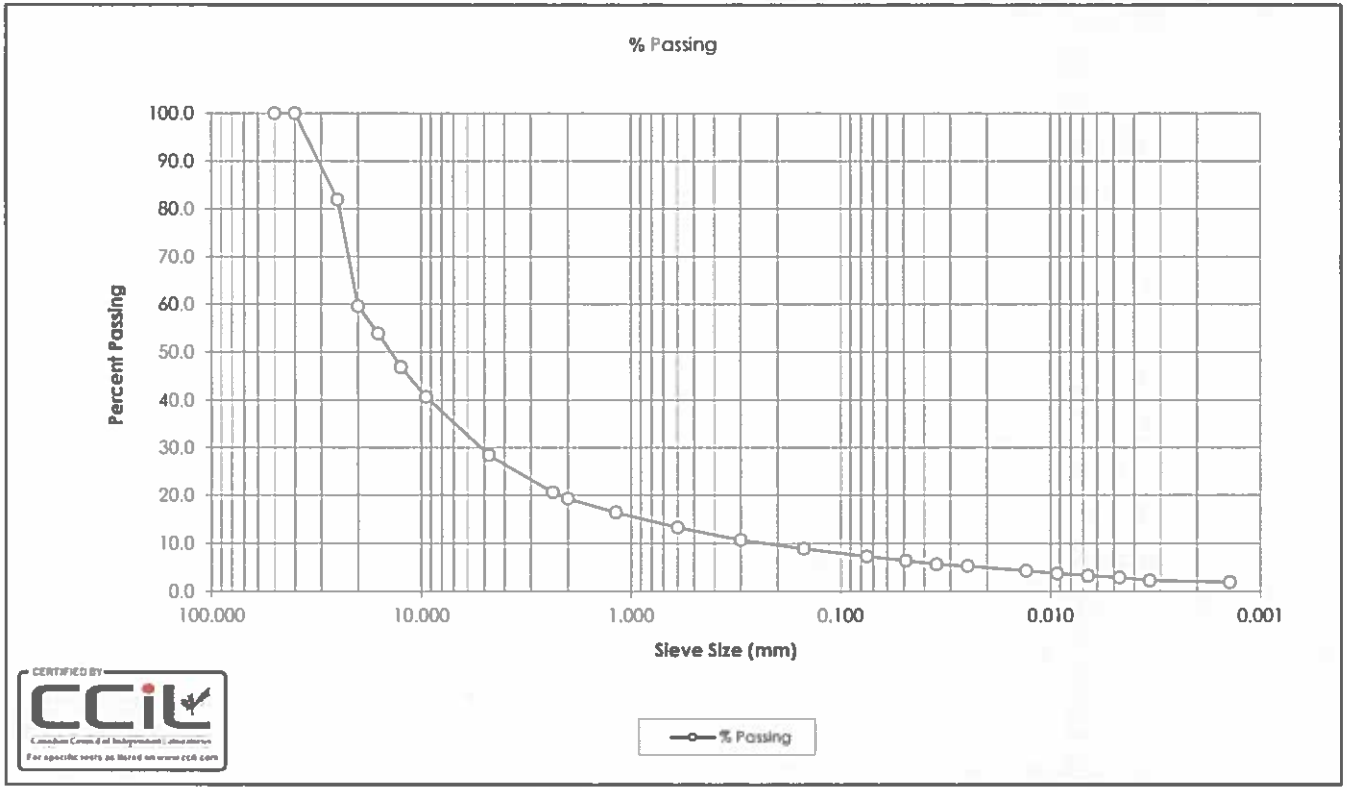
Canada T2C 1G4
Tel: (403) 253-7876

SAMPLE No.: SS4
SOURCE: BH1
TESTED BY: B.Pelkey

DATE RECEIVED: October 25, 2017
DATE TESTED: November 2, 2017
SAMPLE DESCRIPTION: Poorly Graded Gravel with Fines and Sand



Sieve (mm)	Sample % Passing	Sieve (mm)	Sample % Passing
50.0	100.0	0.0093	3.7
40.0	100.0	0.0066	3.3
25.0	82.0	0.0047	2.9
20.0	59.6	0.0034	2.2
16.0	53.9	0.0014	1.9
12.5	46.9		
9.5	40.7		
4.75	28.4		
2.36	20.6		
2.00	19.3		
1.18	16.4		
0.600	13.3		
0.300	10.7		
0.150	8.9		
0.075	7.3		
0.0489	6.4		
0.0350	5.7		
0.0248	5.3		
0.0131	4.3		

Gravel:	71.6%	D_{10}:	0.2438
Sand:	21.1%	D_{30}:	5.4748
Silt:	5.2%	D_{60}:	20.1130
Clay:	2.1%	C_U:	82.48
		C_C:	6.11

Comments: Sample description (USCS) derived from the Grain Size analysis test results.

Reviewed by:

CERTIFICATE OF ANALYSIS

REPORTED TO	Stantec Consulting Ltd. (Calgary) 200 325 25th Street SE Calgary, AB T2A 7H8		
ATTENTION	Bobbi Pelkey	**WORK ORDER**	7110488
PO NUMBER		**RECEIVED / TEMP**	2017-11-06 10:30 / 18°C
PROJECT	113678159.600	**REPORTED**	2017-11-16 13:09
PROJECT INFO			

Introduction:

CARO Analytical Services is a testing laboratory full of smart, engaged scientists driven to make the world a safer and healthier place. Through our clients' projects we become an essential element for a better world. We employ methods conducted in accordance with recognized professional standards using accepted testing methodologies and quality control efforts. CARO is accredited by the Canadian Association for Laboratories Accreditation (CALA) to ISO 17025:2005 for specific tests listed in the scope of accreditation approved by CALA.

Big Picture Sidekicks

You know that the sample you collected after snowshoeing to site, digging 5 meters, and racing to get it on a plane so you can submit it to the lab for time sensitive results needed to make important and expensive decisions (whew) is VERY important. We know that too.

We've Got Chemistry

It's simple. We figure the more you enjoy working with our fun and engaged team members; the more likely you are to give us continued opportunities to support you.

Ahead of the Curve

Through research, regulation knowledge, and instrumentation, we are your analytical centre for the technical knowledge you need, BEFORE you need it, so you can stay up to date and in the know.

If you have any questions or concerns, please contact me at bshaw@caro.ca

Authorized By:

Bryan Shaw, Ph.D., P.Chem.
Client Service Coordinator

TEST RESULTS

REPORTED TO	Stantec Consulting Ltd. (Calgary)	**CARO WO#**	7110488
PROJECT	113678159.600	**REPORTED**	2017-11-16 13:09

Analyte	Result	RL	Units	Analyzed	Qualifier
BH1 SS5 & SS6 Combo (7110488-01) | Matrix: Soil | Sampled: 2017-11-03					
General Parameters					
Sulfate, Water-Soluble	< 0.050	0.050	%	2017-11-16	

APPENDIX 1: SUPPORTING INFORMATION

REPORTED TO	Stantec Consulting Ltd. (Calgary)	**CARO WO#**	7110488
PROJECT	113678159.600	**REPORTED**	2017-11-16 13:09

Analysis Description	Method Ref.	Technique	Location
Sulfate, Water-Soluble in Soil	CSA A23.2-3B / CSA A23.2-2B	Extraction (HCl) / Gravimetry (Barium Sulfate Precipitation)	Richmond

Glossary of Terms:

RL	Reporting Limit (default)
%	Percent
CSA	Canadian Standards Association Chemical Test Methods

General Comments:

The results in this report apply to the samples analyzed in accordance with the Chain of Custody document. This analytical report must be reproduced in its entirety. CARO is not responsible for any loss or damage resulting directly or indirectly from error or omission in the conduct of testing. Liability is limited to the cost of analysis. Samples will be disposed of 30 days after the test report has been issued unless otherwise agreed to in writing.

APPENDIX 2: QUALITY CONTROL RESULTS

REPORTED TO	Stantec Consulting Ltd. (Calgary)	**CARO WO#**	7110488
PROJECT	113678159.600	**REPORTED**	2017-11-16 13:09

The following section displays the quality control (QC) data that is associated with your sample data. Groups of samples are prepared in "batches" and analyzed in conjunction with QC samples that ensure your data is of the highest quality. Common QC types include:

- **Method Blank (Blk)**: A blank sample that undergoes sample processing identical to that carried out for the test samples. Method blank results are used to assess contamination from the laboratory environment and reagents.
- **Duplicate (Dup)**: An additional or second portion of a randomly selected sample in the analytical run carried through the entire analytical process. Duplicates provide a measure of the analytical method's precision (reproducibility).
- **Blank Spike (BS)**: A sample of known concentration which undergoes processing identical to that carried out for test samples, also referred to as a laboratory control sample (LCS). Blank spikes provide a measure of the analytical method's accuracy.
- **Matrix Spike (MS)**: A second aliquot of sample is fortified with with a known concentration of target analytes and carried through the entire analytical process. Matrix spikes evaluate potential matrix effects that may affect the analyte recovery.
- **Reference Material (SRM)**: A homogenous material of similar matrix to the samples, certified for the parameter(s) listed. Reference Materials ensure that the analytical process is adequate to achieve acceptable recoveries of the parameter(s) tested.

Each QC type is analyzed at a 5-10% frequency, i.e. one blank/duplicate/spike for every 10-20 samples. For all types of QC, the specified recovery (% Rec) and relative percent difference (RPD) limits are derived from long-term method performance averages and/or prescribed by the reference method.

Analyte	Result	MRL	Units	Spike Level	Source Result	% REC	REC Limit	% RPD	RPD Limit	Notes
General Parameters, Batch B7K0899										
Blank (B7K0899-BLK1)				Prepared: 2017-11-10, Analyzed: 2017-11-16						
Sulfate, Water-Soluble	< 0.050	0.050	%							
Duplicate (B7K0899-DUP1)			**Source: 7110488-01**	Prepared: 2017-11-10, Analyzed: 2017-11-16						
Sulfate, Water-Soluble	< 0.050	0.050	%		< 0.050				19	
Matrix Spike (B7K0899-MS1)			**Source: 7110488-01**	Prepared: 2017-11-10, Analyzed: 2017-11-16						
Sulfate, Water-Soluble	0.614	0.050	%	0.660	< 0.050	93	63-117			