November 17, 2017 E2K File: 2017-3304

Parks Canada – Banff Field Unit
PO Box 900
Banff, Alberta
T1L 1K2

Attention: Mr. Glenn Exley

**Re: Geotechnical Investigation**
**Proposed Garage**
**Banff, Alberta**

## 1.0 INTRODUCTION

This report presents the results of a geotechnical investigation undertaken by E2K Engineering Ltd. (E2K) for a proposed garage. The garage is to be located within the Tunnel Mountain Village II Operations Compound in Banff, Alberta. It is understood that the proposed garage would be 24'x30' with an 8' high and 16' wide garage door. The proposed structure would be wood framed.

The geotechnical investigation consisted of digging one (1) test pit to a depth of 3.0m within the footprint of the proposed building, soil sampling, and laboratory testing on samples.

The objective of the geotechnical investigation was to obtain detailed subsurface soil information in order to provide recommendations pertaining to geotechnical aspects of the proposed development. This report provides recommendations regarding site preparation, foundation options, frost protection, excavation stability, and other factors which may be relevant.

## 2.0 SITE DESCRIPTION

The subject site is located within the Tunnel Mountain Village II Operations Compound in Banff, Alberta. The site is generally flat with no defined drainage pattern apparent. Surface vegetation is sparse and consists of grass in some areas. Trees are present surrounding the site but not within the footprint of the building. A figure showing the location of the site is attached in the Appendix of this report.

## 3.0 METHOD OF INVESTIGATION

The geotechnical investigation consisted of digging one (1) test pit to a depth of 3.0m below grade. The test pitting program was completed on November 1, 2017, using an excavator supplied by the client. Field work for the investigation including sampling and logging of soils was completed by Mr. Carson Bawkovy of E2K.

The subsurface soil conditions were continuously logged using the Modified Unified Soil Classification System which includes soil types, depths, moisture contents and soil descriptions. Disturbed soil samples were obtained at selected intervals for laboratory testing.

The laboratory testing program included visual classification and moisture content testing for all soil samples recovered during the investigation. Grain size distribution testing and Atterberg limit testing was performed on selected samples in order to further classify the soil and provide index parameters. Sulphate testing was also completed in order to determine the potential for sulphate attack and provide recommendations for concrete type. The results of the testing program are discussed when relevant throughout this report.

## 4.0 SUBSURFACE CONDITIONS

### 4.1 Soil Stratigraphy Overview

The soil profile encountered at the test pit location consisted of gravel fill overlying a gravelly till. Variations in the thickness and condition of soils may occur in areas not investigated. Detailed soil descriptions are provided on the borehole log in the Appendix of this report, and are discussed in greater detail in the sections below.

### 4.2 Recycled Crush Fill

A layer of crushed gravel fill was encountered from the ground surface to 0.4m. The fill was described as poorly graded gravel containing grass. Recycled crushed aggregates including concrete and asphalt were observed within the fill.

### 4.3 Till

Underlying the surficial gravel fill, a layer of till was encountered which extended to the maximum depth of the test pit at 3.0m. The till was described as clayey, sandy, silty, and gravelly. The till was low plastic, dark brown, damp to moist, stiff to very stiff, and contained cobbles and boulders.

Moisture content tests were performed on all samples of the till layer recovered from the investigation. The tests resulted in moisture contents ranging from 7.4% to 16.9%, indicative of the damp to moist in-situ condition of the soil.

Grain size distribution tests were performed on samples of the till taken from depths of 0.4-1.0m and 2.0-3.0m. The test on the sample recovered from a depth of 0.4-1.0m resulted in fines content of 28.7%, a gravel content of 26.8%, and a sand content of 44.5%. The test on the sample taken from a depth of 2.0m to 3.0m resulted in a fines content of 41.4%, a gravel content of 17.6%, and a sand content of 41.0%.

An Atterberg limit test was performed on the non-gravel fraction of the sample recovered from a depth of 1.0m to 2.0m. The Atterberg limit test resulted in a Liquid Limit of 15%, a Plastic Limit of 10% and a Plasticity Index of 5%. The results indicate a low plasticity.

Pocket penetrometer readings within the till resulted in values ranging from 3.5 to 4.0, indicating undrained shear strengths ranging from 175 kPa to 200 kPa.

## 4.4 Groundwater

A standpipe piezometer was not installed within the Test Pit. No seepage was observed within the test pit.

It should be noted that groundwater levels vary seasonally. During the spring months and times of heavy precipitation the long-term groundwater table elevation is anticipated to fluctuate. It should be noted that the groundwater varies with seasonal conditions including, precipitation, temperature, site drainage characteristics, etc.

## 4.5 Frost Susceptibility

Frost susceptibility refers to the degree to which a soil is prone to frost heaving and subsequent thaw weakening. Based on the frost susceptibility classification system outlined in Table 13.1 of the Canadian Foundation Engineering Manual (CFEM), the subgrade soils at this site are considered to have an “F3” classification, which indicates a high degree of susceptibility to frost heave.

## 4.6 Frost Depth Prediction

The design frost penetration depth can be estimated based on the thermal conductivity method outlined in Section 13 of the CFEM. A design freezing index of 1100 degree days freezing was taken for Banff. Moisture contents of 7% were assumed, and it was assumed that the surface cover would consist of asphalt, gravel or concrete. Based on these assumptions, a design frost depth of 2.7m was calculated for this site.

## 5.0 COMMENTS AND RECOMMENDATIONS

Based on the results of the investigation, the testing carried out, and our understanding of the proposed development, we submit the following comments and recommendations related to the geotechnical aspects of the project.

### 5.1 Site Preparation

It is recommended that the uncontrolled fill soils and soils containing grass be removed from beneath the footprint of the building. All deleterious materials such as vegetation, topsoil, fill and soils containing organics, rootlets or frost should be removed from beneath areas requiring grade support. Areas of the site that require subgrade support should be inspected by a geotechnical engineer upon completion of stripping. A proof roll is recommended for larger areas.

### 5.2 Site Grading and Drainage

The finished grade around the building should be sloped away from the building at a minimum slope of 2%. Site grading plans should be established such that water is shed from the surface to a positive drainage system.

Positive drainage away from the structure should be provided. Care should be taken to place and compact any fill adjacent to the building such that settlement of fill does not result in drainage towards the structure. A low permeability material such as clay should be placed in the upper 300mm to minimize infiltration of water beneath the building. The impermeable layer should extend out a minimum of 2m in all directions from the building.

### 5.3 Placement and Compaction of Fill

It is recommended that any fill required to bring the site to grade be placed and compacted in a controlled, engineered manner in order to minimize total and differential settlements. Fill material should consist of a low to medium plastic cohesive soil free of rocks, organics, frost, or other deleterious materials. Alternatively, well-graded crush gravel with little to no fines may be used as fill.

The recommended compaction procedure is to place fill in 200mm lifts at moisture contents within 2% of optimum, and compact the soil to 98% of the Standard Proctor Maximum Dry Density (ASTM Method D-698). A vibratory compaction method such as a plate tamper or smooth drum roller would be suitable for gravel material encountered near ground surface.

Self-weight settlement of newly placed fill of approximately 0.5% to 1.0% of the fill height may be anticipated for well-graded gravel or sand compacted to 98% of the Standard Proctor Maximum Dry Density (SPMDD). For clay fills compacted to 98% SPMDD, settlement of 1.0% to 2.0% of the fill height is anticipated.

## 5.4 Shallow Foundations

Based on our investigation, spread and/or strip footings would be suitable for the proposed structure. Pertinent design parameters and detailed recommendations for shallow foundations are provided in the section below.

### 5.4.1 Footing Depths

Spread and/or strip footing should be founded at a minimum depth of 1.5m below grade for heated structures and 2.8m below grade for unheated structures. For an unheated building, shallower footings may be constructed if an insulation system is implemented.

### 5.4.2 ULS Design Parameters

Based on the field investigation performed, footings founded in the native till material can be designed based on a factored bearing capacity of 200 kPa.

## 5.5 Slab with Thickened Perimeter Footings

A slab with thickened perimeter footings is considered a suitable foundation system for the proposed structure, provided that an insulation system is implemented and minor movement can be tolerated. Thickened perimeter footings should be founded a minimum of 0.5m below grade.

Based on the field investigation performed, the thickened slab on grade may be designed based on a subgrade modulus of 24 – 48 MPA/m.

## 5.6 Settlement

Given the proposed lightly loaded structure and the condition of the subgrade soils, total settlements of less than 25mm are anticipated for a building founded on footings designed based on the ULS parameters provided in this report and providing that our recommendations are followed. Strip footings and thickened perimeter footings should have a minimum width of 0.45m and a maximum width of 1.8m. Pad footings should have a maximum width of 3.0mx3.0m. Site preparation beneath the slab with thickened perimeter footings should be carried out in accordance with the recommendations contained in Section 5.1.

## 5.7 Construction Recommendations and Inspection

The bearing surfaces must be thoroughly cleaned of all loose or disturbed material prior to pouring concrete. An excavator with a smooth cleaning bucket would be suitable for this purpose. The excavation should not be exposed to rain, snow, and freezing temperatures prior to construction.

It is recommended that a bearing inspection be performed by a qualified geotechnical engineer prior to pouring concrete. The purpose of the bearing inspection is to confirm that the soil conditions are the same as those assumed in the design. The bearing inspection would also provide recommendations for remediation of soils if unacceptable soil conditions are encountered.

## 5.8 Insulation

If shallower footings are required or if a slab with thickened perimeter footings is to be constructed, an insulation system should be implemented to prevent the soil beneath the building from freezing. The insulation should extend out 2.44m in all directions and be a minimum of 80mm thick. For an unheated building or slab with thickened perimeter footings the insulation should provide full coverage beneath the structure in addition to extending out 2.44m in all directions. Insulation should be installed a minimum of 300mm below final grade and be installed on top of 300mm of clean granular fill. It is recommended to check for possible interaction effects between the insulation on the new garage an adjacent structures.

## 5.9 Slab-on-Grade

A floating slab-on-grade is considered to be a suitable floor system for a building founded on shallow footings with frost walls.

The potential for heave movements caused by changes in moisture content can be reduced by implementing surface drainage measures around the exterior of the slab and limit potential sources of external water beneath the floor slab.

Slabs should be constructed on a minimum of 150mm thick layer of well graded 20mm crush gravel containing little to no fines. The gravel should be compacted to 98% SPMDD.

Vertical movements are inevitable for a grade-supported floor slab due to settlement of fill, frost heave, shrink-swell cycles and variations in moisture content.

To reduce the potential for vertical slab movement, the following design provisions should be implemented for a slab-on-grade:

- Partition and non-bearing walls should **not** be rigidly connected to bearing walls or columns for a floating slab-on-grade.

- Slabs should be allowed to float on the subgrade and be tied into the foundation walls or grade beams only at doorways.

In addition, the following recommendations should be followed for both a slab-on-grade and a foundation slab with thickened perimeter footings:

- Reinforce the concrete slab and articulate the slab at regular intervals to provide for controlled cracking.

- The installation of buried water supply lines beneath the floor slab should be avoided wherever possible. Waste water lines beneath the floor slabs should consist of PVC pressure pipe with welded joints.

- Provide positive site drainage away from the proposed building footprint.

- Frost should not be allowed to penetrate beneath the floor slab just prior to, during or after construction

- Heating ducts placed beneath the floor slab should be insulated to minimize drying and shrinkage of clay soils.

- Provide flexible connections for any utility connections to the building such that movements of up to 25mm can be tolerated

A modulus of subgrade reaction of 24 - 48 MPa/m may be utilized for the subgrade soils at this site.

## 5.10 Seismic Classification

Seismic design for various structures is based on the 2014 Alberta Building Code (ABC). The primary objective of the ABC earthquake resistant design requirements is to protect the life and safety of the public in response to strong ground shaking. Structures designed in conformance to the code may undergo structural damage but should not collapse as a result of the ground shaking.

The 2014 ABC 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 E2K field investigation, it is appropriate to classify the ground conditions at the subject site as a Class C site, in accordance with the 2014 ABC.

## 5.11 Requirements for Foundation Concrete

Sulphate content testing of the gravel layer at a depths of 2.3 m below existing ground surface resulted in a negligible risk of sulphate attack. Any concrete in contact with this soil can use a CSA Type GU (General Use) Portland cement. An air entrainment agent is recommended for improved workability and durability. The maximum water cement ratio should be 0.5 and an air entrainment agent is recommended for improved workability and durability.

## 5.12 Excavations

It is anticipated that shallow excavations to depths of up to 3.0m may be required for construction of the building and utility installations. Based on the soils encountered within the test pit, cut slopes of 1.0H:1.0V are recommended for the till materials. A 1.0m vertical cut is permitted at the base of the excavation within the till.

If seepage or soft soils are encountered, it is recommended that a qualified geotechnical engineer be contacted to provide recommendations for an appropriate cut slope. Cut slopes of 2.0H:1.0V or flatter may be required depending on the encountered conditions.

It should be understood that the stability of cut slopes will degrade over time due to reduction in moisture contents, loss of cohesion, erosion, and other factors. As such, it is recommended that the work be directed to minimize the length of time that excavations are left open. In addition, the excavation slopes should be monitored by on-site personnel for signs of erosion, tension cracks behind the crest, or signs of sloughing or failure. If evidence of deterioration in the stability of the excavation is observed, it is recommended that a qualified geotechnical engineer be contacted to provide recommended remedial actions.

Stockpiles of materials and excavated soil should be placed away from slope crests by a distance equal to the depth of excavation. Similarly, wheel loads should be kept back at least 1 m from the crest of the excavation. No additional load should be added above the excavation walls. The applicable sections in the Occupational Health and Safety Act must be followed.

# 6.0 LIMITATIONS

Recommendations made within this report are based on the interpreted findings encountered in one (1) test pit. It should be noted that natural conditions are innately variable. Should conditions other than those reported herein, be identified at any stage of development, E2K should be notified and given the opportunity to re-evaluate current information, if required.

The recommendations presented herein, are subject to an adequate level of inspection during construction. Levels of inspection are generally set out by the Alberta Building Code (ABC) and therefore should be followed to not contravene relevant code requirements. The ABC Schedules are an integral part of the development process and stipulates that a "Geotechnical Engineer of Record" shall be assigned to each project falling under code jurisdiction. This title shall not infer any overall responsibility for geotechnical aspects of this construction project, without prior consent of E2K and written clarification of project responsibility.

This report has been prepared with accepted soil and foundation engineering practices for the project specified in Section 1.0 of this report. No third party may rely on the information contained in this report without the express written permission of E2K. No other warranty is expressed or implied.

## 7.0 CLOSURE

We trust the information contained herein meets your present requirements. Should you require inspection services, or further information regarding the geotechnical aspects of this project, please do not hesitate to contact our office.

Yours truly,
**E2K Engineering Ltd.**
**APEGA Permit to Practice: P9582**

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Attachments: Figure 1
Borehole Log
Explanation of Terms and Symbols

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Figure #1
Testpit Location Plan

Note: Borehole Location Approximate
Image from Google Maps

| PROJECT NAME: Parks Canada Garage | LOCATION: Building Footprint | BOREHOLE NO: **BH-01** |
|---|---|---|
| CLIENT: Parks Canada | DRILL TYPE: Test Pit | E2K PROJECT NO: 2017-3304 |
| | NORTHING: EASTING: | ELEVATION: m |

SAMPLE TYPE: CORE SAMPLE | SPT SAMPLE | SPT SAMPLE | NO RECOVERY | CHEMICAL ANALYSIS

| Depth (m) | SOIL SYMBOL | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE NO | SPT BLOWS /300 mm | PLASTIC – M.C. – LIQUID (20 40 60 80) | ▲PID READING (ppm)▲ 100 200 300 400 / ■BLOW COUNT■ 20 40 60 80 / ◆UNCONF. SHEAR STR. (kPa)◆ 100 200 300 400 / ●0.5 x POCKETPEN. (kPa)● 100 200 300 400 | OTHER DATA | ELEVATION (masl) |
|---|---|---|---|---|---|---|---|---|---|
| 0 | | Grass with recycled crushed gravel, poorly graded, moist | | | | | | | |
| | | TILL, Clay, gravelly, silty, very stiff, poorly graded, low plastic, moist, brown, contains pebbles and cobbles | | G1 | | 16.5 | 175 | | |
| 1 | | ...from 1.0m, damp | | | | | | | |
| | | | | G2 | | 7.9 | 200 | | |
| 2 | | | | | | | | | |
| | | | | G3 | | 7.4 | 200 | | |
| 3 | | END OF TEST PIT @ 3.0m | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |

| | LOGGED BY: JP | COMPLETION DEPTH: 3.00 m |
|---|---|---|
| | REVIEWED BY: BE | COMPLETION DATE: 11/7/17 |

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# EXPLANATION OF TERMS AND SYMBOLS

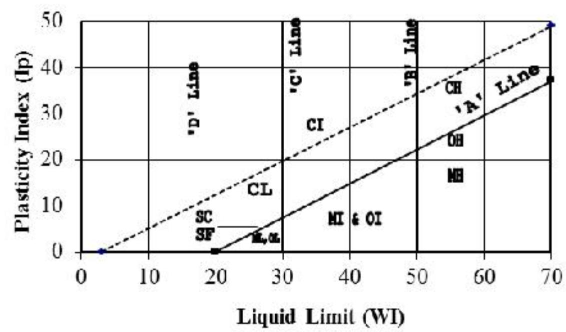
The terms and symbols used on the borehole logs to summarize the results of the field investigation and subsequent laboratory testing are described below. It should be noted that materials, boundaries, and conditions have been established only at the borehole locations at the time of investigation and are not necessarily representative of subsurface conditions elsewhere across the site.

## SOIL DESCRIPTIONS

The soils in the borehole logs have been described using the Modified Unified Soil Classification System in conjunction with description guidelines from the Canadian Foundation Engineering Manual 4th Edition.

| Secondary Constituents | |
|---|---|
| Descriptor | Percentage by Weight |
| And | > 35% |
| y/ey | 20 – 35% |
| Some | 10 – 20% |
| Trace | < 10% |
| | |

Plasticity Chart




| Consistency of Cohesive Soils | | |
|---|---|---|
| Classification | Undrained Shear Strength (kPa) | "N" Blow Count |
| Very Soft | < 12 | < 2 |
| Soft | 12 – 25 | 2 – 4 |
| Firm | 25 – 50 | 4 – 8 |
| Stiff | 50 – 100 | 8 – 15 |
| Very Stiff | 100 – 200 | 15 – 30 |
| Hard | > 200 | > 30 |

| Relative Density of Non-Cohesive Soils | |
|---|---|
| Classification | SPT – N |
| Very Loose | 0 – 4 |
| Loose | 4 – 10 |
| Compact | 10 – 30 |
| Dense | 30 – 50 |
| Very Dense | > 50 |

## SYMBOLS

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Asphalt | High Plasticity Clay | Intermediate Plasticity Clay | Low Plasticity Clay | Fill | Poorly Graded Gravel | Well Graded Gravel | High Plasticity Silt | Intermediate Plasticity Silt |
| Low Plasticity Silt | Low Plasticity Organics | Clayey Sand | Silty Sand | Poorly Graded Sand | Well Graded Sand | Shale | Sandstone | Measured water level |

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## MODIFIED UNIFIED SOIL CLASSIFICATION SYSTEM

| Major Division | | | Symbol | Description | Criteria | |
|---|---|---|---|---|---|---|
| Coarse Grained Soils | Gravel (More than half coarse grains larger than 4.75 mm) | Clean Gravel (little or no fines) | GW | Well graded gravels, little or no fines | $C_u = \frac{D_{60}}{D_{10}} > 4$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$ | |
| | | | GP | Poorly graded gravels and gravel-sand mixtures, little or no fines | Not meeting above criteria | |
| | | Gravel with fines | GM | Silty gravels, gravel-sand-silt mixtures | Fines content > 12% | Atterberg Limit below "A" Line, $w_p < 4$ |
| | | | GC | Clayey gravels, gravel-sand-clay mixtures | | Atterberg Limit above "A" Line, $w_p > 7$ |
| | Sand (More than half of coarse grains smaller than 4.75 mm) | Clean Sand (little or no fines) | SW | Well graded sands, gravelly sands, little or no fines | $C_u = \frac{D_{60}}{D_{10}} > 6$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$ | |
| | | | SP | Poorly graded sands, little or no fines | Not meeting above criteria | |
| | | Sand with fines | SM | Silty sand, sand-silt mixtures | Fines content > 12% | Atterberg Limit below "A" Line, $w_p < 4$ |
| | | | SC | Clayey sand, sand-clay mixtures | | Atterberg Limit above "A" Line, $w_p > 7$ |
| Fine Grained Soils | Silts (Below "A" line, negligible organic content) | $W_L < 50$ | ML | Inorganic silts and very fine sands, rock flour, silty sands with low plasticity | See plasticity chart | |
| | | $W_L > 50$ | MH | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils | | |
| | Clays (Above "A" line, negligible organic content) | $W_L < 30$ | CL | Inorganic clays of low plasticity, gravelly, sandy, or silty clays, lean clays | | |
| | | $30 < W_L < 50$ | CI | Inorganic clays of medium plasticity, silty clays | | |
| | | $W_L > 50$ | CH | Inorganic clays of high plasticity, fat clays | | |
| | Organic silts and clays (Below "A" line | $W_L < 50$ | OL | Organic silts and organic silty clays of low plasticity | | |
| | | $W_L > 50$ | OH | Organic clays of high plasticity | | |
| Highly Organic Soils | | | Pt | Peat and other highly organic soils | Strong colour or odour, often fibrous texture | |

- The soil of each stratum is described using the Unified Soil Classification System modified slightly so that an inorganic clay of "medium plasticity" is recognized
- "REC" denotes percentage sample recovery
- SPT "N" values represent the number of blows by a 63.6 kg hammer dropped 760 mm to drive a 50 mm diameter open sampler a distance of 300 mm after an initial penetration of 150 mm

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