Geotechnical Investigation

Proposed Car Wash Facility
Fort McMurray International Airport
Fort McMurray, Alberta
Project # MX04670

Prepared for:

Avia NG Airport Consultants Inc
Suite 220, 309 16 Ave NW, Calgary, AB, T2M 0H9

28-Feb-19

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Prepared for:
Avia NG Airport Consultants Inc
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1.0 Introduction

1.1 General

Wood Environment & Infrastructure Solutions (Wood) was retained by Avia NG Airport Consultants Inc. (Avia) to complete a geotechnical investigation for the proposed car wash facility at the Fort McMurray International Airport in Fort McMurray, Alberta.

The purpose of the geotechnical investigation was to investigate the subsoil and groundwater conditions at the proposed site location, so that the geotechnical parameters necessary for the design of the foundations, slabs-on-grade and asphalt paved areas could be defined.

Authorization to proceed with the scope of work, as defined in Wood's proposal MP-2711, was received from Avia, in an email dated January 3, 2019.

1.2 Site and Project Description

The proposed car wash facility is located at the Fort McMurray International Airport along Snow Bird Way in Fort McMurray, Alberta. The proposed site is directly east of Highway 69, and directly south of Snow Eagle Drive, and directly west of the Fort McMurray International Airport long-term parking area, as shown in Figure 1, Appendix A. A fence borders the proposed site along the south and west sides.

At the time of the investigation, the site was a cleared, empty lot that was covered with approximately 0.5 m of snow. The overall site grading was flat.

The proposed car wash facility building lot will have a total area of approximately 4,500 m^2, is expected to consist of one single story commercial building with attached wash bays, with no basements, having an approximate total building area of 860 m^2. Asphalt parking and accessways are expected to cover the majority of the area around the building.

2.0 Geotechnical Investigation

Prior to borehole drilling, Wood conducted the necessary utility clearances at the borehole locations through Alberta One Call and a private utility locator. All borehole locations were cleared for above ground and underground utilities before drilling commenced.

On the 10th and 11th of January 2019, Wood supervised the drilling of 4 boreholes (BH19-01 through BH19-04) at the approximate locations illustrated in Figure 1, Appendix A. The boreholes were advanced to depths that ranged between 4.5 m and 9.6 m below existing grade.

The boreholes were advanced using a truck-mounted drill using continuous flight, 150 mm diameter solid-stem augers. Supervision of drilling, soil sampling, and logging of the soil strata was performed by Wood geotechnical personnel. Detailed borehole logs summarizing the sampling, field testing groundwater and subsurface conditions encountered at the borehole locations are presented in Appendix A.

Prior to drilling, Avia provided borehole locations to Wood in an email on December 24, 2018 that were based on the location of the building site and pavement areas on the lot. Wood retained a surveying company to have the provided drill locations laid out in the field using a GNNS GPS receiver and data collector. The ground surface elevation at each borehole was established by the private locator using a GNNS GPS receiver. The borehole ground surface elevations are noted on the borehole logs. It should be noted that the elevations obtained using GNNS GPS receivers are accurate to within about 1 m.

The soil stratigraphy within each borehole was visually classified at the time of drilling in accordance with the Modified Unified Soil Classification System (MUSCS). Soil sampling and evaluation of in-situ soil consistency and relative density consisted of the following:

- Disturbed auger samples were obtained at depth intervals varying from 0.3 m to 1.5 m for moisture content determinations (labeled G#). The moisture content profiles are shown on the borehole logs.
- Standard Penetration Tests (SPT's) were conducted at 1.5 m depth intervals in every borehole to evaluate the consistency and relative density of the various soil strata. SPT results, defined as the number of blows required to drive the SPT split-spoon sampler 300 mm into the soil, were recorded and are noted on the borehole logs as the SPT 'N' values. Where the full 300 mm of penetration was not possible, the number of blows for the penetration attained was noted on the logs (e.g. 50/50 indicates 50 blows for 50 mm of penetration).

The depths to slough (collapsed soil) and groundwater in all boreholes were measured upon drilling completion. A 25-mm diameter PVC standpipe was installed in borehole BH19-01 for short term monitoring of the current groundwater levels. The annulus of the standpipe boreholes, including the slotted sections, were backfilled with drill cuttings up to the slotted length of the standpipe, and a 1 m thick bentonite cap was placed at ground surface. The remaining boreholes were backfilled with a combination of auger cuttings and a surficial benitoite cap. The water level in the standpipe was measured by Wood, 22 days after drilling completion, on February 1, 2019.

Following completion of the field drilling program, a laboratory testing program was conducted on selected soil samples obtained from the boreholes and consisted of: moisture content determinations, water soluble sulphate tests, and Atterberg Limits.

3.0 Subsurface Soil Conditions

3.1 General Stratigraphy

Consistent with the regional geology, anticipated conditions, and our general knowledge of the site, the stratigraphy at the borehole locations generally consisted of muskeg, underlain in descending order by gravel fill, sand, and clay till. The material at the surface to a depth of approximately 1.2 m was frozen in each borehole.

A brief description of each of the soil layers at each site encountered is presented below. For detailed descriptions, the borehole logs in Appendix A should be consulted.

3.1.1 Muskeg

Muskeg was encountered at ground surface in boreholes BH19-01 and BH19-02 and extended to a depth of approximately 1.5 m below existing grade. Although not encountered in every borehole, there is potential for muskeg to be present throughout most of the site.

3.1.2 Gravel Fill

Gravel fill was encountered at ground surface in boreholes BH19-03 and BH19-04 and extended to depths between about 1.8 m to 2.0 m below existing grade. In general, the gravel fill was medium to coarse grained, sandy, contained some silt, was poorly graded, loose to compact, light brown to brown, moist, and frozen at surface. Properties measured in the gravel fill were:

- Moisture Content:
  - Varied between 3 and 10 percent, with the majority of the values around 5 percent
- SPT 'N' Values:

  - One value at 6 and another at 22.
  - These values are indicative of loose (6) and compact (22) densities.

3.1.3 Sand

Sand was encountered in all boreholes below a depth of 2.0 m and extended to a maximum depth of 4.0 m below existing grade. The sand was medium to coarse grained, contained some silt, was well graded, loose to compact, brown to grayish brown, and water bearing. Properties measured in the sand were:

- Moisture Content:
  - Varied between 11 and 24 percent, with the majority of the values between 14 and 20 percent
- SPT 'N' Values:
  - Generally varied between 12 and 18.
  - These values are indicative of compact density, with one (1) value indicating a loose relative density.

3.1.4 Clay Till

The clay till was encountered in all boreholes below a depth of 4.0 m and extended beyond the depths explored. The clay till was generally silty, contained some sand, trace gravel, low plastic, very stiff, grey to dark grey, and damp. Properties measured in the clay till were:

- Moisture Content:
  - Varied between 12 and 23 percent, with the majority of the values between 15 and 17 percent
- SPT 'N' Values:
  - Generally varied between 22 and 27.
  - These values are indicative of very stiff consistency, with two (2) values indicating a hard consistency and one (1) value indicative of stiff consistency. The clay till became hard with increased depth.
- One (1) Atterberg Liquid and Plastic Limit
  - Plastic Limit: 14%
  - Liquid Limit: 27%
  - Indicative of low plastic clay till.

3.2 Groundwater and Sloughing Conditions

In general, sloughing and seepage was encountered during and following drilling activities. Sloughing and seepage generally occurred at depths ranging between 1.1 to 4.0 m and occurred within the sand layer. Slough levels and water levels were measured approximately 10 minutes following drilling at each of the borehole locations. Measured groundwater levels and corresponding elevations are summarized in **Table 1**.

Table 1: Measured Slough and Groundwater Levels

Borehole (m)	Depth to Top of Slough at Drilling Completion (m)	Groundwater Level at Drilling Completion (m)	Groundwater Level on 1 February 2019 (m)	Well Screen Interval (m)
BH19-01	4.6	3.1	3.0	6.6 – 9.1
BH19-02	3.1	3.1	No Standpipe	-
BH19-03	1.8	None	No Standpipe	-
BH19-04	2.4	2.4	No Standpipe	-

It should be recognized that the level of the groundwater table is dependent on meteorological cycles and surface drainage on a regional scale. Higher groundwater levels than those observed in this investigation may be encountered following spring thaw and periods of prolonged precipitation. Seasonal fluctuations under normal conditions are expected to be ±1.0 m from the observed groundwater level, although greater fluctuations are also possible.

3.3 Water Soluble Sulphates

Three (3) water soluble sulphate concentration tests were performed on soil samples obtained from the site. **Table 2** below summarizes the results of the water-soluble sulphate tests, indicating percent water soluble sulphates by dry weight of soil.

Table 2: Water Soluble Sulphate Concentrations

Borehole	Depth (m)	Material Type	Water-Soluble Sulphate (%)
BH19-01	1.5	Sand	0.04
BH19-01	4.4	Clay Till	0.02
BH19-01	8.8	Clay Till	0.02

As per CSA A23.1-09, these values are considered low and indicate a “negligible” potential for sulphate attack on buried concrete.

4.0 Geotechnical Appraisal

Relative to the proposed development, the subsurface soil and groundwater conditions observed in the boreholes are considered to be good.

For the proposed structure, the structural components may be supported on shallow foundations bearing on the compact sand. The approximately 4.0 m depth to where the surface of the clay till was encountered would make founding the footings on clay till uneconomic. Adequate soil cover, or insulation, will be required to maintain perimeter footings below the seasonal frost penetration depth. As the building will be permanently heated, the interior footings may be founded at higher levels in the sand.

Due to sloughing and seepage conditions found in the majority of the boreholes, cast-in-place concrete fiction piles would not be recommended. If requested, recommendations and design parameters for helical screw piles could be provided and would be considered feasible based on the subsurface conditions encountered.

The geotechnical design parameters presented in this report are limed to strip and square footings.

The existing sand subgrade soil is suitable to provide support for concrete floor slabs and pavements.

5.0 Recommendations

5.1 Site Preparation, Grading and Drainage

5.1.1 Subgrade Preparation

Muskeg was encountered in BH19-01 and BH19-02 and should also be stripped and removed from site. The muskeg is not considered acceptable as an engineered fill. Gravel fill was encountered in boreholes BH19-03 and BH19-04 and could be stripped and salvaged for use as engineered fill. Any stripped fill to be reused should be free of organics.

The native sand is considered to be a suitable subgrade material. Where loose, soft or disturbed areas are identified, the area should be excavated to expose a stable subgrade and then should be backfilled with engineered fill. Where fill is required to bring areas back to the top-of-subgrade elevations, it should consist of engineered fill as described in section 5.1.2.

Prior to placing fill that will support slabs or pavements, the area to receive the fill should be proof rolled to check for loose or soft areas. If soft sand conditions are present, Wood should be contacted prior to proof rolling activities. Similarly, where existing fill is removed to achieve design grades, the newly exposed subgrade should be proof rolled. Proof rolling activities should be carried out only when subgrade soils are fully thawed. Proof rolling activities should be conducted with an axle load of 80 kN (eg. Fully loaded tandem axle truck) to check for soft, loose or non-uniform areas. Any soft or loose soil detected should be over excavated and replaced with engineered fill material.

Pleistocene pink clay is common in the Wood Buffalo area and was encountered in BH19-01. Typically, Pleistocene pink clay is over the optimum moisture content for the soil, and it can be a difficult soil with which to attain a stable subgrade. If pink clay soil is encountered during construction it should either be over excavated and replaced with engineered fill or mixed with more stable soil prior to placing it as fill.

5.1.2 Engineered Fill

General engineered fill material consists of low to medium plastic inorganic clay or well-graded granular material. It is anticipated that the clay till encountered at depth would be suitable for use as engineered fill, provided it is free of deleterious material, and is moisture conditioned as required. Given the excavation depths required to expose the clay till, it may not be feasible to re-use it as engineered fill. If trenching activities require excavations to be founded at depths extending into the clay till, it could be stockpiled separately and reused to produce engineered fill providing it meets the requirements outlined in this section.

Engineered fill should be uniformly compacted to at least 98 percent of the standard Proctor maximum dry density (SPMDD) at a moisture content within ±2 percent of the Optimum Moisture Content (OMC) for granular soils, or at OMC to three percent above optimum for cohesive soils. All backfill to over-excavated areas, and fill placed as part of the overall site grading operation should be placed in lift thicknesses compatible with the compaction equipment being used, but no thicker than 0.3 m.

All fill soils should be free from any organic materials, contamination, deleterious construction debris, and stones greater than 80 mm in diameter. Granular material meeting Alberta Transportation (AT) Specification Designation 6 Class 80 would also be suitable for use as engineered fill. Gradation limits for AT Designation 6 Class 80, for use as engineered fill are provided in **Table 3**. Environmental screening should be conducted on any fill source of unknown origin and history. Qualified geotechnical personnel

should monitor the placement and quality of the fill soils. Fill construction and compaction should be monitored on a full-time basis, including regular field density testing during placement.

Table 3: Gradation Limits for Alberta Transportation Designation 6 Class 80

Sieve Designation (mm)	Percent Passing By Weight (by dry mass)
80 mm	100
50 mm	55-100
25 mm	38-100
16 mm	32-85
4.75 mm	20-65
0.315 mm	6-30
0.08 mm	2-10

Where engineered fill is required to support footings or floor slabs, it should consist of well graded, crushed gravel that is free of any organics, frozen soil, contamination or construction debris. The material gradation recommended for structural fill is outlined in **Table 3** for 20 mm minus granular base course (GBC), and is based on the AT standard aggregate specifications for Designation Class 20 aggregate. The GBC should be placed in lifts with a maximum lift thickness of 150 mm and uniformly compacted to a minimum of 100 percent of SPMDD at ± 2 percent of OMC. The fill should extend at least one metre beyond the footprint of any building or slab.

Table 4: Requirements for 20 mm Granular Base Course

Sieve Designation (mm)	Percent Passing By Weight (by dry mass)
20	100
16	84 - 94
10	63 - 86
5	40 - 67
1.25	20 - 43
0.630	14 - 34
0.315	9 – 26
0.160	5 - 18
0.080	2 – 10

5.1.3 Drainage

The exposed subgrade should be graded to promote drainage by maintaining a positive grade and a relatively smooth surface. Site grading, both during and following construction, should be provided such that surface runoff is rapidly shed from pavement/subgrade areas to a positive drainage system. Water should not be allowed to pond on or adjacent to the proposed pavement areas. Where possible,

minimum grades of two percent are recommended to accommodate surface runoff, and to minimize the potential of saturation and degradation of the subgrade. If proper site drainage is not constructed at the beginning of the project, significant subgrade issues can be expected after any rain event. Based on Wood's experience on this site and other in this area, this can result in a requirement for over excavation of wet soils, and increased project costs.

The finished grade around the buildings should be such that surface water drains away from the building. The upper 0.3 m of backfill around the buildings should consist of relatively impervious material such as asphalt, concrete and compacted clay to minimize ingress of runoff water into the soil nearest the building foundations. The impervious surface should extend for a distance of three meters around the building and should be graded at a slope of two percent away from the building.

5.1.4 Winter Construction

Fill placement should be undertaken during frost-free seasons since required degrees of compaction cannot be achieved if the fill or subgrade materials are frozen or are at near-freezing temperatures. If fill is to be placed during the winter months, measures must be in place to maintain fill/subgrade temperatures above freezing, such that required compaction can be achieved. Due to the increased difficulties in placing, conditioning, and compacting clay soils during winter conditions, it is recommended that only granular fill be considered for use if fill placement is proposed during winter months. Since moisture conditioning is almost impossible under winter conditions, even with granular fill, lower in-place densities and greater subsequent settlements should be expected for fill placed during freezing conditions than for fill placed under above-freezing conditions.

5.2 Shallow Foundations

5.2.1 Design

The native sand and clay till are considered to provide a suitable bearing surface for support of strip and square footings. Footings should be founded at a minimum of 1.5 m below grade for frost protection and to allow the footings to be based in native material. As noted previously, existing gravel fill may extend to more than 1.5 m below ground surface. Existing muskeg or gravel fill should be removed to expose a stable foundation subgrade consisting of compact native sand or stiff clay till.

For footings placed on undisturbed native sand or clay till, **Table 5** and **Table 6** provide recommended soil bearing capacity values for strip and square footings, respectively.

Table 5: Soil Bearing Capacities for Strip Footings

Depth (m)	Serviceability Limit State (SLS) (kPa)	Unfactored Ultimate Limit State (ULS) (kPa)
1.5	75	225
3	150	450

Table 6: Soil Bearing Capacities for Square Footings

Depth (m)	Serviceability Limit State (SLS) (kPa)	Unfactored Ultimate Limit State (ULS) (kPa)
1.5	100	300
3	175	525

To obtain the factored ULS bearing pressures, a geotechnical resistance factor of 0.5 should be applied.

5.2.2 Footing Construction

Exterior footings supporting heated structures should be provided with a minimum soil cover of 1.5 m to protect against frost penetration below the footing subgrade. Footings supporting unheated structures should be provided with a minimum soil cover of 3.0 m for frost protection, or equivalent protection should be provided with use of insulation.

The footing excavation should be reviewed by a qualified geotechnical engineer to confirm that the bearing soils exposed are as anticipated in design. If over-excavation is required to extend the excavation through any fill or unacceptable soil, the excavation may be brought back to the design footing elevations with lean-mix concrete. Lean-mix is defined as concrete having a minimum 28-day compressive strength of 5 MPa.

Loose or disturbed materials should be removed from the footing excavation prior to placement of concrete. Hand cleaning may be required to prepare an acceptable bearing surface. The footing subgrade should be protected at all times from rain, snow, freezing temperatures and the ingress of free water. Concrete should not be placed on frozen soil, nor should the soil beneath the footing be allowed to freeze after construction of the footing.

A lean concrete mud slab should be cast overtop of the exposed sand at the base of each footing to mitigate potential disturbance effects from construction foot traffic during placement of the reinforcing steel.

As identified during drilling activities, there is potential for groundwater seepage during construction. If groundwater seepage is encountered, drainage of the footing excavation will be required and is expected to be achievable via gravity drainage into nearby sumps or perimeter ditches within the excavation. The crests of the foundation excavations should be graded to direct surface water runoff away from the excavations.

In areas where the excavations for construction of footings or raft foundations are in excess of 1.5 m deep, the side walls of the excavation should be trimmed back no steeper than 1 horizontal to 1 vertical (45°). Flatter slopes may be required where sloughing or wet conditions are encountered. Alternatively, a shoring system may be incorporated into the design.

5.3 Excavations

Excavations are expected for the building foundations and for utility installations. The side slopes for the excavations should conform to Alberta Occupational Health and Safety guidelines. For preliminary design purposes, excavations through cohesionless soils, such as the sand encountered at the site, should be cut no steeper than 1.5H:1V. Flatter slopes may be required for cohesionless soils if groundwater is present.

When excavations penetrate or are terminated in saturated sand, “flowing” sand conditions are likely to be encountered. To control “flowing” sand conditions, excavations inclinations as flat as 4H:1V would likely be required in conjunction with a free-draining gravel buttress placed over the seepage zone. A geotextile should be placed against the saturated sand to act as a separator prior to placing a gravel buttress.

If the rate of inflow is greater than can be handled with flattened slopes, temporary sumps and/or submersible pumps, then other measures such as well points could be required. Surface grading should be undertaken so that surface water is not allowed to pond adjacent to the excavation and to prevent run-off water from entering the excavation. With a sloped excavation sidewall, some sloughing may be expected and periodic cleaning of debris at the base of excavation may be required.

The stability of any excavations should be monitored by the earthwork’s contractor on a continuous basis. Where certain issues such as cracking, sloughing soils, or groundwater infiltration occur, these issues

and/or conditions should be brought to the immediate attention of Wood so that engineered solutions to the issues can be addressed accordingly.

Stockpiles of materials and excavated soil should be placed away from the slope crest 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. Surface drainage should be directed away from crest of the excavation.

The stability of excavation slopes generally decreases with time and therefore construction should be directed at minimizing the length of time the excavation is left open.

5.4 Floor Slabs

5.4.1 Grade Supported Floor Slabs

The subgrade for the building slab-on-grade may be supported on new engineered fill underlain by the sand. Provided the recommendations outlined in 5.1 are followed, the engineered fill should provide adequate support for a slab-on-grade floor. Following preparation of the subgrade, a levelling course of 20 mm nominal size well-graded crushed gravel at least 150 mm in compacted thickness, is recommended directly beneath the slab. The gravel should be compacted to at least 100 percent of SPMDD. A recommended typical gradation provided in **Table 3** could be used. Other appropriate materials may be considered but should be evaluated by a geotechnical engineer prior to use.

The excavated subgrade beneath slabs-on-grade should be protected at all times from rain, snow, freezing temperatures, excessive drying and the ingress of free water. This applies during and after the construction period.

To minimize the potential negative effects of vertical movements below the floor slab, it would be preferable to allow the slab to float with no rigid connections to the walls or foundation elements, except at the doorways. Alternatively, the slab may be rigidly connected to the foundation walls provided that a parallel construction joint is installed at a distance of about two meters from the points of fixity. Any non-bearing walls supported on the slab should include some tolerance for vertical movement.

Water lines should not be placed below grade supported slabs, both due to the potential for soil movements if leaks develop, and the difficulty of repairing leaks below a slab. Drain lines and sewers located below slabs must be designed with water tight, maintenance free joints.

Some relative movement between floor slabs-on-grade and adjacent walls or foundations, as well as differential movements within the slabs, should be anticipated. Generally, if the recommendations outlined in this report are followed, these movements should be acceptably small. If differential movements are considered intolerable, then an alternative slab support system such as a structural slab would have to be considered.

5.4.2 Drainage Measures

As groundwater was encountered within the boreholes drilled at the site, perimeter weeping tile is recommended along the exterior footing perimeter. The weeping tile is also recommended as a measure to intercept and dispose of surface runoff that may infiltrate along the soil/concrete interface. The weeping tile system should consist of a minimum 150 mm diameter perforated PVC pipe. The pipe should be placed in a trench backfilled by free draining 40 mm minus washed gravel. The trench should be at least 300 mm wide and 300 mm deep and lined with a non-woven geotextile filter such as Nilex C24, to control migration of fines into the lines. The weeping tile should drain to a sump with a pumped, or gravity drainage, discharge to the storm sewer. The drainage gravel should correspond to the gradation outlined in **Table 7**.

In specific areas an under-slab drainage system may be required to protect portions of building from potential groundwater infiltration. An under-slab drainage system consists of perforated drains installed below the floor slab, which are positively drained to a central pumped sump or sumps. The requirement for an under-drain system should be assessed during excavation of building foundations if groundwater is encountered. The following paragraphs outline the general requirements for an under-slab drainage system, in the event that one is required in some areas.

The under-slab drainage system where required below the floor slab should consist of minimum 150 mm diameter perforated PVC pipes. The pipes should be placed in trenches backfilled with free draining 25 mm minus washed gravel. The trenches should be at least 300 mm wide and 300 mm deep and lined with a non-woven geotextile filter to control migration of fines into the lines. A Nilex C24 geotextile, or equivalent, is recommended. Above the trenches and beneath the slab there should be a 200 mm thick layer of drainage gravel. The drainage gravel should correspond to the following gradation:

Table 7: Recommended Gradation for the Drainage Gravel

Sieve Designation (mm)	Percent Passing By Weight (by dry mass)
25 mm	100
20 mm	60-80
15 mm	30-60
10 mm	10-30
5 mm	0-10
2.36 mm	0-5

The drainage gravel should be compacted to at least 98 percent of SPMDD.

The design capacity of the under-drainage system should be assessed during excavation for footings and service trenches, when groundwater conditions can be observed directly.

Both the weeping tile system and any under-slab drainage system should be provided with cleanouts in order to flush the lines in the event of line siltation. The actual design of the sub-drainage system should be developed by the mechanical designer/contractor using the above recommendations as a guideline.

5.4.3 Exterior Grade Supported Sidewalks and Concrete Aprons

The sand that is present on site is considered to be moderately frost susceptible and may develop ice lenses and undergo volume change (heave) if excess moisture is available. Therefore, it is important to provide adequate site drainage and implement precautionary measures to reduce the risk of frost action affecting the unheated exterior grade-supported sidewalks and aprons.

Due to the potential for differential heave between exterior grade-supported structures and structural elements of a heated building, sidewalks and slabs should be free-floating and should not be dowelled into foundation walls grade beams, pile caps or interior slabs, except at doorways.

Consideration can be given to installing rigid insulation below the sidewalks or aprons (driveways) if frost heave is a concern. Additional measures to reduce the risk of frost heave include sloping the aprons or sidewalks away from the building and sealing the interface between the basement walls and the exterior concrete flatwork to limit seepage of surface runoff into the subgrade soils. Where pavement areas are adjacent to walls or grade beams, a separation strip should be installed at the interface.

5.5 Pavements

The pavement structures and construction procedure recommendations provided in this section for light traffic are applicable for access roadways and parking areas with frequent use by cars and light trucks and occasional use by single axle delivery trucks, waste disposal trucks, etc.). In areas where frequent commercial truck traffic is expected, such as drive lanes, the heavier traffic pavement structure should be specified.

Prior to placing base gravel, the subgrade should be prepared as outlined in Subsection 5.1.1. If soft subgrades are encountered some subgrade improvement for paving areas would typically include thicker gravel fill and/or geotextiles or geogrids, the extent of which would be best determined during construction. **Table 8** outlines the recommended light vehicle and heavy vehicle pavement structural sections for access roadways, parking lots and aprons.

Table 8: Preliminary Pavement Sections

Pavement Component	Minimum Thicknesses (mm)	
	Light Traffic/ Parking Area (assumed 1.44 x 104 ESAL's[1])	Heavy Truck Traffic/Drive Lanes (assumed 3.6 x 104 ESAL's)
Hot Mix Asphalt	75	100
Base Course Crushed Granular[2] (20 mm minus)	250	300

Note(s)

Alberta Transportation Specifications:

1. Equivalent Single Axle Loads over 20-year design period
2. See Table 4.

Outlined below are additional construction recommendations pertaining to pavement sections:

- The granular base course should be placed in maximum 150 mm thick lifts (or reduced lift thicknesses as governed by the compaction equipment) and uniformly compacted to a minimum 100 percent of SPMDD at ± 2 percent of OMC to the bottom of the asphalt design elevation.
- All asphalt should conform to, and be placed in accordance with, the current applicable Alberta Transportation asphalt specifications.

Concrete pavement sections should be provided for any areas where the front wheels of garbage trucks will bear during unloading of dumpsters, and for any areas where trailer "dollies" will bear on the pavement. Asphalt pavement used in such areas is at high risk of rutting, and normally develops ruts and cracks within a short time.

5.6 Concrete Type

The results from the sulphate analysis testing conducted on select samples revealed a "negligible" potential for sulphate attack on concrete in contact with native sands and clay till soils at this site. Therefore, concrete in contact with the native soils at this site can be manufactured using CSA Type 10 (GU), normal Portland cement possessing a minimum 28-day compressive strength of 25 MPa. The maximum water cement ratio should be 0.55.

All concrete design and construction should be carried out in accordance with current CAN/CSA-A23.1 specification. An appropriate amount of air entrainment as per the CSA Standard A23.1-00, Clause 14.3 is recommended for all concrete exposed to freezing and thawing at this site for further enhanced durability.

5.7 Seismic Site Classification

The seismic response of the site is classified according to the National Building Code of Canada 2010 (NBCC), which categorizes the soil conditions into 6 types - Class 'A' to 'F'. This site is categorized as Class 'D' according to NBCC 2010. This classification is based on the average shear wave velocity, energy-corrected SPT N values, or undrained shear strength over the top 30 m of the soil profile.

Shear wave velocity data was not obtained from this site, and borings were not advanced to 30 m depth. Thus, this seismic classification is based on the SPT 'N' values within the depths drilled as the site, as well as the assumption that the soil strength below the depths drilled is at least as high as that encountered at the borehole termination depths.

6.0 Geotechnical Testing and Inspection

All engineering design recommendations presented in this report are based on the limited number of boreholes advanced at the site, and on the assumption that an adequate level of inspection will be provided during construction and that all construction will be carried out by a suitably qualified contractor experienced in foundation and earthworks construction. An adequate level of inspection is considered to be:

- for earthworks, including backfill: full time monitoring and compaction testing;
- for footings and grade supported slabs: observation of supporting subgrade prior to concrete placement;

Wood requests the opportunity to review the design drawings and monitor the installation of the new foundation to confirm that the recommendations have been correctly interpreted. Wood would be pleased to provide any further information that may be needed during design and to advise on the geotechnical aspects of specifications for inclusion in contract documents.

7.0 Limitations and Closure

7.1 Limitations

1. The work performed in the preparation of this report and the conclusions presented herein are subject to the following:

    a) The contract between Wood and the Client, including any subsequent written amendment or Change Order dully signed by the parties (hereinafter together referred as the "Contract");

    b) Any and all time, budgetary, access and/or site disturbance, risk management preferences, constraints or restrictions as described in the contract, in this report, or in any subsequent communication sent by Wood to the Client in connection to the Contract; and

    c) The limitations stated herein.

2. **Standard of care:** Wood has prepared this report in a manner consistent with the level of skill and are ordinarily exercised by reputable members of Wood's profession, practicing in the same or similar locality at the time of performance, and subject to the time limits and physical constraints applicable to the scope of work, and terms and conditions for this assignment. No other warranty, guarantee, or representation, expressed or implied, is made or intended in this report, or in any other communication (oral or written) related to this project. The same are specifically disclaimed, including the implied warranties of merchantability and fitness for a particular purpose.

3. **Limited locations:** The information contained in this report is restricted to the site and structures evaluated by Wood and to the topics specifically discussed in it, and is not applicable to any other aspects, areas or locations.
4. **Information utilized:** The information, conclusions and estimates contained in this report are based exclusively on: i) information available at the time of preparation, ii) the accuracy and completeness of data supplied by the Client or by third parties as instructed by the Client, and iii) the assumptions, conditions and qualifications/limitations set forth in this report.
5. **Accuracy of information:** No attempt has been made to verify the accuracy of any information provided by the Client or third parties, except as specifically stated in this report (hereinafter "Supplied Data"). Wood cannot be held responsible for any loss or damage, of either contractual or extra-contractual nature, resulting from conclusions that are based upon reliance on the Supplied Data.
6. **Report interpretation:** This report must be read and interpreted in its entirety, as some sections could be inaccurately interpreted when taken individually or out-of-context. The contents of this report are based upon the conditions known and information provided as of the date of preparation. The text of the final version of this report supersedes any other previous versions produced by Wood.
7. **No legal representations:** Wood makes no representations whatsoever concerning the legal significance of its findings, or as to other legal matters touched on in this report, including but not limited to, ownership of any property, or the application of any law to the facts set forth herein. With respect to regulatory compliance issues, regulatory statutes are subject to interpretation and change. Such interpretations and regulatory changes should be reviewed with legal counsel.
8. **Decrease in property value:** Wood shall not be responsible for any decrease, real or perceived, of the property or site's value or failure to complete a transaction, as a consequence of the information contained in this report.
9. **No third-party reliance:** This report is for the sole use of the party to whom it is addressed unless expressly stated otherwise in the report or Contract. Any use or reproduction which any third party makes of the report, in whole or in part, or any reliance thereon or decisions made based on any information or conclusions in the report is the sole responsibility of such third party. Wood does not represent or warrant the accuracy, completeness, merchantability, fitness for purpose or usefulness of this document, or any information contained in this document, for use or consideration by any third party. Wood accepts no responsibility whatsoever for damages or loss of any nature or kind suffered by any such third party as a result of actions taken or not taken or decisions made in reliance on this report or anything set out therein. including without limitation, any indirect, special, incidental, punitive or consequential loss, liability or damage of any kind.
10. **Assumptions:** Where design recommendations are given in this report, they apply only if the project contemplated by the Client is constructed substantially in accordance with the details stated in this report. It is the sole responsibility of the Client to provide to Wood changes made in the project, including but not limited to, details in the design, conditions, engineering or construction that could in any manner whatsoever impact the validity of the recommendations made in the report. Wood shall be entitled to additional compensation from Client to review and assess the effect of such changes to the project.
11. **Time dependence:** If the project contemplated by the Client is not undertaken within a period of 18 months following the submission of this report, or within the time frame understood by Wood to be contemplated by the Client at the commencement of Wood's assignment, and/or, if any

changes are made, for example, to the elevation, design or nature of any development on the site, its size and configuration, the location of any development on the site and its orientation, the use of the site, performance criteria and the location of any physical infrastructure, the conclusions and recommendations presented herein should not be considered valid unless the impact of the said changes is evaluated by Wood, and the conclusions of the report are amended or are validated in writing accordingly.

Advancements in the practice of geotechnical engineering, engineering geology and hydrogeology and changes in applicable regulations, standards, codes or criteria could impact the contents of the report, in which case, a supplementary report may be required. The requirements for such a review remain the sole responsibility of the Client or their agents.

Wood will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

12. **Limitations of visual inspections:** Where conclusions and recommendations are given based on a visual inspection conducted by Wood, they relate only to the natural or man-made structures, slopes, etc. inspected at the time the site visit was performed. These conclusions cannot and are not extended to include those portions of the site or structures, which were not reasonably available, in Wood's opinion, for direct observation.

13. **Limitations of site investigations:** Site exploration identifies specific subsurface conditions only at those points from which samples have been taken and only at the time of the site investigation. Site investigation programs are a professional estimate of the scope of investigation required to provide a general profile of subsurface conditions.

    The data derived from the site investigation program and subsequent laboratory testing are interpreted by trained personnel and extrapolated across the site to form an inferred geological representation and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour with regard to the proposed development. Despite this investigation, conditions between and beyond the borehole/test hole locations may differ from those encountered at the borehole/test hole locations and the actual conditions at the site might differ from those inferred to exist, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface details and anomalies.

    Final sub-surface/bore/profile logs are developed by geotechnical engineers based upon their interpretation of field logs and laboratory evaluation of field samples. Customarily, only the final bore/profile logs are included in geotechnical engineering reports.

    Bedrock, soil properties and groundwater conditions can be significantly altered by environmental remediation and/or construction activities such as the use of heavy equipment or machinery, excavation, blasting, pile-driving or draining or other activities conducted either directly on site or on adjacent terrain. These properties can also be indirectly affected by exposure to unfavorable natural events or weather conditions, including freezing, drought, precipitation and snowmelt.

    During construction, excavation is frequently undertaken which exposes the actual subsurface and groundwater conditions between and beyond the test locations, which may differ from those encountered at the test locations. It is recommended practice that Wood be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered at the test locations, that construction work has no negative impact on the geotechnical aspects of the design, to adjust recommendations in accordance with conditions as additional site information is gained and to deal quickly with geotechnical considerations if they arise.

Interpretations and recommendations presented herein may not be valid if an adequate level of review or inspection by Wood is not provided during construction.

14. **Factors that may affect construction methods, costs and scheduling:** The performance of rock and soil materials during construction is greatly influenced by the means and methods of construction. Where comments are made relating to possible methods of construction, construction costs, construction techniques, sequencing, equipment or scheduling, they are intended only for the guidance of the project design professionals, and those responsible for construction monitoring. The number of test holes may not be sufficient to determine the local underground conditions between test locations that may affect construction costs, construction techniques, sequencing, equipment, scheduling, operational planning, etc.

    Any contractors bidding on or undertaking the works should draw their own conclusions as to how the subsurface and groundwater conditions may affect their work, based on their own investigations and interpretations of the factual soil data, groundwater observations, and other factual information.

15. **Groundwater and Dewatering:** Wood will accept no responsibility for the effects of drainage and/or dewatering measures if Wood has not been specifically consulted and involved in the design and monitoring of the drainage and/or dewatering system.

16. **Environmental and Hazardous Materials Aspects:** Unless otherwise stated, the information contained in this report in no way reflects on the environmental aspects of this project, since this aspect is beyond the Scope of Work and the Contract. Unless expressly included in the Scope of Work, this report specifically excludes the identification or interpretation of environmental conditions such as contamination, hazardous materials, wild life conditions, rare plants or archeology conditions that may affect use or design at the site. This report specifically excludes the investigation, detection, prevention or assessment of conditions that can contribute to moisture, mold or other microbial contaminant growth and/or other moisture related deterioration, such as corrosion, decay, rot in buildings or their surroundings. Any statements in this report or on the boring logs regarding odours, colours, and unusual or suspicious items or conditions are strictly for informational purposes

17. **Sample Disposal:** Wood will dispose of all uncontaminated soil and rock samples after 30 days following the release of the final geotechnical report. Should the Client request that the samples be retained for a longer time, the Client will be billed for such storage at an agreed upon rate. Contaminated samples of soil, rock or groundwater are the property of the Client, and the Client will be responsible for the proper disposal of these samples, unless previously arranged for with Wood or a third party.

7.2 Closure

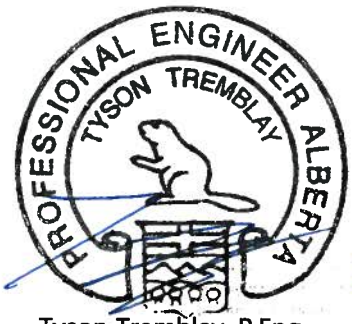
Recommendations presented herein are based on a geotechnical evaluation of the findings at the four (4) borehole locations drilled during the field investigation at the site. If conditions other than those reported are noted during subsequent phases of the work, Wood should be notified and given the opportunity to review the current recommendations considering any new findings. Recommendations presented herein may not be valid if an adequate level of inspection is not provided during construction, or if relevant building code requirements are not met.

Soil conditions, by their nature, can be highly variable across a construction site. The placement of fill and prior construction activities on a site can contribute to variable near surface soil conditions. A contingency amount should be included in the construction budget to allow for the possibility of variations in soil conditions, which may result in modifications of the design, and/or changes in construction procedures.

This report has been prepared for the exclusive use of Avia NG Airport Consultants Inc for specific application to the development described within this report. Any use that a third party makes of this report, or any reliance or decisions based on this report are the sole responsibility of those parties. It has been prepared in accordance with generally accepted soil and foundation engineering practices, no other warrantee is given.

Respectfully submitted,

Wood Environment & Infrastructure Solutions, a division of Wood Canada Limited



28 Feb 2019

Brad Copping, P.Eng.
Geological Engineer
Org Manager

Tyson Tremblay, P.Eng,
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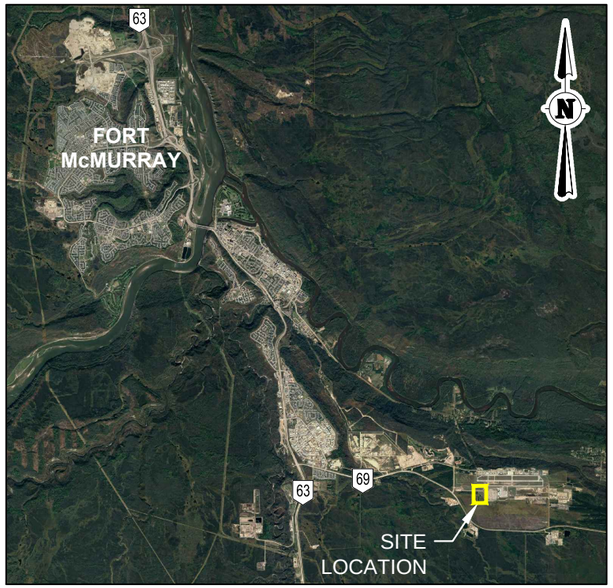
Northern Alberta Materials Branch Manager

Reviewed:

Kevin Spencer, M.Eng., P.Eng.
Senior Associate Geotechnical Engineer

APEGA Permit to Practice Number: P-4546

Appendix A



KEY PLAN
N.T.S.

REFERENCE:
GOOGLE IMAGE CREATED FROM GOOGLE EARTH PRO. IMAGERY DATE OCTOBER, 2018.

0 10 20 30 40 m
1 : 1000

NOTE: THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE WOOD ENVIRONMENT & INFRASTRUCTURE SOLUTIONS REPORT No. MX04670 DATED FEBRUARY 2019.

LEGEND:
BH19-XX BOREHOLE LOCATION

CLIENT:
AVIA NG AIRPORT CONSULTANTS INC

wood.
Environment & Infrastructure Solutions
10204 CENTENNIAL DRIVE, FORT McMURRAY, AB, T9H-1Y5
PHONE 791-0848, FAX 780-790-1194

DWN BY:	CMG
CHK'D BY:	BC
DATUM:	NAD 83
PROJECTION:	UTM Zone 12
SCALE:	AS SHOWN

PROJECT:
PROPOSED CAR WASH FACILITY FORT McMURRAY INTERNATIONAL AIRPORT

TITLE:
BOREHOLE LOCATION PLAN

DATE:	FEBRUARY, 2019
PROJECT No.:	MX04670
REV. No.:	A
FIGURE No.:	FIGURE 1

S:\Cadd\MISC\MX\MX04670\MX04670-001.dwg - FIGURE 1 - 2/15/2019 12:09 PM - clayton.gibeau-Half-Colour_Civil3D.ctb

Avia NG Airport Consultants Inc	YMM Car Rental Facility Geotechnical Investigation	BOREHOLE NO.: **BH19-01**
All Service Drilling Inc	SITE: Fort McMurray, AB	PROJECT NO.: MX04670
Solid Stem Auger	UTM Zone 12N N:6278391 E:485362	ELEVATION: 345.7 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT Test (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Slough; Grout; Drill Cuttings; Sand

BLOW COUNT (N) 20 40 60 80

PLASTIC M.C. LIQUID 20 40 60 80

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	OTHER TESTS COMMENTS	ELEVATION (m)
0	**MUSKEG** organic, trace sand, some woody debris, some rootlets, loose, dark brown, wet		G1			345
			G2			
1	...seepage at 1.1 m		G3		Frost up to 1.2 m below existing grade	
	SAND some silt, medium to coarse grained, trace gravel, well graded, compact, brown to grayish brown, wet, occasional rootlets		D1	18	SO_4 = 0.04%	344
2			G4			
3	...saturated below 2.9 m		G5			343
			D2A	12		
	CLAY TILL silty, some sand, trace gravel, very stiff, medium plastic, gray to dark gray, moist, moderate bitumen odor		D2B			342
4						
	...laminated pink Pleistocene clay at 4.3 m		G6		SO_4 = 0.02%	
5			D3	25		341
						340
6			G7			
			D4	22		339
7						
			G8			338
8	...damp below 7.9 m		D5	27		
						337
9	...trace greenish gray sand (glauconitic) lenses below 9.0 m		G9		SO_4 = 0.02%	
	...hard at 9.2 m		D6	34		
10	**BOREHOLE TERMINATED AT 9.6 m BELOW EXISTING GRADE**					336
	Notes: Minor sloughing and seepage encountered at 1.1 m below existing grade. Borehole remained open to 4.7 m with water accumulating to 1.5 m below existing grade 10 minutes after the completion of drilling. Borehole installed with 25 mm diameter PVC slotted standpipe and backfilled with drill cuttings and bentonite.					335
11						
12						334

wood.
Environment & Infrastructure Solutions
10204 Centennial Drive
Fort McMurray, Alberta, T9H 1Y5

ENTERED BY:	COMPLETION DEPTH: 9.6 m
LOGGED BY: JDS	COMPLETION DATE: 10/1/19
REVIEWED BY: BC	Page 1 of 1

Avia NG Airport Consultants Inc	YMM Car Rental Facility Geotechnical Investigation	BOREHOLE NO.: **BH19-02**
All Service Drilling Inc	SITE: Fort McMurray, AB	PROJECT NO.: MX04670
Solid Stem Auger	UTM Zone 12N N:6278386 E:485334	ELEVATION: 345.1 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT Test (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Slough; Grout; Drill Cuttings; Sand

BLOW COUNT (N) 20 40 60 80

PLASTIC M.C. LIQUID 20 40 60 80

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	OTHER TESTS COMMENTS	ELEVATION (m)
0	**MUSKEG** organic, trace sand, some woody debris, some rootlets, loose, dark brown, very moist		G1			345
			G2			
1			G3		Frost up to 1.2 m below existing grade	344
	SAND some silt, medium to coarse grained, trace gravel, well graded, compact, brown to grayish brown, wet, occasional rootlets		D1	24		
2			G4			343
3	...saturated below 2.9 m		G5			
			D2	13		342
4	**CLAY TILL** silty, some sand, trace gravel, very stiff, medium plastic, gray to dark gray, damp, moderate bitumen odor ...trace pink clay laminated below 4.3 m		G6			341
			D3	23		
5			U1			340
6			G7			339
			D4	53		
7			U2			338
8						337
9			G8			336
	BOREHOLE TERMINATED AT 9.1 m BELOW EXISTING GRADE					
10	Notes: Minor sloughing and seepage encountered at 1.5 m below existing grade. Borehole remained open to 3.0 m with water accumulating to 3.0 m below existing grade 10 minutues after the completion of drilling. Borehole backfilled with drill cuttings and bentonite.					335
11						

wood.
Environment & Infrastructure Solutions
10204 Centennial Drive
Fort McMurray, Alberta, T9H 1Y5

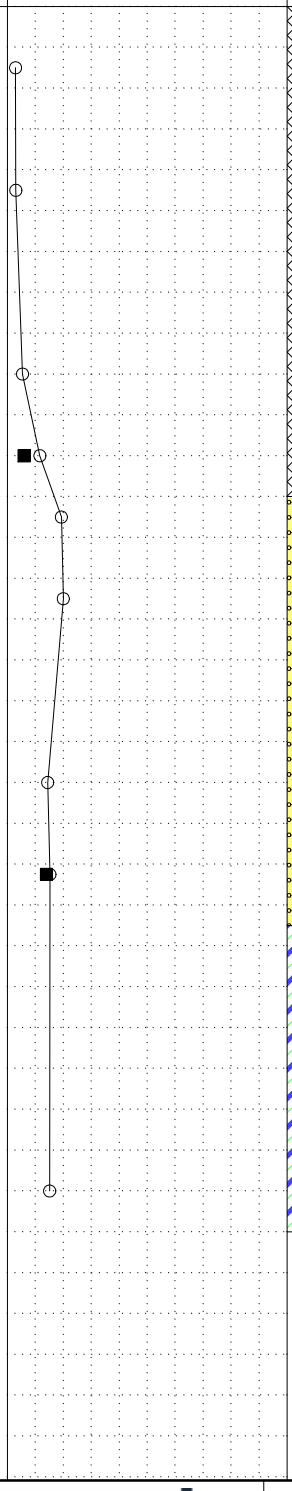
ENTERED BY:
LOGGED BY: JDS
REVIEWED BY: BC

COMPLETION DEPTH: 9.1 m
COMPLETION DATE: 10/1/19

Avia NG Airport Consultants Inc	YMM Car Rental Facility Geotechnical Investigation	BOREHOLE NO.: **BH19-03**
All Service Drilling Inc	SITE: Fort McMurray, AB	PROJECT NO.: MX04670
Solid Stem Auger	UTM Zone 12N N:6278354 E:485377	ELEVATION: 345.1 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT Test (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Slough; Grout; Drill Cuttings; Sand



Depth (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	OTHER TESTS COMMENTS	ELEVATION (m)
0		**GRAVEL FILL** medium to coarse grained, sandy, some gravel, some silt, trace clay, loose, poorly graded, light brown to brown, damp		G1			345
				G2			
1							344
				G3		Frost up to 1.2 m below existing grade	
		...moist below 1.4 m					
		...wet below 1.7 m		D1A	6		
		SAND some silt, medium to coarse grained, well graded, compact, brown to grayish brown, wet, occasional rootlets		D1B			
2				G4			343
				G5			
3							342
				D2	14		
		CLAY TILL silty, some sand, trace gravel, medium plastic, gray to dark gray, moist, moderate bitumen odor					
4							341
				G6			
		BOREHOLE TERMINATED AT 4.6 m BELOW EXISTING GRADE					
5		Notes: Some sloughing and no seepage was observed. Borehole remained open to 1.8 m below existing grade with no water accumulating 10 min after drilling. Borehole backfilled with drill cuttings and bentonite.					340
5.5							

wood.

Environment & Infrastructure Solutions
10204 Centennial Drive
Fort McMurray, Alberta, T9H 1Y5

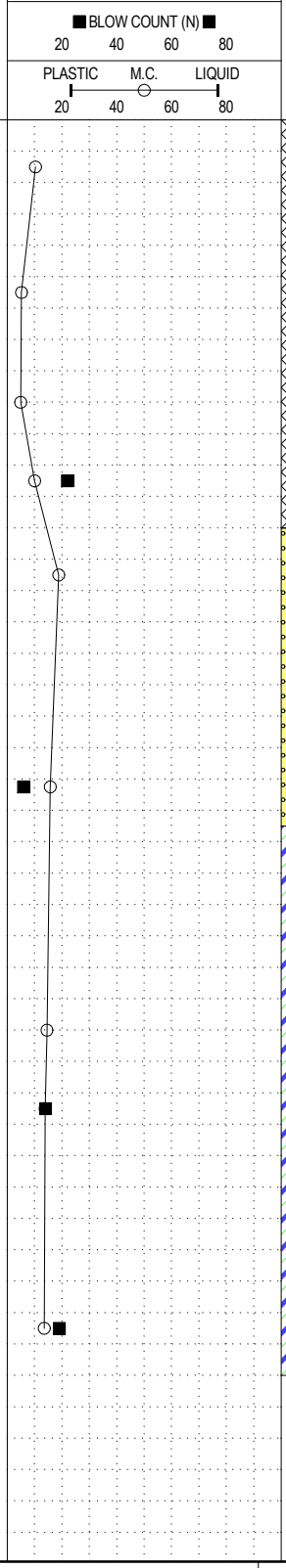
ENTERED BY:
LOGGED BY: JDS
REVIEWED BY: BC

COMPLETION DEPTH: 4.6 m
COMPLETION DATE: 10/1/19

Avia NG Airport Consultants Inc	YMM Car Rental Facility Geotechnical Investigation	BOREHOLE NO.: **BH19-04**
All Service Drilling Inc	SITE: Fort McMurray, AB	PROJECT NO.: MX04670
Solid Stem Auger	UTM Zone 12N N:6278338 E:485318	ELEVATION: 345.2 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT Test (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Slough; Grout; Drill Cuttings; Sand



Depth (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	OTHER TESTS COMMENTS	ELEVATION (m)
0		**GRAVEL FILL** medium to coarse grained, sandy, some gravel, some silt, trace clay, loose to compact, poorly graded, light brown to brown, damp		G1			345
				G2			
1		...seepage at 1.2 m		G3		Frost up to 1.2 m below existing grade	344
		...very moist below 1.7 m		D1	22		
2		**SAND** some silt, medium to coarse grained, well graded, loose, brown to grayish brown, moist, occasional rootlets		G4			343
3				D2	6		342
		CLAY TILL silty, some sand, trace gravel, stiff, medium plastic, gray to dark gray, damp, moderate bitumen odor					
4				G6			341
				D3	14		
5				U1			340
		...very stiff below 5.6 m		D4	19		
6		**BOREHOLE TERMINATED AT 3.5 m BELOW EXISTING GRADE**					339
7		Notes: Minor sloughing and seepage encountered at 1.2 m below existing grade. Borehole remained open to 2.4 m with water accumulating to 2.4 m below existing grade 10 minutes after the completion of drilling. Borehole backfilled with drill cuttings and bentonite.					

wood.

Environment & Infrastructure Solutions
10204 Centennial Drive
Fort McMurray, Alberta, T9H 1Y5

ENTERED BY:	COMPLETION DEPTH: 6.1 m
LOGGED BY: JDS	COMPLETION DATE: 11/1/19
REVIEWED BY: BC	Page 1 of 1

MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

MAJOR DIVISION			GROUP SYMBOL	GRAPH SYMBOL	COLOUR CODE	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 75µm)	GRAVELS MORE THAN HALF THE COARSE FRACTION LARGER THAN 4.75mm	CLEAN GRAVELS (LITTLE OR NO FINES)	GW		ORANGE	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, 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		ORANGE	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY GRAVELS (WITH SOME FINES)	GM		ORANGE	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12 %	ATTERBERG LIMITS BELOW "A" LINE OR P.I. LESS THAN 4
			GC		ORANGE	CLAYEY GRAVELS, GRAVEL-SAND- CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
	SANDS MORE THAN HALF THE COARSE FRACTION SMALLER THAN 4.75mm	CLEAN SANDS (LITTLE OR NO FINES)	SW		YELLOW-BLACK	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		YELLOW-BLACK	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY SANDS (WITH SOME FINES)	SM		YELLOW-BLACK	SILTY SANDS, SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12 %	ATTERBERG LIMITS BELOW "A" LINE OR P.I. LESS THAN 4
			SC		YELLOW-BLACK	CLAYEY SANDS, SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75µm)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	w_L < 50%	ML		GREEN	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT COMPRESSABILITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (SEE BELOW) $I_p = w_L - w_P$ $I_L = \frac{w - w_P}{w_L - w_P} = \frac{w - w_P}{I_p}$ I_p = PLASTICITY INDEX I_L = LIQUIDITY INDEX	
		w_L > 50%	MH		BLUE	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDS OR SILTY SOILS OF HIGH COMPRESSABILITY		
	CLAYS ABOVE "A" LINE NEGLIGIBLE ORGANIC CONTENT	w_L < 30%	CL		GREEN	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY OR SILTY CLAYS, LEAN CLAYS		
		30% < w_L < 50%	CI		GREEN-BLUE	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS		
		w_L > 50%	CH		BLUE	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS		
	ORGANIC SILTS & CLAYS BELOW "A" LINE	w_L < 50%	OL		GREEN	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	WHENEVER THE NATURE OF THE FINES CONTENT HAS NOT BEEN DETERMINED, IT IS DESIGNATED BY THE LETTER "F", E.G. SF IS A MIXTURE OF SAND WITH SILT OR CLAY	
		w_L > 50%	OH		BLUE	ORGANIC CLAYS OF HIGH PLASTICITY		
HIGHLY ORGANIC SOILS			Pt		PURPLE	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOUR OR ODOUR, AND OFTEN FIBEROUS TEXTURE	

SPECIAL SYMBOLS

LIMESTONE		LEAN OIL SAND / RICH OIL SAND	
SANDSTONE		SHALE	
SILTSTONE		FILL (UNDIFFERENTIATED)	

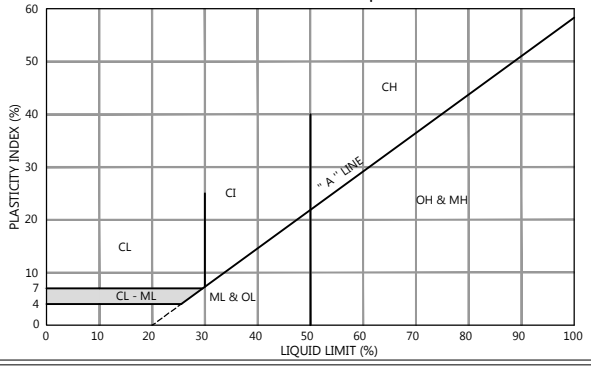
SOIL COMPONENTS

FRACTION	U.S. STANDARD SIEVE SIZE		DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS	
GRAVEL	PASSING	RETAINED	PERCENT	DESCRIPTOR
COARSE	76mm	19mm	35-50	AND
FINE	19mm	4.75mm		
SAND			20-35	Y/EY
COARSE	4.75mm	2.00mm		
MEDIUM	2.00mm	425µm	10-20	SOME
FINE	425µm	75µm		
FINES (SILT OR CLAY BASED ON PLASTICITY)	75µm		1-10	TRACE

OVERSIZED MATERIAL

ROUNDED OR SUBROUNDED:	NOT ROUNDED:
COBBLES 76mm TO 200mm	ROCK FRAGMENTS > 76mm
BOULDERS > 200mm	ROCKS > 0.76 CUBIC METRE IN VOLUME

PLASTICITY CHART FOR SOILS PASSING 425 µm SIEVE



NOTES:

1. ALL SIEVE SIZES MENTIONED ON THIS CHART ARE U.S. STANDARD A.S.T.M. E.11
2. COARSE GRAIN SOILS WITH 5 TO 12% FINES GIVEN COMBINED GROUP SYMBOLS, E.G. GW-GC IS A WELL GRADED GRAVEL SAND MIXTURE WITH CLAY BINDER BETWEEN 5 AND 12% FINES.

wood.
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