





## 1.0 INTRODUCTION

*Chilkoot Geological Engineers Ltd.* was retained by the *City of Dawson* through the *Government of Yukon* to conduct a geotechnical investigation at the *Art & Margaret Fry Recreation Center* located in Dawson City, Yukon.

The purpose of the investigation was to determine the potential cause of undesirable structural movements that have been noted at the facility such that the proper structural upgrades are considered during potential future work. The movements were identified during survey monitoring programs that have been conducted at the facility since August 2007 following facility upgrades that resulted in surficial slab movements. During the monitoring episodes, the data suggested that the structural columns were also undergoing differential movements beyond the magnitude specified in the original geotechnical report. At the time of our project team discussions in June of 2009, our firm indicated that the movements associated with the structural columns were attributed to either a bearing capacity failure or else a thaw degradation (thermal) issue.

Since such time, more detailed characterization of the noted movements has been conducted through geodetic surveys, in an attempt to classify the movement as settlement or else heave. In addition, the geodetic survey has allowed for the magnitude of differential movement for the entire facility to be determined. Previous differential survey work was limited to assessing three separate areas of the facility due to survey limitations. A description of the magnitudes noted during the November survey can be found in Section 4.5, below.

The geotechnical investigation was formulated following project team meetings held on June 29 & 30, 2009 which were summarized in a Structural Upgrade Report dated July 15, 2009, prepared by Mr. Ian McKay, MAIBC, MRAIC, LEED AP of *PBK Architects Inc.*



Authorization to proceed was granted by YTG's project manager, Mrs.C.Heath, MRAIC, on August 6, 2009.

The investigative was conducted in accordance with our July 31, 2009 proposal.

Fieldwork was conducted between October 3-18, 2009.

The work was purposely delayed until October such that a general comparison of the sub-surface conditions with those encountered during the investigation conducted in 2007 could be made.

The 2007 investigation was conducted to assess the feasibility of establishing a concrete slab-on-grade ice surface and conducting remedial foundation work on existing slab-on-grade components through excavation/backfill construction methodologies.

All work was conducted or else directly overseen by our firm's president, Mr.T.Dhara, P.Eng.

Detailed descriptions describing the work programs have been provided in *Section 2.0*, below.



## 1.1 Site Description

The *Art & Margaret Fry Recreation Center* is a multipurpose recreation facility that is comprised of a curling rink, ice arena, administration and utility areas.

The original arena and curling rink facility was a pre-engineered building constructed in 1978. It is understood that the foundation system for the original facility was comprised of a spread-footing pilaster grade-beam system found upon an underlying granular stratum.

The structure is bound by 4<sup>th</sup> Avenue to the west, *Diamond Tooth Gerties* building to the south, 5<sup>th</sup> Avenue to the east and a parking area to the north. Other nearby structures include the *JJJ Hotel* and cabins across the street from 5<sup>th</sup> Avenue, the *Parks Canada Historical Warehouse* located northeast of the facility and a Church and residences located north of the parking area. Some ancillary sheds are located across the street on 4<sup>th</sup> Avenue in a large parking area.

An expansion to the facility in 2000 included the construction of a two storey Administration Building (with a crawlspace) as well as enlargement of the ice arena, curling lounge and mechanical room areas. A combination of spread footing pilaster grade-beam and slab-on-grade foundation systems was utilized. The spread footing pilaster system was specified in order to match the pre-existing footing system of the original structure. Since such time, the newly established slab-on-grade components have experienced visible movements and as such, a survey program was established in 2007 to monitor their differential movements.

The topography is relatively flat with minor variations in the existing ground profile.

A selection of site photographs have been provided in *Appendix F – Photographs*.



## 1.2 Related Studies

The geotechnical investigation was conducted further to our *Geotechnical Feasibility Study* submitted to YTG on August 14, 2007 and our *Geotechnical Report* dated January 16, 2008.

In addition to the geotechnical studies eight (8) *Survey & Groundwater Monitoring Reports* have been compiled by our firm since August 2007.

These studies should all be considered an integral part of this report as they provide geotechnical information regarding the sub-surface conditions building movements.



## 2.0 GEOTECHNICAL INVESTIGATION

The geotechnical investigation was comprised of a literature review, field and laboratory work programs.

### 2.1 Literature Review

As our firm has been involved with various projects related to the facility, we are well versed in the literature that has been available to date. A summary of these documents that required only minimal review was presented in our 2007 Geotechnical Report.

The recently secured *Construction Monitoring Report* prepared by *J.R.Paine & Associates Ltd.* immediately following facility upgrades in 2000, became the primary focus of our literature review, as this document was not available until just recently. In addition to the report, a number of miscellaneous documents associated with the construction were also reviewed. These documents included general correspondence between *FSC*, *TSL*, *Arctic Foundations* and *J.R.Paine & Associates Ltd.* during facility upgrades.

In brief, the *Construction Monitoring Report* provided good insight into the groundwater conditions encountered during construction, presence of contaminated soils in the location of the former underground storage tanks and compactive effort in the area of the mechanical room expansion area.

The rate of groundwater influx was considered high and originated at the interface between Soil Units # 3 & # 4 and within isolated seams located within Soil Unit # 3. The report indicated that groundwater appeared to flow from the south to the north.



The report discussed the removal of approximately 23 dump truck loads of potentially hydrocarbon contaminated soils from the area of the underground storage tanks located near the Curling Rink Lounge area. The report indicated that soils were removed to the limits defined by the specifications and that a Photo Ionization Detector was utilized to confirm adequate clean-up at the limits of the excavation.

The report confirmed compaction of (White Channel) granular backfill in the Curling Rink Lounge area to 95% of its corresponding maximum Standard Proctor density.

## **2.2 Fieldwork Program**

Our investigation was comprised of three subsurface investigation programs which included auger drilling, test-pit excavation and bedrock drilling exploration programs. Each program assisted in characterizing a particular parameter of the granular alluvial deposit upon which (it is understood) the structures spread-footing pilasters are founded.

### ***2.2.1 Site Reconnaissance***

The site reconnaissance was conducted on October 2, 2008 to note relevant site features and layout anticipated testhole locations.

### ***2.2.2 Subsurface Utility Locates***

The utility locates involved contacting *Yukon Energy Corporation Ltd (YECL)*, *Northwestel Ltd* and the *City of Dawson* to ensure that underground infrastructure would not be affected by drilling operations. In brief, *YECL* indicated that there were no underground utilities that would be affected by drilling at the proposed testhole



locations. *Northwestel Ltd.* identified an underground fiber optic bundle on the north side of Queen Street and another leading from *Diamond Tooth Gerties* offices to the southeast through the rear parking lot area. The *City of Dawson, Public Works Department* confirmed sewer, storm and waterline locations and marked subsurface (decommissioned) thermosyphon locations within the Ice Arena. The approximate locations of these underground utilities are as noted on the *Borehole & Testpit Location Plan* enclosed in *Appendix A*.

### **2.2.3 Auger Drilling Program**

The auger drilling program was conducted between October 6 & 18, 2009.

The boreholes were advanced by *Donjek Services* utilizing a CME-75 drill mounted on an FN-60 Nodwell under the direction of *Chilkoot Geological Engineers Ltd.*'s. The drill rig was modified to allow for diamond coring utilizing wet-rotary means.

The auger drilling program consisted of advancing eleven (11) boreholes in and around the facility to obtain soil samples and characterize local and regional subsurface conditions. Two (2) of the boreholes were advanced within the Ice Arena with the remainder advanced around the facility. With the exception of BH 6-09, all boreholes encountered frozen granular alluvial materials. BH 6-09, located at the approximate center of the ice arena, encountered 1.52 meters of thawed alluvial material comprised of well washed coarse sand and gravel until refusal was encountered.

Boreholes were advanced until refusal was encountered within the alluvial deposit at an average depth of 4.03 meters. This depth was consistent with the depth of refusal encountered during the previous investigation (4.15 meters).

Both 150 mm solid-stem and 200 mm. hollow-stem continuous flight augers were utilized during the drilling program. The use of the hollow-stem augers



allowed for retention of relatively undisturbed soil samples through standard penetration testing (SPT) methodologies and allowed for an assessment of the relative density of sub-surface soils.

In brief, the standard penetration test measures the number of blows (N-value) required to drive a 50 mm. diameter uncased sampler tube a distance of 300 mm utilizing a 63.5 kg hammer dropped from a height of 760 mm. These N-values allow for correlation of the noted resistance relative to the materials bearing capacity.

The SPT analysis generally classified the density of the granular alluvial deposit as very dense indicating bearing capacities consistent with those specified in the original geotechnical report compiled by *J.R.Paine & Associates Ltd.*

*Borehole Locations*

The boreholes were advanced at the approximate locations noted on the *Borehole & Testpit Location Plan* enclosed in *Appendix A*.

The boreholes were advanced in order to characterize project areas as follows;

<u>Boreholes</u>	<u>Characterized</u>
BH 1, 5, 8 & 9	Exterior Conditions
BH 2 & 3	Bedrock Characterization & Thermistor Installation
BH 4, 10 & 11	Monitoring Well Installations
BH 6 & 7	Interior Arena Conditions

Both solid-stem, hollow-stem and diamond coring drill methodologies were employed. One (1) borehole (BH 5-09) was advanced solely utilizing 150 mm. diameter continuous flight solid-stem augers. Two (2) boreholes were advanced utilizing diamond coring drill methodologies (BH 2-09 & BH 3-09). The remaining eight (8) boreholes were advanced utilizing 200 mm. (inner diameter) hollow-stem



augers. In some instances the solid-stem augers were employed during hollow-stem drilling operations to facilitate auger advancement and target transitional zones.

### *Soil Logs*

Borehole (and Testpit) logs were maintained by *Chilkoot Geological Engineers Ltd.*'s President, Mr.T.Dhara, P.Eng., during drilling operations. The soil logs were compiled utilizing a combination of field notes, visual observations and laboratory analysis.

The following information was maintained during drilling;

Soil description

(depths, color, relative moisture content and density, gradation/plasticity, inclusions, oxidation, transition zones)

Sample depths and types

Depth of groundwater

Other pertinent geotechnical information

Comments regarding drilling effort

Temperatures -

Intermittent temperature readings were recorded utilizing a digital-thermometer (TPI Model 342, Type K Thermo-coupler). Temperatures were noted to decrease by approximately 0.3° degrees Celsius within the split-spoon sample tube (length of 0.45 meters). The temperatures noted on the borehole logs were generally taken from the tip of the sampler tube, where the sample was least influenced from frictional heat caused as a result of driving.

Unconfined Compressive Strength -

A *Humboldt Manufacturing Ltd.* pocket penetrometer was intermittently utilized on cohesive (fine-grained) soils to provide relative estimates (in kg/cm<sup>2</sup>) of the materials unconfined compressive



strength. The readings varied between  $< 0.5$  to  $> 4.5$  kg/cm<sup>2</sup> as noted on the borehole logs.

#### Material Classification -

The results of the laboratory analysis formed the basis of the material classification however, field observations were also utilized. Unfrozen soils were classified utilizing the *Unified Soils Classification System (USCS)*. Where frozen soils were encountered, the *National Research Council (NRC)* classification system was utilized.

#### Photographs -

Photographic documentation of the field work, soils samples and site conditions were maintained during the course of the investigation. A selection of these photographs has been provided in *Appendix F – Photographs*.

The *Soil Logs* and outlines of the classification systems utilized have been provided in *Appendix B*.

#### *Borehole Termination*

Refusal was encountered in 10 of the 11 boreholes. The eleventh borehole was terminated following the successful retrieval of a rock core. Excluding the two exploratory boreholes (BH 2-09 and BH 3-09) the average depth of refusal was 4.03 meters below the existing ground surface (but varied between 3.66 meters and 5.38 meters). The depth of refusal was similar to that encountered during the 2007 investigation which was noted to be 4.15 meters.

With the exception of the two exploratory boreholes, boreholes were terminated due to encountering dense alluvial deposits as described in *Section 3.0 - Subsurface Conditions*. The exploratory borehole BH 2-09 encountered abrupt refusal utilizing solid-stem augers at a depth of 17.83 meters. Based upon the auger action during drilling, stratigraphy encountered and depth, the refusal was likely due to the presence



of bedrock. The depth noted correlated with the known depth of bedrock near the *S.S.Keno* located on Front Street which is in the order of 17 meters. The second exploratory borehole, BH 3-09 was terminated at a depth of 11.89 meters following the successful retrieval of a rock core.

#### ***2.2.4 Test-pit Program***

The purpose of the test-pit program was to assess the feasibility of excavation in the region of the curling lounge, retain a soil sample of the basal alluvial deposit and assess its continuity with depth.

While we originally proposed to excavate a single test-pit (in the south-eastern parking lot near *Gerties* offices), soil conditions allowed for the excavation of an additional two (2) test-pits in the northern parking lot area. This allowed for the retention of representative samples from several locations for comparison purposes. A total of eight (8) soil samples of the granular alluvial deposit were retained. A summary of the retained samples has been presented in Table I. In brief, the retained samples all noted ice-rich soil conditions within the granular alluvial deposit (Soil Unit # 4).

An assessment of the granular alluvial deposits continuity with depth could not be readily facilitated given its extremely dense nature. The depth of penetration into the granular alluvial deposit utilizing a frost bucket was generally limited to on average, 0.25 meters. The auger drilling program was however successful in identifying a weaker soil unit (# 3) inter-bedded within Soil Unit # 4, approximately 0.34 meters below the interface between the two soil units as described in Section 3.1.3, below.



### ***2.2.5 Bedrock Exploration Program***

Based upon the two exploratory boreholes (BH 2-09 and BH 3-09), which were advanced to (or near to) bedrock, the granular alluvial deposit measured approximately 7.8 meters thick and terminated at an average depth of 11.44 meters. Cut marks from the diamond core barrel on several of the larger pieces of gravel suggest that the granular alluvial deposit is frozen at depth as noted on the photos attached in Appendix I. If the deposit were thawed, the diamond core barrel would likely have retrieved the entire piece of gravel rather than contacting and cutting it. This observation was confirmed following the temperature readings of thermistor (thermal monitoring) strings that were installed through the deposit in the two boreholes. The steady nature of drill stem advancement suggests the absence of ice lenses and organic deposits.

BH 2-09 was advanced on the north side of the facility (in the parking lot) to a depth of 17.83 meters, at which point refusal was encountered. Regolithic (highly fractured/weathered bedrock) material was encountered at a depth of 11.53 meters. A rock core could not be retained from the borehole as the core barrel was lost downhole, resulting in borehole termination. Auger action at the depth of auger refusal suggests that bedrock would be located near the depth of refusal at 17.83 meters which is consistent with the known depth of bedrock at the *S.S.Keno*.

BH 3-09 was advanced within 2 meters of the south-east corner of the Curling Rink Lounge. This borehole encountered regolithic material at 11.35 meters and bedrock at 11.89 meters. Two rock cores (measuring 1.52 meters and 0.91 meters in length and 2 inches in diameter) were retained from the borehole.



### ***2.2.6 Monitoring Well Installations***

Three (3) monitoring wells were installed during the investigation to assist in future groundwater monitoring. The wells were installed in BH 4-09, 10-09 & 11-09.

The well installed at BH 4-09 will allow for greater characterization of the subsurface, particularly given the potential for hydrocarbon contaminated groundwater which was encountered near BH 19-07 during our initial geotechnical investigation.

The well at BH 10-09 was installed to replace a destroyed monitoring well (BH 3-07). Monitoring of groundwater elevations at this location will assist during thermal data collation as BH 1-07 thermistor string (No.1) is located nearby.

The monitoring well at BH 11-09 was installed to assist in overall site characterization.

Details regarding groundwater observations have been described in *Section 3.2*, below.

### ***2.2.7 Thermistor Installation Program***

Two thermistor (temperature monitoring) strings were installed in the alluvial stratum during the bedrock exploration program. The strings were installed through the entire alluvial deposit on both the north and south sides of the facility. Over time, this will allow for thermal monitoring of the soil unit upon which the structure is founded. Prior to our recent investigation, the installation depth of thermistor strings at the facility was limited to 1.86 meters into the alluvial deposit due to drilling limitations.

The locations of the two newly installed thermistor strings (No.4 & No. 5) will allow for a comparison of thermal data on the north and south side of the facility within the



foundings strata. In addition, as String No. 4 was installed approximately 10 meters north of the facility and String No. 5 was installed within 2 meters of the Curling Lounge, the building influence of the heated crawlspace and potential thaw-bulb can be compared to a relatively undisturbed zone.

### ***2.2.8 Sampling Program***

Soil samples were retained at regular intervals during the field work by utilizing either a 20 diameter split-spoon sampler during SPT testing or else by obtaining grab samples directly from the auger flighting (or excavator bucket). The use of the split-spoon sampler allowed for retention of relatively undisturbed samples.

A total of 117 samples were obtained during the investigation. This included a total of 40 split-spoon samples, 63 grab samples, 9 diamond coring samples, 2 water recirculation (cuttings) samples and 3 water samples.

Once soil samples were retained, they were described in the field on the soil logs. Soil samples were then sealed in air-tight plastic bags and numbered consecutively in order to allow for subsequent laboratory classification and analysis.

The water samples were contained in glass bottles to allow for chemical laboratory analysis. The water samples were retained from monitoring wells BH 17-07, BH 19-07 and BH 4-09 following well development.

Following sample retention, soil samples were transported to *Chilkoot Geological Engineers Ltd.*'s Whitehorse laboratory facilities to undergo more detailed examination and laboratory analysis described in *Section 2.3*, below. The water samples and a soil sample (for metals analysis - No. 2 from TP 1-09) were sent directly to *Exova* labs in Surrey, B.C. for chemical analysis.



**2.2.9 Survey Program**

The survey program involved surveying the elevations and locations of the testpits, boreholes and monitoring wells. The locations were measured spatially relative to local building features.

A survey of the testholes noted elevations that varied between 99.17 meters and 99.51 meters. The top of the fire hydrant located on 5<sup>th</sup> Avenue was given an arbitrary elevation of 100.00 meters.

The testpits, boreholes, monitoring wells and thermistor strings were located as shown in *Appendix A– Borehole & Testpit Location Plan*.

A summary of the corresponding elevations has been provided in *Table II – Stratigraphic Summary*.

**2.3 Laboratory Work Program**

The laboratory work programs were comprised of physical and chemical laboratory analysis. The chemical laboratory program was conducted to assist in characterizing the hydrocarbon contamination that was encountered during the 2007 investigation.

**2.3.1 Physical Laboratory Analysis**

The physical laboratory analysis was conducted at *Chilkoot Geological Engineers Ltd.*'s Whitehorse laboratory facilities.

The analysis was comprised of;

Moisture Content Determination	ASTM D 2216-92	104 Samples
Soil Classification	ASTM D 2487-93	114 Samples



Grainsize Distribution Analysis	ASTM D 422-633	32 Samples
Atterberg Limit Analysis	ASTM D 423/424	3 Samples

The results of the laboratory analysis have been summarized in the *Soil Logs* enclosed in *Appendix C*.

*Moisture Content Determination & Soil Classification*

The laboratory testing program included natural moisture content (MC) determination and laboratory classification of all retained soil samples.

The results of the moisture content analysis have been presented on the *Soil Logs* enclosed in *Appendix B*.

*Grainsize Distribution Analysis*

Grainsize Distribution Analysis were conducted in order to assist in soil classification utilizing the *Unified Soils Classification System*.

The results of the analysis have been provided in *Appendix C – Grainsize Distribution Analysis*.

*Atterberg Limit Analysis*

The results of the Atterberg Limit Analysis were as follows;

<b>Borehole / Sample No.</b>	<b>Natural Moisture Content</b>	<b>Plastic Limit (%)</b>	<b>Liquid Limit (%)</b>	<b>USCS Classification</b>
7-09 - 87	37.2	22.3	25.3	ML
9-09 - 96	36.1	22.7	25.2	ML
10-09 - 103	36.1	21.7	24.9	ML



The natural moisture contents of the samples tested were noted to be above their respective liquid limits.

### ***2.3.2 Chemical Laboratory Analysis***

The chemical laboratory analysis was conducted at *Exova (Labs)* in Surrey, B.C. to assess the degree of hydrocarbon contamination that was encountered. The samples were chosen following screening utilizing a Photo Ionization Detector (PID).

The soil and water analysis assessed concentrations of the following;

Mono-aromatic Hydrocarbons

Volatile Petroleum Hydrocarbons

Extractable Petroleum Hydrocarbons

Polycyclic Aromatic Hydrocarbons/ PAH Surrogate Recovery

The results of the chemical analysis have been enclosed in *Appendix D – Chemical Laboratory Analysis*.

A summary of the chemical laboratory results ( $\mu\text{g/g}$ ) in relation to applicable guidelines has been presented as follows;

*Results of Chemical Analysis for Soil Samples*

Criteria	BH 2-09 No. 33	BH 2-09 No. 34	BH 5-09 No. 66	BH 5-09 No.66b	BH 5-09 No. 67	BH 5-09 No. 69	Soil Standard
VPH (6-10 minus BTEX)	< 50	< 50	< 50	< 50	< 50	< 50	200
VPH (6-10)	< 50	< 50	< 50	< 50	< 50	< 50	200
LEPH	339	218	<b>1400</b>	1040	< 20	< 20	1000
HEPH	946	<b>2130</b>	120	110	35	< 20	1000

*Results of Chemical Analysis for Water Samples (November 2009)*

Criteria	Water Results 4-09	Water Results 17-07	Water Results 19-07	Water Standard
VPH (6-10 minus BTEX)	< 50	< 50	60	1500
VPH (6-10)	< 50	< 50	90	1500
LEPH	< 100	< 100	<b>1300</b>	500
HEPH	100	< 100	< 100	1000

*Results of Chemical Analysis for Water Samples from BH 19-07 (Since Oct. 2007)*

Criteria	October 2007	June 2009	Nov. 2009	Water Standard
VPH (6-10 minus BTEX)	1230	< 50	60	1500
VPH (6-10)	<b>1600</b>	< 50	90	1500
LEPH	<b>1500</b>	200	<b>1300</b>	500
HEPH	<100	< 100	< 100	1000



The levels of hydrocarbon contamination for some of the criteria were in excess of the corresponding standards.

The standards utilized for comparison purposes were the Generic Numerical Water Standards (CSR Schedule 3) in accordance with *Yukon Government -Contaminated Site Regulations*.

The results of the metals analysis conducted on Sample No. 2 retained from TP 1-09 has been attached in *Appendix D – Chemical Laboratory Analysis*. In brief, the analysis noted relatively high levels of Nickel and Chromium.



### 3.0 SUBSURFACE CONDITIONS

The subsurface conditions are characterized by the stratigraphic, groundwater and bedrock conditions which have been described as follows;

#### 3.1 Soil Stratigraphy

The soil stratigraphy was comprised of the following five soil units which overlie bedrock;

***Unit # 1 – Fills;***

which are predominately coarse grained and contain an appreciable amount of fines, overlying;

***Unit # 2 – Peat Stratum;***

which is wet to saturated and rich in organics with varying amounts of silt, overlying;

***Unit # 3 – Alluvial Channel (Silt) Deposits;***

which are predominately comprised of silt but contain finer clay sized materials and/or coarser granular materials and may include cobble to boulder sized materials, overlying;

***Unit # 4 – Alluvial Valley (Gravel) Deposits;***

which are coarse grained and contain cobble and possibly boulder sized materials, overlying;

***Unit # 5 – Regolith;***

which is comprised of highly weathered and fractured bedrock.



The soil conditions for Soil Units # 1 through # 3 were consistent with those encountered during the 2007 investigation.

Detailed descriptions of Soil Units # 1 through # 3 have been provided in our previous *Geotechnical Report* dated January 16, 2007 as well as *Soil Logs* attached in *Appendix B*. While the conditions of Soil Unit # 4 were also consistent with those noted during the previous investigation, additional information regarding its thickness, composition and thermal conditions was retained. This information has been discussed in detail below. Soil Unit # 5 ó Regolith was identified during our investigation and has also been described below.

As the study area is located within a region of discontinuous permafrost, the thermal conditions of the soil units varies. The installation of thermistor strings as described in Section 2.2.7 above, has allowed for detail characterization of the thermal regime. These conditions have been discussed in greater detail in Section 4.6 ó Thermal Analysis.

### ***3.1.1 Unit # 1 – Fills***

The fills are comprised of predominately coarse-grained White Channel Gravel but also includes finer-grained granular materials. Deleterious materials were encountered within the fills such as wood chips, organic inclusions and silt nodules.

The relative moisture contents ranged from damp to wet/saturated.

### ***3.1.2 Unit # 2 –Peat Stratum***

A peat stratum underlay the fill in most boreholes. The exception to this was in BH 3-09, 4-09, BH 7-09 and BH 11-09, where the soil unit was absent and the fill was directly underlain by Soil Unit # 3.



The peat is highly compressible and is comprised of partially decomposed residue of mosses, rootlets and similar fibrous organics with varying amounts of silt, sand and gravel.

The relative moisture contents ranged from moist to wet/saturated.

### ***3.1.3 Unit # 3 – Alluvial Channel (Silt) Deposits***

Alluvial channel deposits, predominately comprised of silt with varying amounts of clay, sand and gravel, were encountered at all test locations.

The silt was generally wet to saturated and was frozen in some locations.

The deposit was noted to grade coarser with depth, at some locations, as exhibited by an increase in sand and gravel content. Cobbles and possibly boulder sized materials may be encountered near the base of the stratum.

Some inter-bedding of this deposit with Soil Unit # 4 was noted in BH 10-09. Specifically, a 40 mm thick sandy silt seam was noted approximately 0.34 meters below the interface between Soil Unit # 3 and # 4.

As with all alluvial deposits, organics and/or massive ice may be encountered within the deposits as the result of channel infilling.

The deposits were noted to be moist to saturated and generally non to low-plastic.

Frozen conditions were encountered within the Silt Stratum in the 11 of the 14 of the testholes. The frozen conditions were assessed by utilizing a combination of digital thermometer, pocket-penetrometer and visual observations.



Where the strata was noted to be in a thawed condition, its consistency was at some locations noted to be soft to very soft with SPT  $N_{60}$  values ranging between 1 and 4. Typical values obtained with the pocket penetrometer were less than  $0.5 \text{ kg/cm}^2$ . The Atterberg Limit Analysis noted that the natural moisture contents exceeded their corresponding liquid limits in the three samples analyzed, indicating predominately liquefied conditions.

The two boreholes advanced inside the Ice Arena (BH 6-09 & BH 7-09) encountered thawed conditions. In some instances (BH 3-09 & 4-09), the presence of frozen conditions could not be confirmed or refuted. The materials identified with these unknown conditions have been described as 'possibly frozen' on the *Soil Logs* enclosed in *Appendix B*.

The classification of the frozen materials (utilizing the *NRC Classification System*) comprised the majority of the sub-groups. As noted by the *NRC Classification System*, the materials would be considered 'usually thaw-unstable' with the exception of the Nbn designation. The Nbn designation was considered 'usually thaw-stable'

### ***3.1.4 Unit # 4 – Alluvial Valley (Gravel) Deposits***

The Alluvial Valley Deposits are comprised of coarse-grained granular soils which are frozen at depth. More detailed characterization regarding its thermal regime has been discussed in Section 4.6, below. The steady nature of drill stem advancement suggests the absence of ice lenses and organic deposits, however, as with all alluvial deposits, organics and/or massive ice may be present as the result of channel infilling.

The deposit was noted to be clean, coarse and contain high percentages of cobble to boulder sized materials.



The thickness of the deposit was determined to be 7.57 and 8.54 meters at the two exploratory borehole locations (BH 2-09 & BH 3-09).

#### *Grainsize Distribution Analysis*

A total of 13 grainsize distribution analysis were conducted on Unit # 4 materials. Details regarding the moisture contents, material composition and soil classification have been summarized in *Table I*.

With the exception of BH 6-09 located at the center of the Ice Arena, the deposit was noted to be frozen when encountered. BH 6-09 encountered 1.52 meters of thawed, well washed coarse sand and gravel. The frozen deposits were classified in accordance with the *National Research Council Classification System*, as;

*V<sub>c</sub>*, - indicating segregated ice visible by eye less than 25 mm thick coating soil particles. Specifically, ice coatings up to 2 mm thick were noted on gravel size particles with ice saturation in the order of 1% volume, by visual estimate.

Ice coatings on gravel particles were encountered during the previous investigation in BH 21-07, Sample 108B.

*V<sub>x</sub>* ó indicating individual ice crystals or inclusions less than 1 mm. in size and approximately 1 % ice saturation by volume.

*N<sub>bn</sub>* ó indicating segregated ice not visible by eye, well bonded with no excess ice.



### ***3.1.5 Unit # 5 – Regolith***

Highly weathered and fractured bedrock was encountered below Soil Unit # 4 in both the exploratory boreholes.

The thickness of the regolith varied considerably between the two borehole locations. BH 2-09 advanced on the north side of the facility encountered approximately 6.3 meters of regolithic material, while the borehole (BH 3-09) advanced on the south side of the facility encountered only 0.54 meters of regolith.



## **3.2 Groundwater Conditions**

### ***3.2.1 General***

Unlike the investigation conducted in 2007, groundwater was not generally encountered during drilling operations.

### ***3.2.2 Groundwater Observations***

Groundwater observations were noted during, at the end and immediately after drilling operations and have been marked on the *Soil Logs* enclosed in *Appendix B*.

In general, the groundwater elevations coincide with the base of the fills or else peat deposits. Groundwater readings have been attained from the monitoring wells on an intermittent basis since October 2007. A summary of the groundwater observations to date has been enclosed in *Table III –Groundwater Summary*.

## **3.3 Bedrock**

### ***3.3.1 Field Conditions***

Bedrock was encountered at south side of the facility in BH 3-09 at a depth of 11.89 meters. Two rock cores measuring 1.52 meters and 0.91 meters were subsequently retained from the borehole. For quantitative purposes, the Rock Quality Designation (RQD) index was utilized to assess the rock mass.

In brief, the RQD is determined by measuring the sum of core pieces that are greater than 100 mm in length divided by the entire core run.

The corresponding RQD index of the retained cores was 51% and 44% respectively, indicating generally fair to poor conditions.

25-50% would be considered poor with 50-75% fair and 75-90% good.



The rock encountered was classified as a chloritic quartzite.

The exploratory borehole advanced on the north side of the facility (BH 2-09) encountered solid-stem auger refusal at a depth of 17.83 meters. A rock core could not be retained from the borehole as the diamond core barrel was lost down-hole during drilling operations thus preventing further auger advancement or coring. Based upon the auger action however, it is likely that the refusal encountered was due to the presence of competent bedrock. This depth of refusal collates well to the depth of bedrock located at *S.S.Keno* on Front Street which is known to be approximately 17-18 meters.

### **3.3.2 General**

Locally, the bedrock is comprised of Devonian, Mississippian and possible older age rock of the *Nisina Assemblage*, as well as Carboniferous and Permian age rock of the *Klondike Schist* and *Anvil Assemblages*.

These assemblages are described by *Yukon Bedrock Geology, G.S.C. Open File 3754*, as follows;

#### ***Nisina Assemblage***

The *Nisina Assemblage* is generally comprised of graphitic quartzite and muscovite quartz-rich schist with interspersed marble.

#### ***Klondike Schist Assemblage***

The *Klondike Schist Assemblage* is a poorly understood assemblage of metamorphosed pelitic/volcanic rocks and minor marble which may include phyllite of uncertain association.



Specifically, *Klondike Schist* can be subdivided into chlorite-rich and muscovite-rich members thought to have been derived from mafic and felsic volcanic or volcanoclastic rocks, respectively. Also present in the unit are strongly foliated quartz and feldspar augen schist (metaporphry) and fine-grained quartzose metasediments.

### ***Anvil Assemblage***

The *Anvil Assemblage* is predominately comprised of an oceanic assemblage of mafic volcanics, ultramafics, chert and pelite, limestone and gabbroic rocks.

Detailed bedrock geology maps and compositional descriptions can also be found in *Bedrock Geology and Mineralization of the Klondike Area (East & West), Files 1985-1 & 1984-3*, respectively



## 4.0 DISCUSSIONS & RECOMMENDATIONS

### 4.1 General

The presence of ice-rich granular alluvial deposits as well as inter-bedded fine grained materials at the transitional zone (near the interface of the silt and granular strata) at some locations, is cause for concern and may explain the reason that differential movements are occurring within structural components of the facility.

The results of the auger drilling program revealed that Soil Units # 1 through # 3 located within the facility (BH 6-09 & BH 7-09) were thawed to the depth of the granular alluvial deposit (Soil Unit # 4). The upper 1.52 meters of Soil Unit # 4 within borehole BH 6-09 was also thawed. Boreholes BH 3-09 and BH 4-09, which were located within 2 meters of the Curling Rink Lounge, also exhibited potentially thawed conditions within Soil Units # 1 through # 3. These thawed conditions may be the result of thermal influence of the building upon the sub-surface soils.

### 4.2 Soil Bearing Capacity

The SPT analysis confirmed that the soil bearing capacities at the founding elevation (top of Soil Unit # 4) are consistent with those recommended in the original geotechnical report prepared by *J.R.Paine & Associates Ltd.* These bearing capacities are maintained even where the Soil Unit (#4) is thawed, as evidence by the SPT  $N_{60}$  values retained in BH 6-09.

### 4.3 Lateral Stability of Structural Columns

The lateral stability afforded to the structural columns by the surrounding soil mass (at the time of drilling) will vary with the depth of thaw. The thaw penetration is characterized by the data retained from thermistor strings No.1 through No. 3 as



discussed in Section 4.6. In brief, current data suggests that thaw extends to the base of Soil Unit # 3 during the course of the summer followed by refreeze during the late fall and winter months. As such, a decrease in the lateral stability afforded by the frozen soil column would occur during thaw. Future collation of the thermal data will allow for a more detailed assessment of the lateral stability which depends upon a combination of soil density, composition, temperature and other factors.

#### **4.4 Comparison with 2007 Soil Conditions**

There was no notable difference in the conditions of the soils relative to their conditions when last drilled two years ago.

#### **4.5 Geodetic & Differential Surveys**

The data retained from the survey monitoring programs suggests that the differential movement of the footing system appears to be exceeding the originally recommended tolerances in the *J.R.Paine & Associates Ltd.* geotechnical report.

Geodetic surveys have been conducted since June 2009 in order to establish the elevations of several points with the facility. Specifically, the measured points now allow for the elevations of the remaining structural columns to be determined within the three separate survey areas (Curling Rink Lounge Crawlspace, Curling Rink/Ice Arena and Administration Building Crawlspace) following the differential survey.

The total differential movement noted to the end of November was calculated as 86 mm (and ranged from settlement of 13 mm to heave 73 mm). However, it should be noted that the 13 mm of settlement was noted on a concrete slab located in the Curling Rink Lounge Crawlspace. Based upon the structural columns alone, the total differential movement was noted to be 70 mm (heave of 3 mm to heave of 73 mm).



The amount of total differential movement since Jun 2009, has been displayed in Figure 1.

Given the preliminary nature of the geodetic surveys, the degree of error has not yet been fully quantified and as such the magnitudes of movement noted may not accurately reflect true field conditions. The error can be better assessed over time as more data is collected and anomalies become more readily apparent. The movements are best described in our survey monitoring reports which are being submitted on regular basis following each survey event. We intend to submit the report for the November 2009 survey within the next week. The submission was delayed as clarification was required from our sub-consultant over the holidays.

Preliminary assessment of the data suggests that the Administration Building Crawlspace data may reflect inherent geodetic survey error given the low magnitude of differential movement and standard deviation noted. The differential movement was noted to be 10 mm with a standard deviation of 2 mm. When compared to the June 2009 datum the data suggests the structural columns have heaved between 63 mm and 73 mm. Such a large level of displacement yet low magnitudes of differential movement and standard deviation would suggest that some amount of geodetic survey error may be inherent during survey of the primary benchmark.

Excluding the Administration Building data, the differential movement of the Ice Arena and Curling Rink Lounge Crawlspace areas was noted to be 20 mm with a standard deviation of 4.5 mm. The values of noted displacement since June 2009 ranged between heave of 3 mm and heave of 23 mm.



#### 4.6 Thermal Analysis

Thermal data has been retained on the data-logger that is located in the Mechanical Room of the facility. The data-logger obtains data from the five (5) installed thermistor strings on a daily average basis. Strings No.1 through No.3 were activated in July 2009 and thus the temperature regimes for these shallower strings has been recorded since such time. String No.4 and No.5 were installed during our recent investigation and so the amount of retained data does not allow for as detailed an assessment with respect to seasonal fluctuations.

The data for each of the thermistor strings has been presented in Ground Temperature Profiles and Thermal Data Spreadsheet, which display the fluctuations on a monthly basis. This information has been present in Appendix E ó Thermal Analysis.

In brief, String No.1 and No.2 shows full refreeze of the soil column between Sept 30 and Oct.31.

String No.3 (located in the *Diamond Tooth Gerties* office parking lot) showed thawed conditions at several locations below the depth of 2.37 meters and extending into the granular alluvial deposits at the time of data collection (November 22).

Data retained from String No.4 and String No.5 indicate that the alluvial deposit on the north side of the facility measures on average 1.04 degrees Celsius colder than the south side of the facility. On average, the granular alluvial deposit on the north side measured minus 1.36 degrees Celsius while the temperatures on the south side measured minus 0.32 degrees Celsius. Long-term monitoring will allow for more representative data to be retained as the thermal influence of drilling operations may have affected the recently retained data in Strings No.4 and No.5, to some degree.



#### **4.7 Potential Settlement Due to Thaw of Ice-Rich Granular Soil**

The long-term stability of the spread footing pilaster system in the event of deep thaw is difficult to ascertain but some rough estimates can be made, as follows;

For discussion purposes, thaw penetration into the granular alluvial deposit would result in the melting of the ice coatings and an equivalent degree of settlement. Based upon a 1% ice saturation by volume, 1 meter of thaw would result in approximately 10 mm of settlement. In a worst case scenario, if the entire granular alluvial deposit is ice-rich, then at a 1% degree of ice saturation, thaw of the 7.8 meter thick deposit would result in approximately 78 mm of settlement. Preliminary assessment of thermal data would suggest that thaw of the entire deposit would be very unlikely given its thermal mass. Long-term monitoring of the two newly installed thermistor strings within BH 2-09 and BH 3-09 will allow for more detailed assessment of the thaw potential. Thaw of the entire deposit during the remaining life of the structure would not be expected. Retained data from the upcoming spring, summer and fall will allow for more detailed assessment as to the potential for future settlement.

If the footings are founded within the silt stratum (Unit # 3) or else ice-rich Unit # 4 materials with ice saturation levels greater than 1 percent, then the long-term stability of the foundation system would likely be compromised to a greater degree.

#### **4.8 Excavation Feasibility in Crawlspace Areas**

The excavation feasibility during potential cross-bracing work in the location of the Curling Rink Lounge (and other locations) will be largely dependent upon the depth to the watertable and saturated soils. While the testpit program noted minimal amounts of groundwater seepage during excavation and frozen conditions within Soil Unit # 3, the soil conditions within the lounge area would likely differ from the testpit locations. Based upon the *Construction Monitoring Report*, the sub-surface materials



in the location of the mechanical room slab and Curling Rink Lounge expansion areas are comprised of imported White Channel gravels. The excavation feasibility within these regions will be dependent upon sidewall stability which will be poor below the depth of the watertable. Construction dewatering may assist in lowering the watertable such that depth of excavation can be maximized. The use of mini-excavators and/or hand excavation will be required given the restrictive nature of the confined crawlspaces.

#### **4.9 Structural Stabilization**

If required, the structure can be stabilized by installing piles to the underlying bedrock. Discussions with the structural consultant and other project team members would be required to assess the configuration and number of piles required.

The use 6 inch or 8 inch diameter piles can be facilitated through specialized drill equipment such as a Series 300/350 sonic drill. This drill will be small enough to fit within the existing confined spaces with the Ice Arena yet robust enough to facilitate pile installation. Operations will be restricted due to spatial limitations imposed by the height of the ceiling/rafters and crawlspace floor joists and presence of structural columns, walls and adjacent structures/infrastructure. The lower roof height within the Curling Rink may require the use of battered piles to assist in the installation. In addition, the material characteristics will require further consideration given its very dense nature, poor stability and/or contaminated state.

#### **4.10 Artificial Ice Slab**

Remediation of the existing slab-on-grade foundation components will be not be feasible. However, new slabs-on-grade can be established at the facility by constructing a suspended structural slab founded upon installed piles which extend to the underlying competent bedrock.



#### **4.11 Project Team Discussions**

A cost-benefit analysis would be required following discussions with other project team members to assess the need and viability of structural stabilization and artificial ice slab construction.



## 5.0 CONCLUSIONS

Based upon the information obtained during our field and laboratory work programs, it appears that the structural movements may be related to primarily freeze-thaw cycles rather than soil bearing capacity issues.

The investigation revealed the presence of ice-rich granular alluvial deposits at some locations which may suggest that settlement may be associated with thaw degradation. Inter-bedded fine grained silt seams would be also be a cause for concern if the footings are located above these zones and freezing were to occur as fine grained materials are susceptible to volumetric expansion upon freezing. The freeze cycles would result in a limited amount of heave (barring the creation of ice-lenses). In addition, in the thawed state, the fine grained soils would not allow for as high a bearing capacity as was specified in the original geotechnical report.



## 6.0 ENVIRONMENTAL CONSIDERATIONS

Hydrocarbon contaminated groundwater and soils were identified during our investigation.

While our firm conducted a limited amount of environmental sampling, a Phase II Environmental Site Assessment (ESA) would be required in order to better characterize and assess the environmental liabilities associated with the site.

The contaminants were characterized through *Chemical Laboratory Analysis* as described in *Section 2.3.2*. The analysis described the chemical signature of the hydrocarbon contamination was similar to that of diesel fuel.

The presence of hydrocarbon contamination that was encountered at the site appears to have originated from the underground storage tanks that were removed from the area of the Curling Rink Lounge (during the facility upgrades conducted in 2000) as well as potential refueling operations associated with the above ground storage tanks at *Diamond Tooth Gerties* and the Recreation Center.

The presence of sub-surface contamination was documented in the *Construction Monitoring Report* that was prepared by *J.R.Paine & Associated Ltd.* As the report was not clear in whether or not all the contaminated soils were removed from the site, it is likely that a contaminant plume/soils were left in place or accidentally missed and thus continue to be a contaminant liability.

While the extent of contamination can only be confirmed through extensive chemical laboratory analysis, the screening of soil samples utilizing a Photo Ionization Detector (PID) showed volatilizing organic compound (VOC) readings as follows;

TP 1-09 of 43 ppm and 47 ppm at depths of approximately 3.0 to 3.5 meters.

BH 2-09 of 209 ppm at a depth of 1.5 meters, and



BH 5-09 of 128 ppm at the surface.

Boreholes BH 2-09 and BH 5-09 samples were characterized through detailed laboratory analysis. The results were summarized in Section 2.3.2. In brief, the results suggest that the contamination present may be limited to upper portions of Soil Unit # 3 in BH 2-09 and the upper portions of Soil Unit # 1 in BH 5-09. The proximity of these boreholes to the above ground storage tanks is of interest as they may be a source of the contamination resulting from refueling operations.

TP 1-09 contaminant signatures may be remnants from the former Underground Storage Tanks that were located in the nearby area.

The presence of hydrocarbon contamination may require additional consideration to construction feasibility during potential future upgrades, depending upon the depth and locations of required excavations.

The groundwater contamination appears to be limited to the region near BH 19-07.

Additional discussions regarding environmental considerations have been provided in our 2007 geotechnical report.



## 7.0 CONSTRUCTION COST ESTIMATE

While preparation of construction cost estimates were beyond our scope-of-work, we have estimated a ball-park number for the installation of piles that will allow for construction of a suspended structural slab for discussion purposes.

The cost for pile installation may be in the order of \$ 1.5 million dollars.

Additional costs would of course be required for the demolition and removal of the existing slab-on-grade components and brine trench as well as construction of the structural slab itself.

If pile installations are to be considered, we would recommend that the bedrock contact be profiled in greater detail utilizing ground penetrating radar and/or air-track drilling. More detailed profiling of the bedrock contact will allow for the preparation of more accurate cost estimates.

The subsurface conditions in the area of the Administration Building crawlspace are conducive to the use of ground penetrating radar as the fine grained soils (which generally attenuate the radar signal) have been removed from the soil column in this area.

The use of an air-track drill rig, may allow for cost effective delineation of the bedrock contact.



## 8.0 REPORT LIMITATIONS

This report is intended for the sole use of *City of Dawson*.

No portion of this report may be used as a separate entity; it is intended to be read in its entirety.

Any use of this report by a third party is the responsibility of such third party.

The content within this report reflects our best judgment in light of the information available to *Chilkoot Geological Engineers Ltd.* at the time of report preparation.

The recommendations provided are based upon the subsurface conditions encountered at the time of our investigation, current construction techniques and generally accepted engineering practices.

The anticipated construction conditions have been discussed within this report, but only to the extent that they may influence design decisions. Any references to construction methods contained herein, express our opinion and are not intended to direct contractors on how to carry out construction.

The soil and ground conditions at this site are dynamic and thus subsurface conditions will change over time.

Prospective contractors should be aware that the data presented may not be sufficient to assess all factors that may have an affect upon construction. It is important to emphasize that a geotechnical investigation is, in fact, a random sampling of a site and the comments made are based upon the results obtained at the testhole and sample locations.



Due to the geomorphological nature of the deposits encountered, interpolations of native subsurface conditions between the test locations have not been made or been implied.

The report is limited in the fact that monitoring of thermal, groundwater and spatial regimes are ongoing and thus the recommendations may be modified to suit newly acquired information. Long-term monitoring over the course of several seasons will allow for more detailed characterization of the movements and assessment of the thaw potential of the granular alluvial stratum.

Phase I & II Environmental Site Assessments and a Risk Analysis would be required in order to better assess remedial options associated with the presence of the hydrocarbon contamination.



Thank you for providing *Chilkoot Geological Engineers Ltd.* with the opportunity to conduct the above noted work.

We trust that the information we have provided will be suitable for your purposes, however, if you should have any questions or concerns, please feel free to contact the undersigned at your convenience.

Respectfully Submitted,

**CHILKOOT GEOLOGICAL ENGINEERS LTD.**

Tares Dhara, P.Eng.  
President

TD/td

