The City of Dawson
PO Box 308
Dawson City, Yukon
Y0B 1G0

File No: 500ï 001-09

February 3, 2010

Survey & Monitoring Services
Art & Margaret Fry Recreation Center
Dawson City, Yukon
November 2009

Attention: Mr.N.Carlson, Superintendent of Works

Dear Mr. Carlson;

The following report summarizes our firmôs November 2009, bi-monthly observations with respect to monitoring both structural and non-structural movements associated with the above noted facility. The information contained herein is meant to supplement our preceding survey and geotechnical reports.

We apologize for the delay in report submission as clarification regarding our sub-consultants survey data was required over the holidays. Clarification has since been received as described in Section 1.0, below.

1.0 Survey, Data Collation & Establishment of Datum's

The movements were identified during survey programs that have been conducted at the facility by our firm since August 2007. The initial survey program was implemented following facility upgrades that resulted in surficial slab movements. Over time, the data suggested that the magnitude of differential movements of the structural columns (upon which the building is founded), were beginning to exceed the parameters (of ± 25 mm) outlined in the original geotechnical report (by *J.R.Paine & Associates Ltd*.). As such, a geodetic survey program was established during the summer of 2009, to determine elevations and better characterize the movements.

The geodetic field survey was conducted by our sub-consultant, *Underhill Geomatics Ltd.* (*UGL*) on November 10, 2009. Their results were received via e-mail on December 20, 2009, and have been attached in Appendix A.

> In brief, their survey noted heave in the majority of the Recreation Center points and in all the School points since the time of the last survey, which was conducted in September 2009.

Their work included surveying geodetic elevations of three primary benchmarks within the facility such that the elevations of the remaining structural columns could be determined by our firm following our differential survey. In addition, they surveyed the underside of the roof trusses (within the Curling Rink and Ice Arena areas) and Administration Building floor elevations to provide information such that the historical performance of the structure could be assessed.

As this was the third time that geodetic elevations were measured, we were able to compare the movements associated between the last two epochs as noted in the collated data which has been presented in Tables 1 through 5.

All differential survey field work was conducted by the undersigned between November 19 and November 22, 2009, in accordance with our proposals dated September 25th, 2007 and April 9, 2009. In addition to the differential survey, our firm retained thermal data from the data-logger to assess the local thermal regime as discussed in Section 4.0, below.

The work involved utilizing a (*Leica Rugby 100)* laser level to measure the difference (in millimeters) between the laser beam and pre-established datum(s). The datumøs were established on various points of interest (i.e. structural columns, ice arena hockey boards and concrete retaining wall/slab areas) as noted in Table 6**.**

The values of movement were then collated relative to three benchmark elevations that were determined by *Underhill Geomatics Ltd.* The differential data allowed for the elevations of the individual columns to be determined and and hence, the magnitude and direction of movement that may be occurring.

Over time, the survey data will provide better insight into the movement and either support or refute the findings of our recent geotechnical investigation (completed January 27, 2010). In brief, the geotechnical investigation indicated that the primary cause of the structural column movements is likely due to thaw-degradation (settlement) of ice-rich bearing soils combined with frost heave (of underlying/adjacent frost susceptible materials).

Clarification of Survey Discrepancy

In brief, the clarification, which was received via e-mail on January 20, 2010, indicated that an error in measuring the Administration Buildings benchmark (Column B 27) had occurred.

As discussed in our Geotechnical Report - Addendum No.1 (dated January 28, 2010), the error occurred as the measurement from the underside of the pile

cap was conducted. The benchmark on the structural column is highlighted on the column with survey ribbons (flagging tape). The error occurred as the measurement from the underside of the pile cap to the benchmark on the column was not consistent. One measurement, measured to the base of the ribbon while the subsequent survey measured to the top of the ribbon. The error was rectified by utilizing the underside of the pile elevation as the primary benchmark instead of the elevation of the mark on the column as the elevations are arbitrary (the change in elevation is of primary concern, not the actual elevation). The use of the underside of the pile cap will be utilized in the future to minimize the potential for future error(s).

2.0 General Observations

The magnitude of differential movement of the facilities structural columns is currently within the originally prescribed design parameters (of ± 25 mm).

A summary of the total movement that the structural columns have undergone (since the establishment of the geodetic survey datum on July 1, 2009) has been presented in Table 1 and on the foundation plan attached as Figure 1.

Following data collation, the following trends were noted;

Summary of Recreation Center Structural Column Movements					
Period 2009	**Min Movement**	**Max Movement**	**Average Movement**	**Standard Deviation**	**Total Differential**
June to Sept	-0.013	0.002	-0.006	0.0033	0.015
Sept to Nov	0.004	0.027	0.019	0.0046	0.023
June to Nov	0.003	0.023	0.013	0.0034	0.020

All values are in meters.

The data suggests that between June and September, movement was comprised of primarily settlement and that since September, the movement has been comprised entirely of heave.

In evaluating the data on a local basis (in the three survey areas), the following trends were noted since July, 2009;

Area	Date 2009	Since Last Survey		Since July 2009		Differential	Standard Deviation
		Min	Max	Min	Max		
Administration Building	Aug.31	-0.011	-0.006	-0.011	-0.006	0.005	0.0011
	Nov.19	0.018	0.027	0.012	0.018	0.006	0.0017
Ice Arena & Curling Rink	Aug.30	-0.008	0.002	-0.008	0.002	0.010	0.0022
	Nov.20	0.004	0.020	0.003	0.017	0.014	0.0036
Curling Rink Lounge	Aug.31	-0.013	0.002	-0.013	0.002	0.015	0.0047
	Nov.19	0.015	0.023	0.006	0.023	0.017	0.0053

All values are in meters.

2.1 School Survey

In comparison, the four columns surveyed on the Queen Street entrance of the school all noted approximately 20 mm of heave (since July 2009) which is consistent with that noted in most of the structural columns located within the facility.

2.2 Administration Building

The structural columns located within the Administration Building continue to display the least amount of differential movement and standard deviation when compared to the rest of the facility.

The performance of the foundation system in this area of the facility would be considered excellent based upon the data retained to date.

2.3 Curling Rink and Ice Arena

The columns located on the south side of the Curling Rink generally showed the least amount of heave in the facility which may be a result of thermal influence of the sun and adjacent (*Gerties*) structure.

Elevations obtained through (*UGL*) leveling surveys from the southern, underside of the Curling Rink roof trusses noted clear trends in the data. Namely, the elevations of the (seven) trusses were noted to decrease from west to east by approximately 360 mm. The first six trusses decreased steadily by approximately 85 mm. with a notable decrease of approximately 275 mm between the sixth and seventh truss.

The standard deviation of the differential movements (of the trusses) during the last two (2) survey epochs were each noted to be 1 mm.

Assuming that the roof trusses were installed at the same elevation, the historical performance of this area of the facility would be considered poor. However, the low magnitude of the standard deviation (of the differential movement) suggests that the greatest amount of movement has already occurred and that future movement may be within tolerable limits. Long-term monitoring will allow for a better assessment of this observation.

The elevations of the underside of roof trusses within the Ice Arena varied considerably as a differing survey methodology (reflectorless EDM) was utilized to obtain the data. As noted in the *UGL* report, this was the only survey method that could be readily employed given the site constraints (height of trusses). As this was the first survey where the differential movements of the Ice Arena roof trusses could be determined, future surveys may allow for variations in the data to "level out" survey error. On average, the northern portion of the roof trusses (which span north-south), were noted to be approximately 46 mm higher than the southern portions. The elevations of the northern portions varied by approximately 31 mm while the southern portions of the trusses varied by approximately 64 mm.

On average, the structural columns located on the 5th Avenue (east) side of the Ice Arena appeared to have heaved only 8.7 mm, which is less than the facility average of 14 mm. Those on 4th Avenue (west) side heaved on average 15.7 mm.

2.4 Curling Rink Lounge Crawlspace

Of the three areas, the Curling Rink Lounge Crawlspace once again exhibited the greatest amount of differential movement and standard deviation.

2.5 Ice Arena - Hockey Boards

As the hockey boards were recently re-leveled, a new datum was established with which to assess future movements.

The datum was established 230 mm above the benchmark (BM 1) located on Column A 1.

2.6 Slab Areas

Concrete slab points were surveyed in the Ice Arena, Mechanical and Zamboni Rooms as noted in Table 5A & B and Figure 2.

Table 5A presents the data based upon the arbitrary elevation (100.00 m) of Point # 1, such that a long-term evaluation of the data (since September 2008) could be conducted.

Table 5B displays the geodetic elevations of the retained data, however, as the elevations were only established in July of 2009, the shorter period of data collection should be considered. The geodetic elevations, do however allow for a better assessment as to the true direction of movement of the slab points.

Perimeter Ice Arena Slabs

The data suggests that the majority of movement is settlement that is occurring at the location of the brine trench along the southern edge of the ice arena. Another notable area appears to be on the 5th Avenue side of the Ice Arena where approximately 50 mm of settlement appears to have occurred (near Column A 17). Most other slab points noted 10 mm of settlement or less.

Mechanical Room Slab

As per previous survey episodes, the generally unsupported condition of the mechanical room slab and its influence upon nearby structural columns is of concern.

Point # 34 (located on the northwestern corner of the slab) noted approximately 200 mm of overall settlement. This is considerably greater than the remainder of the slab points where on average 32 mm of settlement has been noted since February 2009.

Zamboni Room

Based upon the geodetic survey data, the slab has been noted to have heaved approximately 10 mm since July 2009.

3.0 Groundwater Monitoring

Monitoring of the groundwater observations wells was conducted on November 21, 2009. Our observations have been summarized in Table 7.

4.0 Thermal Monitoring

The data obtained from the data-logger was downloaded by our firm and was assessed as part of our geotechnical investigation. Detailed discussions regarding the retained data can be found in our geotechnical report submitted January 27, 2010.

In brief, the data notes colder temperatures in the north when compared to the southern strings.

We have included the *Ground Temperature Profiles* and *Thermal Data Spreadsheet*, which display the monthly fluctuations in Appendix B for ease of reference.

5.0 Conclusions

The differential movement noted within the facility since July 2009, is less than the limits specified in the original geotechnical report.

From a geotechnical perspective, the least amount of heave would be expected to occur on the southeastern side of the structure due to the thermal influence of the sun (and possibly adjacent structure) and this trend was noted in the data obtained.

The data suggests that while undesirable movements have occurred in the past (trending to the southeastern regions of the facility), the recent magnitudes of differential movement (and particularly the standard deviation) suggest that future movement may be within tolerable limits.

If the retained data over time shows seasonal fluctuations and trends are within acceptable parameters, then long-term usage and up-grading of the facility will be possible.

6.0 Recommendations

6.1 Assessment by Structural Consultant

The structural engineer should be consulted to better assess the value of the data retained through the various survey components and determine if the programs can be modified to better suit their requirements.

6.2 Ongoing Monitoring

The differing values of data obtained from within the Curling Rink Lounge Crawlspace vary from the consistency of the data within the other two areas (Administration Building & Ice Arena/Curling Rink) and hence, this area should be closely monitored by *City of Dawson*, Public Works personnel. Specifically, they should monitor the conditions of the structural columns and trusses within the Curling Rink and Lounge Crawlspace and inform our firm (or the structural consultant) if their conditions are noted to change.

6.3 Structural Isolation of Columns from Adjacent Concrete

The concrete slab (and retaining walls) adjacent to the structural columns within the mechanical room area should be removed from within 0.5 meters of the individual columns such that disturbance from the slab movement is minimized. This should include exposing the structural columns on the west and south sides of the mechanical room (along with column CL 10).

6.4 Removal of Existing Concrete Slabs

The concrete slabs and brine trenches should be removed to minimize their detrimental potential upon adjacent foundation components and maximize the life of the structure.

6.5 Survey Monitoring Frequency & Duration

As a minimum, we recommend monitoring the facility at the bi-monthly frequency until July 2010, such that a full year of geodetic data has been retained at this frequency.

Adjustment to the monitoring frequency, will be dependent upon the results of the future data as well as requirements of the structural engineering consultant. Future monitoring episodes will allow for better assessment of the foundations performance and more detailed characterization of data trends.

We recommend some degree of survey and thermal monitoring so long as the facility is occupied.

6.6 Adjustments to Survey Program

As we have gained better insight as to the value of the data obtained, we recommend that the survey be modified as follows;

Underhill Geomatics Ltd. survey should be modified as follows;

Curling Lounge Crawlspace

The survey of the structural columns within the Curling Lounge crawlspace should be discontinued (save the single benchmark), as the survey data obtained by our firm utilizing the laser level collates within approximately ± 1 mm of their data (obtained through double-run leveling).

Ice Arena

This was the first epoch where the underside of the Ice Arena roof trusses were surveyed through the use of a reflectorless EDM (total station). Although the error for retained data was noted to be approximately ± 10 mm (by *Underhill Geomatics Ltd*.) we recommend that this survey continue as subsequent data

may provide insight as to the performance of the roof truss system as well as allow for the error to be quantified in greater detail.

Administration Building

The survey of the hallway floors could be discontinued as their movement collates well with that of the underlying structural columns.

As the elevations of Points # 2 & # 3 are within several millimeters of one another, the data suggests that it the long-term performance of the floor (and hence underlying foundation system) has been good.

Discussions will be held with *UGL* as some of these points may need to be retained in order to assess the elevation within the Administration Building crawlspace.

School Survey

We recommend that survey of the School columns be expanded to include accessible columns located on the 5th Avenue side of the structure in order to obtain a better level of confidence with respect to the consistency of the data

7.0 PROJECT LIMITATIONS

No allowances have been made for inherent survey errors which have been discussed in our preceding reports.

Future surveys may allow for a greater degree of confidence with respect to the data collected and assist in identifying potential trends so long as the cumulated movement over time becomes greater than the survey error.

In interpreting the data, one must bear in mind the various dates that the datumôs were established and how this may have an effect in skewing the data, when local data is considered on a whole.

The study is limited as the geodetic survey of elevations has only been conducted within the last several months and that no data is available prior to the onset of monitoring or between monitoring episodes.

Thank you for providing our firms the opportunity to conduct the above noted work. 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

Attached: *Appendix A – Underhill Geomatics Ltd. Survey Data & Report*
Appendix B – Thermal Data Analysis
Figures 1 & 2
Tables 1-7

TD/td