AECOM

ISSUED FOR USE

GEOTECHNICAL EVALUATION
WHISTLE BEND SUBDIVISION
WHITEHORSE, YT

W14101171

August 2009

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1.0 INTRODUCTION

EBA Engineering Consultants Ltd. has completed a pre-design geotechnical evaluation of the 700 hectare Whistle Bend Subdivision study area and has addressed geotechnical concerns pertinent to specific off-site servicing issues relative to the proposed residential subdivision development. Work completed and recommendations related to this project are presented in this report.

1.1 AUTHORIZATION

Authorization to proceed with this assignment was provided by Mr. Tom Becker, MCIP of AECOM by email on May 16, 2008.

1.2 SCOPE OF WORK

The scope of work for this study is consistent with EBA's proposal dated March 18, 2008, which was accepted by AECOM. Tasks include:

- Phase 1 – "Concept Development & Community Consultation": EBA's scope of work included the collection of existing geotechnical data and input into the off-site engineering report. Subsequent to discussions with AECOM team members, it was agreed that off-site issues to be addressed included the possible upgrades to the Valleyview and Porter Creek Reservoirs; the extension of existing watermains for water supply and fire suppression; the geotechnical evaluation of alternative access roads to the site; alternative water supply for fire suppression; storm water retention and disposal, and the location of area gravel sources.
- Phase 2 – "Detailed Planning and Engineering Pre-Design": EBA's scope of work included a terrain risk assessment of the study area and the completion of a geotechnical evaluation to determine soil and groundwater conditions throughout the development area and the preparation of a report addressing geotechnical aspects pertinent to subdivision development.

2.0 COLLECTION OF EXISTING REPORTS

2.1 OFF-SITE REPORTS

Existing information collected and reviewed in order to address the offsite engineering issues listed above (refer to the Phase 1 scope of work) includes:

- Terrain mapping from the Southern Lakes series terrain maps and Agricultural Branch surficial terrain map for the Whitehorse area
- 1995 Geotechnical Evaluation – Rangeway Road Reconstruction (EBA File: 0201-95-11731) – a total of eleven boreholes were advanced, with six boreholes drilled along the

existing Rangeway Road corridor between Wann Road and the bus turn-around located next to the Northlands Trailer Park.

- 2004 Geotechnical Evaluation – Phase III Section of Porter Creek Watermain (EBA File: 1200125) – a total of three boreholes were advanced in the immediate vicinity of the existing Porter Creek reservoir (one by EBA and two by others).
- 2005 Geotechnical Evaluation – Pine Street Extension - Porter Creek Area D (EBA File: 1200138) – desktop study including the delineation of terrain and geotechnical conditions between the Alaska Highway at the Kopper King Trailer Court extending east to Mountainview Drive.

2.2 EXISTING REPORTS WITH RELEVANT WHISTLEBEND STUDY AREA INFORMATION

Information collected and reviewed for this evaluation includes:

- Terrain mapping from the Southern Lakes series terrain maps and Agricultural Branch surficial terrain map for the Whitehorse area
- 1975 Geotechnical Evaluation – Porter Creek Lagoon (EBA File: E-1022) – a total of four boreholes were advanced
- 1988 Geotechnical Evaluation – Porter Creek Lagoon Sludge Pit (EBA File: 0201-4904) – three testpits excavated throughout proposed sludge pit
- 1995 Geotechnical Evaluation – Rangeway Road Reconstruction (EBA File: 0201-95-11731) – a total of eleven boreholes were advanced, with 6 boreholes drilled along the existing Rangeway Road corridor between Wann Road and the bus turn around located next to the Northlands Trailer Park, as well as five additional boreholes drilled along the proposed golf course access road
- 1995 Geotechnical Evaluation – Porter Creek Transfer Pipeline, Whitehorse Sewage Treatment Facility (EBA File: 0201-95-12025) – six boreholes were drilled on the Porter Creek side of the river and are considered pertinent to the Lower Bench evaluation

3.0 SITE DESCRIPTION

3.1 SITE LOCATION

The Porter Creek Bench area of Whitehorse, as identified in the 1987 and 2002 OCP's is bordered between the Yukon River on the east side, Range Road on the west side, the McIntyre Creek valley on the south side and the Porter Creek Sewage Outfall Line access road on the north side.

3.2 SITE HISTORY

The study area is predominantly undeveloped. However, the area is located next to the Mountainview Golf Course and is home to a decommissioned sewage lagoon in the northwest corner of the site; a CBC transmitter site; a NavCan aircraft beacon; the Horse and Rider Association facility; the Heiland Farm, as well as Ta'an Kwach'an and Kwanlin Dun First Nation settlement lands. Power line right-of ways and numerous trails dissect the site and are utilized for recreational purposes.

4.0 FIELD WORK

The geotechnical field investigation program was completed in two phases. Phase 1 included a four day borehole drilling program completed between December 8, 2008 and December 11, 2008. A total of 20 boreholes were drilled to various depths utilizing a Nodwell Mounted CME 75 drill rig owned and operated by 15317 Yukon Inc. of Whitehorse, Yukon. Phase 2 included the excavation of a single testpit in the kettle depression located close to the Golf Course on March 24, 2009. On March 27, 2009 an attempt was made to drill a single borehole in the area along the south side of the Valleyview Reservoir. However, the amount of snow along the roadway up to the reservoir parking lot restricted access to the site so this borehole could not be completed.

Details of the site investigation completed to address the off-site engineering issues and the site specific Whistle Bend investigation program are summarized in the following sections.

4.1 OFF-SITE ENGINEERING DRILLING & TESTPITTING PROGRAMS

Drilling and testpitting programs completed to address off-site engineering issues included:

- On December 8, 2009 three boreholes were drilled in the vicinity of the alternate access road route (borehole locations based on the November 14, 2008 preliminary concept plan prepared by AECOM) connecting Mountainview Drive and Range Road to ensure the roadway could be cut to an elevation that would comply with appropriate geometric design standards. The actual access road location has been moved slightly south but the data collected from borehole W14101171-BH01, –BH02 and –BH-03 is still considered relevant.
- On December 9, 2009 four boreholes were drilled along Range Road close to McIntyre Creek in order to assess potential for horizontal directional drilling (HDD) during water line upgrades to the Whistle Bend Subdivision. Borehole W14101171-BH04 was drilled along the north side of Range Road east of McIntyre Creek, W14101171-BH05 was drilled within 2 m of the actual water course of the south side of Range Road and boreholes W14101171-BH06 and –BH07 were drilled on the east side of Range Road north of McIntyre Creek.
- On March 24, 2009 a single testpit was excavation in the base of the kettle depression located near the north end of the golf course. Originally, this investigation was to assess the kettle depressions found along the northern perimeter of the study area as a possible fire suppression water source. However, cost benefit analysis has subsequently eliminated this as an option so the depression is being considered as a storm water disposal site.

At each testhole location, detailed logs were prepared describing the geotechnical (soil, groundwater and bedrock) conditions encountered. Representative soil samples were collected at regular intervals throughout the depth of each testhole and upon completion; the testholes were backfilled to grade and flagged for future reference.

4.2 ON-SITE GEOTECHNICAL INVESTIGATION

Within the actual Whistle Bend Subdivision area, EBA has good testhole coverage for the northwest quadrant (13 testholes for the old Porter Creek Sewage Lagoon & Sludge Pit site as well as the outfall line to the new Sewage Lagoon) and the south end of the site (8 testholes along Range Road and the Golf Course Access Road).

To augment the existing testhole data, thirteen additional boreholes were drilled to a depth of between 6 m and 7.5 m to establish soil conditions throughout the central portion of the proposed subdivision. This work was completed on December 9, 10 and 11, 2008.

Again, detailed logs were prepared describing the soil (groundwater and bedrock were not an issue) conditions encountered at each location; representative soil samples were collected at regular intervals throughout the depth of each borehole; and upon completion, the boreholes were backfilled to grade and flagged for future reference.

5.0 LABORATORY TESTING

All samples collected during the field investigation programs described above were returned to EBA's Whitehorse laboratory. The laboratory testing program included natural moisture content determination on all samples collected and particle size distribution testing on select samples for classification purposes.

Along with basic index testing, two samples (borehole W14101171-BH09 at 4.5 m and borehole W14101171-BH20 at 3.0 m) were shipped to ALS Laboratory Group for soluble sulphate testing of the fine grained glaciolacustrine silts found at depth throughout the study area. Results from these tests will be utilized in the selection of cement type for building foundations and underground utilities structures (manholes, vaults, etc.).

6.0 GEOTECHNICAL CONDITIONS

6.1 OFF-SITE ENGINEERING SITES

This section describes the geotechnical and general site conditions encountered along the proposed access road between Mountainview Drive and Range Road; the portion of the Range Road right-of-way at McIntyre Creek which will have to be addressed for water main construction; and in the kettle depression located beside the Mountainview Golf Course (storm water disposal site) as well as conditions anticipated at the two existing water reservoir sites being considered for expansion in order to ensure adequate water volumes for residential use and fire suppression.

6.1.1 Alternate Access Between Mountainview Drive and Range Road

The proposed alternate access road route ties into Mountainview Drive approximately 350 m south of 12th Avenue (close to the YEC sub-station), and runs east up a fairly steep slope onto the same bench that the south end of Tamarack Drive is on and then proceeds down gradient (along a steep slope) to the proposed tie-in with Range Road approximately 120 m south of the existing golf course access road.

Borehole W14101171-BH01 was drilled to a depth of 9.0 m (1 m deeper than the approximate depth of cut through the top of the bench) on the crest overlooking Mountainview Drive. Soil conditions noted at this location were comprised of near surface silty sand, becoming coarser below 2.0 m. Clean, compact gravel and sand was encountered below 4.0 m and extended to the completion depth of 9.0 m.

Borehole W14101171-BH02 was drilled part way down the Range Road side of the bench. Again, silty sand was noted to a depth of 2.0 m with clean compact sand and gravel encountered from 2.0 m to the borehole completion depth of 5.0 m. Two attempts were made to drill past 5.0 m, with refusal on bedrock or a very large boulder experienced on both attempts at this location.

Borehole W14101171-BH03 was drilled along the ditch line on the west side of Range Road. Approximately 0.3 m of poor quality fill (sand and silt) was noted over the organic fill line. Sand with some silt was encountered from 0.3 m to 1.3 m and was underlain with wet (greater than 20% moisture), soft, glaciolacustrine silt. Wet soft soils are likely the result of Range Road acting as a physical barrier for surface runoff running off the east facing slope.

Evidence of erosion potential was noted along the power line overlooking Range Road where deep erosion channels exist under the power line.

Pre-design considerations for the alternate access road construction include:

- The material from the cut at the top of the bench will be suitable as embankment fill on the Mountainview Drive and Range Road sides. It is suggested that the siltier surficial soils be placed throughout the base of the fill areas so that the coarser, cleaner granular soils can be utilized as a suitable, non frost susceptible subgrade material.
- Ditches along the slopes proceeding down to either Mountainview Drive or Range Road should have ditch plugs or some form of energy dissipater to prevent ditch line erosion.
- The recovery section leading onto Range Road may require additional measures. It is EBA's standard recommendation that all paved roadways have a minimum granular structure of 1.7 m in order to minimize potential for frost heave damage. Wet subgrade conditions (as encountered in Borehole W14101171-BH03) may dictate the use of a medium weight non-woven geotextile to act as a barrier between the glaciolacustrine soils and granular fill placed during alternate access road construction.

6.1.2 Water Main Crossing at McIntyre Creek

Conversations with Rick Savage, R.E.T. of Quest Engineering has indicated that the preferred route of the water supply line to the Whistle Bend Subdivision will be an extension of the water line originating at the Valleyview Reservoir and currently running along Range Road to the Northlands Trailer Park area. An extension of this waterline will require crossing McIntyre Creek.

Where Range Road crosses McIntyre Creek, the creek is a narrow and incised with water carried under the roadway in two CSP culverts. The road grades on either side of the creek crossing are relatively steep (9.6% on the south side and 7.3% on the north side of the creek). As well, Range Road crosses the creek on a fairly tight curve (200 m radius – 120 degree curve) and the roadway surface is quite narrow over the culverts.

McIntyre Creek is underlain by ancient alluvial sediments which are interbedded and highly variable (sandy gravels interbedded with glaciolacustrine silt soils) as noted in Boreholes W14101171-BH04; -BH05, -BH06, and BH07.

Options for crossing McIntyre Creek include horizontal directional drilling (HDD); trenchless methods such as pipe ramming or pipe jacking; or an open cut trench. Based on EBA's preliminary review of the site geometry and soil conditions, the following considerations are presented for review:

- HDD may not be the preferred crossing option. A HDD installed pipe (200 to 300 mm diameter) would require a drill path length of well over 50 m based on a radius of curvature of 125 m and a depth of burial below entry/exit point of 2.5 m. Since the slopes on either side of the creek are quite steep, the actual drill path length would have to be significantly longer. As well, the drill path would not only need to navigate through the vertical curve, it would also have to follow a fairly tight horizontal curve. Although these technical challenges can be overcome by experienced contractors, the crossing may be more easily achieved by other methods.
- Given the short crossing length and the relatively shallow depth of burial required, trenchless methods such as pipe jacking or pipe ramming are considered to be appropriate and more cost effective. The entry and exit pits can be located quite close together on opposite sides of the culvert, making the actual pipe ram/jack distance quite manageable. Depending on the exact site conditions (the condition of the existing culverts, the depth to groundwater and the amount of flow through the culverts at the time of construction), it may even be possible to complete the crossing by ramming a carrier pipe a few metres beneath the existing culverts using a large excavator.
- The desire to use HDD or other trenchless methods to complete the McIntyre Creek crossing is commendable in order to minimize the potential for damage to the existing creek bed and fish habitat. However, consideration should be given to the potential benefit of an open cut crossing of the creek, done in conjunction with a replacement of the existing culverts with an open bottom (fish friendly) culvert.

6.1.3 Valleyview Pumphouse

Water to the Whistle Bend Subdivision will likely originate at the Valleyview Pumphouse which may require significant expansion. A file search completed by City of Whitehorse staff discovered that in 1965, the Department of Public Works Canada completed a geotechnical investigation in advance of the Valleyview Reservoir construction as part of the 1965 Whitehorse Water System project. Three boreholes were drilled, 1 in the parking area and 2 within the reservoir site footprint. Each of the boreholes drilled were advanced at least 3 m into competent bedrock (granodiorite). Depths to bedrock varied from 2.5 m just north of the parking area to between 6 m and 7.5 m within the actual reservoir site. Overlying the bedrock was a homogeneous blend of sand, gravel, and silt (TILL) with cobbles and boulders up to 300 mm in size. No groundwater was noted on the logs and is not anticipated at his site.

No as-built information was collected and reviewed as part of this project; however, it is assumed that during the original construction of the reservoir, some blasting of the bedrock surface was necessary to facilitate construction. It is also likely that no over-blasting of the bedrock surface was completed in order to avoid problems caused by blasting against the reservoir structure in anticipation of future expansion. Therefore, expansion of this reservoir site will likely require additional pre-design geotechnical input, such as:

- Volume of overburden to be removed to reach design elevations or bedrock.
- Volume of rock excavation required to reach design elevations (depth to bedrock appears variable).
- Technical input into blasting next to the existing reservoir structure (if required), such as "Smooth-Line" or "Cushion" blasting and commencing the blasting program in the central portion of the expansion area and then working towards the perimeter to minimize potential for damage.
- Safety concerns inherent to "mucking out" the excavation and ensuring that the sidewalls are properly scaled.
- Evaluation of the walls of the excavation to determine whether or not rock bolts may be required to stabilize large slabs or wedges (along joints)
- Geotechnical input into foundation preparation, lateral wall loads and seismic site classification will also be required.

6.1.4 Porter Creek Pumphouse

The second water supply option for the Whistle Bend Subdivision is the expansion of the Porter Creek Pumphouse located in the Kulan Industrial Subdivision. Two boreholes were drilled at the reservoir site (date unknown and it is suspected that the work was initiated by the Department of Public Works Canada). Both boreholes were drilled to refusal in suspected bedrock. Depths to bedrock varied from 4 m towards the front of the reservoir and 8.5 m towards the west side of the reservoir. Soil conditions overlying the bedrock were variable with silt till and fractured rock overlying the bedrock in Borehole 1 and interbedded till, silty sand, and coarser granular sediments overlying bedrock in Borehole 2. Groundwater was noted at 5 m in testpit 1200125-TP01, located in Lindeman Road ditch line in front of the reservoir site. This testpit was excavated by EBA in 2004 during the Porter Creek Watermain – Phase III project.

As with the Valleyview Reservoir, no as-built information was collected and reviewed as part of this project. Therefore, expansion of this reservoir site will require additional pre-design geotechnical input similar the design aspects listed in the Valleyview Reservoir section above.

6.1.5 Storm Water Retention & Disposal – Kettle Depression Near Golf Course

To assess potential for storm water disposal into an exfiltration pit, a single testpit was excavated in the large kettle depression near the north end of the golf course on March 24, 2009.

Conditions noted in testpit W14101171-TP21 include 0.5 m of seasonally frozen organics (with grass ground cover) overlying wet, soft, silty sand interbedded with organics from 0.5 m to approximately 2.0 m; wet, soft, glaciolacustrine silt from approximately 2.0 m to 4.0 m; and saturated sand from 4.0 m to the base of the testpit excavation at 6.0 m. Groundwater was entering the testpit at approximately 4.0 m. It should be noted that due to sloughing testpit sidewalls, exact depths to groundwater and soil transitions were difficult to determine.

This depression, along with the depression located west of this depression has potential for storm water retention. The soil conditions encountered the depression where testpit W14101171-TP21 was excavated also suggests that storm water disposal in the sand encountered below 4.0 m may also be possible. However, constructing an exfiltration pit may be challenging due to steep slopes limiting equipment access and soft, wet and unstable soil conditions throughout the floor of the depression will result in sloughing soils while excavating the exfiltration pit.

6.2 WHISTLE BEND ON-SITE GEOTECHNICAL CONDITIONS

This section presents terrain hazard assessment information, general site conditions and detailed geotechnical conditions encountered throughout the proposed limits of the Whistle Bend Subdivision.

6.2.1 Terrain Hazard Assessment

The study area is located between the Yukon River on the north and east sides, the Upper Bench portion of Porter Creek to the west and McIntyre Creek to the south characterized by moderately-well drained to well-drained soils and is typically forested with pine, spruce, aspen and some poorly drained areas with willows. Most of the area is gentle gradient terrain. Some low to moderate relief occurs along the escarpment overlooking McIntyre

Creek at southwest corner of the study area; within the kettle depressions at the north end of the study area and on the eolian sand dune in the central southwest portion of the development area. Steep gradient escarpment slopes along the Yukon River at the eastern boundary are bare of vegetation and exhibit some shallow gullying and washing erosion.

Sub-surface materials throughout the study area are characteristic of a deglaciation depositional environment with discontinuous glaciofluvial sands and gravels of variable thickness overlying glaciolacustrine silt at depth and capped by a veneer (< 1 m) to blanket (1-3 m) of eolian sand. Thick glaciolacustrine silts with minor sand and some thin clay beds are exposed along the Yukon River. Eolian sands are discontinuous and thicken in places where low relief dunes were formed. In the central southwest a prominent eolian dune forms a medium-relief, irregular ridge. Subsurface data at the eastern and western extents of the lower bench area indicate an absence of glaciofluvial sands and gravels, where a veneer or blanket of eolian sand directly overlies lacustrine silt. Much of the central area probably has a similar stratigraphy, with sandy gravels appearing and thickening in the northwest corner of the area (section of Range Road close to the intersection with Hickory Street and Wann Road).

Since most of the slopes within the central portion of the proposed development area are gentle with minimal relief, there is minimal terrain risk. However, the glaciolacustrine escarpment slopes overlooking the Yukon River are very susceptible to mass movement processes such as debris flows, toppling, mud flows and other landslide mechanisms. Active slope movement processes are common on glaciolacustrine escarpment slopes, which make them very sensitive to any development which may alter the drainage regime. For instance, erosional gullies and shallow landslides were observed on the steep escarpment along the Yukon River (southeast site boundary) and a landslide into the Yukon River was noted on a forested glaciolacustrine slope near a golf course fairway in the northeast.

6.2.2 Whistle Bend Geotechnical Conditions

On the accompanying site plan (Figure 1), the locations of all testholes (from the recent evaluation and previously completed projects) used for this geotechnical evaluation are presented and detailed logs with basic soil classification laboratory test data for each testhole are presented in Appendix B on this report.

Soil conditions, proceeding from the slope defining the east edge of the upper bench to the Yukon River can be summarized as:

- Soil conditions throughout the Porter Creek Upper Bench, along Larch Street., Cedar Crescent, Balsam Crescent and Evergreen Crescent, are fairly consistent with medium to fine grained silty sand overlying coarse glaciofluvial gravel. The contact between the gravel underlying the Upper Bench area and the soils considered typical of the Whistle Bend area can be observed within exposures on the west side of Range Road approximately 400 m south of the Wann Road intersection and along the Porter Creek Transfer Pipeline route 200 m east of the Larch Street – Oak Street intersection.

Borehole log 11731-BH01 defines the properties of the typical glaciofluvial gravels underlying the Upper Bench area. The slope down to the Lower Bench area east of Balsam and Cedar Crescents is quite broad and steep. Surface water being carried down gradient (rain and snow melt) appears to be responsible for increased moisture contents in the glaciolacustrine silt soils along the west side of the Porter Creek Lagoon Access Road (immediately south of the Transfer Pipeline route where thick willow shrubbery covers much of the area).

- Proceeding in an easterly direction towards the Yukon River, varying thicknesses of eolian sand overlying glaciolacustrine silt soils is common at all locations where testholes were advanced. Generally, less than one metre of sand exists over the underlying glaciolacustrine soils. However, in specific locations, significant thicknesses of sand have been noted (previously completed boreholes 12025-BH02; 11731-BH07; 11731-BH09; 11731-BH10 and 11731-BH11 as well as recently drilled boreholes W14101171-BH09, -BH11, -BH13, -BH15 and –BH20) where boreholes were located on eolian sand landforms.
- Soil conditions along the bank overlooking the Yukon River are a little more complex. The bank along the east side of the lower bench is typical of most of the area with sand overlying glaciolacustrine silt (around the golf course and the bank overlooking McIntyre Creek. The banks overlooking the portion of the Yukon River which defines the north side of the site is comprised of granular soils. The soil stratigraphy is defined by Borehole 12025-BH05 where granular soils were noted to below 20 m. As mentioned in the Terrain Analysis section of this report, air photo interpretation has delineated kettle features along the north side of the site as well, which are commonly underlain by coarse granular sediments. This glaciofluvial soil unit has been noted on both sides of the river during the geotechnical work completed during the 1995 Whitehorse Sewage Treatment Facility geotechnical evaluation as well as the air photo interpretation work completed for this project.

7.0 RECOMMENDATIONS

7.1 WHISTLE BEND SUBDIVISION DEVELOPMENT RECOMENDATIONS

Aspects of subdivision development and construction addressed in the following sections include roadway structure design and construction; underground utilities installation, thermal analysis considerations; excavation and material reuse.

7.1.1 Pavement Structure Design – Whistle Bend; Alternate Access & Range Road Upgrades

Previous pavement structure design work was completed by EBA during the Rangeway Road Reconstruction project in 1995, when EBA was contracted by the City of Whitehorse in 1997 to review the existing Rangeway Road pavement structure and evaluate the roadway for increased bus traffic. California Bearing Ratio (CBR) testing was completed on typical sub-base and basecourse gravels and based on anticipated bus traffic, it was determined that for a BST surfaced roadway, 150 mm of basecourse gravel over 600 mm of sub-base gravel was adequate over silty subgrade soils, while 150 mm of basecourse gravel over 300 mm of sub-base gravel was adequate for the sand subgrade soil sections. However, it must be stated that the recommendations provided were developed for a BST surfaced roadway and the design does not address the potential for seasonal frost heave damage. Under paved roadways with concrete sidewalks and curb & gutter, EBA recommends a minimum of 1.7 m of non-frost susceptible granular structure to not only ensure adequate pavement structure but also to minimize the potential for frost heave damage and subgrade softening during spring thaw. This recommendation applies to all roadway design and construction associated with the Whistle Bend development, including upgrades made to Range Road and the construction of the new alternate access road to Mountainview Drive, as well as the streets throughout the Whistle Bend Subdivision. To summarize, the minimum roadway structure must include 75 mm of hot mix asphalt (HMA), 150 mm of basecourse gravel (20 mm crushed gravel) and at least 300 mm of sub-base gravel (50 mm crushed gravel is preferred but 100 mm pit run sub-base gravel is acceptable). The actual thickness of gravel placed as subgrade/sub-base gravel will be dependant upon what is necessary to ensure 1.7 m of non-frost susceptible roadway structure.

Specific to pavement structure design within the Whistle Bend Subdivision, the testholes drilled and have identified two predominant subgrade soil types. During roadway construction, either glaciolacustrine silt or uniformly graded eolian sand will be encountered. The glaciolacustrine silts are considered to be prone to softening in a moist to wet state and are very frost susceptible. The eolian sand found overlying much of the site is generally damp to dry and very well drained. The sand is not considered a frost heave threat but past experience on projects with similar subgrade soils has shown that roadway construction on a uniform sand subgrade can be challenging.

Therefore, some portions of the development area will likely require subcuts of up to 1.7 m (glaciolacustrine silt subgrade sections), while areas with more than 1.7 m of sand overlying the silts will require very minimal subcuts. Figure 2 presents approximate areas which have greater and less than 1.5 m of sand over the frost susceptible silt for reference.

Imported granular materials used on this project must comply with the City Servicing Standards Manual. The gradation specifications for sub-base and basecourse gravels are presented in Table 1, on the next page.

TABLE 1 RECOMMENDED GRANULAR MATERIALS SPECIFICATIONS			
50 mm CRUSHED SUB-BASE GRAVEL		20 mm CRUSHED BASECOURSE GRAVEL	
SIEVE SIZE (mm)	% PASSING BY MASS	SIEVE SIZE (mm)	% PASSING BY MASS
50.000	100		
25.000	60 – 100	20.000	100
12.500	40 - 90	12.500	64 - 100
5.000	20 - 65	5.000	36 - 72
1.250	9 –35	1.250	12 - 42
0.315	5 - 23	0.315	4 - 22
0.080	2 - 10	0.080	3 - 8

If alternate materials are being considered (such as 200 mm Gran E or 100 mm Gran B sub-base gravels, which may be readily available for use), EBA will conduct particle size analysis testing and then provide an opinion regarding acceptability for use.

Compaction specifications for the prepared subgrade and the materials placed as sub-base, and basecourse are as follows:

- The subgrade should be shaped, graded, moisture conditioned and compacted to 98% of maximum dry density using standard effort (ASTM D698). It is critical that all areas of instability be repaired (additional subcut and backfill with coarse granular materials) prior to placing the actual sub-base course.
- A prepared non-frost susceptible sub-base course (50 mm crushed sub-base gravel – two lifts which are 150 mm in compacted thickness), is to be placed, moisture conditioned to facilitate the compaction process, and compacted to at least 98% of maximum dry density using standard effort (ASTM D698).
- Basecourse (20 mm crushed gravel – 150 mm in compacted thickness) is to be placed, moisture conditioned and also compacted to at least 98% of maximum dry density using standard effort (ASTM D698). If the total granular structure is comprised of basecourse gravel, it would be EBA's preference that the basecourse be placed in 2 lifts.

7.1.2 Underground Utilities Installation

Underground utilities installation, including water & sewer lines, as well as services to individual lots or structures, storm sewer system construction and shallow electrical utilities (power and communications lines) can all be constructed using conventional construction methods (tracked excavator equipped with a clean-up bucket will likely be acceptable).

Excavation of utility trenches must conform to the Yukon Occupational Health & Safety Regulations. The predominant soil profile will be dry sand over moist to wet glaciolacustrine silt. Trench side slopes may have to be cut to 1.5:1 (horizontal:vertical) in areas where the dry uniformly graded sands cause significant sloughing into the utility trenches.

All sand excavated from utility trenches will be acceptable for reuse as pipe bedding or trench backfill. The glaciolacustrine silt may have to be wasted if it is too wet to compact, otherwise it can be used as backfill over the pipe bedding but not within 1.7 m of final roadway elevations.

It is recommended that a Class "B" pipe bedding configuration (as presented in the Whitehorse City Servicing Standards Manual) be specified for this site. This insures proper protection of the buried utility lines during backfill. Bedding may be imported bedding sand or bedding stone. Imported bedding sand and stone should conform to the gradation specifications presented in Table 2 and should be at least 150 mm thick below the pipe and 300 mm thick above the pipe.

TABLE 2 RECOMMENDED PIPE BEDDING MATERIALS SPECIFICATIONS

BEDDING SAND		25 mm BEDDING STONE	
SIEVE SIZE (mm)	% PASSING BY MASS	SIEVE SIZE (mm)	% PASSING BY MASS
10.000	100	25.000	100
5.000	80 – 100	20.000	70 - 100
2.000	55 - 100	12.500	55 - 100
0.630	25 - 65	10.000	30 - 80
0.250	10 – 40	5.000	0 - 40
0.080	2 - 15	2.000	0 - 10

It is EBA's opinion that the sand found throughout the Whistle Bend site is also acceptable for use as pipe bedding. During construction, periodic particle size analysis testing should be performed to ensure on-going acceptability.

7.1.3 Storm Management Plan

The AECOM Stormwater Management Plan submitted to the City of Whitehorse in July, 2009 has been reviewed by EBA and is considered appropriate for this subdivision development. Positive comments presented during the EBA review include:

- All exfiltration pit locations are situated off roadways, minimizing the potential for subgrade soil saturation which can result in an increase of frost heave potential along streets;
- The conceptual infiltration pit design proposed for use is similar to previous EBA submissions. Comments included that the design hydraulic conductivity may have to be adjusted based on actual soil conditions and therefore, the sizing and configuration of the pits may have to be adjusted based on actual conditions;

- On some of the commercial, apartment and condominium sites, the actual location of the infiltration pits may require adjustment to take advantage of varying thicknesses of sand over the glaciolacustrine silts,
- The proposed use of the kettle depressions for future phases of development is also considered acceptable. However, additional geotechnical work may be required at the final design stage;
- Overall, the use of various strategies such as bio swales, rain gardens and infiltration pits is appropriate for a subdivision which has an elaborate trail network and significant green space areas.

7.1.4 Concrete

It is recommended that all concrete utilized for sidewalks, curb & gutter, exterior pads and aprons be designed, mixed, and placed in accordance with the Canadian Standards Association standard CAN/CSA-A23.1-04. According to this standard, concrete should be designed to at least satisfy minimum environmental durability requirements as defined by its exposure class, which in this case would be F-2 (concrete in an unsaturated condition but exposed to cycles of freezing and thawing. It is recommended that the following properties be specified:

- Maximum water cement ratio 0.5,
- Minimum specified compressive strength of 30 MPa (as per City of Whitehorse Servicing Standards Manual),
- 5% to 7% entrained air,
- Nominal aggregate size of 20 mm is recommended.
- Concrete placed as sidewalk or curb & gutter are typically placed over good quality basecourse gravels therefore, Type GU (previously designated as Normal Type 10) cement is acceptable for use during surface works construction. Concrete placed at depth, which may be in contact with the glaciolacustrine soils must address soluble sulphate attack. Tests previously completed (4 tests) on glaciolacustrine silt soils in the vicinity of the Transfer Pipeline determined that the levels of soluble sulphates ranged from moderate to severe. Two additional tests completed during the current geotechnical evaluation suggested levels were mild but positive to negligible. This is not an unusual occurrence as soluble sulphate concentrations in soils are believed to associated with fairly dry climates causing the sulphates to wick up from the lower salt bearing soil strata (in this case the glaciolacustrine soils). On sites where levels can be as high as moderate to severe, the use of Type HS – High Sulphate Resistant (formally known as Type 50) cement is usually recommended. However, since the recent and historical results are quite variable, it is suggested that all concrete (other than the surface works concrete discussed above) produced with 25% flyash replacement (by weight of cement) to mitigate the potential for sulphate attack and damage. This

recommendation applies to building foundations, manholes, and all other concrete structures which may be in contact with the glaciolacustrine soils.

- In addition to the above requirements, CAN/CSA-A23.1-04 also provides recommendations for hot and cold weather concrete placement, which must be adhered to. These include protecting freshly placed concrete from extreme heat or freezing temperatures.

7.1.5 Geothermal Analyses

A thermal analysis was completed for the Porter Creek Transfer Pipeline in 1995. The analysis was completed utilizing EBA's proprietary finite element program GEOTHERM. For the soil conditions along the Transfer Pipeline (which are considered typical of the whole Whistle Bend area) a pipe burial depth of 3.9 m was recommended. The recommendation was based on seasonal frost depth determinations plus an assumed pipe diameter to ensure that the pipe is entirely below seasonal frost penetration depths.

EBA and the City of Whitehorse have been monitoring seasonal frost penetration at the Takhini Firehall (area where soil conditions are consistent with the Lower Bench area – ie. sand over silt) and based on the data collected, it was recommended that a 3.6 m minimum depth of burial for uninsulated service lines be utilized during the Takhini West-South Reconstruction project.

7.1.6 Foundations

Residential structure foundations must be constructed in accordance to the National Building Code of Canada, 2005. Generally, residential structures will be supported by conventional foundation systems, (strip & spread footings or monolithic thickened slab-on-grade foundations). This is considered acceptable for use throughout the Whistle Bend Subdivision. All commercial structures as well as apartments and condominium structures should have site-specific geotechnical evaluations completed prior to construction.

The two main concerns for foundations in the Whistle Bend Subdivision will be the potential construction of footings on fine grained, frost susceptible soils (houses with full basements) and the control of roof runoff and surface water in subdivisions with high density housing. To mitigate the potential for frost heave damage to foundations, the use of perimeter insulation may be required in some instances, but most importantly, the control of roof runoff and surface water must be considered (perimeter drainage systems may be required in some instances).

7.2 RECOMENDATIONS FOR FINAL DESIGN GEOTECHNICAL SERVICES

During the final design phases of this project, it is recommended that EBA provide the following services:

- Once the roadways throughout the initial phases of development have been cleared, it is recommended that an additional series of shallow testpits should be excavated to establish subcut depths and volumes;
- At each of the infiltration pit locations, a testpit can also be excavated to establish preferred locations, actual hydraulic conductivity of the accepting soils, and adjustments to the size of the infiltration pit.
- If considered appropriate, additional soluble sulphate testing can also be completed to establish the most appropriate cement type. However, as mentioned above, it may preferable to specify the use of flyash, which has become common on LEED projects.

8.0 LIMITATIONS AND CLOSURE

This report and its contents are intended for the sole use of AECOM and their agents. EBA does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than AECOM or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in EBA's Services Agreement and in the General Conditions provided in Appendix A of this report.

We trust this report satisfies your requirements at this time. Please contact the undersigned if we can provide further assistance.

Sincerely;
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