Minto Explorations Ltd.

GEOTECHNICAL DESIGN REPORT
"DRY" STACK TAILINGS STORAGE FACILITY
MINTO MINE, YUKON

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1.0 INTRODUCTION

The Minto Project is a copper-gold deposit located about 240 km north of Whitehorse in the Yukon and is owned by Minto Explorations Ltd. (Minto). The general location of the Minto Project is shown in Figure 1. The deposit is being developed as an open pit mining operation and is currently in the construction phase with production targeted for mid 2007. EBA Engineering Consultants Ltd. (EBA) was retained by Minto to undertake the geotechnical design of the proposed "Dry" Stacked Tailings Storage Facility (DSTSF) and provide information for the development of the Tailings Management Plan to support a Quartz Mining License (QML-0001). The overall tailings management plan will be developed concurrently by Access Consulting Group (Access) and presented in a separate document. EBA received approval from Minto to proceed with the geotechnical design of the DSTSF facility in November 2006. This report presents a summary of the findings and analytical work associated with the geotechnical design of the DSTSF.

1.1 SCOPE OF WORK

EBA's scope of work was specifically the geotechnical design of the tailings facility, and did not include a detailed tailings deposition plan. Drawings for construction will be prepared based on the design information presented in this report.

2.0 BACKGROUND INFORMATION

EBA developed the geotechnical design from the following background information:

- A drawing supplied by Hatch, overall mine development consultants, entitled "General Tailings Process Flow Sheet No.5" Drawing Number 100-10-005, Rev A;
- A spreadsheet supplied by Hatch on December 6, 2006 detailing the tailings tonnages for year-1 through to year-8;
- A spreadsheet developed by Access, the project environmental consultants on November 17, 2006 detailing the mine site meteorological data collected to date;
- Four e-mailed documents supplied by Access on November 17, 2006 detailing past snow surveys;
- Regional information supplied by Canadian Geological Survey Pacific Geosciences Centre on January 20, 2006 quantifying the risks associated with earthquakes;
- A report by Hallam Knight Piesold entitled "Minto Creek Surface Hydrology Report" detailing mine site hydrology; and
- A memorandum supplied by Access on December 4, 2006 entitled "Memorandum CCL-MC1" by Clearwater Consultants Ltd. detailing a mine site hydrology update.

In addition, EBA also used the following information from EBA's files:

- A 1995 report entitled "Geotechnical Design Tailings/Water Retention Dam" detailing previous geotechnical investigations and stability analyses;
- A report entitled "1996 Geotechnical Drilling Program" describing previous geotechnical investigations; and
- A 1996 report entitled "Minto Waste Rock Stability Evaluation" summarizing previous geotechnical investigations and stability analyses for the project site when it was being considered as the "south waste dump" in 1996.

Background information has also been obtained from Hatch, Access Consulting, and Minto Explorations during the preparation of this document.

3.0 MINE SITE LAYOUT

The Minto Mine is located approximately 240 km northwest of Whitehorse and is accessed either by land via the North Klondike highway and Minto access road, as shown on Figure 1, or by air. Access by land requires crossing the Yukon River; this is completed by barge in the summer and ice road in the winter. There is a short period of time in the spring and fall that land access is not possible, as neither the ice road nor barge is available for use.

The main infrastructural components of the mine comprise the Access Road, Open Pit, Process Plant, Accommodation Complex, Water Dam, Waste Rock Dump, Ice-Rich Overburden Dump, Airstrip and the "Dry" Stacked Tailings Storage Facility. The locations of these components are depicted in Figures 1 and 2.

This report focuses on the geotechnical design of the "Dry" Stacked Tailings Storage Facility (DSTSF) which occupies an area of approximately 0.4 km^2 and is located southeast of the Process Plant as shown in Figures 2 and 3.

4.0 TAILINGS PRODUCTION AND CHARACTERIZATION

4.1 TAILINGS DISPOSAL ALTERNATIVES

There are three methods for managing tailings waste from milled and processed ore in common usage. The most frequent disposal process is to pump it as a slurry to a retention basin where the solids sediment into a pond with a cover of process water. The pond bottom sediments generally have low shear strength and must be retained behind a tailings dam. The solids to water mass ratio in the slurry is usually in the order of 40 to 50% therefore a high proportion of supernatant water must be managed at the disposal site. This disposal method is attractive for tailings that can produce acidic process water if they are exposed to air. The adoption of a slurry tailings disposal method is contingent on site topography that can provide the large storage volumes required for both the solids and water produced.

More recent northern mining developments have favoured disposal processes that remove as much of the process water as practical in the mill before directing the product to the disposal basin. This disposal method requires dewatering the tailings stream to a solids content in the order of 65% before deposition. The material produced, sometimes referred to as "paste tailings", is deposited in a smaller basin with minimal excess water to manage within the disposal facility. The system lends itself to effective water management within the facility with the solids retained behind a filter dike that lets the free water pass to a downstream water dam. This alternative is adaptable to mountainous regions where V-shaped valley retention ponds with small available storage volumes require high dams to store the water quantities produced by a conventional slurry system. In an arctic environment where formation of permafrost into the tailings deposit can simplify site reclamation, thickened tailings is a very attractive option because the lack of a water cover and higher deposition density enhances the freezing process.

The dewatering process at the ore processing plant can be further enhanced to remove most free water from the tailings stream. This is accomplished with either mechanical pressure filters or vacuum filters. Tailings that are produced in this manner have the consistency of damp sand and can be handled and placed like construction material. The handling and placement process is often referred to as "dry stacking". The benefits of such a system are that the material placement can be engineered to be self contained without a retaining structure. Stability issues commonly associated with failure of tailings impoundments, such as dam failure and liquefaction, do not apply to an engineered stack system.

The original concept for tailings disposal for the Minto mine (Robinsky, 1995) was to dewater the tailings at the mill to a paste consistency and place them hydraulically within the upper basin of Minto Creek. The early testing showed that the tailings would flow at a slope of about 5% and that excess water would accumulate downstream behind the water dam. In later years of the mine, some tailings solids were predicted to accumulate behind the water dam reducing the water storage capacity. The project water license was issued based on the paste tailings deposition plan developed by Robinsky. In order to comply with the conditions of the water license, the tailings would have to meet a minimum criterion for solids density in the slurry of 68% before deposition.

A review by EBA in 2006 found that, this system, although theoretically possible for the site, introduced substantial risk from a practical operating perspective. The test data showed that minor variations in slurry density from the design parameters would result in the material flowing downslope directly into the water reservoir behind the dam. This would have serious consequences to the operation, therefore, an intermediate retention dam was proposed to ensure effective separation of the tailings solids from the process water. The addition of an internal tailings solids retention dyke was not in compliance with the water license. Moreover, there were some technical and environmental advantages to further enhancement the water removal process by addition of pressure filters. This would produce material that could be "dry stacked" and would be self-supporting. The option was attractive because it reduced the overall footprint of the deposition stack, removed tailings from Minto Creek and provided improved opportunities for progressive reclamation. The design described in this report is predicated on the dry stack option in order to realize these important benefits and ensure compliance with the water license.

4.2 TAILINGS PRODUCTION

It is understood from the tailings flowsheet that flotation tailings will be transported by conveyor from the Process Plant to a location within the DSTSF at a solids content of about 83% by mass. The life of mine plan supplied by Hatch indicates that the total production of tailings will be in the order of 5,517,000 tonnes during the eight year mine life. The anticipated tailings production by year is presented in Table 1 below.

TABLE 1: ANTICIPATED TAILINGS PRODUCTION

Year	Production (tonnes)
1	489,940
2	766,960
3	812,350
4	824,930
5	820,160
6	836,690
7	847,600
8	118,330
Total	**5,516,950**

4.1 TAILINGS CHARACTERIZATION

EBA undertook two separate laboratory programs to evaluate the geotechnical properties of a tailings sample provided by Minto. The first program was completed in May 2006 and formed part of the feasibility study. The second program was completed in November 2006 to supplement the data required for the "dry" tailings stack design and tailings management plan.

4.1.1 Initial Laboratory Testing Program May 2006

Tailings samples were sent to EBA's laboratory in Edmonton. Initial sample preparation involved removing the supernatant water and combining the solids to form one composite sample. Samples for the following testwork were sub-sampled from the composite sample.

The following tests were undertaken:

- Particle size distribution (sieve and hydrometer analyses): ASTM D422;
- Specific gravity determination: ASTM D854;
- Atterberg limits: ASTM D423 and D424; and
- Moisture density relationship (Standard Proctor): ASTM D698.

4.1.1.1 Laboratory Test Results

A summary of the laboratory test results is presented in Table 2. The laboratory result sheets are attached in Appendix B.

TABLE 2: LABORATORY TEST RESULTS

Type of Test	Results
Particle size distribution	Clay: 6%, Silt: 35%, Sand 59%
Specific gravity determination	Specific gravity of solids: 2.79
Atterberg limits	Liquid Limit: 23, Plastic Limit: 16, Plasticity Index: 7
Moisture density relationship	Optimum moisture content: 17.5%, Standard Proctor Maximum Dry Density (SPMDD): 1685 kg/m^3

Note: The above tests report moisture content as a percentage ratio of the mass of water divided by the mass of dry solids, this is consistent with geotechnical engineering practice.

4.1.2 Second Laboratory Testing Program November 2006

The tailings sample was a sub-sample from the composite sample used originally in the initial testing. However, it had been used for physical characterization testing by others between this testing program and the initial testing program.

The following tests were undertaken on the tailings sample.

- Particle size distribution (sieve and hydrometer analyses): ASTM D422.
- Atterberg limits: ASTM D423 and D424.
- Constant Head Permeability Test: ASTM D5084.
- Direct Shear Test: ASTM D3080.

4.1.2.1 Laboratory Test Results

A summary of the laboratory test results is presented in Table 3 and the laboratory result sheets are attached in Appendix B.

TABLE 3: LABORATORY TEST RESULTS

Type of Test	Results
Particle size distribution	Clay: 7%, Silt: 36%, Sand 57%
Atterberg limits	Liquid Limit: 20, Plastic Limit: 16, Plasticity Index: 4
Constant head permeability test	$k = 9.65 \times 10^{-8}$ m/s
Direct Shear Test	Peak Strength: $\theta' = 35.1°$, $c' = 11$ kPa

Note: The above tests report moisture content as a percentage ratio of the mass of water divided by the mass of dry solids -- this is consistent with geotechnical engineering practice.

4.1.3 Summary of Tailings Geotechnical Characteristics

The above testing programs have found the tailings to typically comprise of approximately 6% clay, 35% silt and 59% sand sized particles with a specific gravity of 2.79. Two separate Atterberg Limit tests determined a Plastic Limit of 16%, the Liquid Limit ranged between 20 and 23% and the corresponding Plasticity Index ranged between 4% and 7%. In geotechnical terms the tailings can be described as sand and silt, trace of clay.

The Standard Proctor test determined an optimum moisture content of 17.5% at a maximum dry density of 1685 kg/m^3. Shearbox tests undertaken at an average density of 1640 kg/m^3 and average moisture content of 20% determined an internal angle of shearing resistance of 35.1° and a cohesion intercept of 11 kPa at peak shear strength. At a density of 1640 kg/ m^3 the material was determined to exhibit a hydraulic conductivity of 9.65×10^{-8} m/s.

5.0 SITE CONDITIONS

5.1 GENERAL SURFICIAL GEOLOGY

Boreholes drilled within the plan area of the DSTSF have determined that overburden thicknesses may range up to 45 m based on exploration drilling. These deposits are thought to be an extension of an infilled valley which also passes through the southern end of the open pit. The overburden soils generally comprise colluvial sediments of silt and sand with trace gravel, and thin out to the south and east of the DSTSF site.

5.2 SURFACE FEATURES

The DSTSF site is located over a gently sloping (about 3° to 10°) terrain, south and upslope of the mill buildings and Minto Creek.

The terrain steepens to the south and southwest of the DSTSF. The access road to the airstrip bisects these slopes upslope of the stack area. A diversion ditch has been constructed along the upstream side of this road (see Figure 2).

The tailings facility area originally had sparse to locally dense tree cover, however the region was subject to a forest fire in 1995 that has resulted in areas of fallen trees with deciduous species regrowth.

5.3 SUBSURFACE CONDITIONS

Geotechnical information from previously projects undertaken by EBA on or near the site was reviewed as part of this study. This information was compiled during several studies in the mid 1990's, typically for the design for the mill site, a waste rock dump originally proposed for the site and the water retention dam that remains an important part of the project.

Eleven existing geotechnical boreholes, shown on Figure 3, (Nos. 94-G11, 94-G11A, 94-G21, 96-G07 through 96-G13 and 96-G16) were drilled and sampled in the vicinity of the proposed DSTSF. Five of these (Nos. 96-G07 through -G12 excluding -G10) are within the footprint of the facility. Boreholes 96-G10, -G13, and –G16 were drilled within 100 m of the west and northwest perimeter of the facility while boreholes 94-G11, -G11A and -G21 were drilled approximately 150 m to 250 m to the northeast. The boreholes were drilled to depths ranging from 4.8 to 24.4 m. The results from the laboratory and the field-testing programs are shown on the borehole logs, where applicable. The borehole logs along with the accompanying grain size distribution curves are presented in Appendix C.

A ground temperature cable was installed to a depth of 12 m in Borehole 94-G11, 20 m in Borehole 94-G21 and 10 m in 96-G08 at the time of the investigations in 1994 and 1996. Temperature data was collected intermittently for the first year after installation. These instruments are no longer serviceable but the available ground temperature data is presented with the appropriate borehole log in Appendix C.

The geotechnical investigations indicate that the subsurface conditions generally comprise a thin veneer of peat and vegetation overlying a fine-grained silt or silt and sand overlying coarse-grained sand. The exception is Borehole 94-G21 which noted a clay layer from ground surface to 18.9 m.

The fine grained sand and silt is believed to be of colluvial origin while the coarser sand is considered to be a residual soil (residuum). Throughout the mine site these residual soils grade into weathered bedrock. The engineering characteristics of these overburden soils are discussed in Section 7.

5.3.1 Groundwater

No groundwater was reported in any of the boreholes drilled within the DSTSF, but is expected within the active layer during the summer and fall.

5.3.2 Permafrost

Permafrost was encountered in each of the boreholes drilled within the vicinity of the proposed DSTSF, at varying depths. The maximum recorded active layer thickness was about 1.0 m in September 1996, directly under the DSTSF footprint.

The observed ice contents in the five boreholes (Nos. 96-G07 through -G12 excluding -G10) within the footprint of the DSTSF typically ranged from Nbe to visible ice at 10% to 20% of the total volume. Two of the boreholes, 96-G09 and 96-G12, showed ice intervals of 1.5 and 4.0 m thick within the upper 10 m. More detailed information is available in the borehole logs presented in Appendix C.

Initial data from the ground temperature cable installed in 96-G08 indicated a relatively uniform ground temperature of close to -0.8ºC after equilibration with slight seasonal warming over the top 2 or 3 m. The active layer depth was close to 1 m. This cable could not be found in the summer of 2006 and may have been destroyed.

Initial data from the ground temperature cables installed in 1994, 94-G11 and 94–G21, indicates similar temperatures as 96-G08 with a relatively uniform ground temperature of close to -0.8ºC at depth and seasonal warming over the top 5 m. The active layer depth was up to 3 m in 94-G11 and 4 m in 94–G21 (these are on existing disturbed trails). Readings from 2006 for 94-G11 indicate similar ground temperatures and active layer thickness. Cable 94-G21 has not been located to date.

5.3.3 Bedrock

Depths to bedrock (granodiorite) are indicated to range up to 45 m based on exploration borings drilled nearby. Weathered bedrock outcrops are present within the vicinity of the airstrip, south of the upper reaches of the “dry” stack tailings facility. There is no exposed bedrock within the proposed DSTSF. The bedrock is considered too deep at this site to have any significant effect on the system design.

6.0 DESIGN BASIS OF THE “DRY” STACKED TAILINGS STORAGE FACILITY

6.1 TAILINGS VOLUME AND PROPERTIES

The mine plan indicates that 5,517,000 tonnes of tailings will be produced over an eight year period. The tailings will be transported by conveyor to the DSTSF at 83% solids and mechanically placed to form an engineered “dry” stack. The tailings material at 83% solids is equivalent to a gravimetric moisture content of 20%[1]. Referencing this moisture content against the moisture density relationship detailed in Appendix C, the mechanically engineered tailings should achieve a density of 1,600 kg/m^3 which is equivalent to 95% of the Standard Proctor Maximum Dry Density. On this basis a storage volume of 3,758,000 m^3 will be required to accommodate the 5,517,000 tonnes of tailings at a placed density of 1,600 kg/m^3.

Laboratory tests undertaken on samples of tailings material have characterised the material as silty sand with a trace of clay and generally exhibits the properties of a cohesionless

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[1] Moisture content is the percentage ratio of the mass of water divided by the mass of dry solids -- this is consistent with geotechnical engineering practice.

material. On the basis that the tailings will be placed at a solids content of approximately 83% and a dry density of 1,600 kg/m^3, little or no bleed water is expected to emanate from the tailings upon placement and compaction. Accordingly, the tailings can be classified as a "dry" stackable material and will be in an unsaturated condition upon placement.

It should be noted that at the above proposed tailings solid content of 83 % solids by weight exceeds the stipulated solids content of 67.5 % in terms of the Water Use Licence QZ96-006 issued by the Yukon Territory Water Board dated November 2005, reference paragraph 47.

6.2 SITE AND ALIGNMENT SELECTION

A tailings site was selected east of the Process Plant within the valley profile above the Minto Creek as shown in Figures 2 and 3 that will meet the storage requirement for 3.8 million m^3. This particular site is in close proximity to the mill and minimizes potential impacts on Minto Creek.

The DSTSF area covers an area of approximately 0.4 km^2 and is designed to provide for storage and confinement of the tailings. The toe of the stack is at an elevation of approximately 758 m, which has been designed to be above the flood level of Minto Creek and well above the reservoir level created by the water dam. The stack will have an outer slope of 4:1 (horizontal:vertical) or 14 degrees and a final stack crest elevation close to 788.5 m. The tailings will be up to 26 m deep in the central area of the DSTSF.

6.3 TAILINGS "DRY" STACK CONCEPT

"Dry" stacked tailings is a recognised method of tailings storage and has been used worldwide including an number of northern mining operations (e.g. Greens Creek Mine, Juneau Alaska, Raglan's Mine in Northern Quebec and Pogo Gold Project near Delta Junction Alaska). "Dry" stacked tailings essentially involves controlled and engineered placement of vacuum or pressure filtered tailings (sometimes referred to as filter cake) in layers to progressively form a stable stack of dense tailings. "Dry" tailings is generally referred to tailings with a moisture content at or below the liquid limit however, this is somewhat dependant on the tailings material characteristics. This method allows the storage of tailings in a dewatered and unsaturated form. In addition, "dry" stacked tailings also allow for progressive reclamation of the outer slopes of the tailings stack with increasing stack height.

As summary of the advantage of "dry" stacking was presented on a report entitled "Examination of Revegetation Methodologies for Dry Stack Tailings in Northern Environments" published by the Mining Environmental Research Group, Government of Yukon (2003) and has been shown to have many long term geotechnical and environmental benefits.

6.4 MINTO “DRY” STACKING PLAN

The DSTSF at the Minto Mine will include; an access road, tailings stack starter bench, slope drainage blanket, finger drains along existing valley drainages, and diversion berms for run-on surface water management.

The tailings starter bench, constructed from waste rock, will provide a horizontal working bench on to which the initial tailings will be mechanically placed, spread and compacted in controlled lifts. The tailings stack will be progressively developed using a bottom up construction approach and will eventually occupy the footprint area designated in Figure 2.

Fundamental to the long term global stability of the stack is; controlled insitu density of the tailings following placement, encouraging seasonal frost penetration, and management and maintenance of the stack under-drainage and surface water diversion berms.

6.5 DESIGN AND CONSTRUCTION CONSIDERATIONS

The primary considerations for the design and management of the tailings stack are as follows:

- Provide a geotechnically stable tailings stack at all stages of construction, with particular attention to permafrost and foundation conditions;
- Surface water management and control to limit surface erosion and washing of the tailings into the water reservoir.. This must include management of both run-on water (i.e. water entering into the DSTSF) and run-off water (i.e. water captured within the DSTSF and directed out of the DSTSF);
- Develop the facility in stages to encourage preservation of winter freezing within the stack and limit permafrost degradation from the foundation soils;
- Incorporate field observation and performance monitoring of the stack. During the initial stages of tailings placement this will enable review of design assumptions;
- Account for winter operations, specifically, placement and compaction of the tailings and the water management system (surface water diversion berms and finger drains); and,
- Consider available construction materials.

The following basic criteria were adopted for the design of the tailings stack:

- Design capacity of 5,517,000 tonnes placed at an average bulk density of 1.6 t/m^3;
- Annual tailings production will range from approximately 490,000 to 848,000 tonnes for about eight years;
- Solids content of 83% for the soil-water mixture delivered to the facility;
- Placement and compaction of tailings occurs on a continuous basis;

- Compaction in 500 mm lifts to at least 95% Standard Proctor Maximum Dry Density (per ASTM D698); and
- Maximum annual cumulative thickness of 3.0 m in any one area of the facility.

7.0 TAILINGS STACK DESIGN

7.1 LAYOUT AND GEOMETRY

The trees within the footprint of the DSTSF will be sheared off above the root bulb during the winter and removed from the drainage blanket footprint. Elsewhere under the stack the trees will be sheared off and flattened. The tree clearing will be undertaken incrementally, thus clearing areas only required for the following year tailings placement with the view to maintaining the vegetation cover in the remaining areas to minimize potential degradation of the permafrost. Initially tree clearing will be concentrated towards the toe of the DSTSF (i.e. towards the Minto Creek) in order to place and construct a 120 m wide by (minimum) 1.5 m thick toe drainage blanket and a toe starter bench, details of which are shown in Figure 3. These will be constructed of waste rock material overlain by a filter material, details of which are also shown in Figure 3. Four finger drains have also been incorporated into the design to intercept existing seepage flows beneath and from the DSTSF, if any. Upon completion of the above, spreading and compaction of the tailings material will commence using a bottom up placement sequence.

The stack will be a crescent shaped structure, following the contours of the slope, as shown on Figure 2. The ultimate stack will have a crest elevation at 788.5 m and have a 4:1 sideslope. The maximum thickness of the tailings stack will be in the order of 26 m. This stack will provide sufficient storage for the projected tailings tonnage on the basis of an insitu dry density of 1,600 kg/m^3.

7.2 THERMAL EVALUATION

7.2.1 Analysis Methodology

Thermal analyses were carried out to predict the permafrost response within the foundation soils., The thermal model was calibrated against the measured ground temperatures at the site. Various cases with different assumed tailings placement rates and final heights were simulated. Parametric and sensitivity studies for some cases were also conducted.

Analyses were carried out using EBA's proprietary two-dimensional finite element computer model, GEOTHERM. The model simulates transient, two-dimensional heat conduction with change of phase for a variety of boundary conditions. The heat exchange at the ground surface is modelled with an energy balance equation considering air temperatures, wind velocity, snow depth, and solar radiation. The model facilitates the inclusion of temperature phase change relationships for soils, such that any freezing depression and unfrozen water content variations can be explicitly modelled. The model has been verified by comparing its results with closed-form analytical solutions and many different field observations. The model has successfully formed the basis for thermal evaluations and designs of tailings dykes, dams, foundations, pipelines, utilidor systems, landfills, and ground freezing systems in arctic and sub-arctic regions.

7.2.2 Parameters and Results

Parameters and results from the thermal analysis are described in detail in the Technical Memo "Thermal Analysis of "Dry" Stacked Tailings Area" presented in Appendix D. Specific sections include climatic data, calibration, cases simulated, soil index and thermal properties, results and discussions, and air temperature sensitivities.

7.2.3 Discussion

The following conclusions and recommendations can be drawn from the thermal analysis results:

- The minimum 1.5 m thick sandy gravel drainage blanket recommended for placement over the original ground to drain potential excess porewater should also provide benefit in limiting thaw penetration into the original ground due to tailings placement.
- The predicted long-term tailings temperatures for tailings placement rates of 1.5 m/year and 3.0 m/year are colder than those for a tailings placement rate of 6.0 m/year. Therefore, it is recommended to limit the tailings placement rate to less than 3.0 m/year to promote freeze-back of the summer-placed tailings.
- A thin initial summer-placed tailings layer would promote freeze-back during the following winter, and result in colder tailings/ground temperatures during later stages of the mine life.
- Reduced snow cover will result in colder tailings/ground temperatures. It is recommended that snow be regularly cleared off the tailings surface.
- Snow will tend to accumulate on the lower area along the toe of the tailings perimeter slopes due to both natural snow-drifting and intentional snow-clearing from the tailings surface. It is anticipated that a haul road will be constructed around the toe of the lower portion of the tailings perimeter slopes. It is recommended that snow be regularly cleared off both the slope toe area and the road surface to promote deeper seasonal frost penetration into the original ground.
- The long-term air temperatures at the Minto site may increase with time. Sensitivity thermal analyses using estimated mean air temperatures indicate that the predicted thaw penetration into the original ground could be 0.1 m to 0.4 m deeper than that for the corresponding cases presented in Table 6 in Appendix D. It is recommended that the air temperatures at the Minto site continue to be monitored over the life of the mine, to verify design assumptions.

- It will be necessary to monitor the ground temperatures within and below the stack to predict permafrost response for refinement of placement methods and develop closure designs.

7.3 STABILITY EVALUATION

7.3.1 Analysis Methodology

Limit equilibrium analyses were conducted to determine the factor of safety against slope failure during construction and maintenance of the stack. All analyses were conducted using the commercially available two-dimensional, limit equilibrium software, SLOPE/W (Geo-Slope International Ltd., Version 5.17). The principles underlying the method of limit equilibrium analyses of slope stability are as follows:

- A slip mechanism is postulated;
- The shear resistance required to equilibrate the assumed slip mechanism is calculated by means of statics;
- The calculated shear resistance required for equilibrium is compared with the available shear strength in terms of factor of safety; and
- The slip mechanism with the lowest factor of safety is determined through iteration.

Factor of safety is used to account for the uncertainty and variability in the strength and porewater pressure parameters, and to limit deformations.

Earthquake loading has been modeled using a pseudostatic peak horizontal ground acceleration.

Stability analyses were carried out for a typical cross-section of the tailings stack. The foundation at this location was inferred to be silt and sand with varying percentages of gravel, grading into residuum and weathered granodiorite bedrock at depth.

The presence of permafrost with ground ice in the foundation soils will be a controlling factor in assessing stack stability. It is the design intent to retain the permafrost within the foundation or at least slow the rate of regression to provide time for dissipation of pore pressure resulting from thaw. There is a direct link between the predicted permafrost behaviour and the potential critical failure mechanisms. It has been postulated, based on previous EBA experience, that some thaw at the base of the active layer will occur and that the shear strength acting along the thawed frozen interface will be a controlling factor in the stack design. The focus of the stability analyses is therefore a deep failure plane cutting through the stack to a receding permafrost interface in the foundation soil. The failure would then follow the potential weak layer and exit at the toe of the slope.

Other shallow potential failure options have been considered but these are of minor consequence and are not considered a controlling mechanism. For purposes of the limit equilibrium analyses the underlying permafrost is considered much stronger than the unfrozen soil therefore the risk of shear failure through the frozen ground is slight. The permafrost soil is warm and can deform or creep under a sustained load. The potential for creep displacements occurring deep within the permafrost has not been specifically analysed as the distribution of ground ice within the soil is poorly understood at the site. Creep displacements, if they were to occur would be identified in the deformation monitoring system and by manifestation of cracking in the slope. These movements are slow, seldom resulting in substantial earth movement and there would be adequate time for mitigative measures such as construction of a downslope rock buttress.

7.3.2 Design Criteria

The guidelines for minimum design factor of safety have been adopted from the British Columbia Interim Guidelines for Investigation and Design of Mine Dumps (Waste Rock Design Manual).

The design criteria adopted from the guidelines are included in Table 4.

TABLE 4: DESIGN FACTORS OF SAFETY

Stability Condition	Minimum Design Factor of Safety
Long Term Stability	1.3
Seismic (Pseudo-static) Stability	1.1

The Waste Rock Design Manual recommends that seismic stability should be evaluated using pseudostatic horizontal accelerations that correspond to a 10% probability of exceedance in 50 years. When work was originally undertaken on this project in the mid 1990's, the Canadian Geological Survey Pacific Geosciences Centre provided a value for the peak horizontal acceleration for the project site of 0.15 g. An updated value for the site has been provided by the Pacific Geosciences Centre and the current peak horizontal acceleration that corresponds to a 10% probability of exceedance in 50 years is 0.055 g. The reasoning for the decrease in the peak ground acceleration provided by the Pacific Geosciences Centre is that seismic data collection has increased substantially in the Yukon in recent years. A better understanding of ground motion and improved modelling has resulted in revised predictions, which are considered to be more accurate and representative for the project area.

7.3.3 Material Properties

The material properties chosen for the tailings stack and foundation materials in the stability analyses are presented in Table 5. The properties for the materials were selected based on the completed laboratory testing, and properties used in the design of the existing facilities on the site.

Table 5: Material Properties used in Stability Analyses

Material	Angle of Internal Friction (º)	Cohesion (kPa)	Unit Weight (kN/m³)
Tailings	28	--	19.4
Waste Rock	35	--	20.0
Active Layer/Thawed Permafrost	28	--	18.4
Permafrost	--	--	--

7.3.3.1 Tailings

The shear strength parameters, internal friction angle and cohesion, were determined by evaluating the results of a direct shear test on a sample of tailings material. The results determined that the peak shear strength parameters were θ´ = 35.1º and c´ = 11 kPa,. However, the tailings showed some evidence of strain weakening; therefore, lower strength parameters of θ´ = 28º and c´ = 0 kPa were used for the stability analyses.

7.3.3.2 Waste Rock

Waste rock from the open pit will be used to construct the drainage blanket, finger drains, starter bench and exterior shell.

Steffen, Robertson and Kirsten Ltd. (SRK) reviewed Minto rock core taken during a 1993 exploration program and produced a report containing geotechnical properties of the rock mass on site with respect to open pit design, hanging wall design and underground mining design issues (SRK, 1994). The bedrock is described as weathered to a depth of about 30 m and it was recommended that ripping with dozers could be used for pit excavation (SRK, 1994). It is believed that this observation justifies that some of the waste rock excavated from the open pit could be treated as "soil like" waste rock with a friction angle of 35°. It is anticipated that the majority of the waste rock produced will be "rock like" with a friction angle of 37º to 38º.

Although it is recommended and expected that only competent waste rock from the open pit will be used for construction, there is the potential for some "soil like" materials to be incorporated. Therefore, the lower friction angle of 35º was used in the stability analyses. The engineer on site during construction will verify that only competent rock is being used, and will direct the contractor to take any "fine grained" loads to the waste dump.

The 35º design friction angle is consistent with values used in previous analyses for the water dam (EBA, 1995) and main waste rock dump (EBA, 1998).

7.3.3.3 Active Layer and Recently Thawed Permafrost

The active layer soils and upper permafrost that may be expected to thaw over the life of the structure is typically a silt and sand with trace to some fine gravel. This material is believed to be representative of the colluvium found on the surface in other areas of the mine site. Direct shear testing of a silty sand colluvium sample from Testpit 97-01 (within the vicinity of the open pit) indicates this material could exhibit strain-softening behaviour with a peak friction angle of 35° and a residual friction angle of 28°. In the present analyses, the residual friction angle of 28° has been used considering that downslope movement and reworking of this material has occurred over time, or that recently thawed permafrost will be in a looser condition than the active layer soils.

The active layer is expected to increase in thickness by up to 0.2 m over the life of the mine. This is predicted to occur at a slow rate; therefore, it is expected that any excess porewater pressures will dissipate as they are generated. However, a pore pressure parameter (Ru) of 0.4 for all unfrozen natural foundation soil below the stack has been adopted for the stability analyses.

7.3.3.4 Permafrost

The permafrost soil found beneath the tailings stack is typically a silt and sand with trace to some fine gravel. For the purpose of these analyses, this material has been modelled to act as bedrock to force the critical failure surface to the contact of the thawed and frozen material.

7.3.4 Porewater Pressure Conditions

7.3.4.1 Natural Stratigraphy

The geotechnical drilling at this site suggested that the existing active layer was relatively dry as there was no free groundwater observed in the boreholes. However, the design accounts for the possibility of the thawing of permafrost and water transport through the drainage blanket. Therefore, it is possible that a shallow perched groundwater table may exist for short periods of the year. For the present stability analyses, a groundwater table at original ground surface was used.

7.3.4.2 Tailings

The potential for a phreatic surface developing within the stack was not considered due to the following:

- The moisture content of the placed tailings, although slightly above the optimum moisture content, will still result in the deposit being in an unsaturated state;
- Construction of the DSTSF will control surface water on the tailings stack; and
- Construction of a drainage blanket beneath the critical tailings slope will allow any excess water to drain away and not build up porewater pressures within the tailings.

- It is anticipated that the deposit will be layered with extensive permafrost conditions created by winter-placed tailings that will remain frozen.

7.3.5 Stability Analyses

The static and pseudostatic analyses have been evaluated assuming that a thin layer at the top of existing permafrost will thaw with some pore water liberated, resulting in reduced shear strength. The active layer and thawed permafrost soil have been assigned a pore pressure parameter (Ru) of zero for a fully drained condition or 0.4 to account for the possibility of porewater pressure build-up within the thawed foundation soil. As expected, the stability of the tailings stack is governed by the case where Ru = 0.4. Based on the thermal analyses predictions, the expected actual site conditions will be closer to Ru = 0 due to the slow rate of thaw.

7.3.5.1 Static Case

The results of the minimum factors of safety calculated during the static stability analyses are summarized in Table 6. Figure 6 presents the typical cross section used for the analyses and the resulting critical slip surface.

TABLE 6: SUMMARY OF STABILITY ANALYSES RESULTS - STATIC

Case		Minimum Factor of Safety of the Tailings Stack
1	Static, only drainage blanket constructed, groundwater table at original grade	3.87
2	Static, drainage blanket/full stack, groundwater table at original grade	2.26
3	Static, drainage blanket/full stack/waste rock slope cover, groundwater table at original grade	2.27
4	Static, only drainage blanket constructed, groundwater table at original grade, Ru = 0.4	1.82
5	Static, drainage blanket/full stack, groundwater table at original grade, Ru = 0.4	1.42
6	Static, drainage blanket/full stack/waste rock slope cover, groundwater table at original grade, Ru = 0.4	1.45

These results indicate that the factor of safety for the tailings stack with a slope gradient of 4:1 exceeds the minimum 1.3 recommended by the Waste Rock Design Manual.

7.3.5.2 Pseudostatic (Earthquake) Case

The results of the minimum factors of safety calculated during the static stability analyses are summarized in Table 7. Figure 6 presents the typical cross section used for the analyses and the resulting critical slip surface.

TABLE 7: SUMMARY OF STABILITY ANALYSES RESULTS – PSEUDOSTATIC (EARTHQUAKE)

Case		Minimum Factor of Safety of the Tailings Stack
7	Seismic – 0.055 g, only drainage blanket constructed, groundwater table at original grade	2.52
8	Seismic – 0.055 g, drainage blanket/full stack, groundwater table at original grade	1.82
9	Seismic – 0.055 g, drainage blanket/full stack/waste rock slope cover, groundwater table at original grade	1.84
10	Seismic – 0.055 g, only drainage blanket constructed, groundwater table at original grade, Ru = 0.4	1.18
11	Seismic – 0.055 g, drainage blanket/full stack, groundwater table at original grade, Ru = 0.4	1.10
12	Seismic – 0.055 g, drainage blanket/full stack/waste rock slope cover, groundwater table at original grade, Ru = 0.4	1.16

These results indicate that the factor of safety, assuming the current design seismic acceleration of 0.055g, for the tailings stack with a slope gradient of 4:1 meets the minimum 1.1 recommended by the Waste Rock Design Manual.

7.3.6 Discussion

As presented in the above sections, constructing only the drainage blanket (Case 1, 4, 7, and 10) provides a high factor of safety against deep seated failure which is to be expected. The factor of safety against deep seated failure for the construction of the drainage blanket and tailings stack (Case 2, 5, 8, and 11) is slightly less than that of the final cross section (Case 3, 6, 9, and 12) when the tailings stack is armoured with waste rock during the reclamation of the stack.

Progressive reclamation of the tailings stack will include armouring the exposed tailings slope with waste rock on an ongoing basis as the elevation of the stack increases. This will greatly reduce the potential for erosion and shallow failures of the tailings slope.

A critical zone for slope stability is the perimeter slope of the stack at full height. Ensuring that pore pressures do not build-up in this area is critical to the overall stability of the stack, and it is therefore recommended that only free-draining rock be placed on the outside of the waste rock shell. The quality of the waste rock from the pit will be variable. In some instances the waste will be primarily rock and some zones will yield weak rock that is more soil-like. The finer grained materials should only be placed up against the tailings slope and coarse free draining materials in the outer shell.

The results of the stability analyses indicate that the critical area of possible slope instability is the downstream slope of the tailings stack. Consequently, the toe of the stack should be checked for instability following each spring thaw and following major precipitation events. Should there be any indications of impending instability (such as tension cracks or localized slumping), the deformation monitoring data must be reviewed and mitigative measures developed by the Geotechnical Engineer.

The analyses described provide are considered a conservative assessment of the stack stability. The combination of wet thawing permafrost in the foundation at the same time as seismic loading to produce the minimum factor of safety has an extremely low probability of occurrence. The uncertainties associated with the behaviour of the permafrost both within the foundation and within the stack itself justify this cautious approach. The data from a well designed monitoring program could provide justification for reconsidering the design slope angle and steepening it from 4:1 to 3:1 during the operations phase of the mine, and allow an increased capacity without a comprehensive re-design process.

7.4 LIQUEFACTION POTENTIAL

Liquefaction potential of the tailings was assessed by comparing an estimated equivalent "N" value of the tailings compacted to 95% SPMDD to empirical relationships related to earthquake magnitude and location. The tailings are generally fine grained silty sand in an unsaturated state, which are not susceptible to liquefaction. Furthermore, as previously noted, the exterior of the tailings slope will be progressively reclaimed with the placement of a waste rock shell. This shell will provide some additional lateral constraint against any instability within the tailings slope.

The drainage blanket material beneath the lower portion of the tailings stack has no potential for liquefaction due to its coarse grained nature and relatively high insitu density.

8.0 TAILINGS STACK WATER DIVERSION

8.1 GENERAL

The toe of the DSTSF is to be constructed at the outlet of a mountain slope catchment. Several small ephemeral creeks currently collect the surface run-off and route it down the mountain side and into Minto Creek. The total watershed is approximately 3.42 km^2 in size, but approximately 2.5 km^2 of this area is upslope of the airstrip access road and the engineered ditch system that forms a part of this road. Construction of the DSTSF will interrupt the natural drainage paths in the remaining area as shown in Figures 2 and 3.

A water diversion system must be constructed to divert the surface run-off water around and under the tailings facility. During operation, the surface of the tailings stack must be contoured to control direct precipitation on the DSTSF.

Two hydrologic report documents were reviewed to establish the hydrologic site conditions.

- Memorandum CCL-MC1, Clearwater Consultants Ltd., 2006.
- Minto Creek Surface Hydrology Report, Hallam Knight Piesold, 1994.

Information found in Clearwater 2006 memorandum tends to address average flows and is intended for use in water balance calculations. The design of any diversion or routing structures should be conducted for a peak instantaneous flow.

Hallam Knight Piesold 1994 is a more comprehensive hydrology report and contains a section on peak instantaneous flows for several return intervals, which are specific to the tailings facility location. Data presented in this section is described in more detail in Hallam Knight Piesold 1994.

8.2 HYDROLOGICAL CONDITIONS

A regional analysis was conducted on data presented in Hallam Knight Piesold 1994 to determine the peak instantaneous flow rates for six sub-catchment areas in the DSTSF. The frequency analysis for the 3.42 km^2 catchment presented in Hallam Knight Piesold 1994 is included in Table 8. The sub-catchment areas are defined by local topography and are show in Figure 4. The sub-catchment properties are summarized in Table 9 and the peak instantaneous flow rates for the six sub-catchments of the tailings facility are presented in Table 10.

TABLE 8: FREQUENCY ANALYSIS (HALLAM KNIGHT PIESOLD, 1994)

Return Period (years)	Peak Instantaneous Flow (m^3/s)
2	1.8
10	3.0
25	3.7
50	4.3
100	4.6
200	4.9

TABLE 9: PROPERTIES OF SUB-CATCHMENT AREAS

Sub-Catchment	Area (km^2)	Design Slope (%)
Total West Portion	**0.308**	**7.5**
Lower West	0.108	7.5
Upper West	0.081	3.9
Upper Southwest	0.119	5.1
Total East Portion	**0.228**	**7.4**
Lower East	0.080	7.4
Upper East	0.063	6.5
Upper Southeast	0.086	6.5

The new peak instantaneous flow rates were determined using the following equation:

$$Q_u = Q_k \left(\frac{A_u}{A_k} \right)^n$$

Where: Q_u is the Unknown Peak Instantaneous Flow (m^3/s)

Q_k is the Known Peak Instantaneous Flow (m^3/s)

A_u is the Area of the Basin for the Unknown Flow (km^2)

A_k is the Area of the Basin for the Known Flow (km^2)

n is an adjustment exponent

TABLE 10: SUB-CATCHMENT AREA FREQUENCY ANALYSIS

Return Period (years)	Peak Instantaneous Flow Rates (m^3/s)							
	Total West Portion	Lower West	Upper West	Upper Southwest	Total East Portion	Lower East	Upper East	Upper Southeast
2	**0.33**	0.16	0.13	0.17	**0.27**	0.13	0.14	0.11
10	**0.56**	0.27	0.22	0.29	**0.45**	0.22	0.23	0.18
25	**0.69**	0.33	0.27	0.35	**0.56**	0.27	0.28	0.23
50	**0.83**	0.40	0.33	0.43	**0.68**	0.32	0.34	0.28
100	**0.85**	0.41	0.34	0.44	**0.69**	0.33	0.35	0.28
200	**0.91**	0.43	0.36	0.47	**0.74**	0.35	0.37	0.30

8.3 WATER MANAGEMENT SYSTEM

To limit the volume of run-on water entering the DSTSF it is proposed to construct water diversion berms around the perimeter of the proposed facility. These berms will divert run-on from the catchment area above the tailings facility.

Finger drains are to be constructed along existing drainage courses under the tailings stack to intercept near surface seepage, eventually conveying it under the stack towards Minto Creek.

The preliminary sizing of these drains is based on conveying the peak run-off flow obtained from the 1 in 10 event as calculated from data in the above tables. A typical cross section of the finger drains (approximately 7.5 m^2 required) is shown on Figure 3.

The water management system has been designed to function throughout the life of the facility.

9.0 CONSTRUCTION PLAN

9.1 MATERIALS

Construction materials for the DSTSF will comprise waste rock material; 75 mm filter material or equivalent, finger drain material and 200 mm material. All materials will be selected from the open pit or existing borrow sources.

The use of a geosynthetic product as an equivalent to the 75 mm filter material is acceptable, but it must be installed to the manufacturer's specifications or as directed by the Engineer.

9.1.1 Waste Rock Material

The principal use of the waste rock material will be for the construction of the starter bench, drainage blanket/finger drains and the exterior shell of the tailings stack.

The waste rock material will comprise select open pit waste rock with a nominal size of 300 mm. To facilitate proper drainage and no build-up of pore pressure, the fines (<0.080 mm) content must be less than 5% by weight. The maximum particle size allowed is 1.0 m, or as approved by the Engineer.

9.1.2 75 mm Filter Material

The 75 mm filter material or equivalent will be used to act as a separator between the tailings and waste rock material or above/beside the finger drains. This material will act as a filter for the tailings and restrict it from infiltrating the coarser material. The use of a properly bedded heavy-weight non-woven geotextile may be used in lieu of the 75 mm filter material.

The 75 mm filter material must be well-graded sand and gravel with a 75 mm maximum aggregate size and a fines content (i.e. that passing the 0.08 mm sieve size) limited to 15%. The recommended gradation for the filter material is shown in Table 11, or other materials as approved by the Engineer. Select residuum from the open pit will be an acceptable source.

TABLE 11: GRADATION OF 75 mm FILTER MATERIAL

SIEVE SIZE (mm)	% PASSING BY MASS
75.0	100
25.0	65 – 100
12.5	50 – 100
5.0	35 – 90
0.825	17 – 50
0.425	10 – 35
0.160	2 – 23
0.080	0 – 15

9.1.3 Finger Drain Material

The finger drain material must be free draining, and will be comprised of select open pit waste rock with a nominal size of 300 mm. To facilitate proper drainage, the fines (<0.080 mm sieve size) content must be less than 5% by weight. The maximum particle size allowed will be 600 mm, or as approved by the Engineer.

9.1.1 200 mm Material

The 200 mm material will be used to construct the surface diversion berms. It must be a well-graded material with a nominal 200 mm maximum aggregate size and a fines content (< 0.08 mm sieve size) limited to about 15%, or as approved by the Engineer.

9.2 CONSTRUCTION REQUIREMENTS

The following information describes a construction plan for the tailings stack that satisfies requirements for an engineered structure. The proposed construction sequencing and details of the placement and compaction processes can be found in the following sections of this report.

The construction plan must satisfy the following requirements for the structure to meet the design intent.

- The subgrade preparation must sequentially flatten and/or remove all trees from the stack footprint. Disturbance to the organic soil must be minimal. All tree remnants must be removed from below the granular drainage blanket and finger drains.
- The subgrade preparation must be completed in the late winter, sufficiently in advance of spring run-off.
- The waste rock for the starter bench and drainage blanket must be sourced and these components must be constructed prior to the active layer thawing (must be complete by April 30).
- The finger drains must be constructed within the natural drainage courses.
- Tailings placement must be limited to no more than 3.0 m of thickness in any area during a given year, and all tailings must freeze completely in the following winter before any additional tailings are placed.
- Frozen tailings from winter construction should be protected from thawing, where practical.
- The starter bench is to be raised in elevation in conjunction with the tailings stack to provide the required waste rock shell for progressive reclamation.
- A quality assurance program must be implemented that will provide data on fill temperatures, placement water content, lift thicknesses, and insitu density.

The following components are required for construction before start-up of operations as shown in Figures 2 and 3.

- Ground surface preparation over the entire footprint of the tailings stack starter bench and 120 m upslope. Ground surface preparation is limited to the flattening and removal of trees from the area.
- Placement of a tailings starter bench comprising a minimum 2.0 to 2.5 m thick layer of waste rock.
- Placement of a drainage blanket comprising a minimum 1.5 m thick layer of select waste rock overlain by about 0.3 m of 75 mm filter material or equivalent.

- Partial construction of four finger drains along the valley lines as shown in Figure 2. These drains ultimately extent into the upper reaches of the tailings stack catchment area.
- Construction of surface water diversion berms.

The following process is required during mine operations.

- Ground surface preparation in advance of the tailing placement.
- Placement, spreading and compaction of tailings to build up the tailings stack. The tailings lift thickness is to be no more than 0.5 m and compacted to at least 95% SPMDD.
- General maintenance of the surface water diversion berms and finger drains.
- Dust control as required.
- Address localized surface sloughing and slumping issues, if any.
- Keep the tailings area free of snow in the winter to promote deeper seasonal frost penetration.

9.3 SCHEDULE

For construction planning purposes, the following generalized schedule for the stack construction is suggested:

January to March 2007

- Prepare ground surface for the construction for the starter bench and drainage blanket;
- Construct the starter bench and drainage blanket; and
- Prepare ground surface for the Year 1 tailings deposition area.

April 2007

- Placement of filter material, or equivalent.

May 2007 and onwards

- Commence tailings deposition in the Year 1 area;
- Construct the finger drains into the Year 2 tailings deposition area;
- In winter 2007/2008, continue with tailings deposition and prepare surface to Year 3 limits, etc.

9.4 GROUND SURFACE PREPARATION

Surface preparation within the tailings stack area should be limited to the sequential flattening and removal of trees. All trees must be removed from beneath the blanket filter and toe drains, but trees need only be sheared off and flattened under the tailings stack.

This must be completed in the winter with the standing trees being sheared off just above the ground surface. Minimal disturbance to the ground surface is required to protect the underlying permafrost foundation material. Trees that are removed should be stockpiled (not burnt) and then placed against the toe of the starter bench, for additional permafrost preservation.

9.5 MATERIAL PLACEMENT

Materials placement will be detailed in the Construction Drawings, and is summarized in the following sections. The effectiveness of the utilized construction technique will be evaluated in the field by the Geotechnical Engineer and changes to the construction procedure will be made as required.

9.5.1 Waste Rock Material

The waste rock materials for the outer shell and drainage blanket should be placed and compacted in maximum 1.5 m lifts. Compaction of this material will be achieved by routing heavy equipment (i.e. haul trucks,) evenly over each lift. A minimum of 5 passes is recommended. This material must be placed in a manner that will minimize segregation or nesting of coarse particles. The effectiveness of this construction technique will be evaluated in the field by the Geotechnical Engineer and changes to the construction procedure will be made as required. Boulders greater than 750 mm size should be removed from the fill as much as practically possible and pushed to the slope face.

9.5.2 75 mm Filter Material

The 75 mm filter material should be placed in maximum lift thicknesses of 300 mm, with each lift compacted at existing moisture content to approximately 95% of SPMDD.

9.5.3 Finger Drain Material

The finger drain material should be placed on geotextile and nominally compacted, as directed by the Engineer, to minimize settlement by ensuring rock-on-rock contact. This material must be placed in a manner that will minimize segregation or nesting of coarse particles. The effectiveness of the construction technique will be evaluated in the field by the Geotechnical Engineer and changes to the construction procedure will be made as required.

9.5.4 200 mm Material

The 200 mm filter material for surface water diversion berms should be placed in maximum lift thicknesses of 400 mm and each lift compacted to approximately 95% of SPMDD.

9.5.5 Tailings

The tailings should be placed in maximum lift thicknesses of 500 mm, with each lift compacted to no less than 95% of SPMDD. The laboratory results, as presented in Section 6, indicate that 95% of SPMDD equates to a dry density of 1,600 kg/m^3. To achieve this density, the tailings should be at a moisture content of between 12 and 22% (mass of water/mass of dry solids). Processing plans indicate the tailings will have a moisture content of 20% as it enters the DSTSF; therefore, moisture conditioning during placement is not anticipated. During initial tailings placement, a performance specification should be developed to ensure adequate compaction of each lift.

The Atterberg Limits give an indication of the mechanical sensitivity of the tailings material at different moisture contents. The plastic limit (PL) defines the moisture content at which the material changes from being a semisolid to a plastic state and the liquid limit (LL) defines the moisture content at which the material changes from a plastic state to a liquid state. The tailings have a plastic limit of 16% and a liquid limit between 20% and 23%. Given the tailings will have a moisture content of 20% as it enters the DSTSF, trafficability could be impaired with any increase in moisture content.

9.6 WINTER OPERATION

Winter operation will involve the placement of tailings in subzero temperatures and the management of accumulated snowfall.

Tailings placement and compaction must address freezing temperatures. A procedure must be in place prior to operation, to achieve the required tailings placement design criteria in winter conditions.

Snow must be removed from the tailings stack and placement area. The snow can be graded to the downstream side of the waste rock shell.

9.7 QUALITY ASSURANCE

A construction quality assurance program must be developed to ensure that construction-sensitive features of the design are achieved. The elements of the program should include but not be limited to the following:

- Specific engineering approvals at critical times, such as foundation preparation and fill placement;
- Monitoring and field testing of fill materials on a intermittent basis;
- Specific approval of construction procedures for moisture conditioning and placement of all fill materials;
- Periodic processing and review of temperature data collected from ground temperature cables installed in the fill as part of long-term monitoring (see Section 9);
- Defined procedures for reporting with identified responsibilities for decision making during construction;
- Specific requirements and testing frequencies for the Quality Assurance process during construction are to be set out prior to start-up;
- A Tailings Operations, Maintenance and Surveillance manual be completed prior to start up;

- Photographs of the construction progress;
- Preparation of as-built drawings;
- Conduct a summer 2007 field program to determine an effective placement method which ensures design criteria; and
- Conduct a winter 2007/2008 field program to determine an effective placement method which ensures design criteria.

10.0 LONG TERM MONITORING

10.1 PURPOSE

Performance monitoring is an integral part of the design, construction, and operation of the stack. This section describes a recommended minimum monitoring program for the construction and operation phases of the project. The monitoring program serves three functions:

- Monitor the thermal regime of the foundation materials and tailings stack to validate the thermal predictions;
- Monitor the porewater pressure regime of the foundation materials and tailings stack to validate the stability predictions;
- Monitor surface movements of the stack; and

The results of the monitoring program can be the basis of an adaptive management process that continually reviews the operation and optimizes the placement methods. There are potential opportunities to increase slope angles and lift thicknesses based on appropriate performance data. Additional information on the components of the monitoring program is presented in the following sections. The recommended instrumentation program will be shown on the construction drawings.

10.2 THERMAL REGIME

An instrumentation program is recommended for implementation. A total of five ground temperature cables are to be installed. The manually obtained ground temperature data should be collected and reviewed on a monthly basis.

10.3 PIEZOMETERS

Three piezometers are recommended. These instruments will confirm the assumed phreatic surfaces used for the stability analyses and monitor any build up of porewater pressure.

10.4 DEFORMATION AND SETTLEMENT

The starter bench and tailings stack should be surveyed to determine the as-built profile and to establish a basis for determining future settlements.

Settlement monuments will be installed along the crest of the waste rock starter bench. They should be surveyed and reviewed after construction, after one year and then periodically at the discretion of the Engineer to monitor settlement and horizontal movements.

Should an area show signs of distress, survey pins should be installed and monitored to assess future remedial actions.

11.0 ANNUAL INSPECTION

It is recommended that an annual site inspection be conducted by the Geotechnical Engineer during the operational period to document the performance of the DSTSF. After closure, a revised and less frequent schedule can be adopted. The specific tasks of these visits include:

- inspection of the internal and external slopes for any signs of distress;
- inspection of the crest of the stack for any signs of transverse cracking;
- inspection of the stack for any signs of discharge from the base ; and
- review of temperature, porewater pressure, settlement and movement data to confirm conformance with design assumptions.
- Prepare an annual report that summarizes the data and provides recommendations for maintenance or modification of the tailings management plan.

12.0 LIMITATIONS

Geological conditions are innately variable and are seldom spatially uniform. At the time of this report, information on stratigraphy at the project was at identified borehole locations from past studies. In order to develop recommendations from this information, it is necessary to make some assumptions concerning conditions other than at the specifically tested locations. Adequate monitoring should be provided during construction to check that these assumptions are reasonable.

The recommendations prepared and presented in this report are based on the geotechnical data gathered by EBA from previous reports and the current laboratory testing. The provided data, in the form of geotechnical boreholes and associated laboratory index property test results, has been supplemented by EBA's direct observations of the site.

This report and the recommendations contained in it are intended for the sole use of Minto Explorations Ltd. 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 if the information presented in this report is used or relied upon by any party other than that specified above for the proposed DSTSF. Any such unauthorized use of this report is at the sole risk of the user. Additional information regarding the use of this report is presented in the attached General Conditions, which form a part of this report.

13.0 CLOSURE

EBA trusts that this report satisfies you requirements. Please do not hesitate to contact the undersigned should you have any questions or comments.

Respectfully Submitted,
EBA Engineering Consultants Ltd.

J.P.W. BERKERS

J. RICHARD TRIMBLE

Jan 11/07

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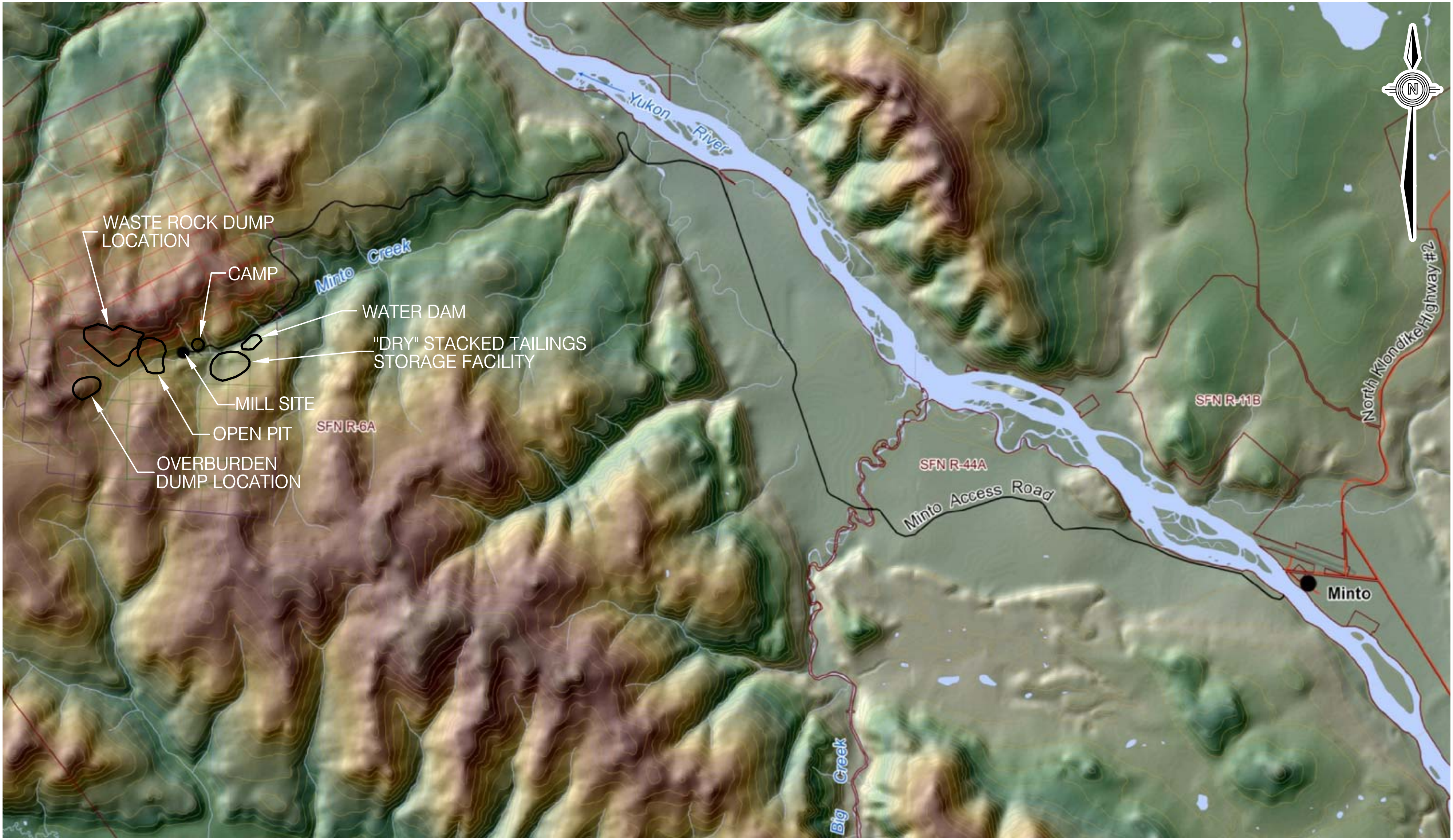
FIGURES

Q:\Whitehorse\Data\0201drawings\Minto\TAILINGS MANAGEMENT JPB\Report figures\1200173 Figure 1 Loc Plan.dwg [FIG 1 8.5X11L] January 04, 2007 - 5:11:16 pm (BY: CHAD COWAN)



CLIENT

Minto Explorations Ltd.

EBA Engineering Consultants Ltd.

Geotechnical Report
"Dry" Stacked Tailings Storage Facility
Minto Mine, YT

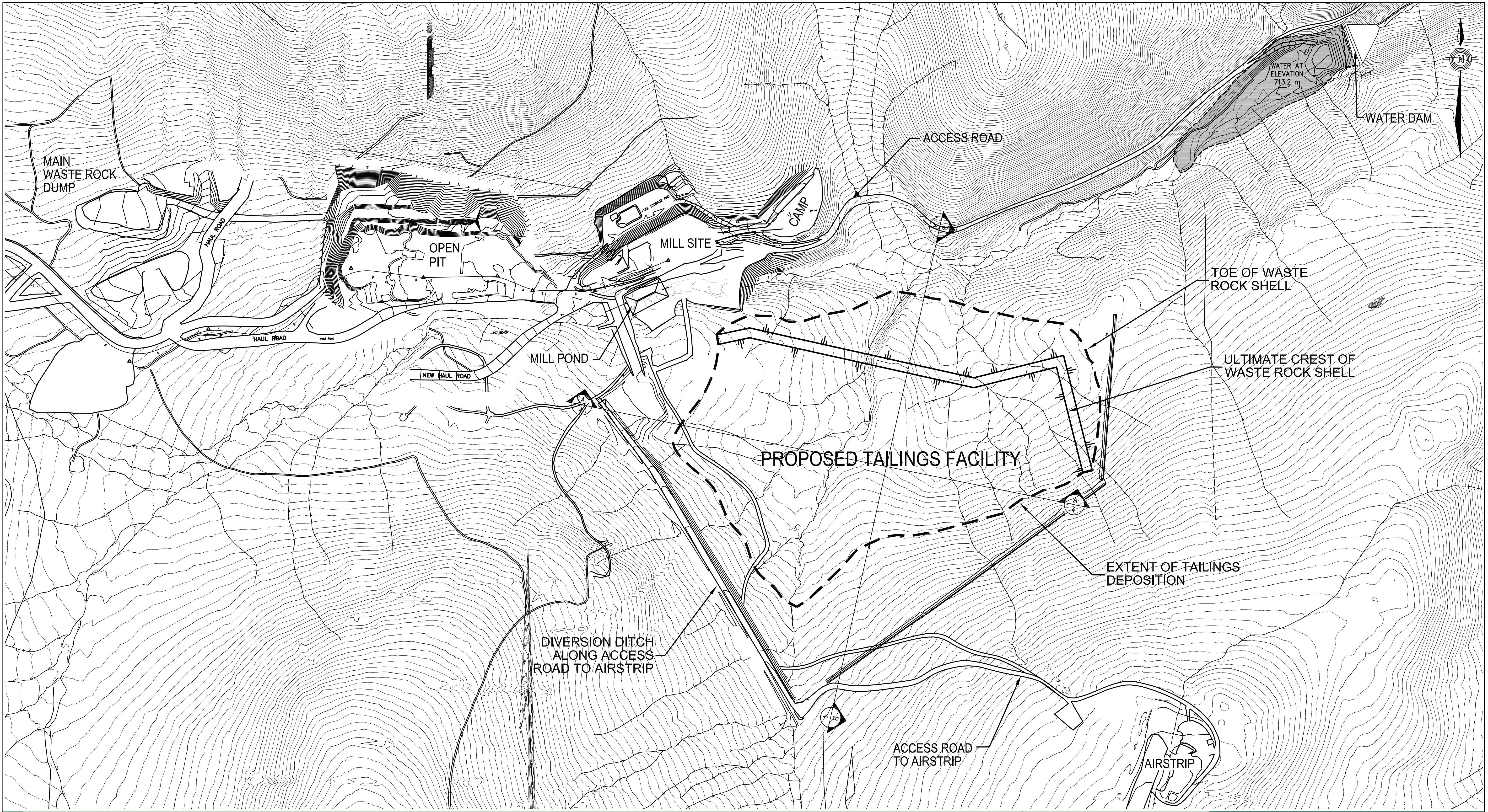
Location Plan

PROJECT NO.	DWN	CKD	REV
1200173	JSB	JRT	0

OFFICE	DATE
EBA-WHSE	January 5, 2007

Figure 1

Q:\Whitehorse\Data\0201drawings\Minto\TAILINGS MANAGEMENT JPB\Report figures\1200173 Figure 2 Site Plan.dwg [LAYOUT1] January 11, 2007 - 10:09:53 am (BY: JAMES BUYCK)



0 250 500 750 metres

SCALE 1 : 7500

CLIENT

Minto Explorations Ltd.

EBA Engineering Consultants Ltd.

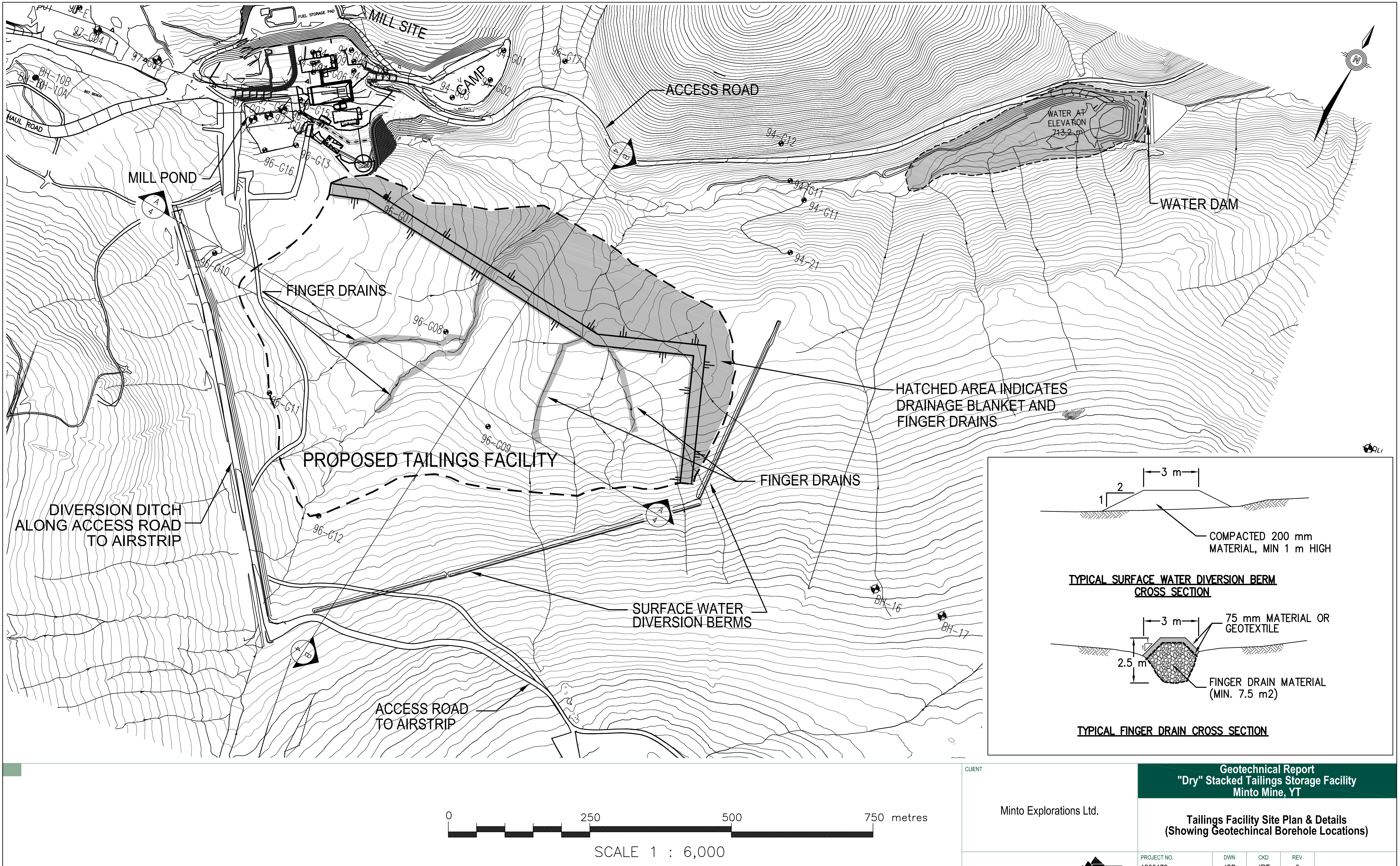
Geotechnical Report "Dry" Stacked Tailings Storage Facility Minto Mine, YT

General Site Plan

PROJECT NO.	DWN	CKD	REV
1200173	JSB	JRT	0
OFFICE	DATE		
EBA-WHSE	January 5, 2007		

Figure 2

Q:\Whitehorse\Data\0201drawings\Minto\TAILINGS MANAGEMENT JPB\Report figures\1200173 Figure 3 Tailings Plan.dwg [LAYOUT1] January 11, 2007 - 9:57:23 am (BY: JAMES BUYCK)



CLIENT

Minto Explorations Ltd.

EBA Engineering Consultants Ltd.

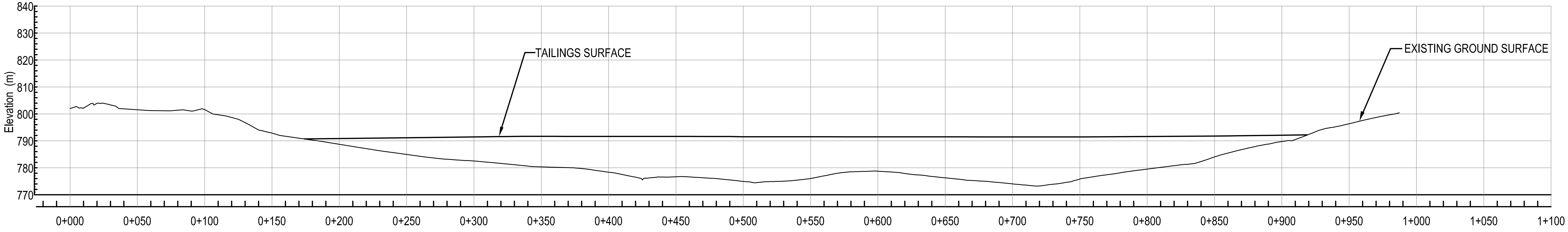
Geotechnical Report
"Dry" Stacked Tailings Storage Facility
Minto Mine, YT

Tailings Facility Site Plan & Details
(Showing Geotechincal Borehole Locations)

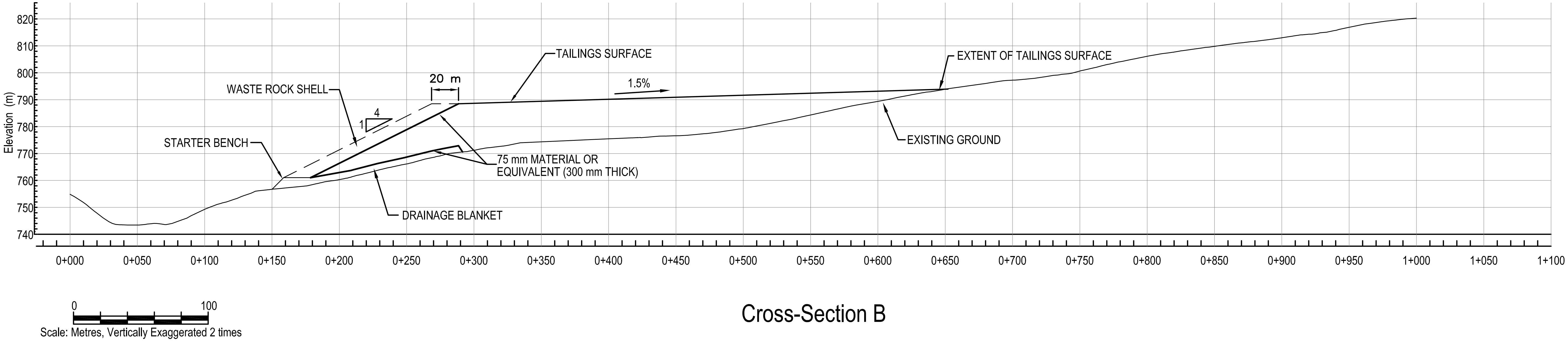
PROJECT NO.	DWN	CKD	REV
1200173	JSB	JRT	0
OFFICE	DATE		
EBA-WHSE	January 5, 2007		

Figure 3

Q:\Whitehorse\Data\0201drawings\Minto\TAILINGS MANAGEMENT JPB\Report figures\1200173 Figure 4 xsection.dwg [LAYOUT1] January 04, 2007 - 5:14:27 pm (BY: CHAD COWAN)



Cross-Section A



Cross-Section B

CLIENT

Minto Explorations Ltd.

Geotechnical Report
"Dry" Stacked Tailings Storage Facility
Minto Mine, YT

Tailings Facility
Typical Cross Sections

EBA Engineering
Consultants Ltd.

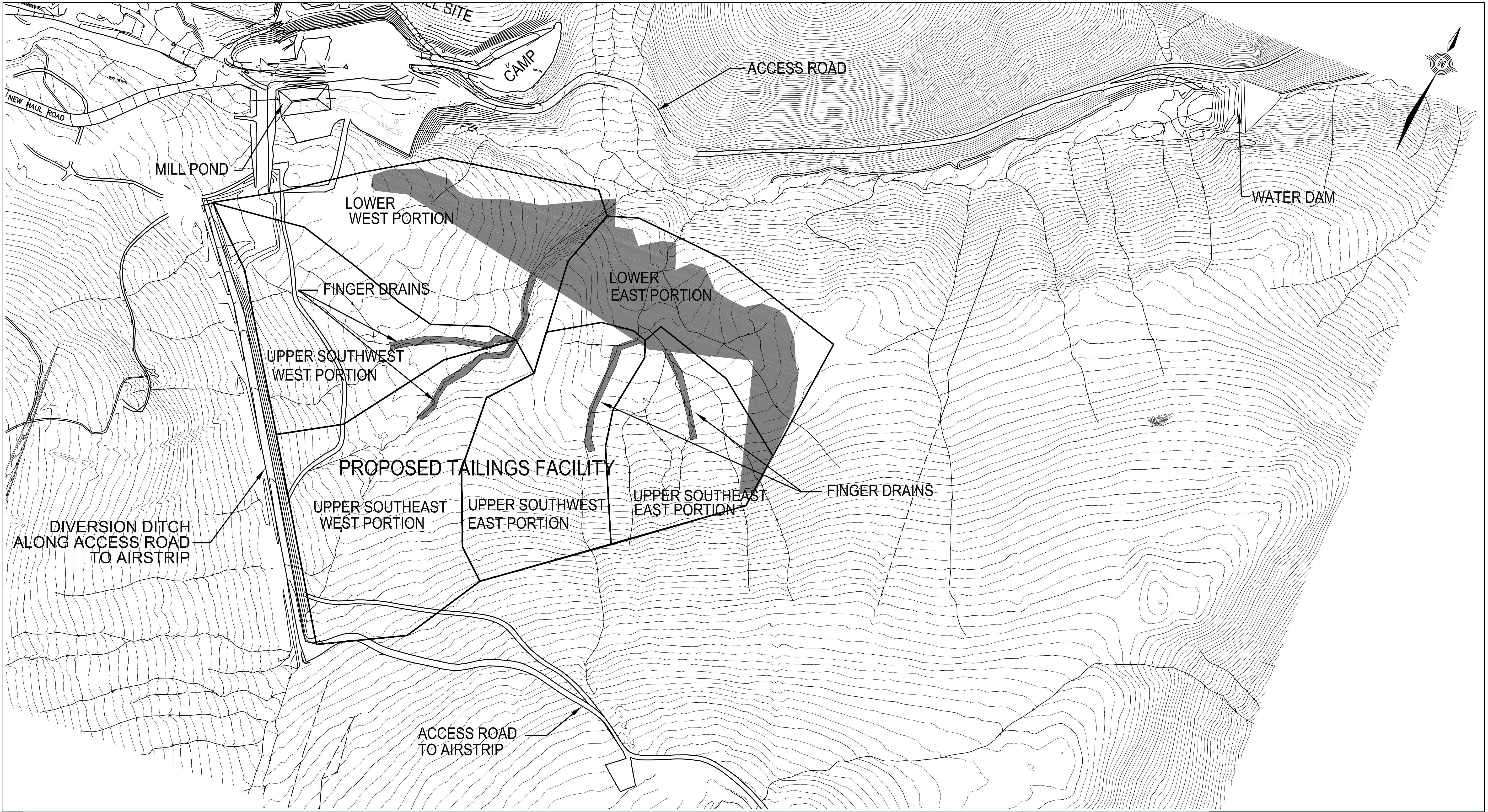
PROJECT NO.	DWN	CKD	REV
1200173	JSB	JRT	0

OFFICE
EBA-WHSE

DATE
January 5, 2007

Figure 4

Q:\Whitehorse\Data\0201drawings\Minto\TAILINGS MANAGEMENT JPB\Report figures\1200173 Figure 5 Catchment.dwg [LAYOUT1] January 04, 2007 - 5:15:17 pm (BY: CHAD COWAN)



0 250 500 750 metres

SCALE 1 : 6000

CLIENT

Minto Explorations Ltd.

EBA Engineering Consultants Ltd.

Geotechnical Report
"Dry" Stacked Tailings Storage Facility
Minto Mine, YT

Tailings Facility
Surface Drainage Subcatchments

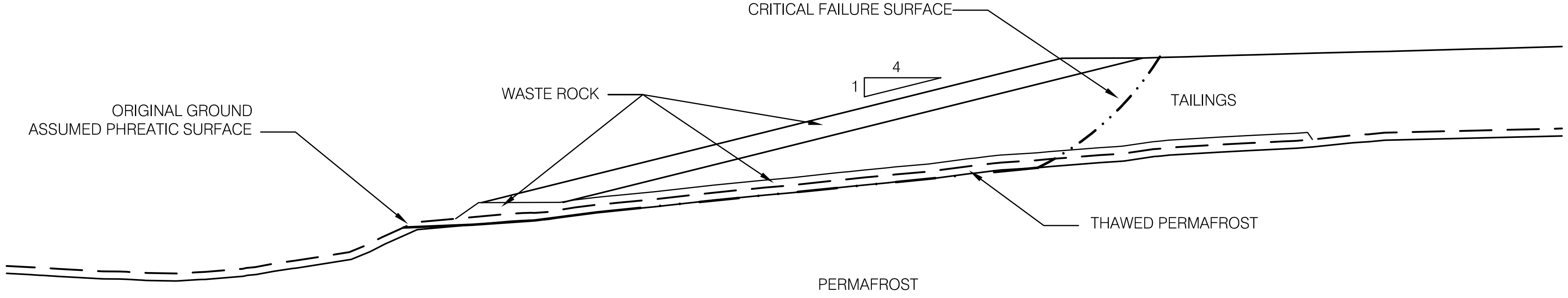
PROJECT NO.	DWN	CKD	REV
1200173	JSB	JRT	0
OFFICE	DATE		
EBA-WHSE	January 5, 2007		

Figure 5

SOIL PARAMETERS

MATERIAL	BULK DENSITY (kN/m3)	FRICTION ANGLE (DEGREES)	COHESION (kPa)
TAILINGS	19.4	28	0
WASTE ROCK	20.0	35	0
THAWED PERMAFROST	18.4	28	0
PERMAFROST	--	--	--

	MINIMUM FACTOR OF SAFETY DOWNSTREAM
STATIC, FINAL SECTION, Ru = 0	2.27
STATIC, FINAL SECTION, Ru = 0.4	1.45
EARTHQUAKE, FINAL SECTION, Ru = 0	1.84
EARTHQUAKE, FINAL SECTION, Ru = 0.4	1.16



SECTION A–A’

0 20 40 60 80 100 metres

SCALE 1:1250

CLIENT

Minto Explorations Ltd.

EBA Engineering Consultants Ltd.

Geotechnical Report
"Dry" Stacked Tailings Storage Facility
Minto Mine, YT

Tailings Facility
Slope Stability Analyses

PROJECT NO.	DWN	CKD	REV
1200173	JSB	JRT	0
OFFICE	DATE		
EBA-WHSE	January 5, 2007		

Figure 6

APPENDIX

APPENDIX A GENERAL CONDITIONS

GEOTECHNICAL REPORT – GENERAL CONDITIONS

This report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of EBA's client. EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than EBA's client unless otherwise authorized in writing by EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

3.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

4.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

5.0 SURFACE WATER AND GROUNDWATER CONDITIONS

Surface and groundwater conditions mentioned in this report are those observed at the times recorded in the report. These conditions vary with geological detail between observation sites; annual, seasonal and special meteorologic conditions; and with development activity. Interpretation of water conditions from observations and records is judgmental and constitutes an evaluation of circumstances as influenced by geology, meteorology and development activity. Deviations from these observations may occur during the course of development activities.

6.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

7.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

8.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

9.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

10.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

11.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

12.0 SAMPLES

EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the client's expense upon written request, otherwise samples will be discarded.

13.0 STANDARD OF CARE

Services performed by EBA for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practising under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

14.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

15.0 ALTERNATE REPORT FORMAT

Where EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed EBA's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by EBA shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by EBA shall be deemed to be the overall original for the Project.

The Client agrees that both electronic file and hard copy versions of EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EBA. The Client warrants that EBA's instruments of professional service will be used only and exactly as submitted by EBA.

The Client recognizes and agrees that electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

APPENDIX

APPENDIX B TAILINGS TEST RESULTS

MOISTURE - DENSITY RELATIONSHIP

ASTM D698, D1557, or D2049

Project: Minto Copper Mine, YK

Project No.: 0201-1200173

Client: Minto Exploration Inc.

Soil Description: SAND (uniform, fine), tr. silt - brown

Sample Location:

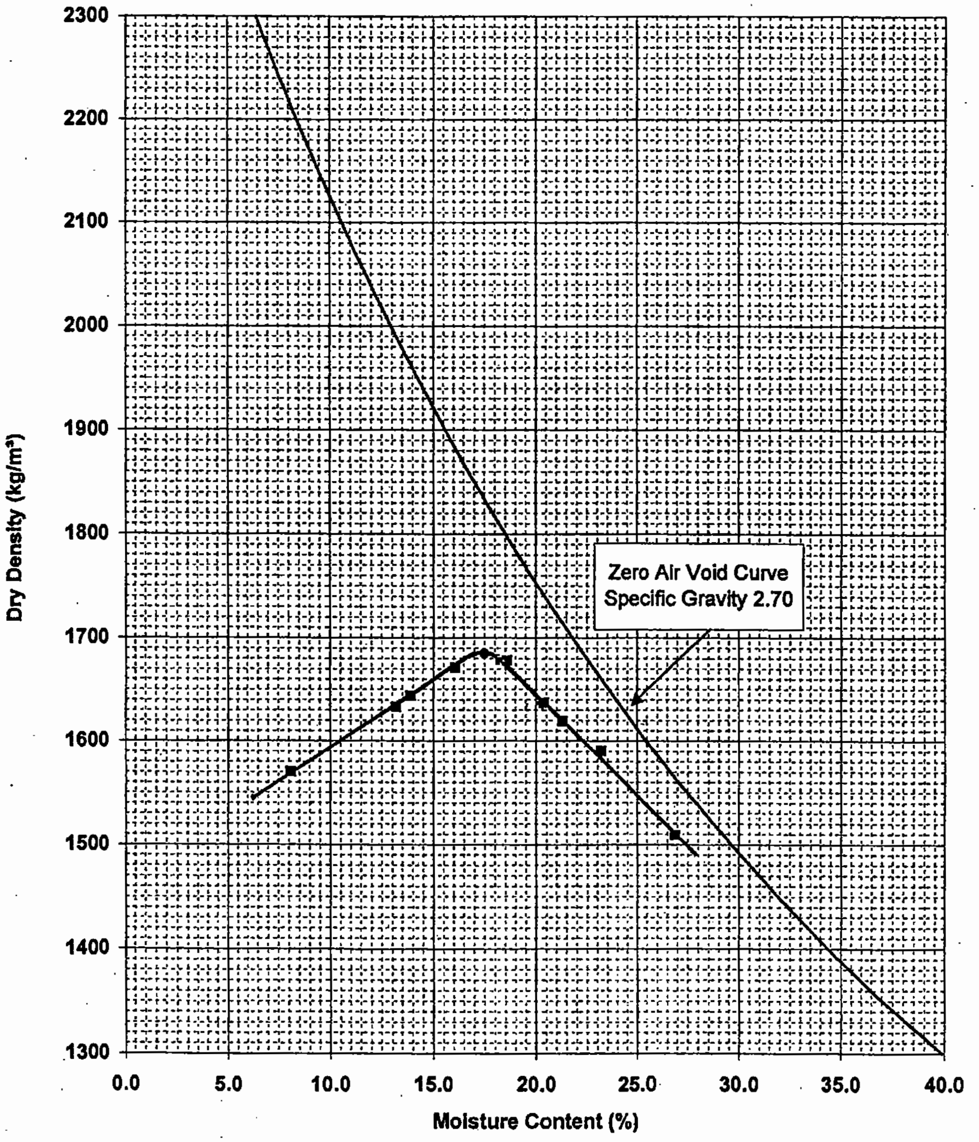
Sample Number: 920

Date Tested: 06/05/30

Moisture Content (as received): 12.2%

Maximum Dry Density: 1685 kg/m³

Optimum Moisture Content: 17.5%



STANDARD PROCTOR

ASTM D698

Hammer Mass: 2.494 kg

Hammer Drop: 304.8 mm

Number of Layers: 3

Number of Blows/Layer: 25

Diameter of Mould: 101.4 mm

Height of Mould: 116.3 mm

Mould Volume: 0.000938 m³

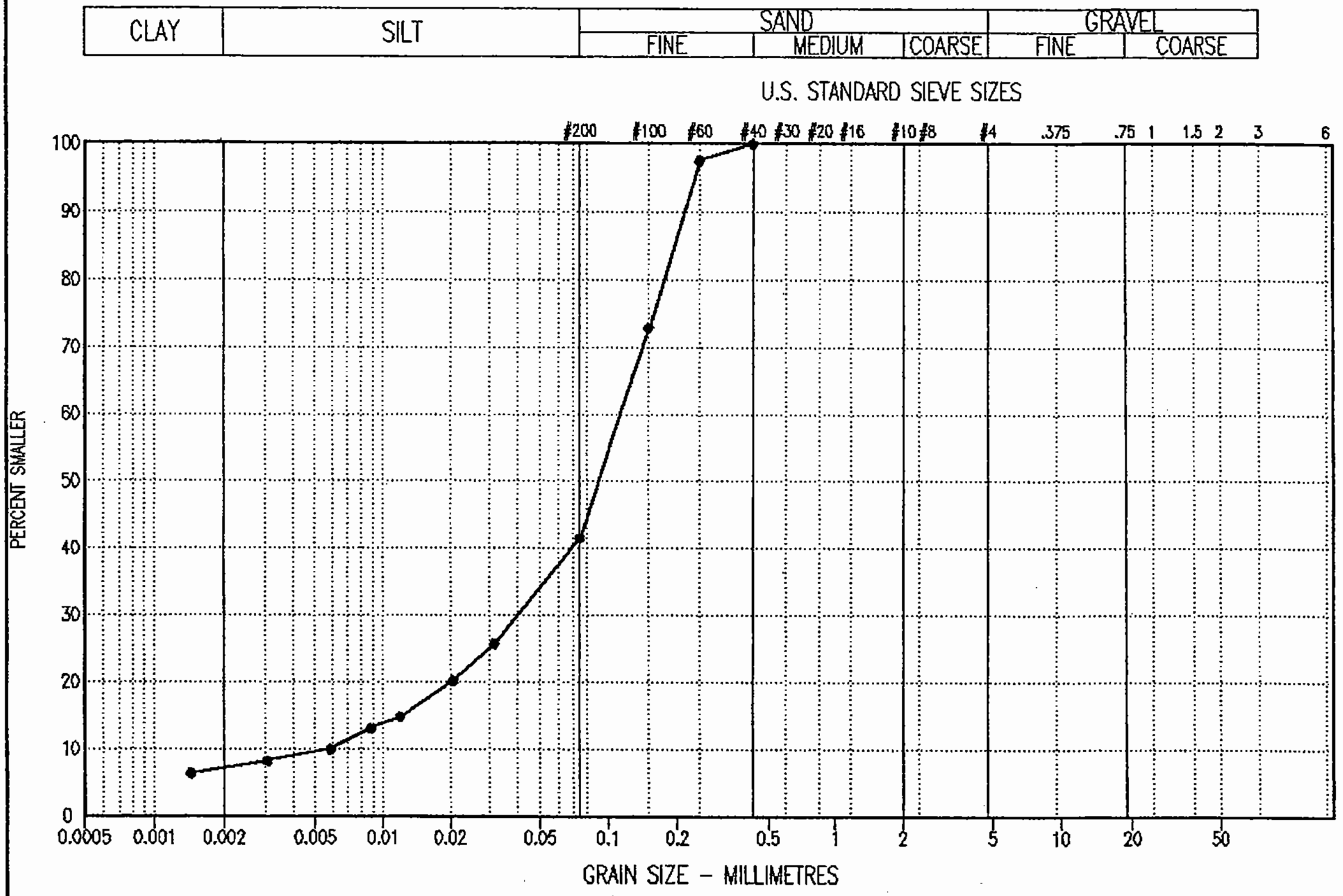
Compactive Effort: 593.5 kJ/m³

REVIEWED BY:

REMARKS:

EBA Engineering

PARTICLE SIZE – ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (ft)	DESCRIPTION				Cu	Cc	U.S.C
			CLAY %	SILT %	SAND %	GRAVEL %			
●—●	7–BUCKETS	0.00	6.0	35	59	0	20.0	2.7	SM

Project: 0201–1200173

Date Tested: 06/05/29

BY: KP

Tested in accordance with ASTM D422 unless otherwise noted.

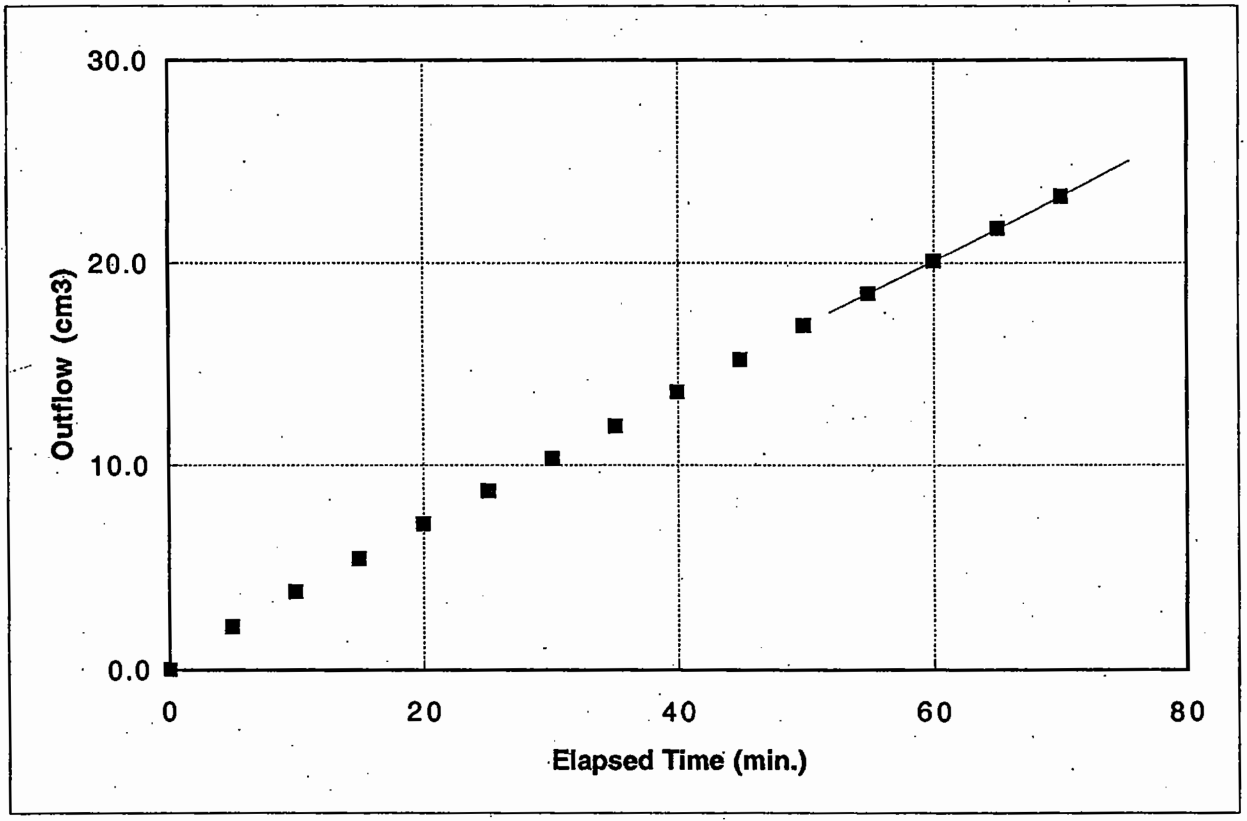
CONSTANT HEAD PERMEABILITY TEST **MINTO MINE**

Job Number: 1200173
Sample No.: 1358
Date: 06-11-30
Test No: P-1

Time	Buret (cc)	Elap. (min)	Outflow (cc)
10:22	16.8	0	0.0
10:27	18.9	5	2.1
10:32	20.6	10	3.8
10:37	22.2	15	5.4
10:42	23.9	20	7.1
10:47	25.5	25	8.7
10:52	23.9	30	10.3
10:57	22.3	35	11.9
11:02	20.6	40	13.6
11:07	19.0	45	15.2
11:12	17.3	50	16.9
11:17	15.7	55	18.5
11:22	14.1	60	20.1
11:27	12.5	65	21.7
11:32	10.9	70	23.3

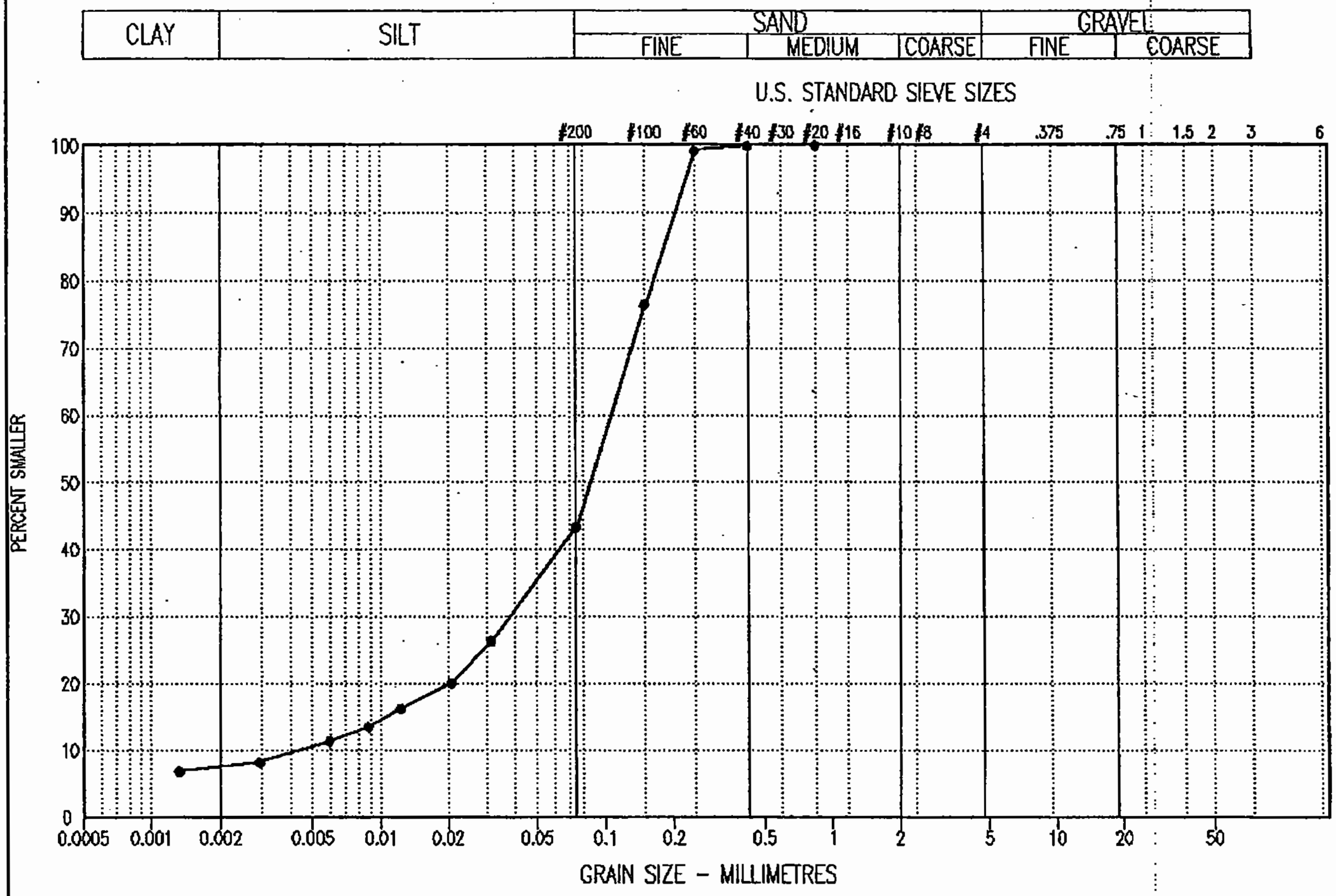
Diameter=	71.14	mm
Height=	50.60	mm
Volume=	201.13	cm^3
Head Diff.=	1	psi
Q=	0.005	cm^3/sec
i=	13.90	
A=	39.75	cm^2

K= 9.65E-06 cm/sec



EBA Engineering

PARTICLE SIZE – ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (ft)	DESCRIPTION				Cu	Cc	U.S.C
			CLAY %	SILT %	SAND %	GRAVEL %			
●—●	1358	0.00	7.0	36	57	0	23.8	3.1	SM

Project: 0201-1200173 Date Tested: 06/11/24 BY: KP

Tested in accordance with ASTM D422 unless otherwise noted.

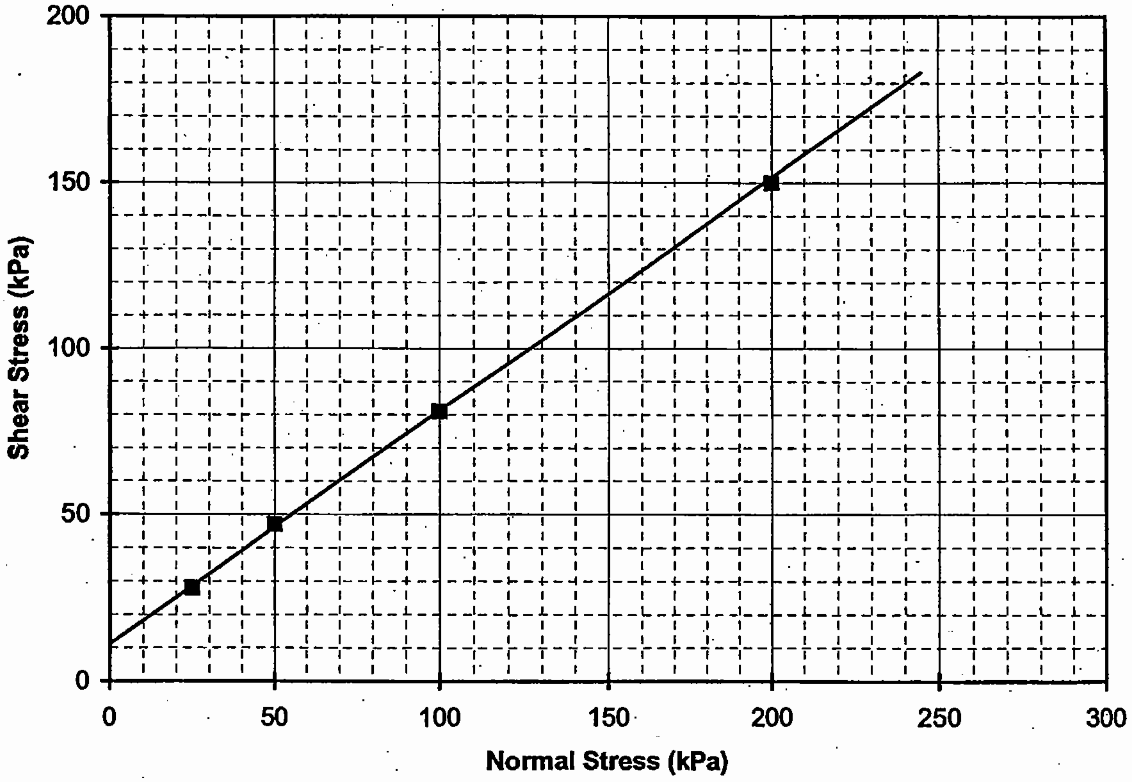
Summary of Direct Shear Test Results

Project : Minto Mine

Project No. : 1200173

Sample No.: 1358

Date : 06-11-29



Inferred Shear Strength Parameters :-

	Cohesion Intercept (kPa)	Inferred Angle of Shearing Resistance (Degrees)
Peak Strength	11	35.1
Residual Strength	n/a	n/a

EBA Engineering Consultants Ltd.

Direct Shear Test

Project No.: 1200173
Date Tested: 06-11-20

Sample No.: 1358
Test Number: DS-1

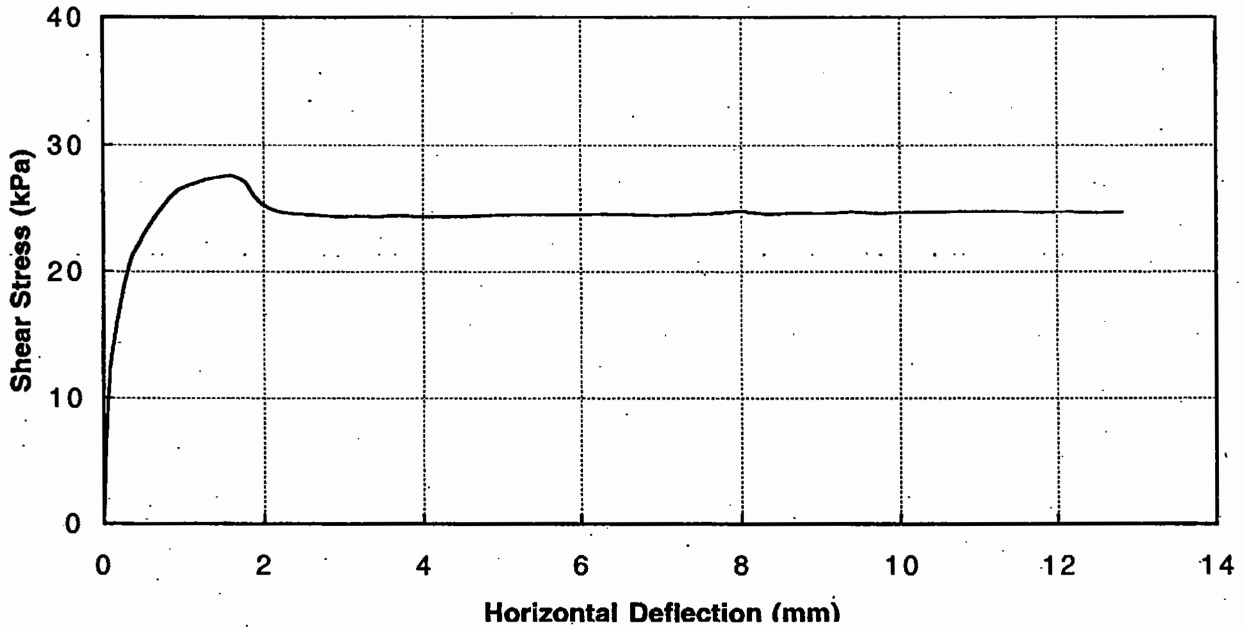
Initial Sample Conditions

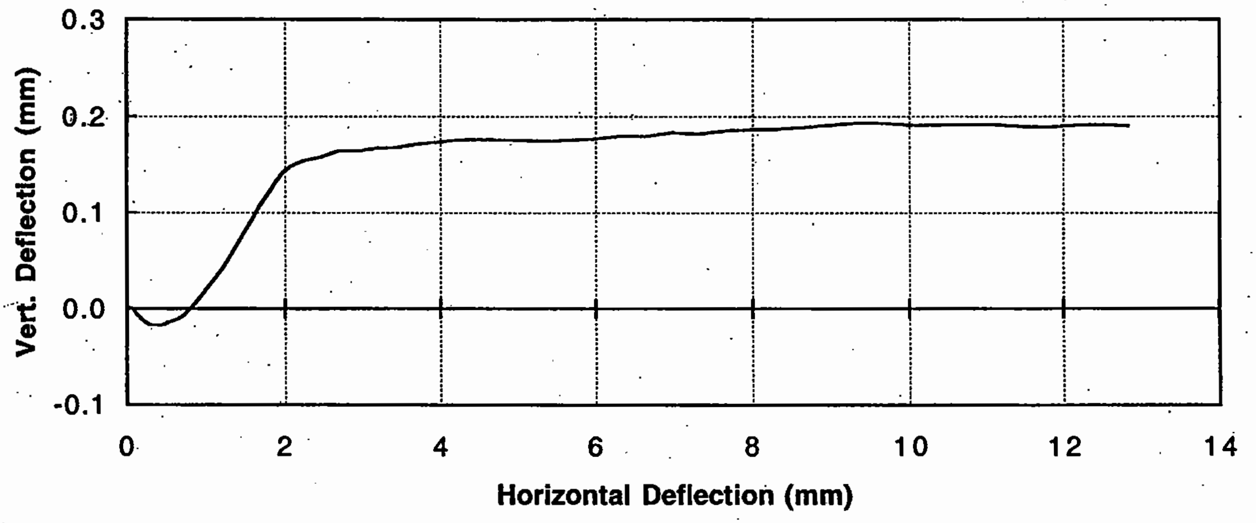
Moisture Content (%): 19.5
Wet Density (Mg/m^3): 1.968
Dry Density (Mg/m^3): 1.647

Horiz. Disp. (mm)	Vert Disp. (mm)	Shear Stress (kPa)
0.00	0.000	0.0
0.04	0.001	8.2
0.09	-0.001	12.5
0.13	-0.006	14.4
0.17	-0.010	16.0
0.22	-0.013	17.5
0.26	-0.016	18.9
0.31	-0.017	20.1
0.35	-0.018	21.2
0.45	-0.017	22.2
0.49	-0.016	22.7
0.54	-0.015	23.2
0.63	-0.012	24.1
0.72	-0.008	24.9
0.82	0.001	25.7
0.94	0.012	26.4
1.08	0.028	26.8
1.22	0.042	27.1
1.28	0.050	27.2
1.35	0.058	27.3
1.42	0.068	27.4
1.49	0.078	27.5
1.58	0.091	27.6
1.68	0.106	27.4
1.78	0.118	27.1
1.88	0.130	26.0
1.97	0.141	25.4
2.07	0.148	25.0
2.16	0.151	24.8
2.26	0.154	24.6
2.46	0.157	24.5
2.70	0.164	24.4
2.94	0.164	24.4
3.18	0.167	24.4
3.43	0.168	24.4
3.68	0.171	24.4
3.93	0.173	24.4
4.21	0.175	24.3
4.51	0.176	24.4
4.81	0.175	24.4
5.11	0.175	24.5
5.41	0.174	24.5
5.70	0.175	24.5
6.00	0.177	24.5
6.29	0.179	24.5
6.63	0.179	24.5
6.98	0.183	24.4
7.31	0.182	24.5
7.66	0.185	24.6
7.99	0.186	24.8
8.34	0.187	24.5
8.69	0.189	24.6
9.03	0.191	24.6
9.38	0.193	24.7
9.73	0.193	24.6
10.08	0.191	24.7
10.43	0.191	24.7
10.78	0.191	24.7
11.13	0.191	24.7
11.47	0.190	24.7
11.81	0.189	24.7
12.16	0.191	24.7
12.50	0.191	24.6
12.84	0.190	24.7

Direct Shear Test

Peak Stress = 28 kPa





Sample Number:	1358
Normal Stress(kPa):	25
Displ. Rate(mm/min.):	0.024
Test No.:	DS-1

EBA Engineering Consultants Ltd.

Direct Shear Test

Project No.: 1200173
Date Tested: 06-11-22

Sample No.: 1358
Test Number: DS-2

Initial Sample Conditions

Moisture Content (%): 19.5
Wet Density (Mg/m^3): 1.965
Dry Density (Mg/m^3): 1.645

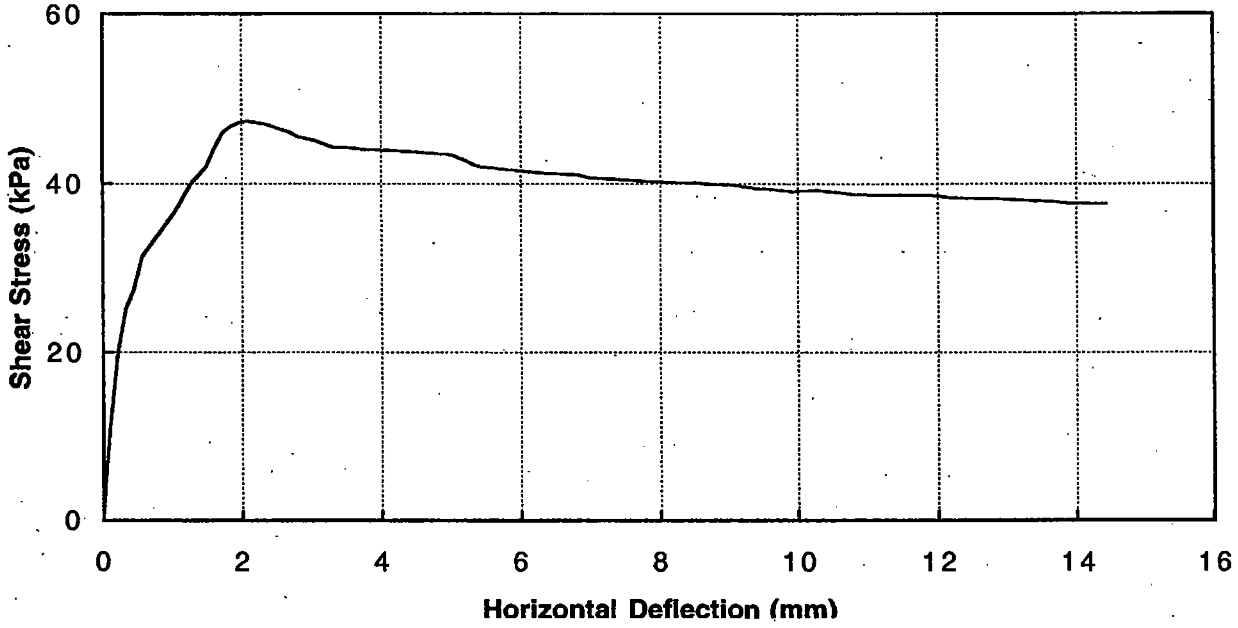
Horiz. Disp. (mm)	Vert Disp. (mm)	Shear Stress (kPa)	Horiz. Disp. (mm)	Vert Disp. (mm)	Shear Stress (kPa)
0.00	0.000	0.0	6.83	0.220	41.0
0.11	0.000	12.0	7.00	0.222	40.7
0.21	-0.011	20.0	7.34	0.224	40.5
0.32	-0.016	25.2	7.85	0.227	40.2
0.44	-0.020	27.5	8.19	0.228	40.2
0.56	-0.024	31.3	8.54	0.229	40.1
0.80	-0.029	34.0	8.71	0.229	40.0
1.03	-0.029	36.7	9.06	0.230	39.8
1.17	-0.027	38.7	9.23	0.230	39.6
1.25	-0.023	39.8	9.41	0.228	39.4
1.48	-0.012	42.0	9.58	0.226	39.3
1.61	-0.007	44.2	9.93	0.222	39.1
1.73	0.012	46.0	10.28	0.221	39.2
1.85	0.022	46.8	10.45	0.219	39.0
1.97	0.040	47.2	10.63	0.217	38.9
2.09	0.056	47.3	10.80	0.212	38.7
2.33	0.096	47.1	10.98	0.202	38.7
2.70	0.134	46.0	11.32	0.197	38.6
2.82	0.143	45.6	11.84	0.191	38.6
3.06	0.157	45.1	12.01	0.188	38.5
3.31	0.172	44.3	12.18	0.185	38.3
3.43	0.175	44.3	12.35	0.183	38.3
3.56	0.177	44.2	12.69	0.182	38.2
3.81	0.186	44.0	12.87	0.182	38.2
3.94	0.190	44.0	13.38	0.181	38.0
4.29	0.200	43.9	13.55	0.181	37.9
4.64	0.203	43.6	13.72	0.180	37.8
5.00	0.208	43.4	13.90	0.179	37.7
5.17	0.208	42.9	14.07	0.178	37.6
5.34	0.209	42.2	14.25	0.179	37.6
5.44	0.210	42.0	14.42	0.179	37.6
5.97	0.209	41.5			
6.31	0.217	41.2			

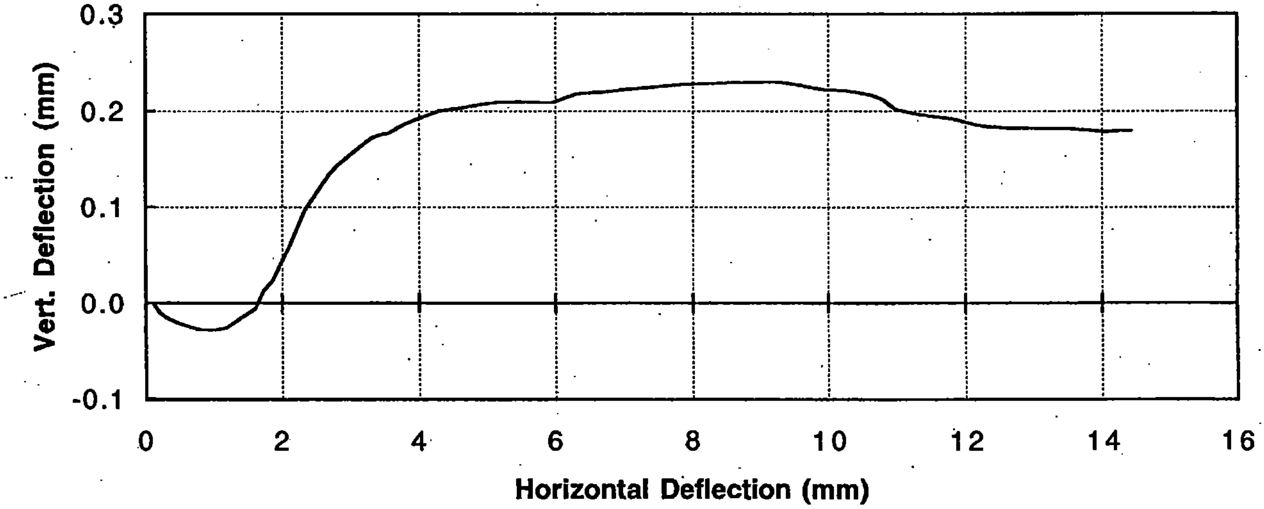
eba

EBA Engineering Consultants Ltd.

Direct Shear Test

Peak Stress = 47 kPa





Sample Number: 1358
Normal Stress(kPa): 50
Displ. Rate(mm/min.): 0.024
Test No.: DS-2

EBA Engineering Consultants Ltd.

Direct Shear Test

Project No.: 1200173
Date Tested: 06-11-22

Sample No.: 1358
Test Number: DS-3

Initial Sample Conditions

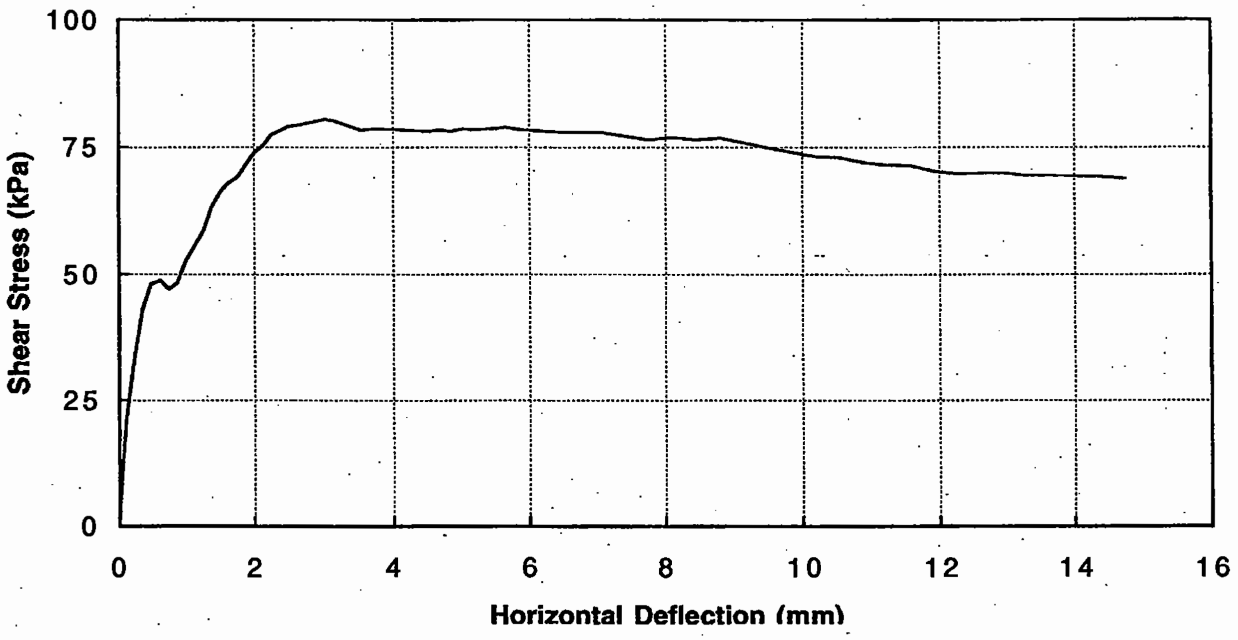
Moisture Content (%): 19.6
Wet Density (Mg/m3): 1.968
Dry Density (Mg/m3): 1.645

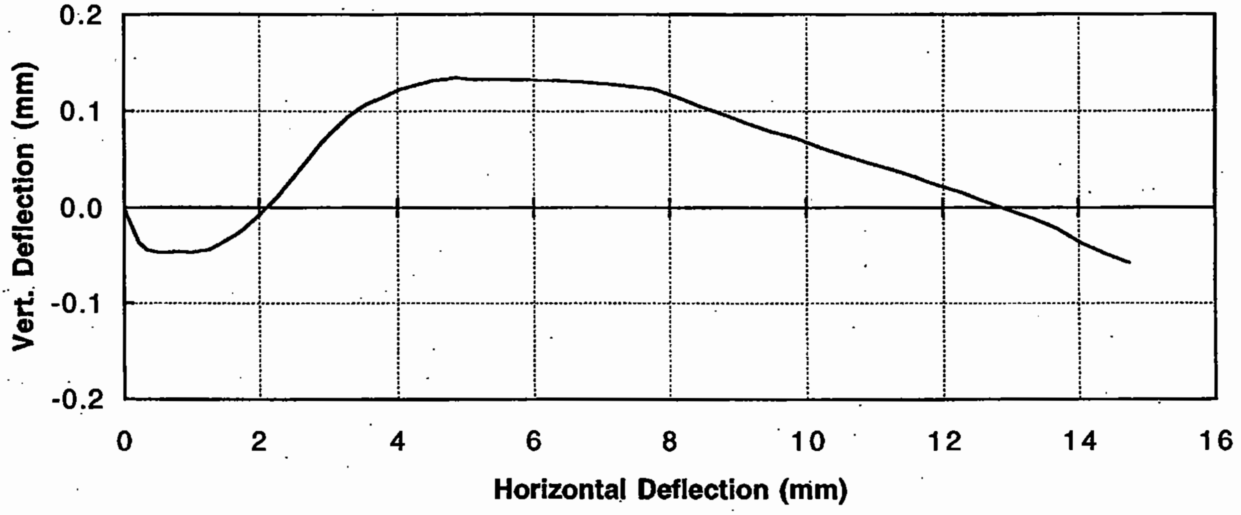
Horiz. Disp. (mm)	Vert. Disp. (mm)	Shear Stress (kPa)
0.00	0.000	0.0
0.10	-0.017	20.4
0.22	-0.037	32.6
0.34	-0.045	42.9
0.47	-0.047	48.0
0.60	-0.047	48.7
0.73	-0.046	47.0
0.86	-0.047	48.3
0.99	-0.047	52.6
1.25	-0.044	58.4
1.37	-0.040	63.2
1.50	-0.035	66.3
1.63	-0.030	67.9
1.76	-0.023	69.0
2.01	-0.008	73.9
2.14	0.001	75.3
2.26	0.010	77.5
2.52	0.032	79.2
2.65	0.044	79.5
2.91	0.067	80.1
3.03	0.077	80.5
3.16	0.086	80.2
3.28	0.094	79.6
3.42	0.101	79.0
3.54	0.106	78.4
3.79	0.114	78.7
3.92	0.119	78.6
4.05	0.122	78.6
4.17	0.125	78.4
4.52	0.132	78.2
4.69	0.133	78.4
4.86	0.135	78.2
5.03	0.133	78.7
5.20	0.133	78.6
5.55	0.133	78.9
5.66	0.133	79.0
5.83	0.132	78.6
6.01	0.132	78.4
6.36	0.131	78.1
6.54	0.131	77.9
7.06	0.129	77.9
7.23	0.127	77.6
7.41	0.126	77.2
7.76	0.123	76.6
8.11	0.115	77.0
8.46	0.105	76.6
8.82	0.096	76.9
9.17	0.087	75.9
9.52	0.078	74.9
9.86	0.072	74.1
10.20	0.062	73.2
10.56	0.054	73.0
10.90	0.047	71.9
11.25	0.040	71.5
11.59	0.031	71.3
11.94	0.023	70.2
12.28	0.016	69.8
12.63	0.006	69.9
12.98	-0.003	69.9
13.33	-0.011	69.5
13.68	-0.022	69.5
14.04	-0.037	69.3
14.39	-0.048	69.2
14.74	-0.058	68.9

EBA Engineering Consultants Ltd.

Direct Shear Test

Peak Stress = 81 kPa





Sample Number:	1358
Normal Stress(kPa):	100
Displ. Rate(mm/min.):	0.024
Test No.:	DS-3

eba

EBA Engineering Consultants Ltd.

Direct Shear Test

Project No.: 1200173
Date Tested: 06-11-20

Sample No.: 1358
Test Number: DS-4

Initial Sample Conditions

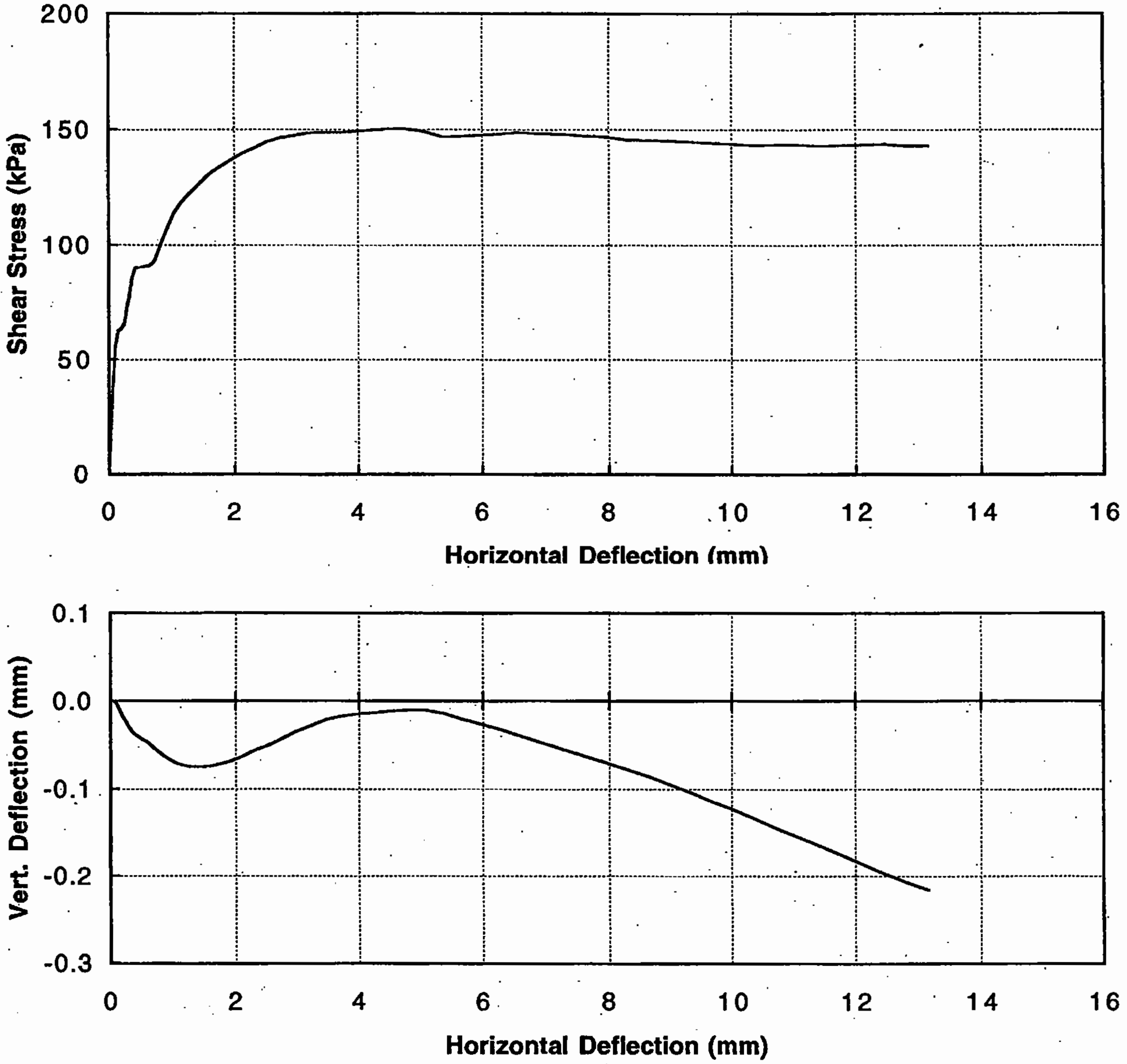
Moisture Content (%): 19.5
Wet Density (Mg/m3): 1.965
Dry Density (Mg/m3): 1.644

Horiz. Disp. (mm)	Vert Disp. (mm)	Shear Stress (kPa)	Horiz. Disp. (mm)	Vert Disp. (mm)	Shear Stress (kPa)
0.00	0.000	0.0	3.47	-0.021	149.0
0.05	0.000	34.0	3.73	-0.017	149.0
0.10	-0.003	55.6	3.98	-0.015	149.3
0.14	-0.010	62.4	4.24	-0.013	149.7
0.19	-0.017	63.2	4.49	-0.011	150.3
0.24	-0.023	65.6	4.79	-0.010	150.2
0.29	-0.029	73.6	5.08	-0.010	149.3
0.31	-0.032	76.4	5.38	-0.014	147.0
0.34	-0.034	80.1	5.67	-0.020	147.1
0.36	-0.037	85.2	5.97	-0.026	147.6
0.41	-0.039	89.9	6.27	-0.032	148.2
0.46	-0.041	90.2	6.57	-0.039	148.8
0.52	-0.044	90.2	6.90	-0.047	148.3
0.57	-0.046	90.5	7.25	-0.054	148.0
0.62	-0.049	90.7	7.59	-0.062	147.3
0.67	-0.052	91.3	7.95	-0.069	147.0
0.72	-0.055	92.7	8.30	-0.078	145.7
0.77	-0.058	95.9	8.65	-0.086	145.4
0.84	-0.062	101.3	9.00	-0.095	145.1
0.94	-0.067	108.2	9.36	-0.105	144.8
1.04	-0.070	113.8	9.71	-0.115	144.2
1.14	-0.073	118.1	10.05	-0.124	143.7
1.29	-0.075	122.2	10.39	-0.135	143.3
1.44	-0.075	126.4	10.74	-0.145	143.6
1.60	-0.074	130.5	11.08	-0.155	143.6
1.75	-0.072	133.6	11.43	-0.165	143.1
1.93	-0.068	136.3	11.79	-0.176	143.3
2.13	-0.063	139.6	12.13	-0.187	143.6
2.33	-0.056	142.0	12.47	-0.198	143.7
2.53	-0.050	144.6	12.82	-0.207	143.1
2.73	-0.044	146.5	13.17	-0.216	143.0
2.96	-0.035	147.4			
3.22	-0.028	148.5			

eba

Direct Shear Test

Peak Stress = 150 kPa



Sample Number:	1358
Normal Stress(kPa):	200
Displ. Rate(mm/min.):	0.024
Test No.:	DS-4

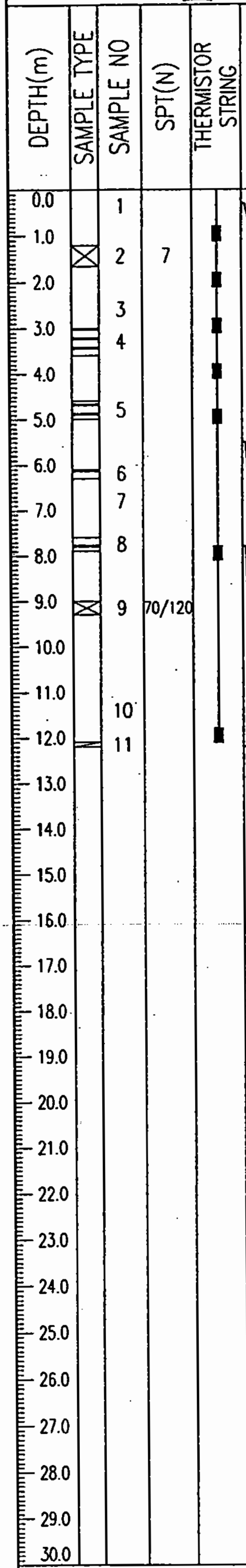
APPENDIX

APPENDIX C BOREHOLE LOGS

PROPOSED COPPER MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 94-G11
TAILINGS DAM (SOUTH CENTRE)	DRILL: CME-75 C/W HOLLOW STEM AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6949205 E388804	ELEVATION: 724.17 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ STANDARD PEN. ☰ 75mm SPLIT SP. ▥ CRREL BARREL ▥ HQ CORE

BACKFILL TYPE ■ BENTONITE ⁙ PEA GRAVEL ▥ SLOUGH ▨ GROUT ▨ DRILL CUTTINGS ▩ SAND



SOIL DESCRIPTION

PEAT – Fibrous; wet; soft; dark brown

ORGANIC SILT (COLLUVIUM) – clayey to some clay, trace of sand, trace of gravel; frequent peat inclusions, occasional cobbles; wet; soft; dark grey

- permafrost below 3.1 m; Nbe with Vx<5%, some Vr 10% ice in Sample No. 4
- becomes cobbly with depth

SAND AND SILT – trace gravel, frequent cobbles; numerous organic fibres and organic inclusions; angular cobbles and gravel; fine to medium sand; unsorted; frozen Nbe or Nbn; light grey

SAND (RESIDUUM) – some silt, trace of gravel; unsorted; well graded, quartz and mica rich angular sand; moist; hard; rushy brown

- slow, hard drilling from 7.8 to 12.2 m

END OF BOREHOLE @ 12.2 m

- thermistor string # 944 installed to 12.0 m

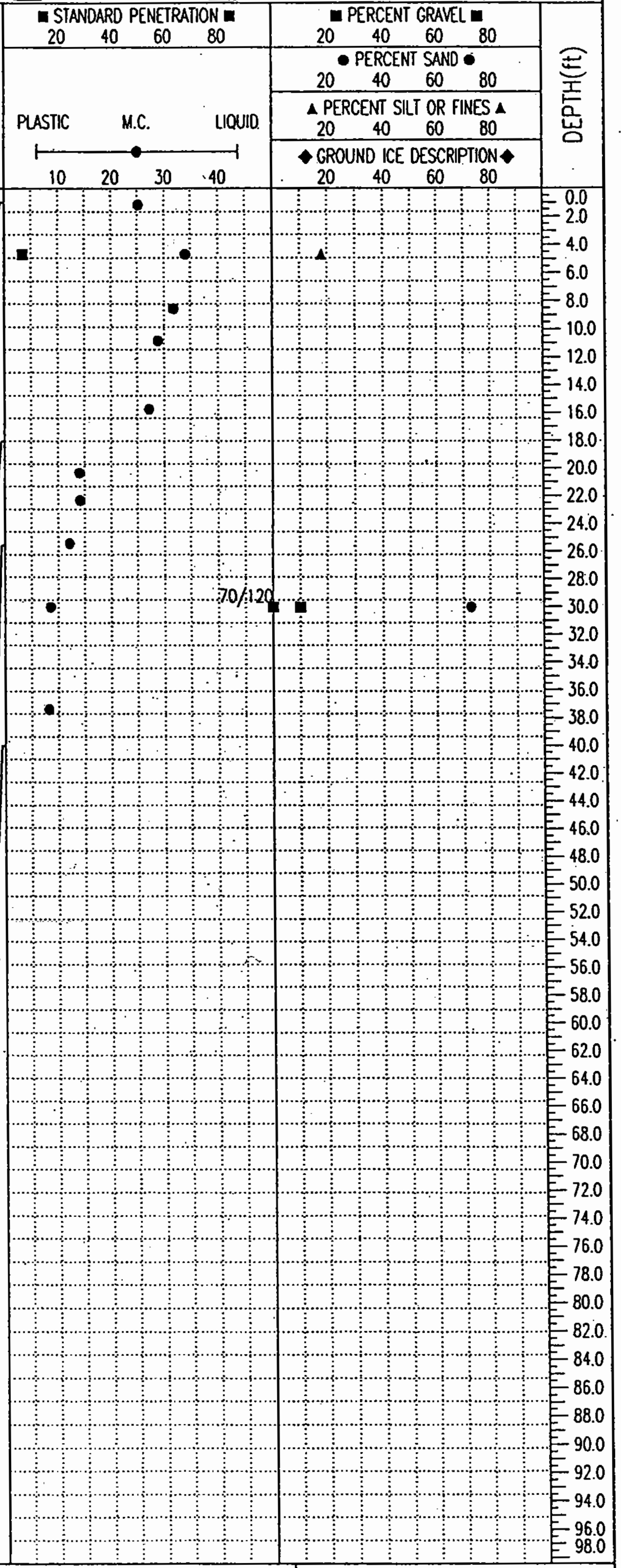
MINE GRID COORDINATES (IMPERIAL UNITS)

Northing – 11661.21

Easting – 14675.26

Elevation – 2375.90

EBA BOREHOLE NO: 11509-BH13



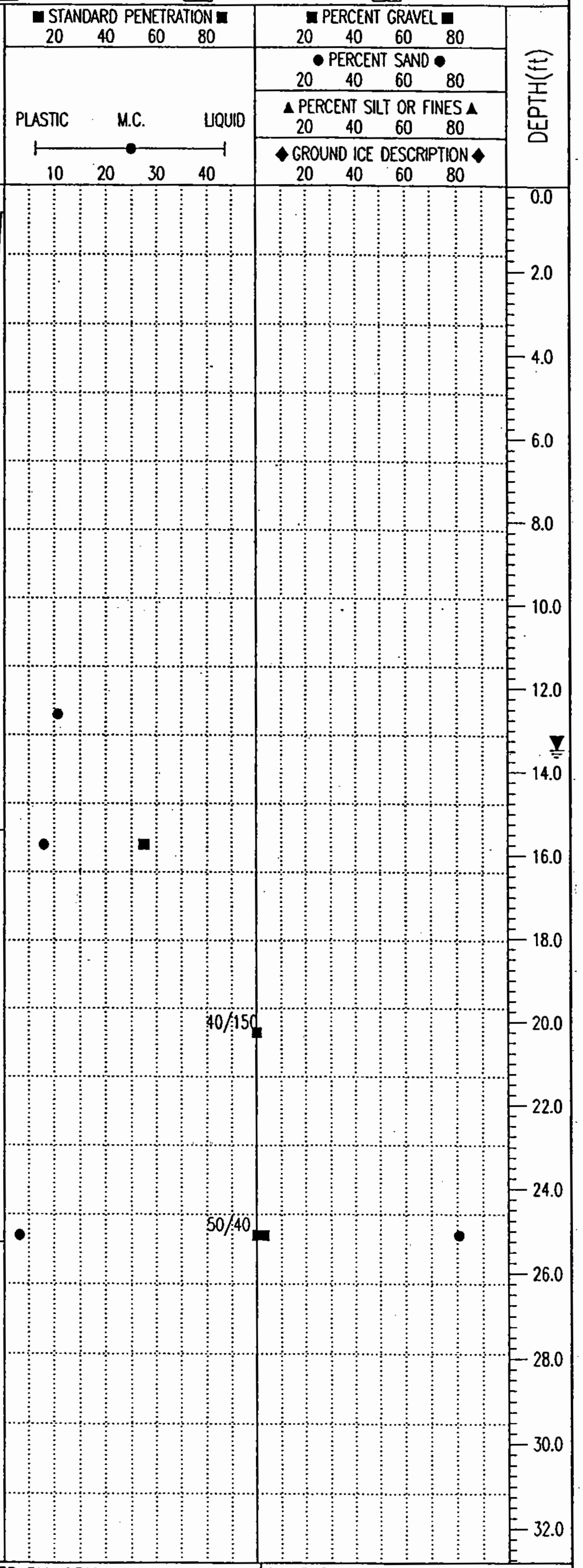
EBA ENGINEERING CONSULTANTS LTD. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 12.2 m
	REVIEWED BY: CRH	COMPLETE: 94/06/25
	Fig. No:	Page 1 of 1

95/06/29 10:50AM (0201-30W)

PROPOSED COPPER MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 94-G11A
TAILINGS DAM (NORTH CENTRE ABUTMENT)	DRILL: CME-75 C/W HOLLOW STEM AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6949227 E388768	ELEVATION: 724.91 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ STANDARD PEN. ☰ 75mm SPLIT SP. ▯ CRREL BARREL ▮ HQ CORE

DEPTH(m)	SAMPLE TYPE	SAMPLE NO	SPT(N)	USC	SOIL SYMBOL	SOIL DESCRIPTION
0.0						ORGANIC SILT – some sand, numerous roots; occosional cobbles and boulders; damp; firm; brown
						SAND (COLLUVIUM) – some silt, some gravel, occasional cobbles and boulders; unsorted; well graded, angular sand; angular, friable gravel; damp; compact; brown – becomes olive grey
		1				
4.0 ▼						– water table @ 4.1 m
	☒	2	55			SAND (RESIDUUM) – some silt, trace of gravel, frequent cobbles, unsorted; matrix supported; angular, quartz and mica rich sand; angular friable gravel; damp; dense; rusty brown
	☒	3	40/150			– slow, hard drilling, 45 seconds for 25 mm
	☒	4	50/40	SM		
						END OF BOREHOLE @ 7.7 m – water table @ 4.1 m MINE GRID COORDINATES (IMPERIAL UNITS) Northing – 11734.87 Easting – 14559.28 Elevation – 2378.30 EBA BOREHOLE NO: 11509-BH15



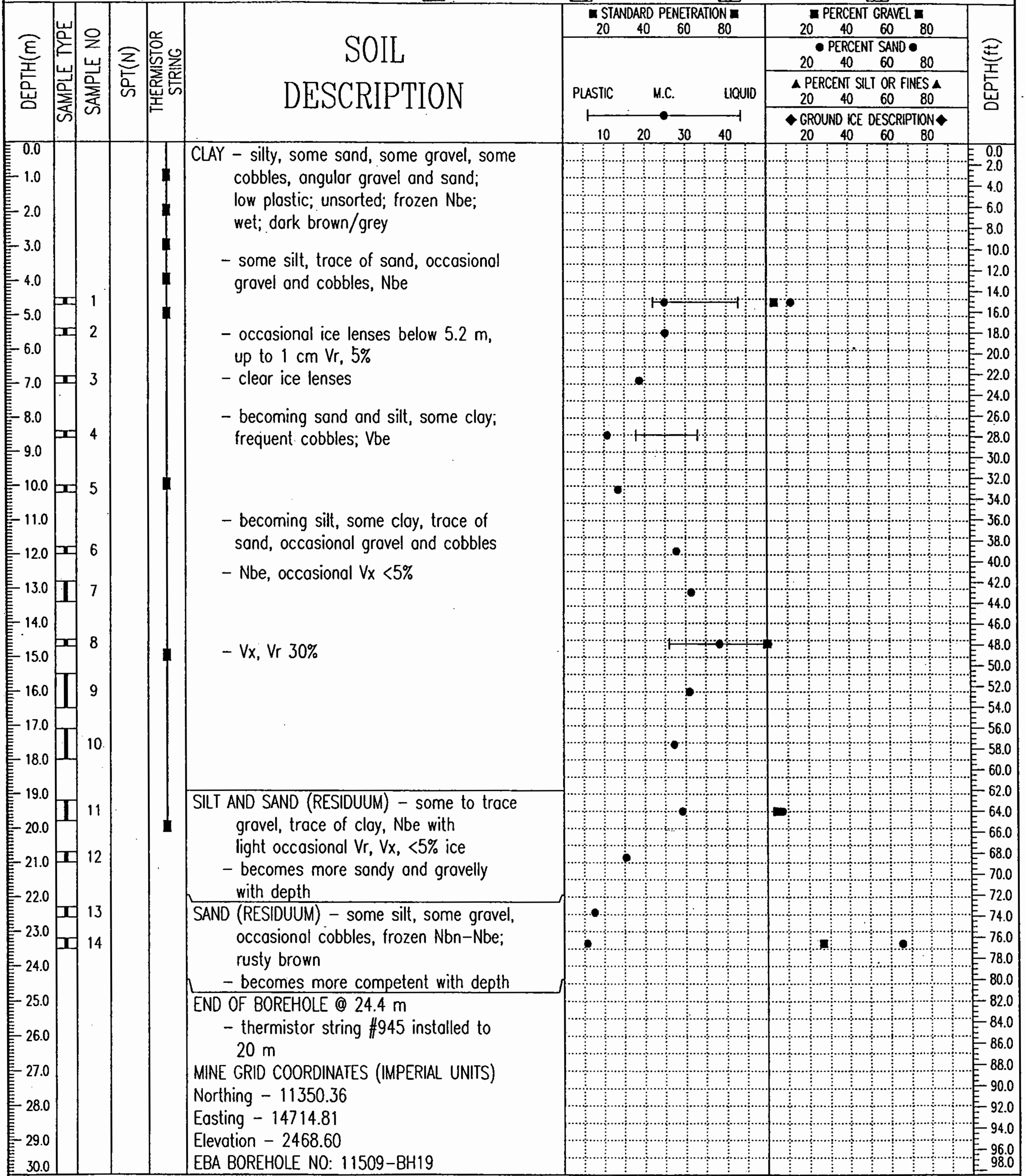
EBA ENGINEERING CONSULTANTS LTD. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 7.7 m
	REVIEWED BY: CRH	COMPLETE: 94/06/26
	Fig. No:	Page 1 of 1

95/06/27 05:05PM (0201-10)

PROPOSED COPPER MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 94-21
TAILINGS DAM (SOUTH ABUTMENT)	DRILL: LONGYEAR 38, 3 7/8 TRICONE, HW	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6949111 E388820	ELEVATION: 752.43 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ STANDARD PEN. ☰ 75mm SPLIT SP. ▥ CRREL BARREL ▥ HQ CORE

BACKFILL TYPE ■ BENTONITE ⁘ PEA GRAVEL ▥ SLOUGH ▨ GROUT ▨ DRILL CUTTINGS ▩ SAND



SOIL DESCRIPTION

CLAY – silty, some sand, some gravel, some cobbles, angular gravel and sand; low plastic; unsorted; frozen Nbe; wet; dark brown/grey

– some silt, trace of sand, occasional gravel and cobbles, Nbe

– occasional ice lenses below 5.2 m, up to 1 cm Vr, 5%

– clear ice lenses

– becoming sand and silt, some clay; frequent cobbles; Vbe

– becoming silt, some clay, trace of sand, occasional gravel and cobbles

– Nbe, occasional Vx <5%

– Vx, Vr 30%

SILT AND SAND (RESIDUUM) – some to trace gravel, trace of clay, Nbe with light occasional Vr, Vx, <5% ice

– becomes more sandy and gravelly with depth

SAND (RESIDUUM) – some silt, some gravel, occasional cobbles, frozen Nbn–Nbe; rusty brown

– becomes more competent with depth

END OF BOREHOLE @ 24.4 m

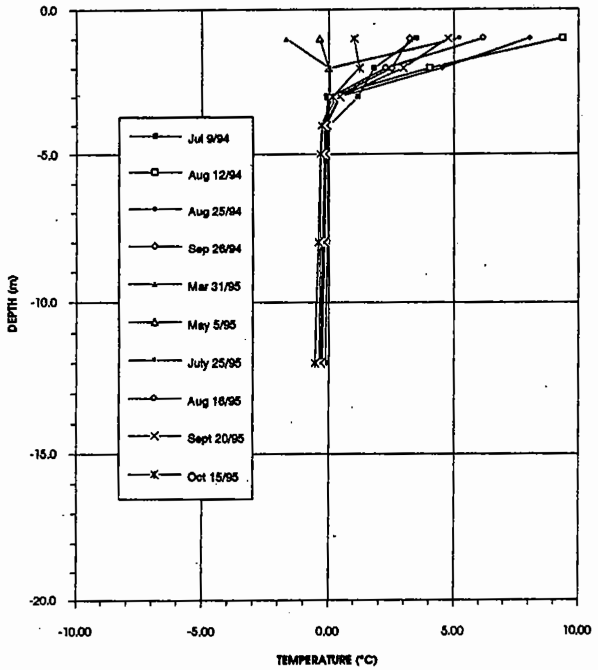
– thermistor string #945 installed to 20 m

MINE GRID COORDINATES (IMPERIAL UNITS)
Northing – 11350.36
Easting – 14714.81
Elevation – 2468.60
EBA BOREHOLE NO: 11509-BH19

EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 24.4 m
	REVIEWED BY: CRH	COMPLETE: 94/08/22
	Fig. No:	Page 1 of 1

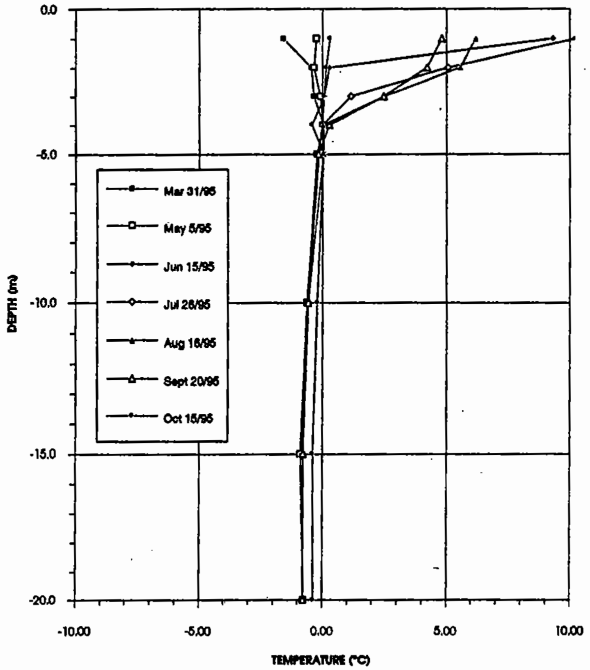
95/07/04 04:59PM (0201-30W)

Thermistor No.: 944
Date Installed: Jun 25/94



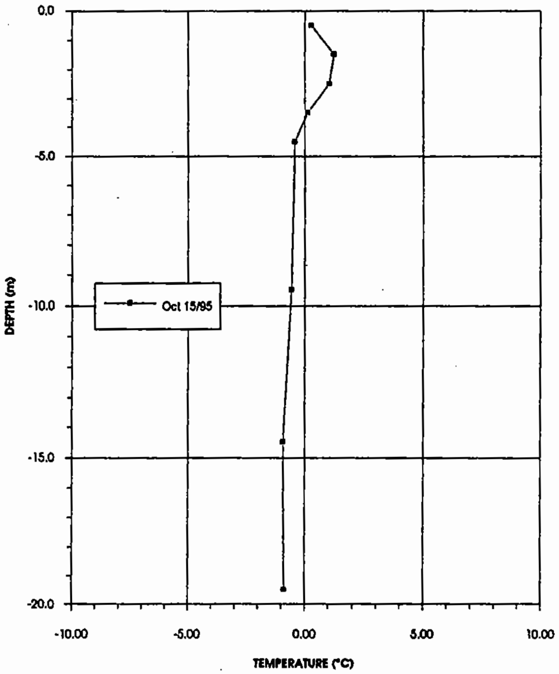
GROUND TEMPERATURE PROFILE
MINTO PROJECT - TAILINGS POND
LOWER SITE (BH 94-G11, El.=724.17 m)

Thermistor No.: 945
Date Installed: Aug.22/94



GROUND TEMPERATURE PROFILE
MINTO PROJECT - TAILINGS POND
UPPER SITE (BH 94-21, El.=752.43 m)

Thermistor No.: 990
Date Installed: Sept. 25/95



GROUND TEMPERATURE PROFILE
MINTO PROJECT - TAILINGS POND
SOUTH ABUTMENT (BH 95-G11 El.=724.8 m)

EBA Engineering Consultants Ltd.

CLIENT
MINTO EXPLORATIONS LTD.

PROJECT
MINTO PROJECT
NORTHWEST OF CARMACKS, YUKON

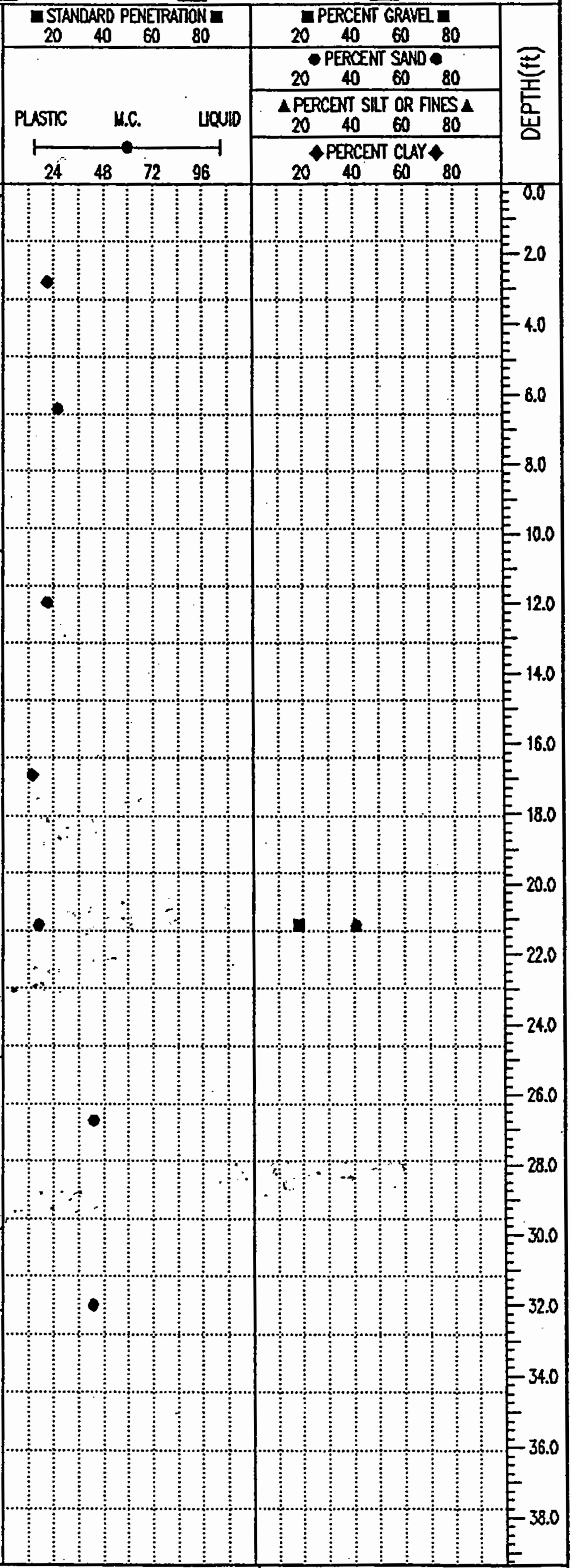
TITLE
GROUND TEMPERATURES
TAILINGS AREA

DATE 95-12-18
DWN. DRG
CHKD. KWJ
FILE NO. 201-11509
FIGURE 5

MINTO CREEK MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 96-G07
GEOTECHNICAL EVALUATION-SOUTH WASTE DUMP	DRILL: CME-75 C/W SOLID SHAFT AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6944790.3 E385412.7	ELEVATION: 2566.30 (m)

SAMPLE TYPE ■ GRAB ◪ NO RECOVERY ☒ STANDARD PEN. ▤ 75 mm SPOON ◫ CRREL BARREL ▮ DISTURBED

DEPTH(m)	SAMPLE TYPE	SAMPLE NO	SPT(N)	USC	SOIL SYMBOL	SOIL DESCRIPTION
0.0						ORGANIC SILT/MOSS
						SILT – sandy, some clay, trace of fine gravel; fine sand and silt matrix, coarse sand clasts; low plastic; (moderate dry strength); frozen at 0.15 m; Nbe; brown – isolated organic silt inclusions to 0.3 m – grading in colour to grey
1.0	◫	1				
2.0	■	2				
3.0						SAND AND SILT – some gravel to gravelly, occasional organic fibers and wood fibers; fine sand and silt matrix; coarse sand clasts; fine to coarse subrounded to subangular gravel; Vx, 10 to 15% ICE; grey – gravel content increasing with depth – zones of low and high gravel content – rough grinding drilling through gravel zones – occasional ICE inclusions to 75 mm; Vx, 10 to 15% ICE; olive grey with light brown inclusions
4.0	◫	3				
5.0	■	4				
6.0	◫	5				
7.0						SILT – some clay to clayey; some fine sand; low plastic; frozen, Vx,r 15 to 25%, lens to 25 mm; grey
8.0	■	6				
9.0						
10.0	◫	7				END OF BOREHOLE @ 9.8 m
11.0						
12.0						

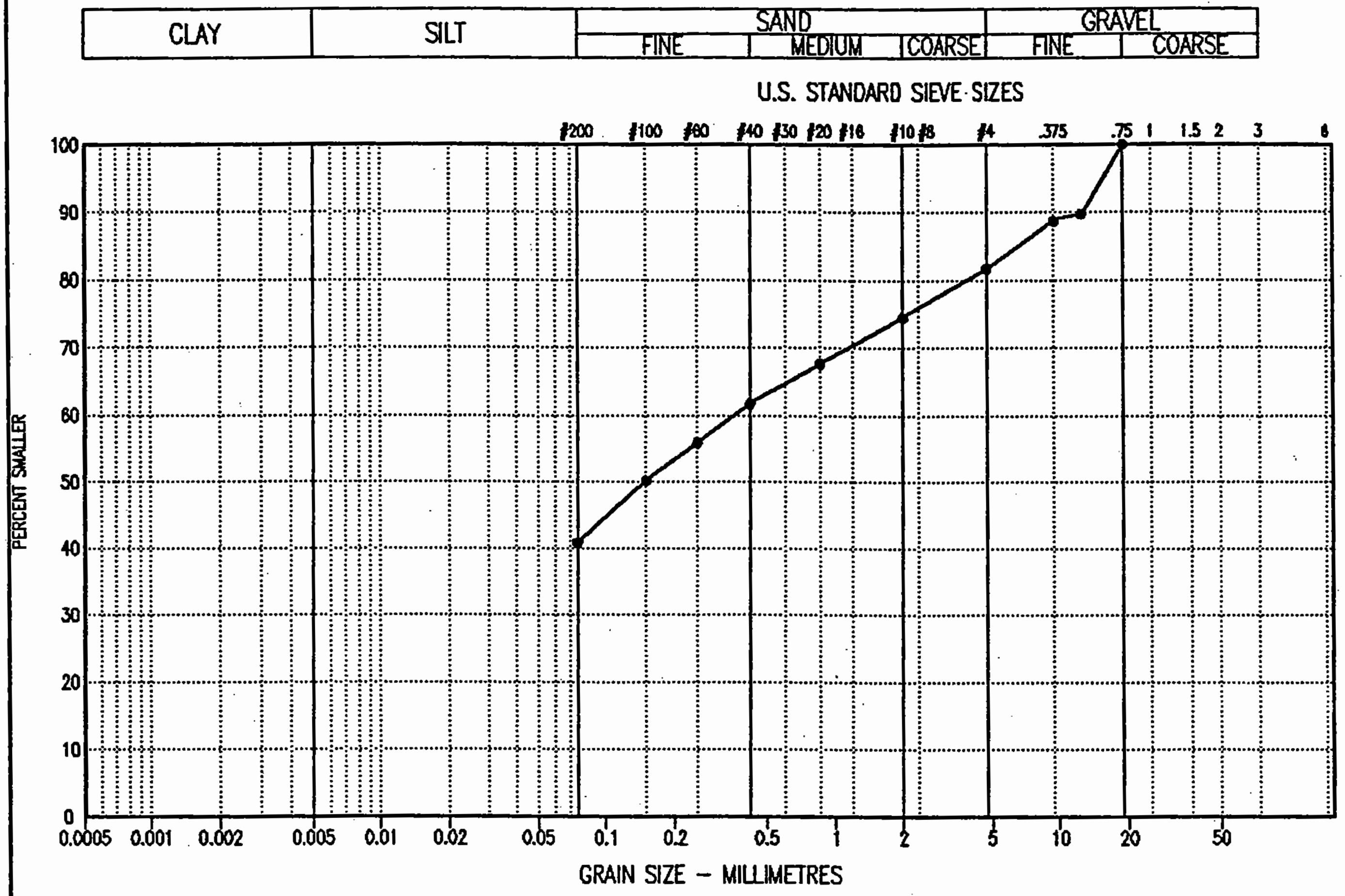


EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 9.8 m
	REVIEWED BY: CRH	COMPLETE: 96/07/07
	Fig. No:	Page 1 of 1

96/08/14 10:37AM (YUKON12)

EBA Engineering

PARTICLE SIZE – ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY & SILT %	 SAND %	 GRAVEL %	Cu	Cc	U.S.C
●—●	96-G07	6.40 - 6.50	40.8	40.8	18.4	20.3	0.4	SM

Project: 0201-11509

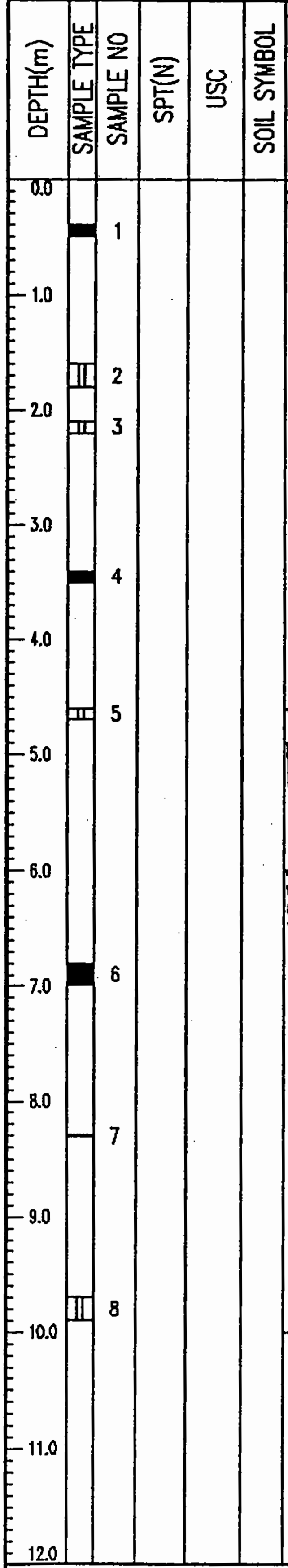
Date Tested: 96/07/11

BY: AA

Tested in accordance with ASTM D422 unless otherwise noted.

MINTO CREEK MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 96-G08
GEOTECHNICAL EVALUATION-SOUTH WASTE DUMP	DRILL: CME-75 C/W SOLID SHAFT AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6944602.8 E385593.3	ELEVATION: 2532.30 (m)

SAMPLE TYPE ■ GRAB ▨ NO RECOVERY ☒ STANDARD PEN. ☰ 75 mm SPOON ▯ CRREL BARREL ▮ DISTURBED



SOIL DESCRIPTION

MOSS/ORGANIC SILT

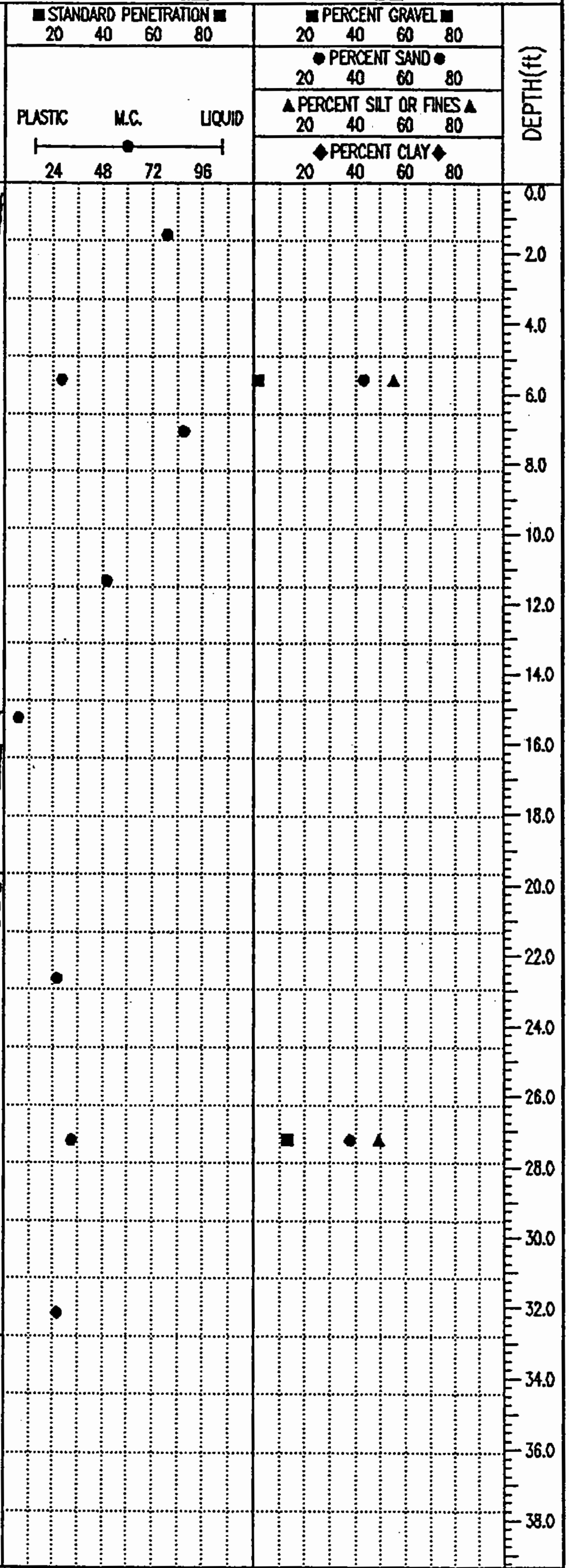
SILT – sandy; light reddish brown

ORGANIC SILT AND SAND – numerous wood fibres and pieces; frozen, Vs,r 15% to 20% ICE, lens < 1 mm; grey
- occasional zones of orange-brown coarse sand within grey silt matrix
- becomes some sand, trace of organics by 1.6 m
- charcoal inclusion @ 1.9 m
- @ 3.0 m, occasional fibrous organics disseminated throughout; Nbe with some zones of V,sr 15% to 20%
- becomes sandy, trace of gravel; Nbe

SAND AND GRAVEL – some silt; fine to coarse sand; fine to coarse, rounded to subrounded gravel; Nbe; olive grey

SAND AND SILT – gravelly; coarse and fine angular gravel; fine to coarse angular sand; matrix supported; light brown with occasional green clasts; Nbe
- becomes some gravel, trace of clay; fine to coarse sand; fine, rounded to subangular gravel; frozen, Nbe, some Vx, 15% ICE; grey
- grinding drilling
- Vx, 15% ICE, lens to 15 mm
- more gravel with depth; gravel to >100 mm
- Vx, 15 to 20% ICE
- rough grinding drilling

END OF BOREHOLE @ 10.0 m
- 10 m thermistor string installed



EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 10.0 m
	REVIEWED BY: CRH	COMPLETE: 96/07/07
	Fig. No:	Page 1 of 1

96/08/13 04:11PM (YUKON12)

Thermistor No.: 1064
Date Installed: Jul. 7, 1996

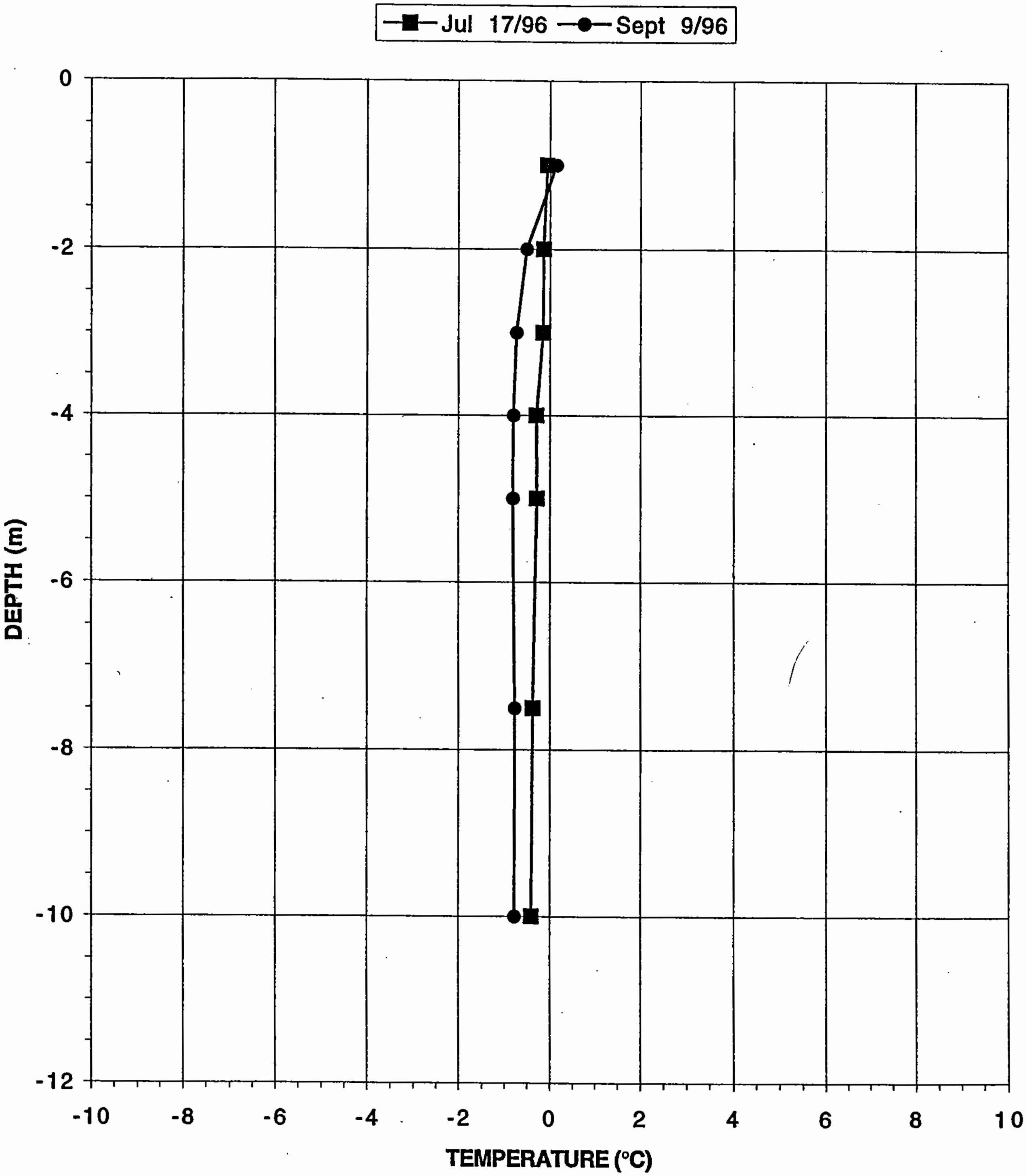
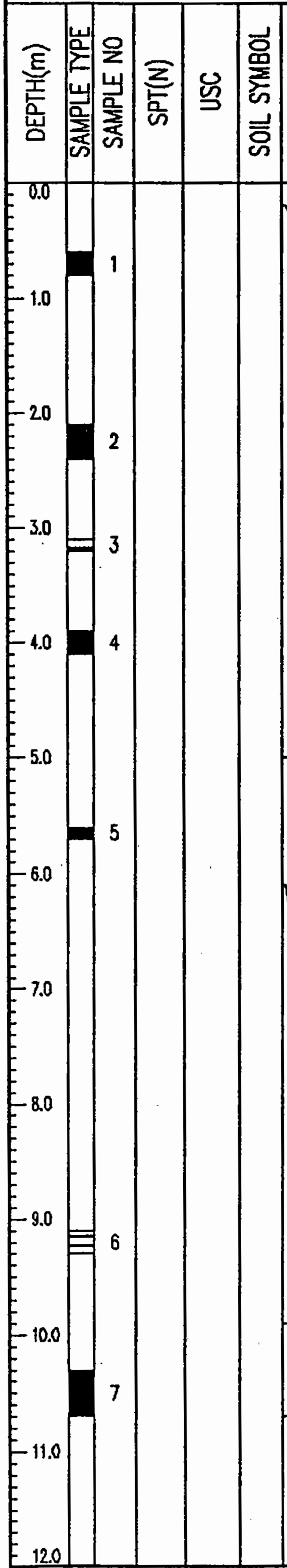


FIGURE 1: GROUND TEMPERATURE PROFILE
MINTO PROJECT - SOUTH WASTE DUMP
(BH 96-G08)

MINTO CREEK MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 96-G09
GEOTECHNICAL EVALUATION-SOUTH WASTE DUMP	DRILL: CME-75 C/W SOLID SHAFT AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6944471.2 E385720	ELEVATION: 2552.90 (m)

SAMPLE TYPE ■ GRAB ◪ NO RECOVERY ☒ STANDARD PEN. ☰ 75 mm SPOON ▯ CRREL BARREL ▯ DISTURBED



SOIL DESCRIPTION

MOSS/ORGANIC SILT – roots

SILT – sandy, trace of fine gravel, trace of clay; low plastic; fine to medium sand; frozen; Vx,r 10 to 15% ICE; brown

– becomes Nbe, trace to some clay, dark olive grey by 1.5 m
– faint organic odour @ 2.0 m

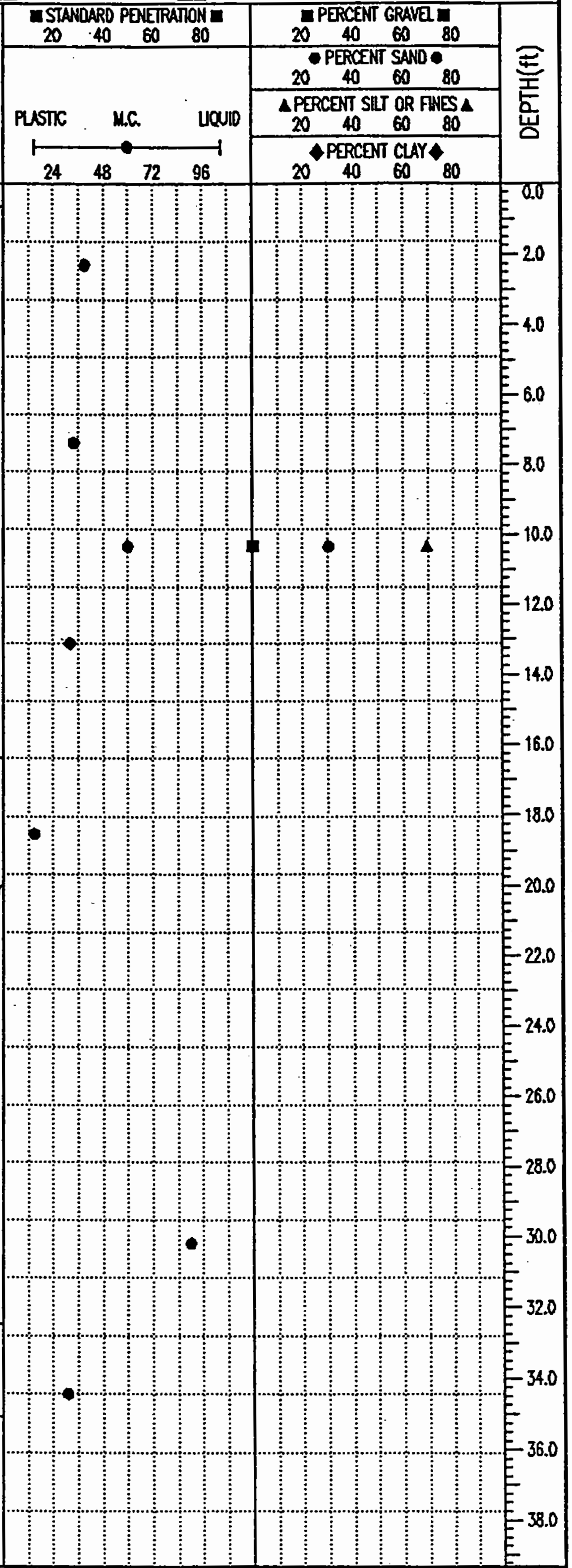
– @ 3.1 m; Vx, 15% ICE, ice grains < 2 mm
– zone of ICE augered up between 3.1 and 4.5 m

– grades into light olive grey, SAND AND SILT – trace to some clay, trace of gravel; fine to coarse sand; subangular, fine gravel; low plastic

ICE AND SILT – trace of sand and clay; 50 to 60% ICE; zones of 80%+ ICE on augers
– soil content varies from 40% to 60%

SAND AND SILT – some clay, trace of fine gravel; Vx, 10 to 20% ICE; light olive brown

END OF BOREHOLE @ 10.7 m



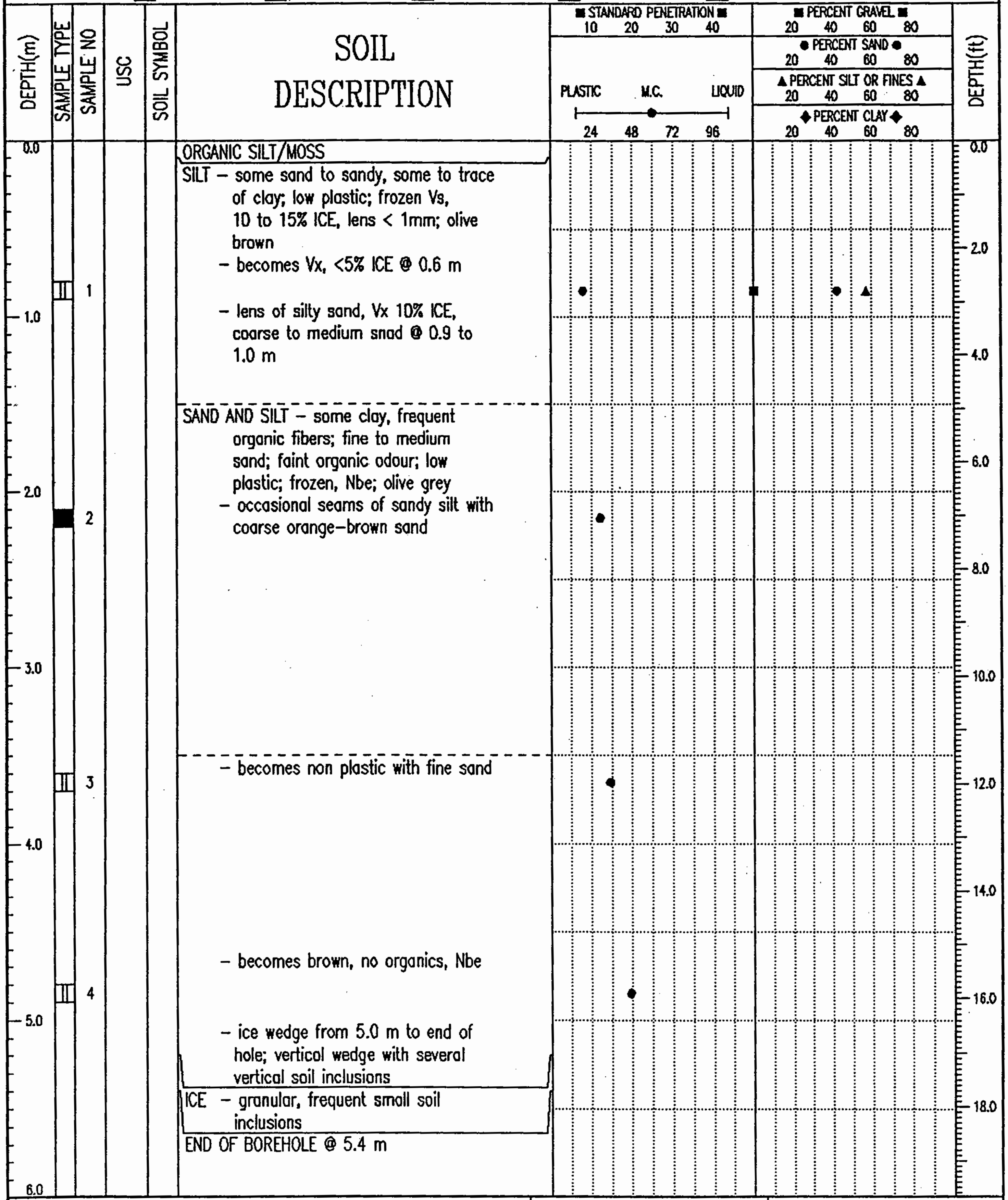
EBA Engineering Consultants Ltd.
Whitehorse, Yukon

LOGGED BY: CRH	COMPLETION DEPTH: 10.7 m
REVIEWED BY: CRH	COMPLETE: 96/07/06
Fig. No:	Page 1 of 1

96/08/13 04:12PM (YUKON12)

MINTO CREEK MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	TEST PIT NO: 96-G10
GEOTECHNICAL EVALUATION-SOUTH WASTE DUMP	DRILL: CME-75 C/W SOLID SHAFT AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6944593.9 E385162.8	ELEVATION: 2609.20 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ STANDARD PEN. ☰ 75 mm SPOON ▥ CRREL BARREL



SOIL DESCRIPTION

ORGANIC SILT/MOSS

SILT – some sand to sandy, some to trace of clay; low plastic; frozen Vs, 10 to 15% ICE, lens < 1mm; olive brown
- becomes Vx, <5% ICE @ 0.6 m
- lens of silty sand, Vx 10% ICE, coarse to medium snad @ 0.9 to 1.0 m

SAND AND SILT – some clay, frequent organic fibers; fine to medium sand; faint organic odour; low plastic; frozen, Nbe; olive grey
- occasional seams of sandy silt with coarse orange-brown sand

- becomes non plastic with fine sand

- becomes brown, no organics, Nbe

- ice wedge from 5.0 m to end of hole; vertical wedge with several vertical soil inclusions

ICE – granular, frequent small soil inclusions

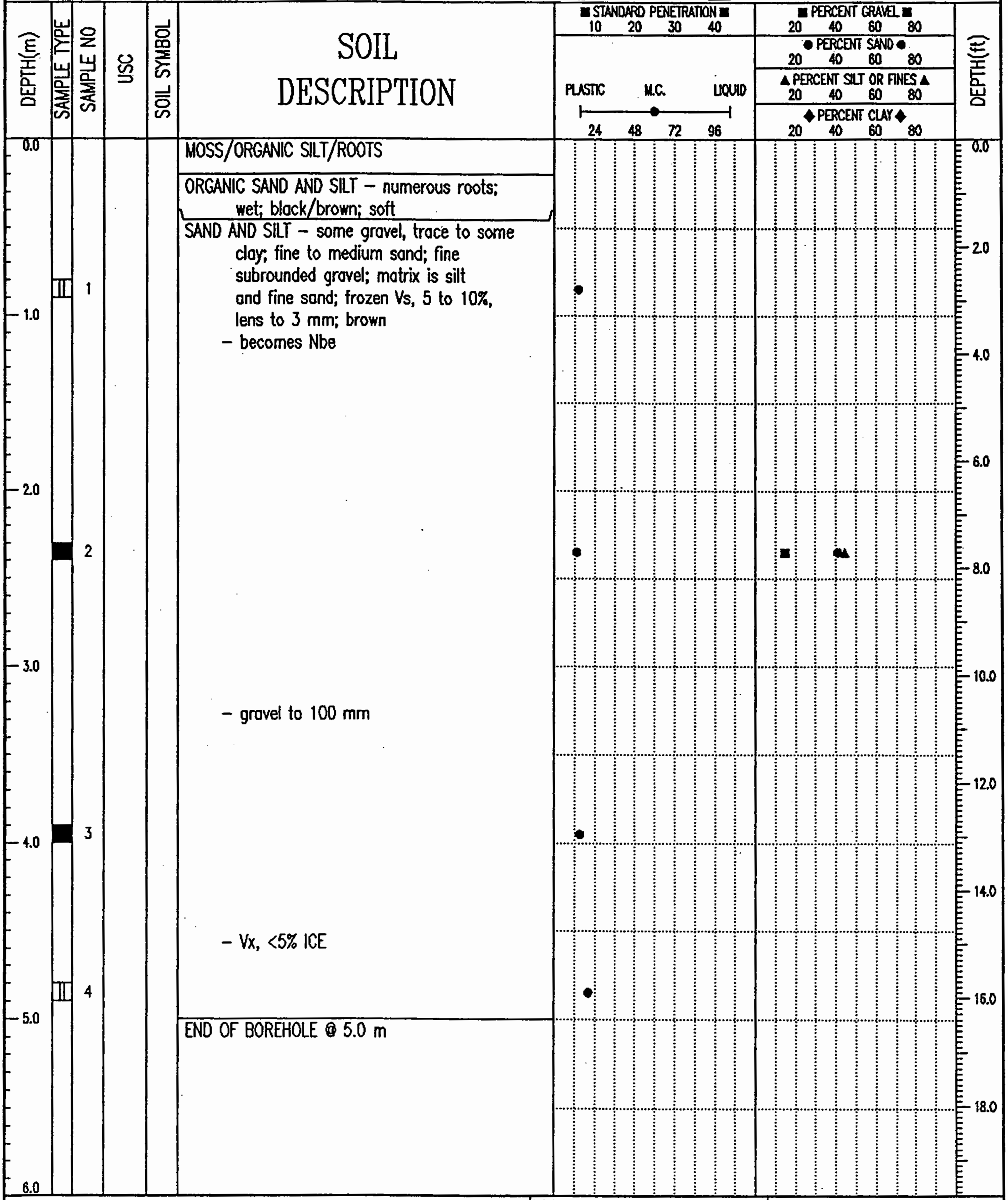
END OF BOREHOLE @ 5.4 m

EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 5.4 m
	REVIEWED BY: CRH	COMPLETE: 96/07/08
	Fig. No:	Page 1 of 1

96/08/13 04:34PM (YUKON-6)

MINTO CREEK MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	TEST PIT NO: 96-G11
GEOTECHNICAL EVALUATION-SOUTH WASTE DUMP	DRILL: CME-75 C/W SOLID SHAFT AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6944395.1 E385337.8	ELEVATION: 2607.50 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▧ NO RECOVERY ☒ STANDARD PEN. ▤ 75 mm SPOON ▥ CRREL BARREL



MOSS/ORGANIC SILT/ROOTS

ORGANIC SAND AND SILT – numerous roots; wet; black/brown; soft

SAND AND SILT – some gravel, trace to some clay; fine to medium sand; fine subrounded gravel; matrix is silt and fine sand; frozen Vs, 5 to 10%, lens to 3 mm; brown
- becomes Nbe
- gravel to 100 mm
- Vx, <5% ICE

END OF BOREHOLE @ 5.0 m

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Whitehorse, Yukon

LOGGED BY: CRH	COMPLETION DEPTH: 5.0 m
REVIEWED BY: CRH	COMPLETE: 96/07/08
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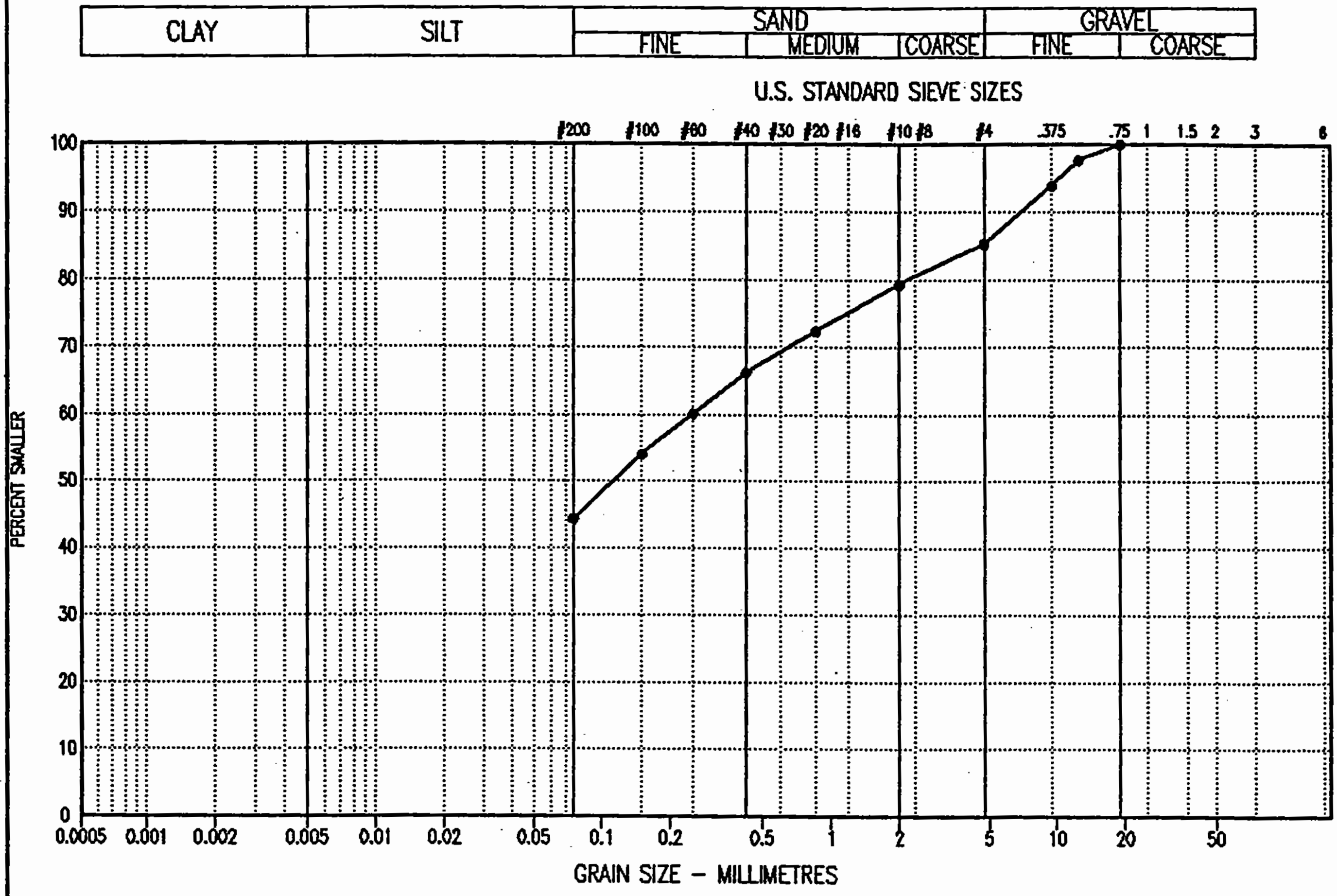
96/08/13 04:35PM (YUKON-6)

EBA Engineering

PARTICLE SIZE – ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION			Cu	Cc	U.S.C
			CLAY & SILT %	SAND %	GRAVEL %			
●—●	96-G11	2.30 - 2.40	44.3	40.9	14.8	14.7	0.6	SM

Project: 0201-11509

Date Tested: 96/07/11

BY: AA

Tested in accordance with ASTM D422 unless otherwise noted.

MINTO CREEK MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	TEST PIT NO: 96-G12
GEOTECHNICAL EVALUATION-SOUTH WASTE DUMP	DRILL: CME-75 C/W SOLID SHAFT AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6944221.3 E385493.2	ELEVATION: 2612.50 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ STANDARD PEN. ☰ 75 mm SPOON ▥ CRREL BARREL

SOIL DESCRIPTION

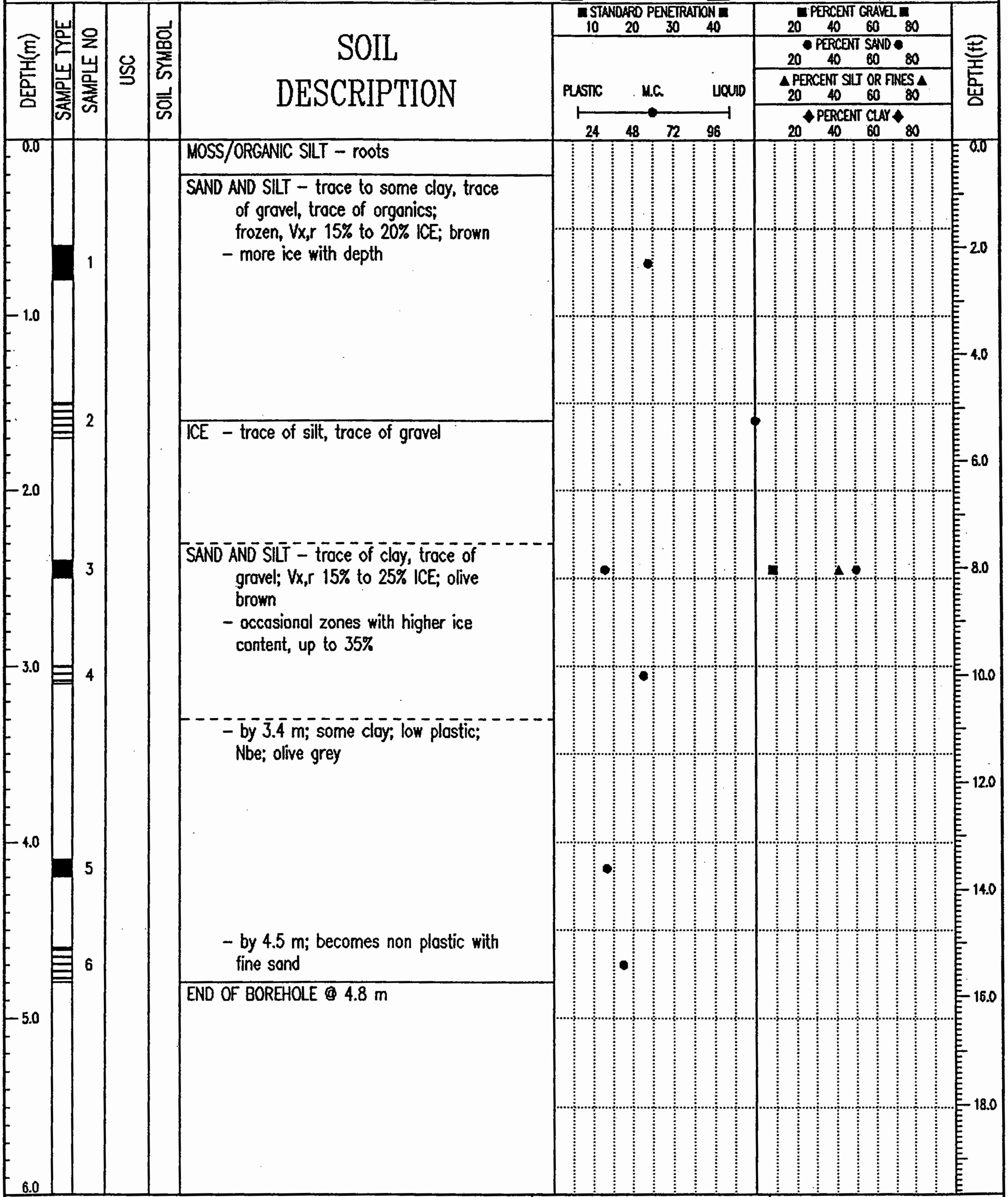
MOSS/ORGANIC SILT – roots

SAND AND SILT – trace to some clay, trace of gravel, trace of organics; frozen, Vx,r 15% to 20% ICE; brown
- more ice with depth

ICE – trace of silt, trace of gravel

SAND AND SILT – trace of clay, trace of gravel; Vx,r 15% to 25% ICE; olive brown
- occasional zones with higher ice content, up to 35%
- by 3.4 m; some clay; low plastic; Nbe; olive grey
- by 4.5 m; becomes non plastic with fine sand

END OF BOREHOLE @ 4.8 m



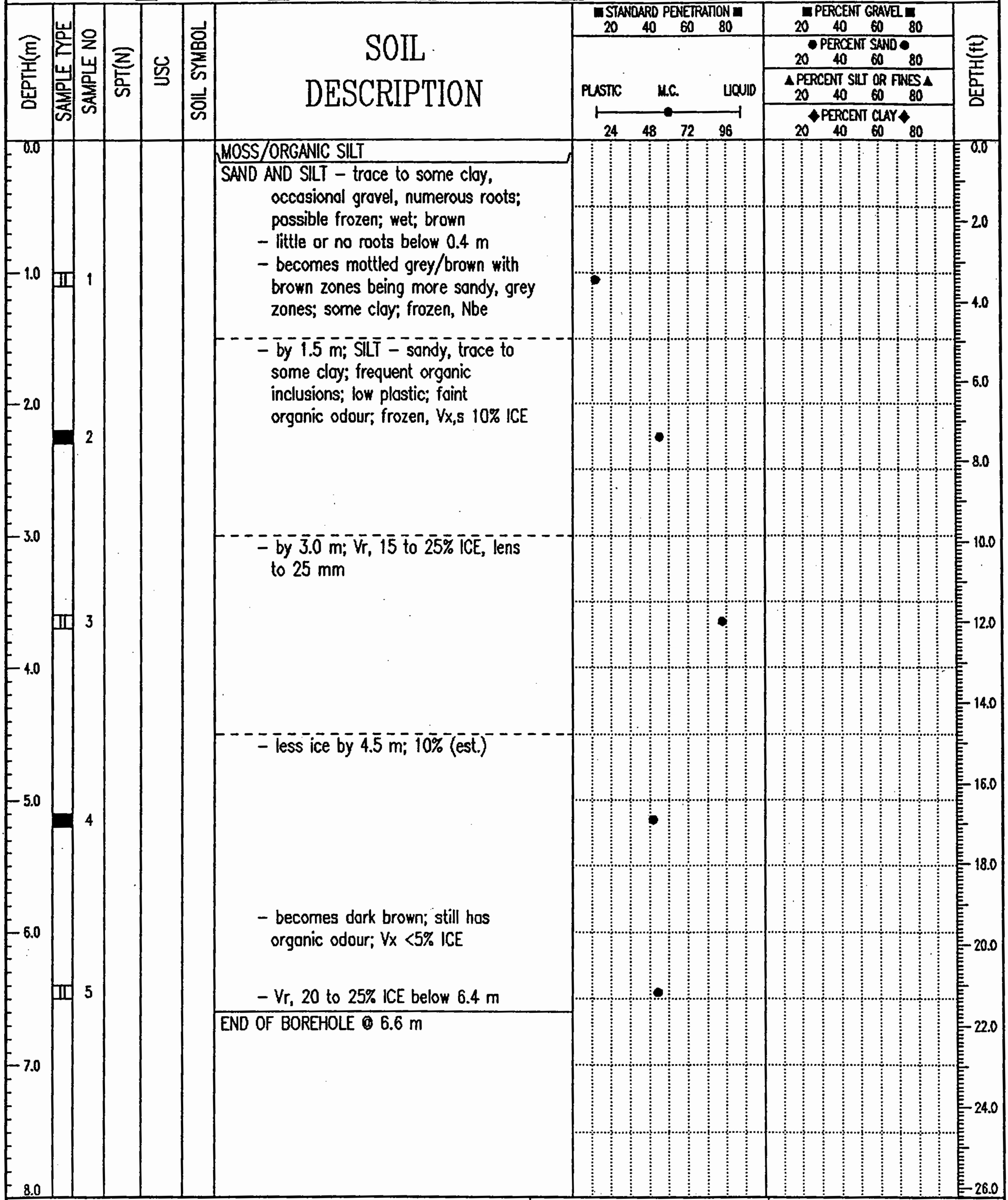
EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 4.8 m
	REVIEWED BY: CRH	COMPLETE: 96/07/06
	Fig. No:	Page 1 of 1

96/08/13 04:36PM (YUKON-6)

MINTO CREEK MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 96-G13
MILL WATER POND – SOUTH ABUTMENT	DRILL: CME-75 C/W SOLID SHAFT AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6944821.6 E385233	ELEVATION: 2585.80 (m)

SAMPLE TYPE ■ GRAB SAMPLE ◿ NO RECOVERY ☒ STANDARD PEN. ☰ 75 mm SPOON ǁ CRREL BARREL

SAMPLE TYPE	SAMPLE NO	SPT(N)	USC	SOIL SYMBOL	SOIL DESCRIPTION
					MOSS/ORGANIC SILT
ǁ	1				SAND AND SILT – trace to some clay, occasional gravel, numerous roots; possible frozen; wet; brown – little or no roots below 0.4 m – becomes mottled grey/brown with brown zones being more sandy, grey zones; some clay; frozen, Nbe
■	2				– by 1.5 m; SILT – sandy, trace to some clay; frequent organic inclusions; low plastic; faint organic odour; frozen, Vx,s 10% ICE
ǁ	3				– by 3.0 m; Vr, 15 to 25% ICE, lens to 25 mm
■ ǁ	4 5				– less ice by 4.5 m; 10% (est.) – becomes dark brown; still has organic odour; Vx <5% ICE – Vr, 20 to 25% ICE below 6.4 m
					END OF BOREHOLE @ 6.6 m



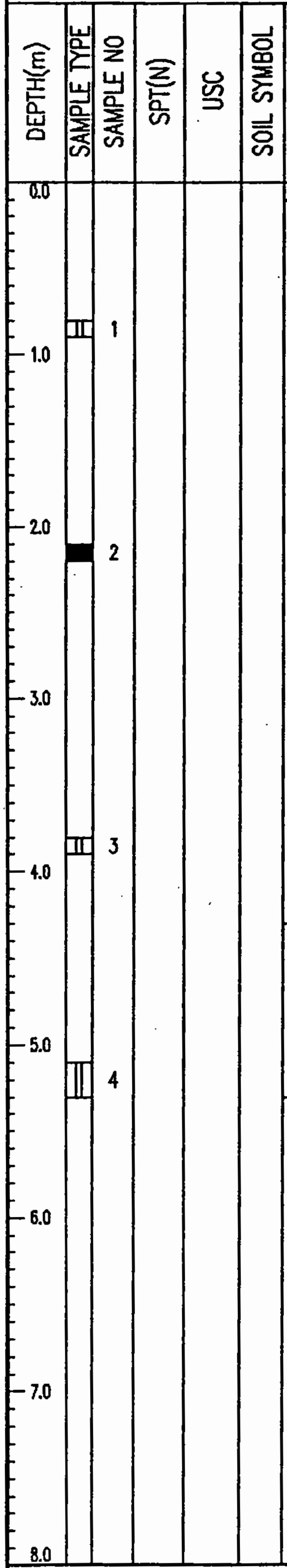
EBA Engineering Consultants Ltd.
Whitehorse, Yukon

LOGGED BY: CRH	COMPLETION DEPTH: 6.6 m
REVIEWED BY: CRH	COMPLETE: 96/07/08
Fig. No:	Page 1 of 1

96/08/14 02:49PM (YUKON-8)

MINTO CREEK MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 96-G16
MILL WATER POND – SOUTH SLOPE	DRILL: CME-75 C/W SOLID SHAFT AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6944794.7 E385183.9	ELEVATION: 2582.80 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ STANDARD PEN. ☰ 75 mm SPOON ▯ CRREL BARREL



SOIL DESCRIPTION

MOSS/ORGANIC SILT

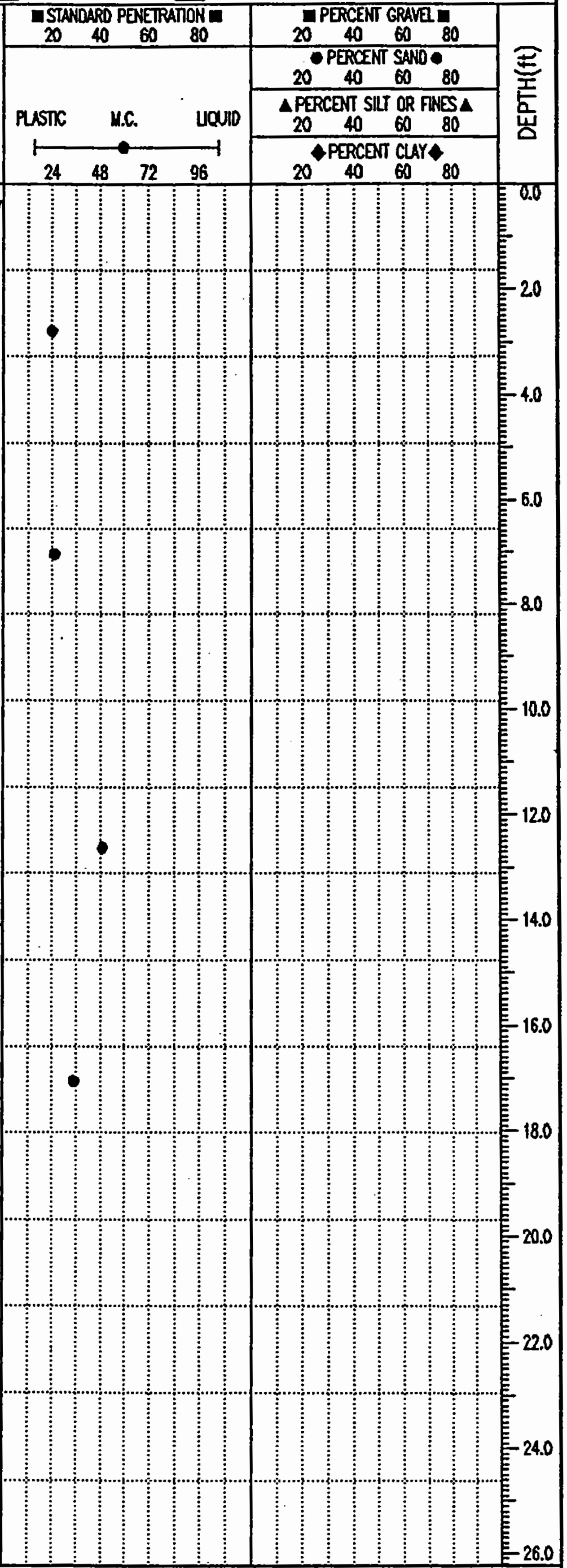
SAND AND SILT – trace of gravel, trace of clay; fine to coarse sand; fine, subrounded to rounded gravel; matrix of silt and fine sand; frozen, Nbe; brown with rusty brown mottling

- occasional wood fibers; faint organic odour
- thawed to 0.3 m
- becomes grey, more clayey with depth
- occasional subangular gravel

- grades into a grey clayey silt and sand – trace of gravel; Vr, 10% to 20% ICE, ice lens to 10 mm, mostly vertical; occasional wood fibres; faint organic odour

- becomes clayey silt and sand clasts in ice matrix with fine gravel inclusions; Vr, 20% to 25% ICE, lens to 15 mm

END OF BOREHOLE @ 5.3 m



EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 5.3 m
	REVIEWED BY: CRH	COMPLETE: 96/07/08
	Fig. No:	Page 1 of 1

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APPENDIX

APPENDIX D THERMAL ANALYSES

TECHNICAL MEMO

CREATING AND DELIVERING BETTER SOLUTIONS

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TO:	Jason Berkers	**DATE:**	December 11, 2006
FROM:	Gordon Zhang	**FILE:**	1200173
SUBJECT:	**Thermal Analysis of "Dry" Stacked Tailings Area Minto Project, YT**		

1.0 INTRODUCTION

EBA Engineering Consultants Ltd. (EBA) was retained by Minto Explorations Ltd. (Minto) to develop a "dry" stacked tailings placement plan and to design the associated facilities for the tailings placement at the Minto mine site. As part of the design, thermal analyses were carried out to predict the thermal regime of "dry" stacked tailings placed over a 1.5 m thick sandy gravel drainage blanket overlying the original ground and to evaluate the impacts of the placed tailings on the thermal regime of the native subgrade during the life of the Minto Mine (2007 to 2014). The thermal model was calibrated against the measured ground temperatures at the site. Various cases with different assumed tailings placement rates and final heights were simulated. Parametric and sensitivity studies for some cases were also conducted. This memo summarizes the methodology, input data, and results of the thermal analyses. Conclusions and recommendations drawn from the results of the thermal analyses are also presented in this technical memo.

2.0 THERMAL ANALYSES METHODOLOGY

Analyses were carried out using EBA's proprietary two-dimensional finite element computer model, GEOTHERM. The model simulates transient, two-dimensional heat conduction with change of phase for a variety of boundary conditions. The heat exchange at the ground surface is modelled with an energy balance equation considering air temperatures, wind velocity, snow depth, and solar radiation. The model facilitates the inclusion of temperature phase change relationships for soils, such that any freezing depression and unfrozen water content variations can be explicitly modelled. The model has been verified by comparing its results with closed-form analytical solutions and many different field observations. The model has successfully formed the basis for thermal evaluations and designs of tailings dykes, dams, foundations, pipelines, utilidor systems, landfills, and ground freezing systems in arctic and sub-arctic regions.

3.0 CLIMATIC DATA FOR THERMAL EVALUATION

Climatic data required for the thermal analyses includes monthly air temperature, wind speed, solar radiation, and snow cover. No long-term climatic data is available from the Minto Mine site. A complete meteorological station was established at the site in September 2005 and data for the station is available up to mid-July 2006 (Access Consulting Group, 2006). Snow surveys have been carried out by J. Gibson & Associates in 1994, 1995, 1998 and 2006 at three locations in the Minto Creek area (Access Consulting Group, 2006).

The closest meteorological station to the Minto site with a long-term climatic record is Pelly Ranch, which is situated about 40 km northeast of the Minto site. In addition, the Carmacks meteorological station is located about 70 km southeast of the site. Measured long-term air temperatures are available for both the stations from the National Climate Data and Information Archive operated by Environment Canada (http://www.climate.weatheroffice.ec.gc.ca). Comparison of the measured air temperatures at the two stations for 29 years of the overlapped periods with complete data indicates that the monthly air temperatures at Carmacks are generally warmer than those at Pelly Ranch. The two stations are located at similar elevations (an average of approximately 490 m), which is lower than the toe of the tailings placement area at an elevation of approximately 760 m. Johnston (1981) reported that climatologists typically estimate a 6°C decrease in temperature for every kilometre increase in elevation for mountain slopes. Therefore, the long-term mean monthly air temperatures at the Minto site for this study were first estimated by interpolating the long-term mean monthly air temperatures at Pelly Ranch and Carmacks based on the distances to the Minto site and then adjusted for the temperature change due to the elevation difference of 270 m. Accordingly, the estimated mean annual air temperature at the Minto site is -5.1°C.

The measured air temperatures for the period from early-September 2005 to mid-July 2006 at the Minto site were warmer (about 1°C in long-term mean annual air temperatures) than the estimated long-term mean values. However, the limited short-term measured air temperatures are not sufficient to verify or adjust the estimated long-term mean values used for this study. Further detailed discussions on the measured and estimated air temperatures at the Minto site are presented in Section 6.0 of this memorandum.

Long-term mean wind speed data are not available at the Pelly Ranch and Carmacks stations. The mean wind speed data for this study was estimated by averaging those from four meteorological stations in the Yukon: Burwash, Mayo, Watson Lake, and Whitehorse (http://www.climate.weatheroffice.ec.gc.ca). Measured wind speed data from the Minto site are available for a short period (September 2005 to July 2006) (Access Consulting Group, 2006). Comparison of the monthly wind speed data indicates that the estimated wind speeds are similar to the measured during the summer of 2006 and higher than the measured during the winter of 2005.

Snow depth surveys at the Minto site were conducted in March, April and May of 1994, 1995, 1998, and 2006. The mean monthly snow depths in March, April and May for this study were estimated by averaging the measured monthly values. The mean monthly snow depths for the other months were estimated based on the mean monthly snow depths at Mayo and then adjusted for the measured snow depth differences between the two sites between March and May. Mayo, located approximately 120 km northeast of the Minto site, is situated in the same snow-depth contour zone as the Minto site based on the snow depth maps presented in Natural Resources Canada's webpage (http://atlas.nrcan.gc.ca).

Norman Wells and Whitehorse are the closest stations to the Minto site (latitude of 62°36') with long-term solar radiation data. Norman Wells (latitude of 65°17') is located about 580 km northeast of the Minto site and Whitehorse (latitude of 60°43') is located about 220 km southeast of the Minto site. The mean monthly solar radiation data at the Minto site for this study were estimated by interpolating the long-term mean monthly solar radiation data at Norman Wells and Whitehorse based on the latitudes of the three sites. Measured solar radiation data are available at the Minto site for the period from September 2005 to July 2006 (Access Consulting Group, 2006). The measured monthly solar radiation data are similar to the estimated.

The long-term mean climatic data estimated for the Minto site for this study is summarized in Table 1.

TABLE 1: SUMMARY OF MEAN CLIMATIC CONDITIONS AT MINTO USED IN THERMAL ANALYSES

Month	Monthly Air Temperature[(a)] (°C)	Monthly Wind Speed[(b)] (km/h)	Month-End Snow Cover[(c)] (m)	Daily Solar Radiation[(d)] (W/m^2)
January	-28.2	7.5	0.40	10.2
February	-21.8	8.9	0.43	39.0
March	-12.4	10.0	0.48	102.0
April	-1.1	11.7	0.08	180.7
May	6.3	11.8	0.00	229.9
June	11.7	10.8	0.00	255.4
July	13.8	9.5	0.00	225.8
August	11.2	9.6	0.00	170.1
September	5.0	10.7	0.01	99.1
October	-4.0	11.9	0.10	41.5
November	-17.1	8.9	0.23	14.2
December	-25.0	7.8	0.31	5.3

Notes:

(a) based on Climate Normals 1971-2000 at Pelly Ranch (Environment Canada website), measured mean air temperatures at Carmacks and Pelly Ranch for the period of 1963 to 2004 (Environment Canada website), and Johnston (1981)

(b) based on Climate Normals 1971-2000 for Burwash, Mayo, Watson Lake, and Whitehorse (Environment Canada website)

(c) based on snow depth survey data at Minto and mean month-end snow data at Mayo (Climate Normals 1971-2000, Environment Canada website)

(d) based on Climatic Normals 1951-1980 at Norman Wells and Whitehorse (Environment Canada, 1982)

4.0 CALIBRATION THERMAL ANALYSIS

A thermistor cable was installed on July 7, 1996 to a depth of 10 m in borehole BH 96-G08 within the footprint of the proposed "dry" stacked tailings placement area at the Minto site. One-dimensional thermal analysis was conducted to calibrate the thermal model with the measured ground temperatures at BH 96-G08. The modelled soil profile consists of a thin (0.1 m) organics layer overlying 4.5 m organic silt/sand, 1.4 m sand/gravel, and 39 m sand/silt over granite bedrock.

The soil index properties were estimated from the borehole log for BH 96-G08 and past experience. Thermal properties of the soils were determined indirectly from well-established correlations with soil index properties (Farouki, 1986; Johnston, 1981). Table 2 summarizes the material properties used in the calibration thermal analysis.

TABLE 2: MATERIAL PROPERTIES USED IN CALIBRATION THERMAL ANALYSIS

Material	Water Content (%)	Bulk Density (Mg/m³)	Thermal Conductivity (W/m-°C)		Specific Heat (kJ/kg°C)		Latent Heat (MJ/m³)
			Frozen	Unfrozen	Frozen	Unfrozen	
Moss/Organics	100	1.00	0.81	0.47	1.89	2.94	167
Organic Silt/Sand	60	1.60	2.36	1.02	1.24	2.03	200
Sand/Gravel	8	2.35	2.61	2.12	0.83	0.99	58
Sand/Silt	28	1.96	2.40	1.34	1.03	1.49	143
Bedrock	1	2.68	3.00	3.00	0.75	0.77	9

Table 3 compares the calibrated ground temperatures with those measured on September 9, 1996 at BH 96-G08.

TABLE 3: MEASURED AND PREDICTED GROUND TEMPERATURES AT BH 96-G08

Depth below Ground Surface (m)	Measured (°C)	Predicted (°C)
1	0.1	0.1
2	-0.5	-0.2
3	-0.7	-0.4
4	-0.8	-0.5
5	-0.8	-0.6
7.5	-0.8	-0.8
10	-0.8	-0.8

Table 3 indicates that there is a good agreement between the measured and predicted ground temperatures. The predicted mean active layer thickness is approximately 1.2 m. The results of the calibration thermal analysis indicate that the input data used in the thermal model are reasonable and can be used to predict the thermal regime of the stacked tailings area.

5.0 THERMAL ANALYSES OF STACKED TAILINGS AREA

5.1 CASES SIMULATED

The planned construction schedules and activities for the stacked tailings placement area at the Minto site include the following:

- removing trees in the tailings placement area during January 2007;
- placing 1.5 m sandy gravel drainage blanket over the area in February 2007; and
- placing tailings in engineered lifts overlying the sandy gravel drainage blanket beginning in May 2007 and continuing through the mine life.

The purposes of the thermal evaluations in the current study are to predict thermal performance of the stacked tailings and to evaluate thermal impacts of the tailings placement on the original ground. Various cases with different assumed tailings placement rates and final heights were simulated. Parametric and sensitivity studies for some cases were also conducted. A total of 15 cases were analyzed and are summarized in Table 4.

TABLE 4: CASES SIMULATED BY THERMAL MODELLING

Case	Ground Conditions Prior to Placing Tailings	Simulated Placement Rate and Schedule of "Dry" Stacked Tailings	Assumed Final Height of Total Tailings Placed (m)	Assumed Percentage of Monthly Average Snow Depth over Long-term Monthly Mean Snow Depth
1	1.5 m sandy gravel drainage blanket placed over the original ground in February 2007 after trees removed in January 2007	No tailings placed	0	15% from February 2007 to September 2007 and 100% after September 2007
2		1.5 m/year: placing the first 0.5 m thick lift of tailings in May 2007, the second 0.5 m lift in September 2007 (after four months), the third 0.5 m lift in January 2008, and so on.	5	65% during the period of placing the tailings and 100% after the final height of the tailings is reached
3			7.5	
4			10	
5		3.0 m/year: placing the first 0.5 m thick lift in May 2007, the second 0.5 m lift in July 2007 (after two months), the third 0.5 m lift in September 2007, and so on.	5	15% during the period of placing the tailings and 100% after the final height of the tailings is reached
6			7.5	
7			10	
8		6.0 m/year: placing a 0.5 m thick lift in each month starting in May 2007.	5	5% during the period of placing the tailings and 100% after the final height of the tailings is reached
9			7.5	
10			10	
11		3.0 m/year: placing the first 0.5 m thick lift in September 2007, the second 0.5 m lift in November 2007 (after two months), the third 0.5 m lift in January 2008, and so on.	10	15% during the period of placing the tailings and 100% after the final height of the tailings is reached
12	Original ground with trees removed in January 2007 but without the sandy gravel drainage blanket	1.5 m/year: placing the first 0.5 m thick lift in May 2007, the second 0.5 m lift in September 2007 (after four months), the third 0.5 m lift in January 2008, and so on.	5	65% during the period of placing the tailings and 100% after the final height of the tailings is reached
13		3.0 m/year: placing the first 0.5 m thick lift in September 2007, the second 0.5 m lift in November 2007 (after two months), the third 0.5 m lift in January 2008, and so on.	10	15% during the period of placing the tailings and 100% after the final height of the tailings is reached
14	Same as Case 1 but with assumed increased snow depth after September 2007			15% from February 2007 to September 2007 and 200% after September 2007
15	Original ground without trees	No tailings placed	0	100 % prior to May 1, 2007 and 200% after May 1, 2007

Case 1 evaluates the long-term thermal conditions of the original ground covered with the 1.5 m thick sandy gravel drainage blanket but without placing any tailings. Cases 2 to 10 simulate various tailings placement rates and tailings final heights. Case 11 is the same case as Case 7 but assumes that tailings are first placed in September 2007 instead of May 2007, which evaluates the sensitivity of the thermal analysis results to the initial tailings placement time. Cases 12 and 13 are sensitivity cases that evaluate the thermal impacts of tailings placed directly over the original ground instead of over the 1.5 m thick sandy gravel drainage blanket as for Cases 2 to 11. Cases 14 and 15 are parametric cases that evaluate the effects of assumed snow depth on the predicted maximum thaw penetration for cases without tailings.

In the thermal analyses, placement of the 1.5 m sandy gravel drainage blanket was modelled as 0.5 m thick three lifts being placed on February 8, 15, and 22, 2007, respectively. The 0.5 m thick lift of the tailings placed in a given month was modelled as four sub-lifts, 0.125 m thick each, being placed on the 7th, 15th, 22nd, and 30th of the month, respectively.

The initial ground temperatures on February 1, 2007 for Cases 1 and 14 and on May 1, 2007 for Cases 12, 13 and 15 were estimated from the calibrated thermal analysis for BH 96-G08. The initial ground temperatures on May 1, 2007 (Cases 2 to 10) and on September 1, 2007 (Case 11) were estimated from the thermal analysis results for Case 1.

The assumed initial temperatures were -4°C for the sandy gravel drainage blanket placed in February 2007, 5°C for the tailings placed in October through May, and 20°C for the tailings placed in June through September.

5.2 SOIL INDEX AND THERMAL PROPERTIES

The soil index and thermal properties for the original ground for the thermal analyses were assumed to be the same as those listed in Table 2 for the calibration thermal analysis for BH 96-G08, except for the moss/organics layer, which was assumed to be compressed after thaw consolidation under loading of the drainage blanket or/and tailings. The assumed soil index and thermal properties for the compressed moss/organics layer are presented in Table 5.

The index properties for the sandy gravel drainage blanket and stacked tailings have been estimated from limited available information and past experience. Thermal properties of the materials were determined indirectly from well-established correlations with their index properties. Table 5 summarizes the material properties used in the thermal analyses.

TABLE 5: MATERIAL PROPERTIES USED IN THERMAL ANALYSES

Material	Water Content (%)	Bulk Density (Mg/m^3)	Thermal Conductivity (W/m-^{o}C)		Specific Heat (kJ/kg^{o}C)		Latent Heat (MJ/m^3)
			Frozen	Unfrozen	Frozen	Unfrozen	
Compressed moss/ organics after thaw consolidation	60	1.60	2.36	1.02	1.24	2.03	200
Sandy gravel placed in winter	3	2.06	1.22	1.42	0.77	0.83	20
Sandy gravel placed in winter after initial thaw	3	2.11	1.38	1.54	0.77	0.83	21
Sandy gravel after thaw consolidation under loadings from tailings	5	2.20	1.89	1.84	0.80	0.90	35
Stacked tailings	20	1.90	2.07	1.39	0.96	1.31	106

5.3 RESULTS AND DISCUSSION

One-dimensional thermal analyses were conducted for all 15 cases listed in Table 4. The predicted maximum thaw penetration into the original ground and associated time during the mine life for each of the 15 cases are summarized in Table 6. The following observations can be made from the results:

- The predicted maximum thaw depth of 1.3 m for Case 1 (placing only the 1.5 m sandy gravel drainage blanket in Feb 2007) is slightly greater than the estimated active layer thickness of 1.2 m for the original ground for BH 96-G08.
- The predicted maximum thaw depths for Cases 2 to 11 are generally similar and have limited sensitivity to the tailings placement rates and final stack heights.
- The predicted maximum thaw depths are greater for the cases where the tailings are placed directly on the original ground instead of the 1.5 m thick sandy gravel drainage blanket.
- The predicted maximum thaw depths greatly increase with increasing snow depth for the cases that simulated the ground conditions without placed tailings.

TABLE 6: PREDICTED MAXIMUM THAW PENETRATION INTO ORIGINAL GROUND FOR 15 CASES

Case	Predicted Maximum Thaw Depth below Original Ground Surface during Life of Minto Mine (2007 to 2014) (m)	Time Associated with Maximum Thaw	Comments Based on Thermal Analysis Results
1	1.3	Summer 2014	The predicted thaw depth is 0.8 m below the original ground surface in summer 2008 and increases to 1.3 m in summer 2014.
2 to 7 and 9 to 10	0.7	Summer 2007	The predicted depth of the unfrozen original overburden soils after summer 2007 is either equal to or less than that in summer 2007.
8	0.9	Summer 2014	The predicted thaw depth is 0.7 m below the original ground surface in summer 2007 and increases to 0.9 m in summer 2014.
11	0.8	Summer 2007	The thawed original overburden soils are frozen back after 2008.
12 and 13	1.4	Summer 2007 and after	The predicted depth of the unfrozen original overburden soils after summer 2007 remains the same as that in summer 2007.
14	2.2	Summer 2014	The predicted thaw depth is 1.0 m below the original ground surface in summer 2008 and increases to 2.2 m in summer 2014.
15	2.1	Summer 2014	The predicted thaw depth is 1.5 m below the original ground surface in summer 2008 and increases to 2.1 m in summer 2014.

It is noted that tailings placement warms up the original ground. The results indicate that the original ground has warmed from approaching -0.8°C to between -0.3°C and 0°C. Figures 1 to 3 present the predicted September 2014 tailings/ground temperature profiles for Cases 2 to 4, 5 to 7, and 8 to 10, respectively. Figures 1 to 3 indicate that the tailings is either unfrozen or marginally frozen with temperatures warmer than -0.3°C. The predicted tailings temperatures for the tailings placement rates of 1.5 m/year (Cases 2 to 4) and 3.0 m/year (Cases 5 to 7) are generally colder than those for the tailings placement rate of 6.0 m/year (Cases 8 to 10).

Figure 4 compares the predicted September 2014 tailings/ground temperature profiles for Cases 7 and 11. Case 11 is the same case as Case 7 but assumes that tailings are first placed in September 2007 instead of May 2007. Figure 4 shows that the predicted tailings/ground temperatures for Case 11 are colder than those for Case 7. This is attributed to the fact that the tailings placed during the summer of 2007 for Case 11 is 1.0 m thinner than that for Case 7, such that the thin 0.5 m thick tailings layer, underlying fill, and original ground for Case 11 are predicted to completely freeze back by the following winter. On the contrary, the portion of the thawed original ground beneath the tailings placed during the summer of 2007 for Case 7 is predicted to remain unfrozen after the following winter. This suggests that a thin initial summer-placed tailings layer will result in colder tailings/ground temperatures during the later stage of the mine life.

Both the thermal analysis results and past experience suggest that ground with thick snow cover would be warmer since snow serves as good thermal insulation. Snow on the surface of the active tailings placement area will likely be cleared, melted, or compressed during tailings placement. Therefore, thin lifts of tailings placed over the large area would result in thin average snow cover on the tailings surface, which, in turn, would result in colder tailings stack temperatures.

6.0 SENSITIVITY EVALUATION OF ESTIMATED MEAN AIR TEMPERATURES

6.1 UNCERTAINTY OF ESTIMATED MEAN AIR TEMPERATURES

The measured monthly mean air temperatures at the Minto site were available for the period from October 2005 to June 2006, as listed in Table 7. The measured air temperatures at Carmacks during the same period are also presented in Table 7 for comparison. However, no measured air temperatures at Pelly Ranch are available for the same period. The data in Table 7 show no clear trend between the measured air temperatures at the two sites. The average temperature during this period is 1.1°C warmer at the Minto site than at Carmacks. This observation is based on the data for a very short period and may not represent the long-term correlation between the two sites. To address the potential uncertainty associated with the estimated long-term air temperatures, another set of long-term mean air temperatures for the Minto site were estimated by interpolating the long-term mean monthly air temperatures at Pelly Ranch and Carmacks based on the distances to the Minto site but without adjusting for the elevation difference. Accordingly, the mean annual air temperature at the Minto site was estimated to be -3.5°C, which is 1.6°C warmer than that for the estimated long-term monthly air temperatures used in the previous thermal analyses. The estimated monthly long-term mean air temperatures at the Minto site for both the following sensitivity studies and the previous thermal analyses are listed in Table 7 for comparison.

TABLE 7: MEASURED AND ESTIMATED AIR TEMPERATURES AT MINTO AND CARMACKS

Month	Measured Monthly Air Temperature from October 2005 to June 2006 at Minto Site[a] (°C)	Measured Monthly Air Temperature from October 2005 to June 2006 at Carmacks[b] (°C)	Estimated Monthly Mean Air Temperature at Minto for Sensitivity Thermal Analyses in Section 6.2[c] (°C)	Estimated Monthly Mean Air Temperature at Minto for Previous Thermal Analyses in Sections 4 and 5[d] (°C)
January	-19.3	-24.1	-26.6	-28.2
February	-11.8	-15.6	-20.2	-21.8
March	-12.0	-13.3	-10.8	-12.4
April	-0.9	0.7	0.5	-1.1
May	7.3	7.4	7.9	6.3
June	13.6	13.3	13.3	11.7
July			15.4	13.8
August			12.8	11.2
September			6.6	5.0
October	-0.9	0.2	-2.4	-4.0
November	-12.7	-11.9	-15.4	-17.1
December	-10.2	-13.3	-23.4	-25.0
Average	-5.2	-6.3	-3.5	-5.1

Notes:

(a) measured at the Minto Camp climate station from October 2005 to June 2006 (Access Consulting Group, 2006)

(b) measured at Carmacks from October 2005 to June 2006 (Environment Canada website)

(c) based on Climate Normals 1971-2000 at Pelly Ranch (Environment Canada website), measured mean air temperatures at Carmacks and Pelly Ranch for the period of 1963 to 2004 (Environment Canada website)

(d) based on Climate Normals 1971-2000 at Pelly Ranch (Environment Canada website), measured mean air temperatures at Carmacks and Pelly Ranch for the period of 1963 to 2004 (Environment Canada website), and Johnston (1981)

6.2 AIR TEMPERATURE SENSITIVITY STUDIES

To evaluate the effects of the uncertainty associated with the estimated long-term air temperatures at the Minto site, a set of sensitivity thermal analyses were conducted using the warmer long-term air temperatures listed in Table 7.

Calibration thermal analyses for BH 96-G08 were repeated using the warmer long-term air temperatures. The soil profile and properties remained the same. Input data such as snow properties and ground surface conditions were adjusted. Table 8 compares the calibrated ground temperatures with those measured on September 9, 1996 at BH 96-G08. The calibrated ground temperatures are almost identical to those listed in Table 3. The predicted active layer thickness under the warmer long-term air temperatures remains approximately 1.2 m.

TABLE 8: MEASURED AND MODELLED GROUND TEMPERATURES AT BH 96-G08

Depth below Ground Surface (m)	Measured (^oC)	Modelled (^oC)
1	0.1	0.1
2	-0.5	-0.2
3	-0.7	-0.4
4	-0.8	-0.6
5	-0.8	-0.7
7.5	-0.8	-0.8
10	-0.8	-0.8

Cases 1, 2, and 7 listed in Table 4 were re-run with the warmer long-term air temperatures and calibrated snow properties. Other climatic data and ground surface properties were assumed to be the same as for the earlier analyses. The initial February 1, 2007 ground temperatures for Case 1 were estimated based on the new calibration thermal analysis for BH 96-G08. The initial May 1, 2007 ground temperatures for Cases 2 and 7 were estimated based on the revised results for Case 1.

Table 9 presents the predicted maximum thaw penetration into the original ground using the estimated warmer long-term air temperatures. The results indicate that the predicted maximum thaw depths for the current sensitivity studies are 0.1 m to 0.4 m deeper than those for the corresponding cases simulated in Section 5.

TABLE 9: PREDICTED MAXIMUM THAW PENETRATION INTO ORIGINAL GROUND FOR AIR TEMPERATURE SENSITIVITY STUDIES

Case	Predicted Maximum Thaw Depth below Original Ground Surface during Life of Minto Mine (2007 to 2014) (m)	Time Associated with Maximum Thaw	Comments Based on Thermal Analysis Results
1	1.4	Summer 2014	The predicted thaw depth is 1.0 m below the original ground surface in summer 2008 and increases to 1.4 m in summer 2014.
2	1.1	Summer 2014	The predicted thaw depth is 0.8 m below the original ground surface in summer 2007 and increases to 1.1 m in summer 2014.
7	0.8	Summer 2007	The predicted thaw depth remains the same during the life of the mine.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations can be drawn from the thermal analysis results:

- The 1.5 m thick sandy gravel drainage blanket proposed to be placed over the original ground to drain potential excess pore water in the original ground and tailings can also provide benefit in limiting thaw penetration into the original ground due to tailings placement.
- The predicted long-term tailings temperatures for tailings placement rates of 1.5 m/year and 3.0 m/year are colder than those for a tailings placement rate of 6.0 m/year. Therefore, it is recommended to limit the tailings placement rate to less than 3.0 m/year to promote freeze-back of the summer-placed tailings.
- A thin initial summer-placed tailings layer would promote freeze-back of the tailings, underlying sandy gravel fill, and original ground during the following winter and result in colder tailings/ground temperatures during the later stage of the mine life. The initial summer-placed tailings should be spread over a large area and in thin lifts to promote freeze-back of the tailings, underlying sandy gravel fill, and original ground during the following winter.
- Reduced snow cover would result in colder tailings/ground temperatures. It is recommended that snow be regularly cleared off the tailings surface.
- Snow tends to accumulate on the lower area along the toe of the tailings perimeter slopes due to both natural snow-drifting and intentional snow-clearing off the tailings top surface. It is understood that a haul road will be constructed around the toe of the lower portion of the tailings perimeter slopes. It is recommended that snow be regularly cleared off both the slope toe area and the road surface to limit thaw penetration into the original ground within the area.
- The long-term air temperatures at the Minto site could be warmer than the estimated. Sensitivity thermal analyses assuming warmer mean air temperatures indicate that the predicted maximum thaw penetration into the original ground will be 0.1 m to 0.4 m deeper than those for the corresponding cases presented in Table 6. It is recommended that the long-term mean air temperatures at the Minto site be reviewed when more data become available and the results of the thermal analyses be re-evaluated.

In addition, it is recommended that tailings/ground temperatures in the tailings placement area be regularly monitored to confirm the ground/tailings thermal conditions and to provide additional information for future mine closure design. The results from this study cannot be directly used for the closure design for the following reasons:

- The actual thermal conditions in the tailings placement area may be different from the predicted in this study due to actual different tailings placement rate, different construction schedule, and other factors. Actual tailings/ground temperature monitoring data would provide a better basis for the closure design.
- Long-term global warming effects were not considered in this study due to the relatively short mine life; however, they should be considered for the closure design.

- It is understood that climatic data will be collected at the Minto site during the mine life. The climatic data used for the current study can then be reviewed and updated for the closure design.

8.0 LIMITATIONS

The thermal evaluations in this study were based on limited available site-specific information and engineering judgement. A number of assumptions were applied in the thermal evaluations. The thermal analyses were solely based on the soil profile at BH 96-G08 under estimated long-term climatic conditions. It is expected that the soil profiles and properties will be different from one location to another over the tailings placement area, and climatic conditions over the mine life could be different from those estimated. Therefore, the actual thermal conditions may differ from those predicted in this study.

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FIGURES

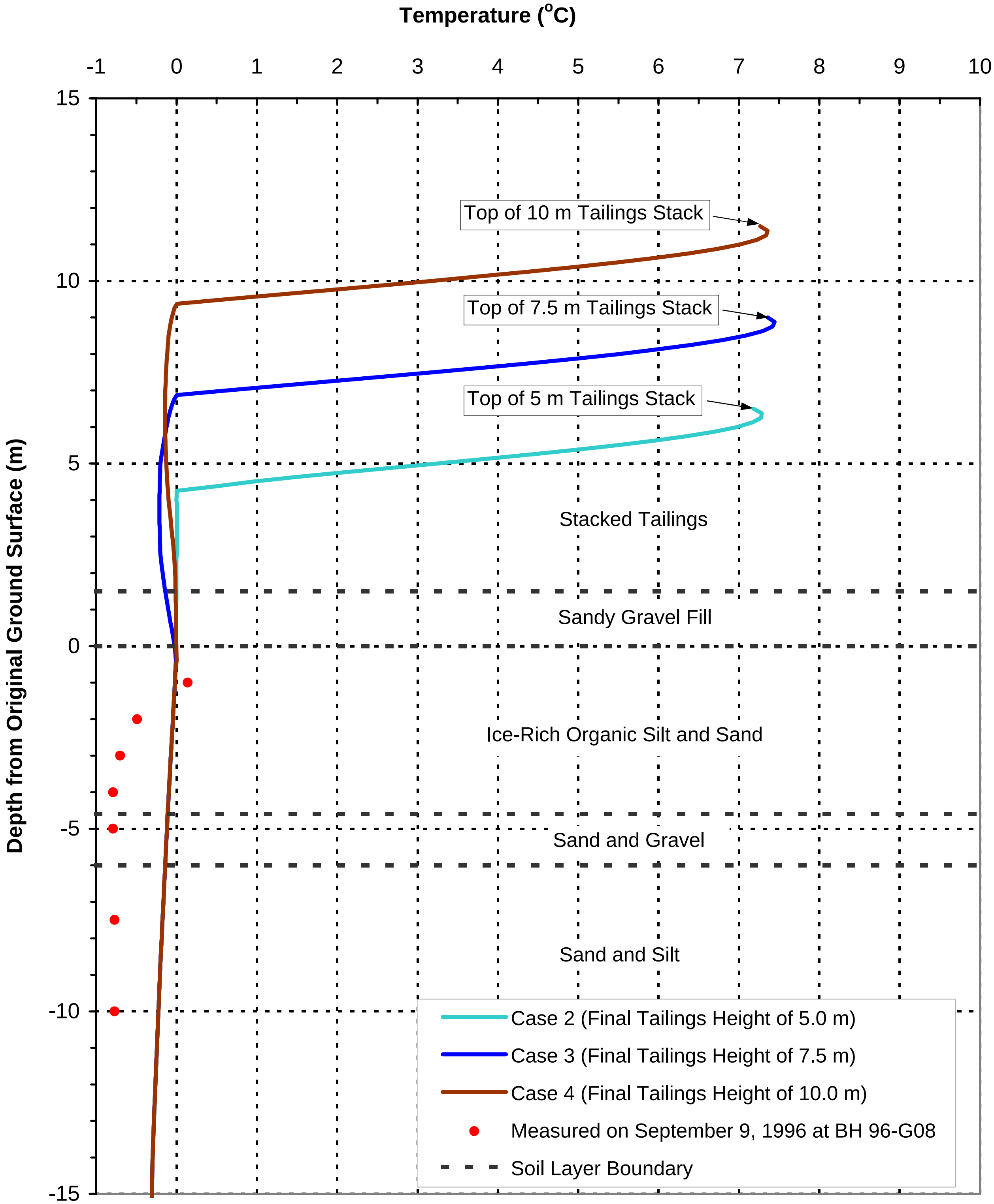

Figure 1

Predicted Tailings/Ground Temperature Profiles in Mid-September 2014 for Cases with Tailings Placement Rate of 1.5 m/year and Various Tailings Final Heights

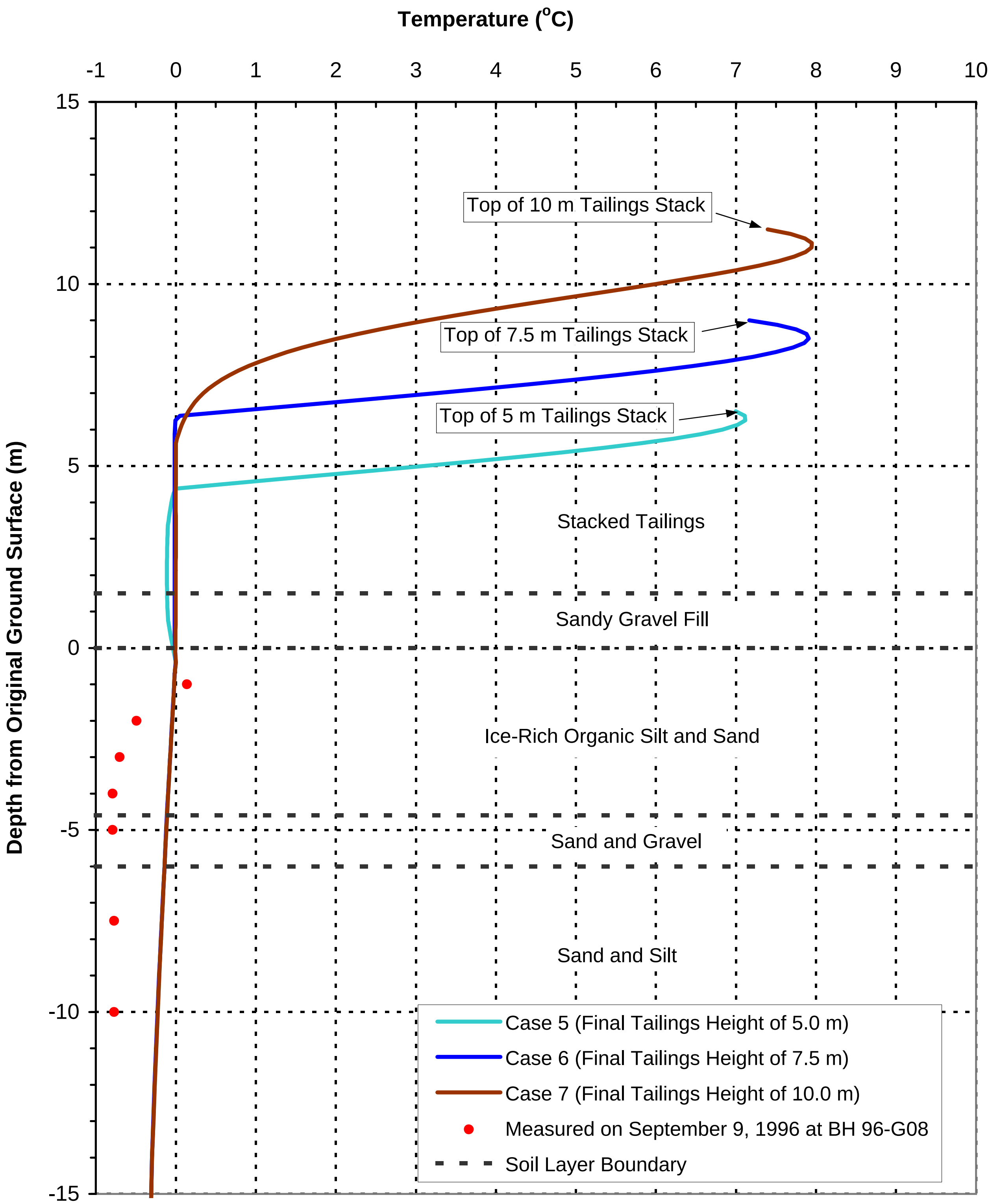

Figure 2

Predicted Tailings/Ground Temperature Profiles in Mid-September 2014 for Cases with Tailings Placement Rate of 3.0 m/year and Various Tailings Final Heights

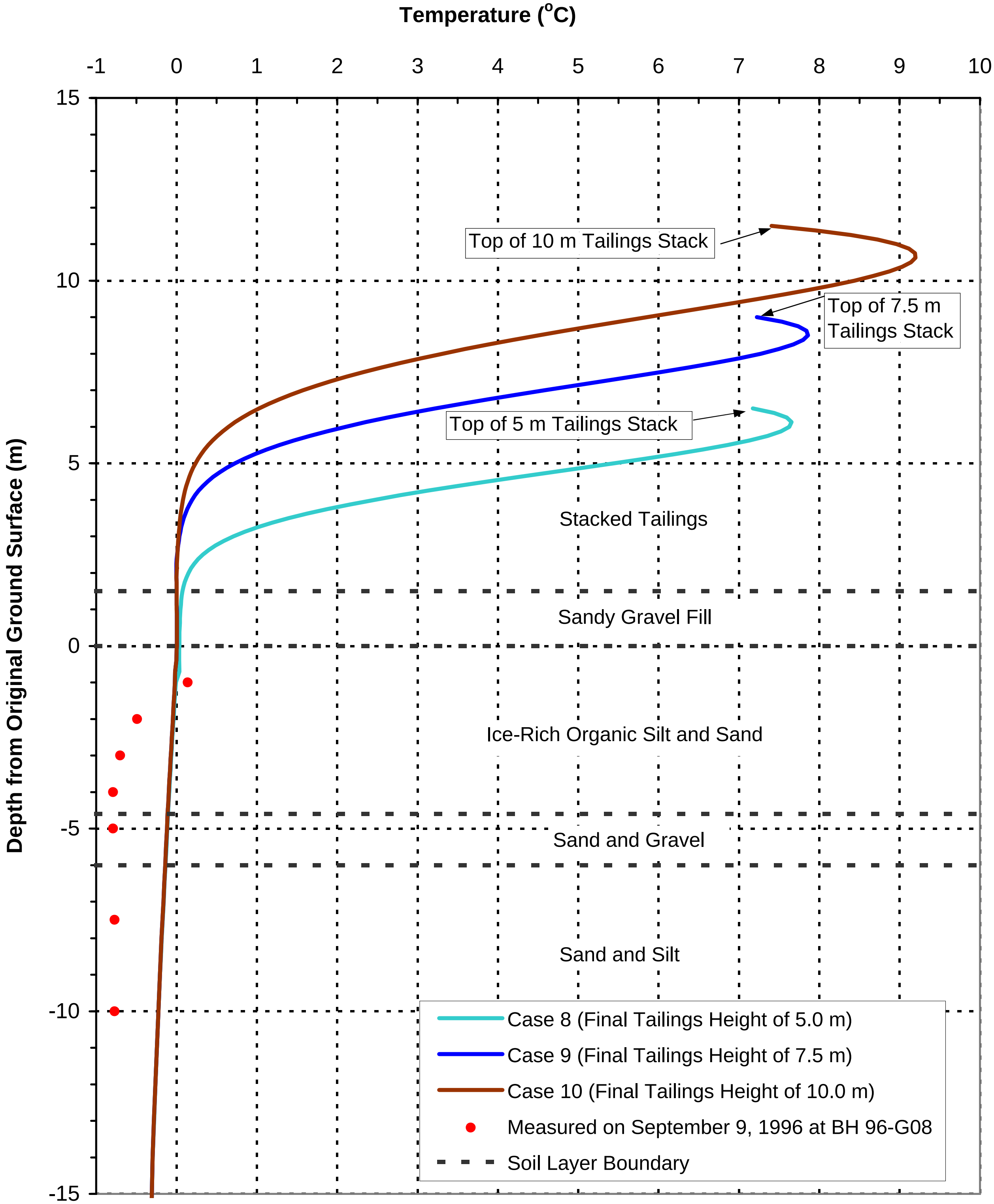

Figure 3

Predicted Tailings/Ground Temperature Profiles in Mid-September 2014 for Cases with Tailings Placement Rate of 6.0 m/year and Various Tailings Final Heights

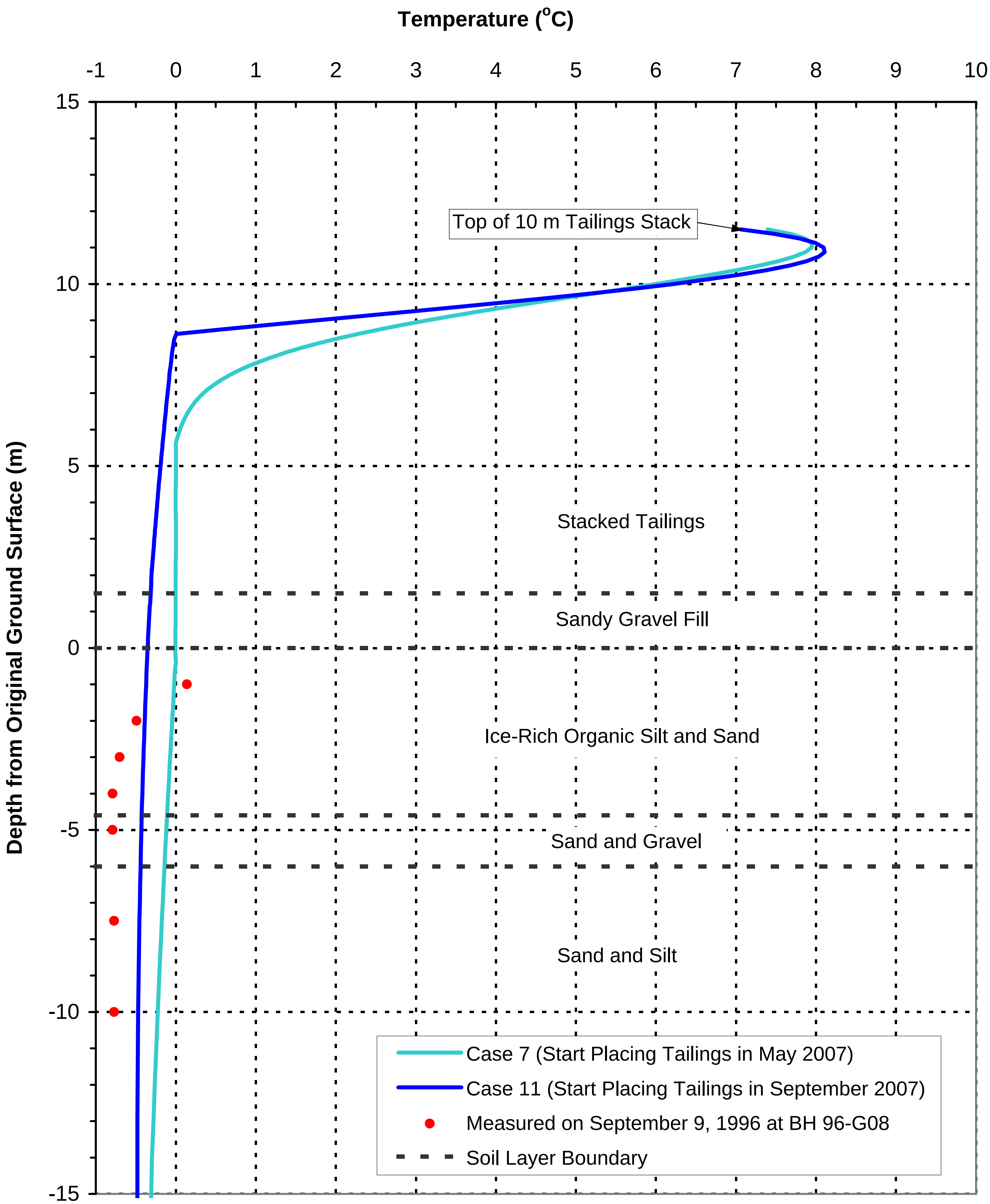

Figure 4

Comparison of Predicted Tailings/Ground Temperature Profiles in Mid-September 2014 for Cases 7 and 11 (Same Tailings Placement Rate of 3.0 m/year and Final Height of 10 m)