GEOTECHNICAL DESIGN
TAILINGS/WATER DAM
MINTO PROJECT, YUKON

0201-95-11509

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Submitted To:

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EXECUTIVE SUMMARY

The proposed Minto Project mine site is located approximately 77 km (48 miles) northwest of Carmacks, Yukon. The site is located along Minto Creek, approximately 9 km (5.6 miles) west of the Yukon river.

This report presents designs for a tailings/water dam and surface water diversion ditch in the tailings disposal basin at the Minto mine site. The tailings disposal design utilizes thickened tailings technology. The thickened tailings will be deposited at a location near the mill site, approximately 1460 m (4800 feet) upstream of the dam site with a surface slope of 5° being achieved on the surface of the tailings.

The tailings/water dam has been located at a site where: no frozen soil (permafrost) exists under the semi-impervious core of the dam, bedrock is found at relatively shallow depths under the dam footprint, the valley is the narrowest and, tailings/water storage could be significantly increased with a modest increase in dam height.

The proposed structure will be a zoned dam comprising: a central core of low permeability material for water retention, a system of filter drains to collect and discharge seepage, an upstream shell comprising native sandy residuum soils and a downstream shell of waste rock from the open pit. The dam design incorporates a "flow-through" spillway that during times of normal flow discharges water through the downstream shell, exiting out of the toe of the dam. During peak flow events, a portion of the overflow water will flow down a rip rap lined spillway on the downstream face of the dam.

This report presents the results of geotechnical site investigations at the dam location, a detailed dam and spillway design, and recommendations for construction and post construction monitoring. Evaluations of dam stability including resistance to seismic loadings have been carried out as well as determination of seepage through the dam and foundation bedrock.

An interceptor/diversion ditch has been designed along the south-facing valley slope to carry overflow water from the mill site to the dam reservoir and intercept surface runoff from the south-facing valley slopes.

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1.0 INTRODUCTION

The Minto copper/gold/silver deposit is located on the Yukon River approximately 240 km (150 miles) northwest of Whitehorse in central Yukon. The in-situ geological reserve for the deposit above a cut-off grade of 0.50% copper is 8,818,000 t (9,700,000 tons) with grades of 1.73% copper, 0.48 g/t (0.014 oz/ton) gold and 7.5 g/t (0.22 oz/ton) silver. Exploration potential exists on the property and exploration will be accelerated once the mine is in production and a positive cash flow has been achieved.

The Minto Project feasibility study has been completed and it is expected that a production decision will be made once approvals and permits have been obtained and project financing has been secured.

The mine and mill have been designed for a throughput of 477,000 t (525,000 tons) of ore per year with an initial mine life of 13 years. Contract mining will be used in the open pit operation.

The process will use conventional bulk sulphide flotation that will recover copper, gold and silver to a single concentrate. The concentrate will be shipped to the port of Skagway, Alaska and from there by ship to an overseas smelter.

A thickened tailings disposal system in which tailings are thickened to a predetermined pulp density, pumped to the disposal area and discharged from a single spigot from a topographic high, has been adopted. The thickened tailings will form a deposit with a natural slope of approximately 5% (2.9°). The sloping tailings surface can be reclaimed at the end of the life of the mine.

The tailings/water retention dam will be located in the valley below the mill. The initial dam will have a height of 32 m (105 feet) and will be 107 m (350 feet) long at the crest. Allowance has been made to permit increasing the height of the dam an additional 3m (10 feet) in the event additional tailings storage capacity is required. Surplus water will flow continuously over a weir and into the "flow-through" downstream shell at times of low flow and down a spillway channel on the downstream face during peak flow events. There will be no flow from the reservoir during the winter period.

2.0 PROJECT DESCRIPTION

The proposed mine site is located at 62.36° N latitude and 137.15° W longitude, approximately 77 km (48 miles) northwest of Carmacks. The site is located along Minto Creek, approximately 9 km (5.6 miles) west of the Yukon river. A general location map is shown in Figure 1.

Access to the site will be across the Yukon River by barge for approximately seven months of the year. An ice bridge will be built to provide access during the winter months. The existing trail on the west side of the river will be upgraded to an all-weather road for a distance of approximately 30 km (18 miles).

Both open pit and underground mining will be used. A general layout of the mine, waste dumps and concentrate stockpiles, the tailings impoundment and mill/residence area is shown on Figure 2. The facilities will occupy an area of approximately 141 ha (345 acres).

3.0 TAILINGS/WATER DAM SITE SELECTION

The final location of the tailings/water dam has been chosen based on the following:

- There is no frozen soil (permafrost) under the semi-impervious core of the dam at this location while frozen soils exist along almost all of the remainder of the north-facing valley slopes. Dam settlement due to permafrost thaw will therefore not be a concern. The three other sites previously investigated, which are upstream of the chosen location all displayed extensive thicknesses of ice-rich frozen soils on the north-facing abutment.

- This is the narrowest portion of the creek valley and therefore the smallest volume of fill material will be required to construct the dam.

- Bedrock outcrops on the south-facing abutment and for the most part is found at relatively shallow depths under the dam footprint.

- The thickened tailings will be deposited with a surface slope of approximately 5 % and at this slope, this location will yield the required tailings storage volume. There is also potential to significantly increase tailings storage with a modest increase in dam height, if eventually required.

- The dam site is located downstream of all future mining impacts on Minto Creek and therefore offers a good water monitoring and control point.

4.0 GEOTECHNICAL FIELD INVESTIGATIONS

Over the years, several geotechnical investigations have been carried out over the mine site area. Included in these investigations was work by Golder Associates in 1974 and 1976 and drilling by EBA Engineering Consultants Ltd. (EBA) in 1994. The locations of all the geotechnical boreholes, coreholes and test pits are shown on Figure 3.

The most recent drilling and sampling program was undertaken at the location of the proposed tailings/water dam in the fall of 1995. Caron Diamond Drilling of Whitehorse provided a Longyear 38 diamond drill equipped with an NQ triple tube core barrel. The drilling was conducted between September 23 and October 2, 1995. During this program, a total of 12 boreholes (95-G01, 02, 04, 05, 07, 08, 09, 10, 11, 12, 13, 14) were drilled in the dam foundation or near the tailings/water dam location. Boreholes were not drilled at locations 95-G03 and G06 because of access problems. A thermistor cable was installed in one borehole, (95-G11), to measure ground temperatures at a location immediately upstream of the dam on the north-facing valley wall. Additionally, nine constant head permeability tests were conducted in the bedrock foundations for the dam.

The skid-mounted drilling rig was moved around the site using a D6 Caterpillar dozer which was also used to construct the trails for drill rig access. The benches and trails cut into the valley slopes also afforded an ideal opportunity to visually examine the overburden soils in a relatively undisturbed state.

The locations of the boreholes drilled during the latest (1995) site investigation program, as well as the locations of the access trails, are shown on Figure 4.

Geotechnical investigations conducted by EBA during the 1994 and 1995 investigations as well as work conducted previously by others, have all been utilized to characterize the geotechnical conditions at the site. Borehole logs for the 1995 and 1994 geotechnical investigations are presented in Appendices A.1 and A.2, respectively.

5.0 GEOTECHNICAL CONDITIONS

5.1 SURFICIAL GEOLOGY

In general, the mine site is underlain by bedrock at reasonably shallow depth, with overburden soils consisting of either silty or gravelly sand materials. At some locations, (i.e. near the proposed tailings dam abutments), bedrock outcrops at surface. However, in the vicinity of the open pit, the overburden soils are as much as 85 m (280 feet) thick.

This area of the Yukon was not glaciated during the latest (Wisconsin) glacial period. Therefore, much of the overburden soil has originated from weathering of the native bedrock materials and, in some instances, has been transported by gravity, frost action and/or surface runoff.

5.2 SUBSURFACE CONDITIONS

The various investigations conducted throughout the years indicate that subsurface conditions vary considerably throughout the mine site. However, on the north-facing valley slope, in the area of interest for tailings disposal, the subsurface conditions generally comprise a thin veneer of peat and vegetation mat overlying a fine-grained silt overlying a more coarse-grained sand. The sand is considered to be a residual soil. Generally, there are less fine-grained silts on the south-facing valley slope and in the valley bottom. Over most of the proposed tailings dam location, the sandy residual soils can be found at or near ground surface. Throughout the mine site these residual soils gradually grade with depth into a weathered bedrock that eventually grades into the underlying more competent bedrock. The engineering characteristics of these overburden soils are discussed in detail in the following sections.

5.2.1 Permafrost

The site is located within a region where permafrost is noted to be extensive but discontinuous, being found over an average of 50 to 90% of the area (NRC, 1995). The results of the various drilling programs conducted throughout the years has confirmed that permafrost is discontinuous at the site. The information suggests that frozen soils exist on the north-facing valley slopes. For the most part, there has been very little frozen soil encountered on the south-facing valley slopes.

Thermistor cables have been installed to measure ground temperatures in several of the boreholes that identified frozen soil.

— possible retrogressive thaw movement! could damage installation

A thermistor cable was installed in Borehole 95-G11. This cable was installed into permafrost soil comprised mainly of ice-rich silty clay. The cable is located on the north-facing valley slope, slightly upstream of the dam but above the eventual level of water impoundment. Thus, the cable should remain intact following construction and can be used to monitor the long term effects of water impoundment on the permafrost soils present on the north-facing slope. The initial ground temperature profile measured by this cable is presented on Figure 5.

EBA also installed two thermistor cables in the tailings disposal area (Boreholes 94-G11 and 94-G21) during the 1994 investigation. The ground temperature profiles measured by these cables are also presented on Figure 5. It can be seen that slightly colder ground temperatures were encountered higher up the north-facing valley slope. The ground temperature was found to be only -0.3°C in Borehole 94-G11, drilled near the creek in the valley bottom, while a temperature of -1.0°C was measured in Borehole 94-G21, drilled on the north-facing slope.

Frozen soils/rock were not encountered on the north abutment of the tailings/water dam. The excavation of the access roads utilized for drill rig movement at the dam location during the 1995 drilling program necessitated sidehill cuts in the valley slopes which provided an ideal opportunity to determine the extent of the various surficial soils down to depths of approximately 4 metres. The visual observation of the soils exposed in the up-hill cut of these trails proved particularly effective in the determination of the boundaries between the permafrost and non-permafrost soils. These boundaries are shown on Figure 4.

5.2.2 Overburden Soils

5.2.2.1 Surficial Peat and Organic Soils

Surficial soils have been found to consist of very fibrous dark brown peat or organic silts and sands. Surficial peat thicknesses of up to 2.9 m (9.5 feet) were indicated in several boreholes drilled in the areas of the open pit and waste dumps by Golder in 1976. The drilling conducted by EBA in 1994 encountered a maximum peat thickness in the tailings disposal area of only 0.2 m (0.7 feet). In most locations peat was not found at ground surface. At these locations the surficial soil was typically found to be organic silt and sand.

5.2.2.2 Colluvium

Colluvium is defined as soil transported down-slope from its original source. Typically these soils consist of silt and/or sand. Within the upper 150 mm (6 inches), the colluvium often contains roots and organics from the surface vegetation, and occasionally a thin layer of volcanic ash.

The thickness of the colluvium varied from 0 to 5.5 m (18 feet) on the north-facing valley slope in the area of proposed tailings disposal. At the tailings/water retention dam location colluvium was found to be up to 7.0 m (23 feet) thick.

The silt colluvium typically contains some sand and a trace of gravel, is of compact consistency, is damp, and is brown in colour. The frozen silts from the north-facing valley slope were found to have moisture contents that vary between 25 and 40% and to display visible ice contents of up to 10%. Particle size analyses on two samples of the silty colluvium indicate an average composition of 5% gravel, 11% sand, 72% silt and 12% clay. Individual particle size distribution test results for the silty colluvium are presented in Appendix B.1.

The sand colluvium is generally well-graded, contains some fines, a trace of gravel and occasional cobbles. It is usually of loose to compact consistency. Particle size analyses on three samples of sand colluvium indicate an average of 5% gravel, 66% sand and 29% fines. Although it has a very similar gradation to the in situ residual soils on site (see below), it is differentiated by its disturbed structure and lower density, which indicates that it has been transported to its present location. Individual particle size distribution test results for the sand colluvium are presented in Appendix B.1.

5.2.2.3 Residuum

A layer of residuum (residual soils) is often found directly underlying the surface colluvial deposits. However, in some instances the residuum is found immediately at ground surface. These soils are similar in composition to the colluvial sands, but were visually distinguished in the field by the resemblance of structure to the underlying parent bedrock.

Standard Penetration Test (SPT) blow counts in the residuum varied from as low as 7 to well over 100 blows per foot, indicating a wide range of consistency from loose to very dense. Typically, the consistency increases with depth, with the upper

3.0 to 4.5 m (10 to 15 feet) being loose to compact and the deeper residuum being very dense.

Moisture contents measured in the sand residuum ranged from 3 to 15%. These sands did not contain visible ice when encountered in a frozen state (on the north-facing valley slope). The EBA boreholes did not penetrate any frozen residuum on the south-facing valley slope.

Grain size analyses were undertaken on 12 samples of residuum (5 from the area of tailings disposal and 7 from the proposed plant site). These tests indicated an average of 75% sand, 16% silt and clay sizes, and 9% gravel. The percentage of sand sizes varied between 66 and 85%, and the range in fines varied from 3 to 33%. This indicates that there are zones or layers that are relatively "clean" and also ones that are relatively "dirty". In general, the gradations indicate a relatively well-graded sand with some silt and clay. Individual particle size distribution test results for the residuum samples obtained are presented in Appendix B.2.

Additional laboratory testing was undertaken on combined samples of these residuum soils to evaluate their characteristics when used as dam fill. Results of these tests are discussed in Section 6.1.2 and are presented in Appendix B.3.

The thickness of the residuum in the tailings disposal area varied from as little as 1.7 m (5.5 feet) in Borehole 94-G16 to over 7.7 m (44 feet) in Borehole 94-G15. The residuum becomes increasingly more dense with depth, grading gradually into the underlying weathered bedrock, making interpretation of the boundary between the sand and the bedrock difficult. Drilling was terminated prior to encountering bedrock or refusal in several of the boreholes; therefore, the maximum thickness of the residuum is uncertain. At the dam location the thickness of the residuum varied between 0 and 4.5 m.

5.2.2.4 Clay

Fine-grained clayey soils were encountered at a few locations during both the 1974 Golder investigation and EBA's 1994 and 1995 programs. Golder identified clay soils in shallow test pits located in the overburden near the open pit. A clay soil layer was also found in EBA Boreholes 94-G21 and 95-G11, located on the north-facing valley slope (see Figure 3).

Potential suitable fine-grained soil for use as material for construction of the dam core was also identified along the access road into the mine site. Four samples were collected by Minto personnel, at several locations close to the east edge of the lease limits. The samples were taken at a location with approximate coordinates 18700N and 16500E. Particle size distribution test results for these samples are presented in Appendix B.4.

The EBA 1994 investigation encountered frozen clayey soils in the upper 19.0 m (62 feet) of Borehole G94-21. Liquid limits for these materials varied between 33 and 69% with corresponding plastic limits varying between 18 and 26%. Particle size distribution analyses for the tested samples showed clay sized particles ranging from 48 to 88%, silt ranging between 11 and 36% and sand and gravel from 1 to 16%. Moisture contents in the clay samples varied between 10 and 38%. For the most part, these soils were not significantly ice-rich although several samples did display visible ice lenses of up to 10 mm thickness and visible ice contents of up to 10%. Particle size distributions for three samples from EBA Borehole 94-G21 are presented in Appendix B.5. Similar clay soils were encountered in the upper 7.5 metres of Borehole 95-G11.

Additional laboratory testing was undertaken on combined samples of the clay materials to evaluate their suitability and characteristics for use as dam core fill. Results of these tests are discussed in Section 6.1.1 and are presented in Appendix B.5.

Visual examination of these clay soils has indicated the presence of thin lamina or varves. This would indicate that these clay soils result from sedimentation in a lacustrine environment. Although this area was not glaciated during the latest (Wisconsin) glaciation, it is believed that earlier glacial events occurred in this area. Therefore, the source of these clay sediments may be the result of a lake (possibly ice dammed) existing at the site during one of the earlier glacial events.

5.2.3 Bedrock

The bedrock present at the dam site and throughout the property, consists primarily of granodiorite. This rock is a hard, crystalline, intrusive igneous rock commonly found in the Minto area. Bedrock was cored in 11 of the 12 holes drilled during the 1995 EBA site investigation. In general it is often difficult to determine where the overburden soils (residuum) ends and where the rock begins since the residuum is a result of in situ weathering of the bedrock.

The parent bedrock ranges in composition from predominantly granodiorite to quartz diorite, with minor quartz monzonite. The average mineral constituents are plagioclase feldspar (50%), quartz (20 to 25%), orthoclase feldspar (10 to 15%) and biotite/hornblende 10 to 15%. Orthoclase and plagioclase feldspar make up the primary grains in the sand that results from weathering of the rock, interspersed with quartz and minor biotite hornblende. This sand is considered to be very resistant to future weathering and degradation in it's present state, as most of the biotite/hornblende has already been weathered away to leave behind the more stable minerals. — doesn't the feldspar weather into clayey minerals?

Core recovery in the bedrock in the dam foundation area varied between 65 and 100 % but averaged over 90 %. The rock quality designation (RQD) was highly variable, ranging from as low as 20 to a high of 80 %. For the most part, the bedrock at the dam location becomes less weathered and less fractured with depth although some highly fractured zones and fractures filled with silts and sands were encountered in a few of the boreholes. For instance a 2.9 metre thick fractured zone (possible shear zone) was encountered in Borehole 95-G04 at a depth of 5.8 metres.

A total of 9 constant head packer tests were carried out in three different boreholes (95-G02, G04 and G14) in the bedrock which would be the foundation for the semi-impervious core. The testing was conducted using a triple packer wireline system obtained from Petur Instruments. The results of this testing are presented in Table 1 and plots of the test results are presented in Appendix A.3.

TABLE 1
PERMEABILITY TEST RESULTS

Borehole No.	Test Depth (metres)	Head (m H_2O)	Flow (L/min)	Permeability (cm/sec)
95-G02	7.5 - 10.8	31.2	1.01	$1.8x10^{-5}$
	7.5 - 10.8	48.5	1.43	$1.6x10^{-5}$
	7.5 - 10.8	29.8	1.39	$2.5x10^{-5}$
	5.0 - 8.4	31.2	0.71	$1.3x10^{-5}$
95-G04	5.6 - 9.0*	24.6	10.5	$2.3x10^{-4}$
	5.6 - 9.0*	38.7	23.3	$3.4x10^{-4}$
	5.6 - 9.0*	24.6	12.0	$2.7x10^{-4}$
95-G14	5.6 - 8.5	31.5	35.2	$7.2x10^{-4}$
	5.6 - 8.5	21.0	24.1	$7.6x10^{-4}$

* test conducted in a highly fractured zone (possible shear zone)

6.0 TAILINGS/WATER DAM DESIGN

It is initially proposed that the dam will be constructed to an elevation of 2260 feet. To provide additional tailings storage, there is a possibility of increasing the height of the dam by 10 feet to an elevation of 2270 feet. Consequently the dam has been designed to accommodate this possible future increase in dam height.

The proposed dam location is shown in plan on Figure 6. Cross sections and subsurface stratigraphy through the dam are shown in Figures 7 and 8. A typical design cross section is presented on Figure 9.

The proposed tailings/water retention structure will be a zoned dam comprising: a central core of low permeability material for water retention; a system of filter drains to collect and discharge any seepage which may occur through the core and foundation of the dam; upstream and downstream shells to provide stability to the structure. The semi-impervious core will be constructed of sandy, silty clay material identified along the access road into the mine site, on the east edge of the lease boundary. The upstream shell of the water retention dam will be constructed with weathered granodiorite (residuum) obtained from the north valley slope upstream of the tailings dam site. Residuum from the open pit overburden may also be used for the upstream dam shell. The downstream shell of the dam will be constructed of shot rock from the open pit waste materials.

The primary reason for adopting the use of waste rock from the open pit for constructing the downstream shell of the dam is to facilitate the construction of a "flowthrough" or "in-built" spillway. This concept involves constructing a spillway over the top of the dam and permitting the water to flow into and through the rock filled downstream shell. This concept has been used in a variety of dams dating back to 1859. Major advances in the construction of in-built spillways were led by Weiss (1951), Wilkins (1956) and Parkin (1963). Examples where this type of spillway has been used in Canada include the Swift Creek flow-through rockfill drain near Elkford, British Columbia described by Lane et al (1986) and a structure for the abandonment of acid-generating metal tailings in the Yukon described by Garga et al (1983).

The dam has been designed to meet the requirements of the Canadian Dam Safety Association (CDSA) Guidelines. Due to the dam's remote location, the potential risk of loss of life and potential environmental and economic losses caused by area is required prior to finalizing the detailed design drawings. The proposed core material is similar to a clayey borrow that was identified in the 1994 investigation, although the new borrow source is less clayey.

The following summarizes laboratory testing conducted on the clay material identified in the 1994 investigation. An average sample of the core material was created by combining together several samples of clay. Atterberg Limit testing of this combined sample indicate a liquid limit of 53% and a plastic limit of 19%. Clay, silt and sand contents of 58, 22 and 20%, respectively, were determined for the combined sample. The moisture-density relationship of the combined material was evaluated by conducting a Standard Proctor Test (ASTM D698). Results of the Proctor test indicate a maximum dry density of 1665 kg/m^3 (104 lb/ft^3) at an optimum moisture content of 20.7%. A multi-stage consolidated undrained triaxial test and a constant head permeability test were performed on reconstituted samples of this clay compacted to approximately 95% of Standard Proctor maximum dry density. The triaxial test indicated a remolded friction angle of 20° and cohesion of 21 kPa (3 psi). The permeability test indicated a permeability of 7.9 x 10^{-9} cm/sec (2.6 x 10^{-10} feet/sec). Test results for the combined clay samples are presented in Appendix B.5.

6.1.2 Upstream Dam Shell

The proposed borrow material for the upstream shell of the tailings dam and all the access roads, drainage ditches, etc. is predominantly the weathered granodiorite bedrock (residuum). This material covers the majority of the south-facing valley wall, and is available in sufficient quantity for all the proposed construction. The residuum is locally overlain by colluvium, which also consists mostly of weathered granodiorite bedrock transported down slope as a result of erosion from above. Both of these materials are classified as SAND-some silt and clay, trace of gravel.

A series of laboratory tests were conducted to determine the suitability of the residuum for use as fill material in construction of the upstream shell of the tailings dam. A large sample of the typical residuum was created by combining several individual samples. A Standard Proctor test (ASTM D698) indicated a maximum dry density of 2125 kg/m^3 (133 lb/ft^3) at an optimum moisture content of 9.0%. The moisture density relationship and particle size distribution results for the combined sample (No. 2187) are presented in Appendix B.3.

~~potential risk of loss of life and potential environmental and economic losses caused by~~ failure will all be low. Therefore the dam has been designed using recommendations pertaining to the CDSA category "Low Consequence".

The estimated quantities of fill materials required for dam construction, based on the cross section presented on Figure 9 are presented in Table 2.

TABLE 2
COMPACTED FILL QUANTITIES FOR DAM CONSTRUCTION

Material	Quantity (m^3(yd^3))
Residuum (upstream shell)	44,833 (58,640)
Rock Fill (downstream shell)	34,673 (45,351)
Core	29,490 (38,572)
Fine Filter	9,956 (13,022)
Coarse Filter	19,540 (25,558)
TOTAL	138,492 (181,143)

In addition to the quantities given above, there will be an estimated 12,820 m^3(16,767 yd^3) of overexcavation required beneath the dam core and downstream filters.

Integral with the dam will be a diversion ditch on the south-facing valley slope which will divert water around the deposited tailings and flow into the water reservoir upstream of the dam.

6.1 EMBANKMENT CONSTRUCTION MATERIALS

The proposed materials for construction of the dam are discussed in the following sections. Particle size distribution specifications for each material are presented in Appendix H.

6.1.1 Semi-Impervious Core

A semi-impervious core will be constructed using a sandy, silty clay material available from an area along the access road at the eastern limits of the lease boundary. Limited laboratory testing has been conducted on the proposed core why 88% ?

A series of three direct shear tests conducted on the combined residuum sample prepared to 88% of the maximum dry density indicate an angle of internal friction of 36°. These test results are presented in Appendix B.3.

A series of laboratory constant head permeability tests were conducted on the combined residuum sample. Results of the permeability tests indicate that the permeability of the remolded residuum compacted to approximately 95% of Standard Proctor maximum dry density is 2 x 10^{-6} cm/sec (6.6 x 10^{-8} feet/sec). Copies of the permeability test results are presented in Appendix B.3.

The possibility of using a fraction of the native residuum as a granular filter was also evaluated. To be used as a filter, the material would have to be screened and washed to remove the majority of the fines. This was evaluated in the laboratory by decanting a combined residuum sample to remove fines and conducting laboratory constant head permeability tests on the washed sample. Results of these tests indicate that the permeability of washed residuum compacted to approximately 95% of Standard Proctor maximum dry density is 3.0 x 10^{-4} cm/sec (1.0 x 10^{-5} feet/sec). Copies of the permeability test results are presented in Appendix B.3.

6.1.3 Rip Rap and Downstream Shell

Rip rap armour will be required for lining the diversion ditch, spillway and on the upstream face of the dam. The proposed source of this material is overburden waste rock from the open pit. The downstream shell of the tailings dam will also be constructed of shot rock from the open pit waste rock. This waste rock will primarily comprise the upper parent bedrock.

6.1.4 Filters

As indicated in Section 6.0, a significant quantity of filter material will be required. This includes a series of filters which will be required downstream of the central core and also underlying the various layers of rip rap. These filters will be primarily composed of screened (and crushed) material from the open pit waste rock. It is also proposed that a "washed" residuum be used for the fine filter downstream of the core, as discussed in Section 6.1.2, above.

6.2 PERMAFROST INTEGRITY

The engineering design of structures, roads and embankments in permafrost regions typically requires preparing designs that will not alter the present state of the permafrost. Any thawing of frozen soils, unless they contain little ice and are dense, can lead to strength loss and instability of foundations, slopes and embankments. The geotechnical investigations conducted to date have indicated the presence of fine-grained soils with variable quantities of visible ice, particularly on the north-facing valley slope. Thawing of these soils, could in some cases lead to a considerable loss of strength and lead to settlement.

The impoundment of water by the tailings dam will inevitably lead to thaw of the frozen soils below the water level on the north-facing valley slope and in the foundations of the tailings dam. This has lead to the selection of a location for the tailings dam in which the dam footprint will be located either directly on competent bedrock or on very dense sand residuum material. An evaluation of the extent of thaw and its impact on the stability of the natural slopes surrounding the tailings disposal area was undertaken and is discussed in further detail in Section 6.7 and in Appendix E.

The presence of permafrost soils on the north-facing valley slope has led to the siting of the dam spillway and diversion ditches on or near, the south-facing valley slope where for the most part, permafrost is not present.

The proposed diversion ditch and access road along the north side of the tailings disposal area will cross a location on the south-facing valley slope where solifluction movements were noted in the 1974 Golder report. The presence of solifluction movements would indicate that frozen soils likely exist in this localized area. The ditch and roadway is therefore designed to maintain the permafrost at this location (see Figures 2 and 13). At this location the road is designed as a fill section with a minimum 1.5 m thickness. This thickness is expected to maintain the surface of the permafrost at or above its current elevation. Where frozen soils are not present along the diversion ditch, the road can be constructed as either a cut or fill section. Details regarding the diversion ditch and access road are provided in Section 7.4.

- road is 1.5 m thick & Fill but spillway cuts into native soil!

6.3 DAM STABILITY

6.3.1 Slope Stability

The dam cross section has been designed to satisfy stability criteria both under static conditions and during an assumed design earthquake acceleration loading.

The primary constituents of the dam comprise the clay core, coarse-grained residuum for the upstream outer shell and waste rock from the open pit overburden. Based on laboratory test information presented in Section 6.1 for clay and residuum, the design parameters selected for these materials, assuming a minimum remolded density of 95 percent Standard Proctor, are as follows:

TABLE 3
SOIL PARAMETERS USED FOR STABILITY ANALYSES

Soil Type	Bulk Density (kg/m³)/(pcf)	c' (psf)	ø
Clay Core	1890/118	0	20°
Residuum (Upstream shell)	2080/130	0	35°
Shot Rock (Downstream shell)	2080/130	0	40°
Filter Material	2080/130	0	35°
Weathered Bedrock	2080/130	0	35°

Laboratory testing on the shot rock is not possible at this stage, therefore, assumed parameters have been used for this material. Similarly for the filter materials, parameters have been assumed that are the same as the remolded residuum.

The laboratory testing for clay borrow was conducted on material which was finer grained than the current borrow source. Therefore the strength parameters utilized in the analyses are considered to be conservative for the material from the currently proposed borrow area.

A seepage analysis was conducted to determine the position of the phreatic surface that would be established through the core due to seepage over the long-term. The results of the seepage analysis are discussed in Section 6.4.1 and in Appendix D. Based on this seepage analysis, a pore pressure grid was generated and imported into the slope stability program for analysis.

Stability analyses were conducted using a computer program (SLOPEW) which utilizes limit equilibrium theory to solve for the factor of safety. The analyses assumed a two dimensional situation, which is considered to be conservative given the steep-walled valley slopes in the vicinity of the dam.

In the event that pore pressures do develop in the clay core during construction, analyses were conducted assuming a $\bar{B}$ of 0.5. This analysis yielded a minimum factor of safety of 2.12. The foundation soils are considered to be relatively free draining and therefore excess pore pressures are not anticipated to be generated during construction of the dam.

The initial case evaluated in the slope stability analysis was the dam in a 'dry' condition with no seepage through or beneath the dam, which is representative of conditions at the end of construction. These analyses indicate a factor of safety of 2.12, with the critical failure surfaces being relatively shallow slip planes parallel to the downstream face of the dam.

Analyses were also conducted for the full impoundment condition using pore pressures derived from the seepage analysis, which is considered to be representative of the steady state seepage conditions with maximum reservoir storage. This analysis yielded a factor of safety of 1.83 for failures at the downstream toe of the dam. Similar analyses for failure surfaces which extend through the centre of the dam indicate a factor of safety of 1.97. The minimum factor of safety recommended by the Dam Safety Guidelines prepared by the CDSA is 1.5 for the steady state seepage condition.

As water will be continually spilled over the crest of the dam and permitted to flow through the downstream shell, a phreatic surface will be generated due to average summer flow conditions. Due to the relatively low predicted summer flows (0.04 m^3/sec), it is estimated that all the water will flow through the coarse filter on the downstream side of the core. Stability analyses conducted with this phreatic surface indicate a factor of safety of 2.10.

In the event of a 1:200 year design flood, 5.0 m^3/sec will flow through the spillway developing a temporary higher phreatic surface in the downstream shell. Using this higher phreatic surface, a factor of safety of 1.50 was calculated for a deep seated slide and 1.09 for a localized slide at the toe of the dam.

A rapid drawdown of the dam is not considered possible and therefore has not been considered in the analysis. If any drawdown within the reservoir were to occur, it would be governed by the capacity of the pumps that will be pumping the water up to the mill. Based on the anticipated water requirements calculated by Minto Explorations Ltd., the water level will be drawndown in the reservoir by a maximum of 1.5 m (5 feet) over the winter months (5 month period). Stability analyses of the upstream face in a submerged condition indicate a minimum factor of safety of 1.77. The minimum recommended factor of safety by the CDSA for the upstream dam face is 1.2 to 1.3.

A detailed discussion of the dam stability analysis is presented in Appendix C.

6.3.2 Seismic Stability

A pseudo-static stability assessment of the dam under earthquake loading was also carried out to evaluate the stability of the dam under an imposed seismic loading condition. The analysis used a pseudo-static approach, as is common state-of-practice, and has assumed that the residuum foundation soils beneath the dam would not liquefy. In the event that soft, loose soils are encountered during base preparation under the dam shells, this material will be overexcavated and replaced with compacted residuum.

Information regarding seismicity for the site was provided by the Earth Physics Branch of Energy Mines and Resources Canada, Pacific Geoscience Centre, in Sidney, B.C. The site is characterized as being in Acceleration Zone 3 and Velocity Zone 4. An acceleration of 0.083 g and horizontal ground velocity of 0.196 m/s would have a 10% probability of being exceeded in 50 years, which equates to an annual probability of exceedance of 1/475.

Using the steady state long term seepage condition and a horizontal load applied by a maximum 0.083g acceleration, the stability analyses determined a minimum factor of safety against slope failure of 1.43. The minimum factor of safety typically accepted for design seismic loading events is 1.2.

6.4 OPERATIONAL CONTROLS

6.4.1 Seepage

The requirements for water in the milling process will require careful water management in the water retention pond to ensure an adequate water supply through the winter months when there is no flow in Minto Creek. Therefore, only minimal seepage loss through the tailings dam can be permitted. A water balance for the mine operation has shown that there is effectively no change to the hydrological regime of Minto Creek downstream of the tailings dam due to the self-regulating nature of the water retention pond. This is reflected in the design criteria for a spillway that will handle the maximum anticipated flow in Minto Creek (1 in 200 year, 24 hour event).

Minto Explorations Ltd. has indicated that the main water supply pond is expected to have sufficient water retention time to settle out any residual fine materials.

An analysis was conducted using a finite element computer program (SEEP/W) to evaluate the seepage of water through and beneath the dam due to the impoundment of tailings and water. Details regarding the analyses are presented in Appendix D. The majority of the flow occurs in the foundation rock below the dam core. Based on the seepage analysis, the seepage rate through the dam is estimated to be 14.3 m^3 (500 ft^3) per day, which is less than 0.5 % of the average daily flow in Minto Creek. One packer test in a very fractured section of Borehole 95-G04 displayed permeabilities of approximately 1 x 10^{-4} cm/sec. If it was assumed that all of the bedrock in the foundation was comprised of this highly fractured rock, the total seepage would increase to approximately 113 m^3 (4000 ft^3) per day. This would be considered an absolute worse case seepage loss. However, the value of 14.3 m^3 (500 ft^3)/day is considered to be a realistic estimate given the bedrock conditions encountered in the majority of the boreholes.

In the long term, as fines settle out of the ponded water stored behind the tailings/water retention dam, and as tailings begin to infill behind the dam, there will be a blanket formed on the upstream face of the dam and on the floor of the valley. This will tend to seal off seepage through and beneath the dam, further reducing seepage.

6.4.2 Process Water Supply

Runoff will be collected and stored in a small mill water storage pond and behind the tailings/water retention dam. The mill water storage pond located just below the mill, will have a depth of 9.1 m (30 feet) and have a capacity of approximately 20,000 m^3 (26,000 yd^3). Water from the tailings thickener, water pumped from the open pit and surface runoff from the upper part of the drainage basin will be collected in the mill water storage pond. The pond will be self-regulating and will overflow continuously via a culvert into the diversion ditch leading to the tailings/water storage basin.

The main water storage pond will initially have sufficient capacity to store approximately 365,000 m^3 (474,000 yd^3) of water. The water storage capacity of the main pond will decrease in time as tailings infill the lower portion of the valley adjacent to the dam structure. The level of water in the main water pond will be set by the base elevation of the spillway (initially 2350 feet).

A reclaim water pump will be set in the main water retention pond, close to the dam. The reclaimed water line will be 75 mm (3 inches) in diameter and will be insulated and fitted with heat tracing. This reclaim water line will be laid on a berm adjacent to the access road between the mill and the dam.

Calculations by Minto Explorations Ltd. indicate that during the winter months there will be a shortfall of process water which has to be made up from the water retention pond. Assuming no surface water flows into the tailings basin for 5 months of the year, there will be a net water loss of 75,300 m^3 (98,490 yd^3) due to seepage loss and water "locked up" in the tailings. This quantity of water loss equates to a maximum drawdown in the reservoir level of 1.5 m (5 feet), which would occur gradually over a 5 month period.

6.5 ENVIRONMENTAL PROTECTION

Based on studies by others, the water flowing from the thickened tailings into the water retention pond and subsequently through the spillway and into Minto Creek will be relatively low in heavy metals. Tailings effluent was found to be non-toxic to fish; in fact, Minto Explorations Limited (1994) expects that it would meet Canadian drinking water standards.

Robinsky (1995) has determined that the thickened tailings will not separate into finer and coarser fractions when they are deposited into the tailings disposal area. Thus, the thickened tailings will not yield water in the main water supply pond containing suspended solids that would eventually be discharged through the spillway into Minto Creek.

6.6 CONSTRUCTION CONSTRAINTS

It is understood that construction is tentatively scheduled for the summer/fall of 1996 such that the tailings/water retention dam will retain the runoff from the following spring freshet. The quantity of water impounded should therefore be sufficient to satisfy the water requirements for mill start up.

The dam will have to be constructed during months when the average air temperature is above freezing in order that the impervious core and dam shell materials can be compacted to their specified density. Construction of the dam will also require temporary damming of Minto Creek during the start of dam construction. It is expected that the typical flows in Minto Creek could readily be handled by construction of a temporary cofferdam located at the upstream toe of the proposed dam location equipped with a suitably sized pump. This cofferdam will subsequently form a portion of the upstream shell of the dam. Additional sumps and pumps may also be required within the limits of the dam footprint depending on groundwater flow below the base of the creek valley.

The excavation of any existing frozen fine-grained soils in the dam foundation, as well as careful identification of competent bedrock below the impervious core must be carried out during construction. More detailed requirements for construction are outlined in Section 8.2 and are presented in Appendix G.

6.7 IMPACT OF TAILINGS AND WATER ON SUBSURFACE CONDITIONS

Impounding of water and tailings behind the tailings dam will alter the geothermal conditions applied to the ground surface. These changed conditions will include a warmer mean annual ground surface temperature on the underwater slopes, which will initiate thaw of the frozen soils typically found along the north-facing valley slope. Thaw of these soils could lead to retrogressive slides above and below any ponded water on this slope. Analyses to evaluate the extent of this thawing and its effect on the stability of the slope and dam foundations have therefore been undertaken. A detailed description of the geothermal analyses carried out is presented in Appendix E.

The predictions indicate that all of the permafrost originally existing below the maximum water level will thaw within about 10 years of water impoundment. Furthermore, thaw of the permafrost soils is predicted to extend as much as 12 m (40 ft) up-slope from the water surface.

The predicted thaw is anticipated to lead to some small slope movements within the thawed ice-rich soils. Movements of the thawed pond-bottom soils are not of themselves a concern since they will eventually be covered and stabilized by the tailings infill. However, it is possible that sloughing conditions could initially extend above the water surface along the perimeter of the pond on the north-facing valley slope. These movements could trigger shallow, retrogressive slides up the valley wall. Therefore, the need for remedial maintenance is anticipated, to provide stability at the onset of any slump movements as they appear above the water surface. These failures can be stabilized by overexcavating the thawed ice-rich soils and replacing them with a section of stable granular fill that is of sufficient dimensions to provide thermal protection against further progressive thaw into up-slope soils. The remedial measures will most likely need to be undertaken during the first winter following water impoundment to the maximum level.

The tailings dam design utilizes a thick semi-impervious core founded directly on bedrock. The shells of the dam, which will be constructed from sand residuum and waste rock, will be founded on natural dense residuum since the ice-rich materials that exist locally under the dam will be excavated during construction (as shown in Figure 9). Although initially frozen on parts of the north-facing valley slope, the natural residuum typically contains no excess ice and exists at moisture contents of less than 10%. Therefore, this material is not expected to settle or display a strength loss to any appreciable extent when thawed. The thawing of the permafrost below the dam is therefore not expected to be of concern from either a settlement or stability viewpoint.

6.8 INSTRUMENTATION

A series of instruments is proposed to monitor the stability and hydrostatic water levels during mine operation. The suggested instrumentation includes: settlement plates, survey points, pneumatic piezometers and thermistors. Figure 10 presents the suggested instrumentation for the tailings/water dam.

EBA has previously installed three thermistor cables in the north-facing valley during the geotechnical investigations conducted at the site. Two of these thermistor cables are installed at locations which will be above the elevation of water impoundment or tailings deposition (Boreholes 95-G11 and 94-G21). These instruments should be monitored during mine operation to assist in evaluation of the effects of the tailings and water on the geothermal conditions existing on this valley slope. Care must therefore be taken to ensure that these installations are not damaged during construction. - or Fail after during slope movements

A total of 10 settlement points should be installed along the crest of the dam. This will include two rows of five points along the upstream and downstream edges of the dam crest as shown in Figure 10. The required settlement points can also serve the dual purpose of measuring horizontal movement (survey points) as well. The settlement plates should comprise a 50 mm (2 inch) diameter steel pipe of at least 1.5 metre length welded to a 60 cm by 60 cm (24 x 24 inch) steel plate. The plates should be installed by burying in the dam fill materials such that only the tops extend 10 cm (4 inches) above the dam crest elevation.

It is suggested that a total of 13 pneumatic piezometers be installed within the soils/rock underlying the dam. A nested set of two pneumatic piezometers should be installed upstream of the core. Three sets of three piezometers should be installed under the dam crest as shown on the plan view of Figure 10. A second set of two piezometers is proposed under the downstream shell. Piezometer locations and elevations are presented on Figure 10. These piezometers should be installed after dam construction in suitably sized boreholes drilled to the required depths.

7.0 SITE HYDROLOGY AND WATER MANAGEMENT

7.1 SITE HYDROLOGY

Hallam Knight Piesold Ltd. has completed an evaluation of the current and expected stream flow and surface runoff quantities for the Minto Creek Valley. This evaluation has indicated that the average monthly stream flow in Minto creek amounts to 0.04 m^3/sec (1.41 ft^3/sec). Based on surface runoff calculations they have also determined that the maximum 1:200 year peak design flow that could be expected in the diversion spillway would be 5.0 m^3/sec (175 ft^3/sec). This volume was utilized in the design of the spillway. Although conservative, this value has also been utilized in the design of the diversion ditch.

7.2 SPILLWAY

A discussed above, the spillway has been designed to handle the 1:200 year design peak flow of 5.0 m^3/sec (175 ft^3/sec). A spillway cut into rock on the north abutment was initially considered as the preferred location for the spillway. However, the average valley slope is approximately 30 to 35° at this location and excavation of a spillway with suitable width into this side slope would require removal of significant quantities of material. In fact, this would involve a rock cut of approximately 30 m (100 feet) height on the north side of the spillway. With a cut slope of this height, there were significant concerns regarding the long term stability and ravelling of the slope. Eventual spalling of material from the cut slope could result in blockage of the spillway and possibly diversion of water onto the downstream face of the dam. Therefore a "flow-through" or in-built spillway, located within the downstream face of the dam has been selected as the most appropriate and cost effective approach for the construction of the spillway. This is also believed to provide the best long term abandonment alternative for a spillway at this location.

The location of the design spillway channel is shown on Figure 6. This design yields a peak slope for the spillway of approximately 2.5H:1V. Detailed cross sections along and across the spillway are presented on Figures 11 and 12. These sections show the incorporation of energy dissipators (flow checks) along the spillway channel as well as a stilling basin at the toe of the dam.

At times of normal water flow it is expected that all of the water will cross the spillway over the crest of the dam and disappear into the coarse shot rock fill which comprises the downstream "flow-through" spillway. Only at times of peak flow is water expected to flow down the spillway channel constructed on the downstream face of the dam.

B.K. Hydrology Service has undertaken a detailed evaluation of the spillway and inlet hydrology with recommendations presented in Appendix F. Detailed recommendations regarding rip rap gradation and inlet and spillway cross sections are also presented in this report.

The recommended spillway design incorporates four separate invert slope angles along its length as indicated on Figure 11. At all locations, the bottom width of the spillway remains at 5.0 m (16.5 feet). Flow characteristics in each of the spillway segments is summarized in the following table:

life of the mine. A lower elevation in the reservoir level after abandonment will not be a detriment to the long term performance of the structure.

Because the geosynthetic clay liner is made from naturally occurring bentonite it should continue to function almost indefinitely.

7.3 TAILINGS DAM FREEBOARD

The tailings dam freeboard has been selected based on an analysis of the maximum expected wave heights that could be generated in the main water storage pond and the rise in water level that would occur in the pond when the spillway is flowing at the maximum design capacity. These two values are added together to determine the required freeboard.

The maximum reservoir water level rise resulting at the time of the maximum flow in the spillway has been calculated to be 0.88 m (2.9 feet).

Maximum wave heights caused by wind have been calculated for the early stages of mine development when the pond could theoretically be at the maximum surface level of 2350 feet, with minimal tailings in the disposal basin. At this stage, the maximum fetch in the reservoir will be approximately 500 m (1640 ft). No wind data is available for the Minto site. Maximum wind speed is available from various locations in the Yukon Territory (Aishiihik, Burwash, Dawson, Mayo, Snag, Teslin and Whitehorse). Review of this data indicated maximum hourly wind speeds varying from 43 to 85 km/hr. For the purposes of this design, the maximum value of 85 km/hr has been utilized. Wind speed is also typically higher over water bodies than over land and therefore in accordance with Linsley (1979) the design wind speed is increased by 10% to 92 km/hr. The 7 minute wind speed recommended as the maximum design wind speed by the Shore Protection Manual (1984) is then obtained by an additional 10% increase. Thus the design wind speed used to determine the maximum wave height is estimated to be 101 km/hr. The average significant wave height for this design wind speed is 0.48 m (from Linsley, 1979). From this, the maximum height for a 5% probability of overtopping will be 0.60 m (2.0 feet).

The maximum head increase of 0.88 m (2.9 feet) coupled with the maximum wave height of 0.60 m (2 feet) occurring in the reservoir when the spillway is flowing at the design peak flow yields a minimum freeboard requirement of 1.48 m (4.9 ft). The dam core actually extends a total of 2.44 m (8 feet) above Elevation 2350.

TABLE 4
SPILLWAY CHARACTERISTICS

Channel Slope H;V	Velocity m/sec (ft/sec)	Flow Depth m (feet)
0	1.9 (6.2)	0.86 (2.82)
10:1	2.7 (8.9)	0.43 (1.41)
4:1	3.6 (11.8)	0.33 (1.08)
2.5:1	4.2 (13.8)	0.25 (0.82)

From the inlet on the upstream face to the centreline of the dam the spillway has a level grade or no slope. From the centreline of the dam to a point 12.2 m (40 feet) beyond, the slope increases to 10H:1V (or 10 %). From this location the slope of the spillway invert increases to 4H:1V (or 25 %) until it intersects the spillway channel paralleling the downstream face of the dam.

The design spillway flow of 5.0 m^3/sec would require 600 mm median size rip rap lining the channel bottom in all but the flat section of the spillway on the dam crest which requires 300 mm median size rock rip rap. The 600 mm median size rip rap should extend for a distance of 15 m (50 ft) beyond the base of the spillway to prevent erosion of the natural channel below the toe of the dam. Flow checks are also included along the spillway to enhance energy dissipation. Details of the flow checks and the stilling basin at the toe are presented on Figure 11.

— with changes to residual [illegible]

The spillway inlet will utilize a sheet pile cutoff wall extending into the dam core at the centreline of the dam to control the water level at the design elevation of 2350 feet. In addition, a geosynthetic clay liner will be attached to the downstream face of the sheet piles extending from the top of the sheet piles to the top of the clay core (as shown on Figure 11). This geosynthetic clay liner will ensure that a constant water level will be maintained at the design elevation even if the sheetpiles leak. To provide additional protection along the crest of the dam beneath the spillway, the geosynthetic clay liner will be extended to the downstream edge of the coarse filter (see Detail 1 on Figure 11). The geosynthetic clay liner will also ensure that the flow in the spillway is forced into the shot rock and coarse filter in the downstream shell of the dam.

– driving sheet piles in compact residual – grad clay?

will you place the clay liner upslope of the sheet piles [illegible]

It is acknowledged that the sheet piles will eventually rust out after abandonment and that water may flow through the spillway at a lower elevation. However, the primary purpose of the sheet piles is to maintain a constant water level during the

Therefore there is an additional freeboard allowance of 1.0 m (3.1 feet) of core material. This core material is considered sacrificial material. Sacrificial material is recommended to account for seasonal freezing of this fill which could lead to cracks developing in the upper core.

[illegible]

7.4 DIVERSION DITCH AND ACCESS ROAD

An access road and parallel diversion ditch will be constructed along the south-facing valley slope as shown in Figure 2. The ditch will transfer overflow water from the mill storage pond to the water retention pond and also intercept surface water flows from the south-facing valley slope, preventing the surface water from flowing onto the tailings surface.

B.K. Hydrology has undertaken an evaluation of the diversion ditch located on the south-facing valley slope. Details of the evaluation are presented in Appendix F. The average slope of this ditch is approximately 3.8%. At peak flow, the channel may have to carry a similar flow to that in the spillway (5.0 m^3/sec or 175 ft^3/sec). At peak flow, water would be flowing at a velocity as high as 2.4 m/sec (7.9 ft/sec) and at a depth of approximately 0.60 m (2.0 ft) in a channel width of 3 m (9.8 ft). Erosion of the ditch will be prevented using rock rip rap in the ditch bottom and sides with a 250 mm (10 inch) median size.

The road and diversion ditch will traverse two distinctly different types of terrain along their length. For the most part they will be constructed on a valley sideslope which consists of unfrozen residuum soils with an average side slope of 26° (Section A, Figure 13). However, the ditch and road must traverse a much gentler slope with an average gradient of 10° in an area where thicker peat soils and permafrost conditions are believed to exist (Section B, Figure 13). These varying soil conditions require different design cross sections. Additionally, the diversion ditch is not required during dam construction but a much wider road is required for construction traffic. Therefore, both design sections incorporate an initially wider road surface which will eventually be partially reconstructed to form the diversion ditch and permanent access road.

The design section for the portion of roadway traversing the permafrost terrain involves a fill section with a minimum road fill thickness of 1.5 metres (5 feet). This design will avoid disturbing the existing surface soil cover and help to preserve the permafrost. Additionally, the ditch has been lined with a geosynthetic clay liner below the rip rap to minimize the potential of thawing the frozen soils, which may occur due to water seeping from the ditch.

The ditch and road cross section in the nonpermafrost areas has been designed as an approximately balanced cut and fill section. A seepage analysis was carried for the ditch cross section in the nonpermafrost areas. This seepage analysis indicated that seepage losses from the ditch would amount to only 1.3 x 10^{-6} m^3/sec/m. The approximate ditch length in the nonpermafrost areas is 1400 m which would therefore yield a total seepage loss of 1.8 x 10^{-3} m^3/sec. This is less than 5% of the average monthly flow in Minto creek (0.04 m^3/sec). The average monthly flow in Minto Creek should be approximately equal to the average monthly flow in the ditch as well.

8.0 CONSTRUCTION PLAN

Construction of the tailings dam will likely commence in the summer of 1996. It is expected that dam construction will require approximately 3 months to complete. As previously noted, construction must be undertaken when the average air temperature is above 0°C. Therefore, construction could commence on the dam as early as April of 1996 although flows in Minto Creek will likely be greatest during the spring freshet. Starting construction after this spring breakup will substantially lessen the requirements for cofferdam construction as well as diversion pumping of the washed residuum from upstream of dam streamflow across the dam.

8.1 BORROW PIT DEVELOPMENT

A borrow pit will be developed on the slope of the south-facing valley wall at a location upstream of the dam to provide suitable sand residuum materials for the construction of the upstream shell. Geotechnical drilling at the camp and mill locations as well as the creation of access roads along this valley slope have indicated suitable quantities of residuum soils in this area. The pit should be developed in such a manner that any silty colluvium contaminated with organics or boulders that may exist at this location are excluded from the material used in shell construction. A geotechnical drilling program will be undertaken at the proposed borrow location in order to confirm the quantity and suitability of the potential borrow materials for use. This material exists in a unfrozen state and therefore pit development can be accomplished using conventional excavation equipment.

A second borrow pit will also be developed at a location along the existing access road (approximate coordinates 18700N, 16500E). Surface sampling along the road has indicated the presence of the silty sandy clay material proposed for use as the dam core. Again, further geotechnical work is required to delineate and confirm the suitability of the deposit and permit preparation of pit development guidelines.

All rip rap, shot rock and manufactured filter materials will be obtained from the overburden granodiorite waste rock materials which will be excavated during stripping of the mine's open pit.

8.2 EMBANKMENT CONSTRUCTION

Detailed recommendations for embankment construction are presented in Appendix G. The following presents an overview of the critical factors which must be addressed during dam construction.

The first stage of embankment construction will commence with stripping of the organics and deleterious materials on the base of the valley. Under both the upstream and downstream shells, stripping will also be extended to include any ice-rich fine-grained permafrost. Coarse grained frozen soils such as residuum or weathered bedrock will not be overexcavated. Within the limits of the core and where the downstream filter contacts the bedrock, the overburden soils and weathered bedrock will be excavated to expose sound, intact bedrock.

The depth of excavation necessary in weathered rock is difficult to establish during design. The depth of weathering is usually very irregular, being controlled by minor variations in joint spacing and rock type. Abrupt changes in the elevation of the surface of the bedrock will likely be encountered. There may be deeply weathered zones extending well below the line of general excavation. Tentatively it has been assumed that an average depth of overexcavation of approximately 3.0m (10 feet) will be required beneath the core and fine filter under the downstream shell of the dam. Deeper excavation including some excavation of sound rock, may be economically feasible to reduce dental work.

During early stages of excavation, careful examination and supervision will be undertaken to confirm with field personnel a common understanding as to the definition of sound rock. This will establish which materials should be removed and which may stay in place. Requirements for removal in the lower foundations of the dam will likely be more stringent, where seepage forces are greater.

?
lower
foundations
middle?

The exposed bedrock surface will be thoroughly cleaned using high pressure air or water to ensure a good bond of concrete or grout to the rock. Joints and cracks should then be filled with concrete or grout. Grout should be broomed and brushed across the top of the joint to ensure that the contact with the core material will be tight and nonerodible.

Depressed areas, holes and other irregularities should be filled with a plastic mix of concrete vibrated into place. Where the bedrock surface is irregular, it is preferable to use extensive concrete fills. The final rock surface should have gentle contours against which soil can be compacted by heavy equipment.

Surface treatment as described above may be difficult to accomplish on steeply sloping abutments. In this case, gunite or shotcrete may be used for filling depressions after the cracks and joints have been cleaned and sealed. Shotcrete and gunite must be placed as several thin coats, usually 50 mm (2 inches) maximum; otherwise the gunite could sag away from the rock.

- silica fume would allow greater thicknesses

For the first lift of fill over the cleaned and grouted rock surface, it is preferable to select the most plastic fill available. Initial lifts for the impervious core on rock foundations must be placed and compacted by methods that will assure proper compaction without damaging the rock surface.

Materials used in the upstream shell will be primarily coarse grained residuum and weathered bedrock. Compaction of these soils will be best achieved using steel drum vibratory rollers. Similarly, the rockfill used for the downstream shell will be compacted most effectively using a (10 ton minimum) vibratory steel drum roller.

- compact rock fill? Not just placed w equipment?

9.0 CONSTRUCTION QUALITY ASSURANCE

Recommendations for quality assurance testing during dam construction and the characteristics of the construction material utilized are provided in detail in Appendix H.

The quality assurance program should include the following:

- Supervision of the clearing and stripping operations.
- Grain size distribution testing of natural and manufactured fill, bedding filter, and rip rap materials at their point of excavation or manufacture.
- Testing of all proposed rip rap materials prior to use to determine abrasion resistance and soundness to determine their resistance to weathering and mechanical processes.
- Supervision of the bedrock surface cleaning and preparation of the bedrock surface below the dam core by a Geotechnical Engineer.
- Inspection of the dam foundation soils and bedrock surface by a Geotechnical Engineer prior to fill placement.
- Compaction testing of all dam fill materials.
- Inspection of the placement of all rip rap, bedding material and geosynthetic clay liner by a Geotechnical Engineer.
- The installation of the geotechnical instrumentation under supervision of a Geotechnical Engineer.

10.0 PERFORMANCE MONITORING DURING OPERATION

A comprehensive dam and tailings basin performance monitoring plan must be undertaken to ensure the safe operation of the facility during mine operation. Additionally, final plans for mine abandonment will benefit from the monitoring of the performance of the dam and diversion ditch as well collection of additional stream flow and climatic data for this location. It is recommended that an ongoing field data collection program include the following:

1. Record the temperatures from the two thermistor cables on a monthly basis.
2. Record pore pressures in each of the pneumatic piezometers on a monthly basis.
3. Record settlements and movements of the dam by conducting surveys of the settlement/survey points every 2 months.
4. Collect daily meteorological data such as temperature, wind speed and precipitation.
5. Record tailings/water level as well as inflow and outflow levels including reclaim water flows.
6. Collect stream flow measurements in Minto Creek downstream of the dam.
7. Monitor tailings surface development by survey to determine volume requirements.
8. Monitor performance of the diversion ditch and spillway to determine maintenance requirements. Remove snow from the diversion ditch prior to spring breakup to avoid blockage.

11.0 ABANDONMENT PLANS

A detailed abandonment plan has been presented in Section 10 - Closure and Reclamation Plan, Volume IV of the Initial Environmental Evaluation (IEE).

Studies will be undertaken once the mine is in production to determine if the tailings can support plant life directly as described in Volume IV of the IEE. Depending upon the results of these studies, the reclamation program may include an overburden cover and/or the addition of fertilizer. The tailings surface will be revegetated with seed mixtures developed during the test programs and will be compatible with willow/sedge and black spruce communities.

The spillway has been designed to handle the 1 in 200 year peak flow expected in Minto Creek. The spillway will be protected from erosion with competent rock rip rap. The final plans for abandonment of the dam and spillway will be largely dependent upon the level of tailings in the disposal basin and the results of monitoring of the dam performance, stream flows and tailings behaviour. Depending on the above, it is proposed that the abandonment plan will involve one of the following scenarios:

- widen the dam spillway considerably to provide a greater factor of safety against erosion.

- breach the dam if tailings are not deposited against the upstream face.

- leave spillway and dam as constructed.

12.0 CLOSURE

We trust that this report satisfies the current submission requirements. It should be noted that additional fieldwork is required along the diversion ditch alignment and in the proposed borrow areas prior to construction in order to confirm the final dam design.

Respectfully Submitted
EBA Engineering Consultants Ltd.

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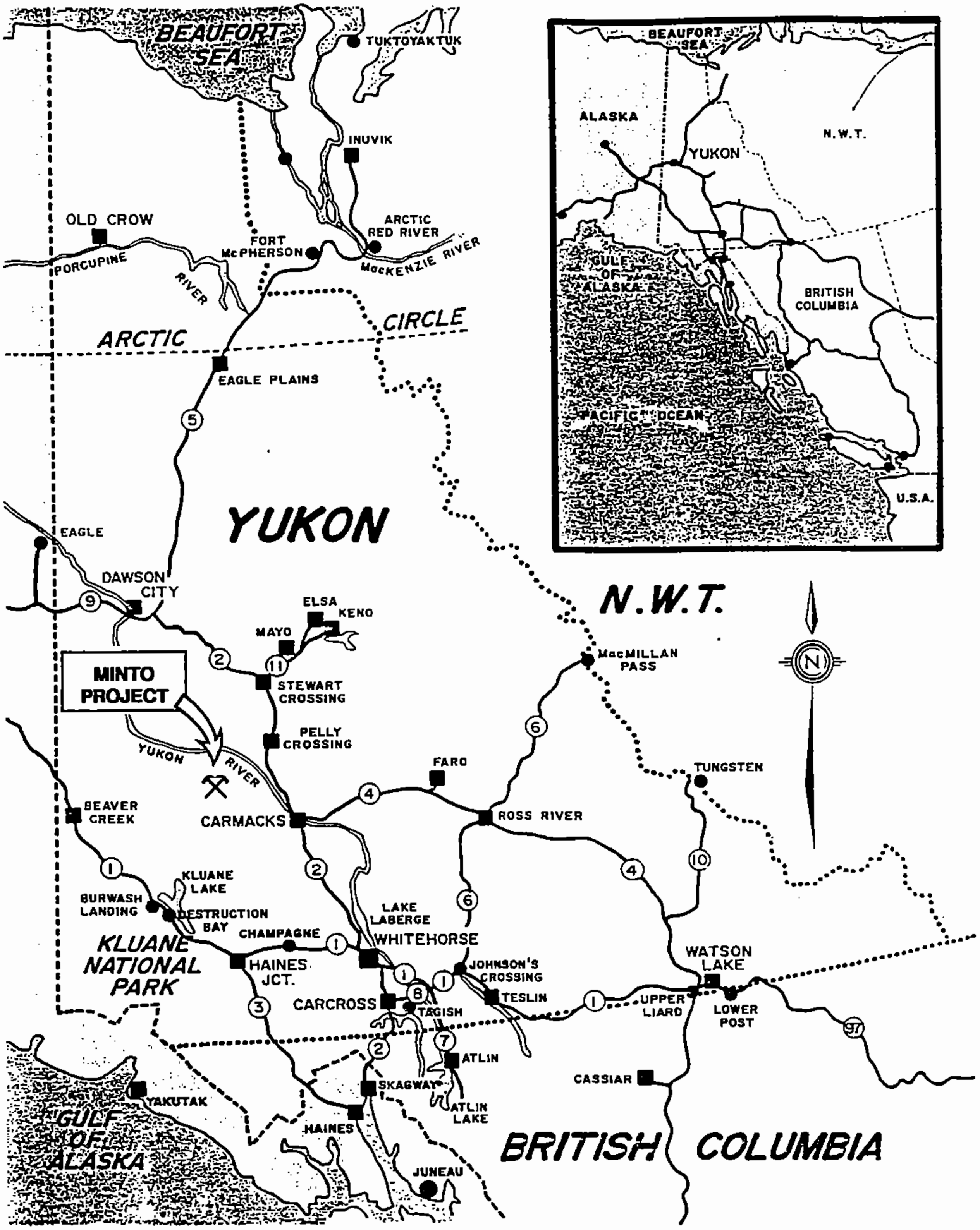
FIGURES



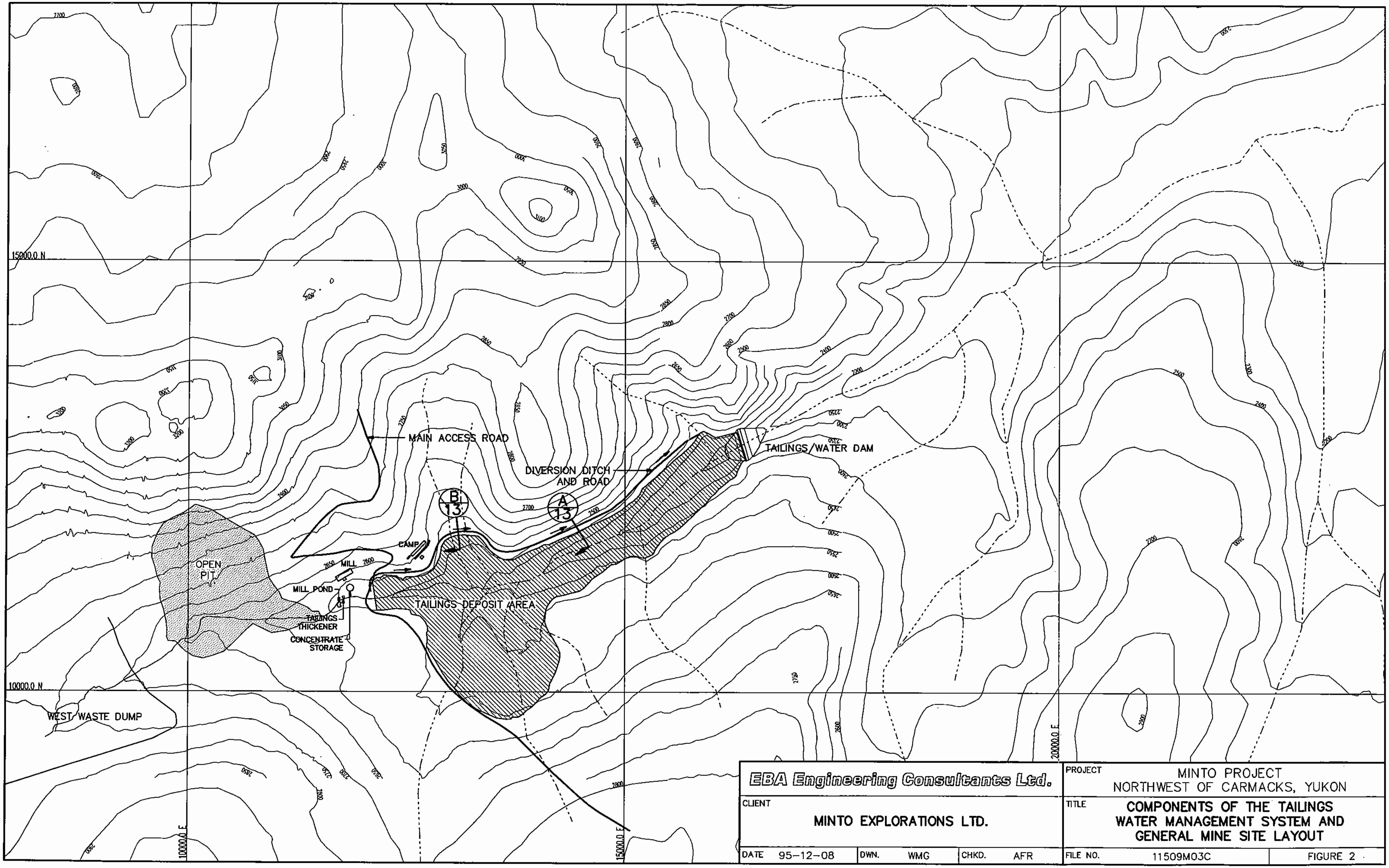
EBA Engineering Consultants Ltd.

PROJECT
MINTO PROJECT

CLIENT
MINTO EXPLORATIONS LTD.

TITLE
GENERAL LOCATION MAP

DATE 95-07-04 | DWN. AJH | CHKD. KWJ | FILE NO. 0201-11509 | FIGURE 1



EBA Engineering Consultants Ltd.

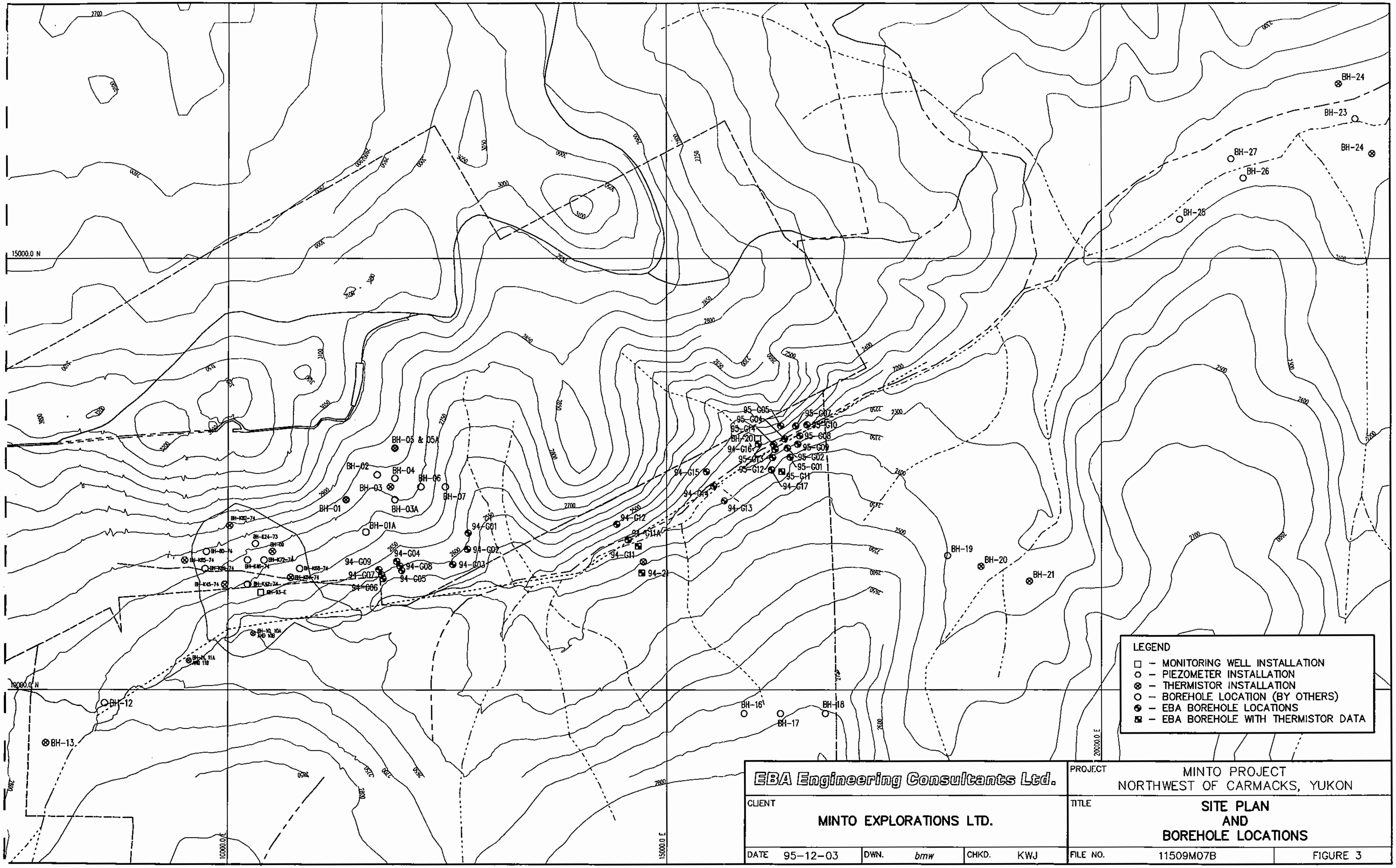
PROJECT
MINTO PROJECT
NORTHWEST OF CARMACKS, YUKON

CLIENT
MINTO EXPLORATIONS LTD.

TITLE
COMPONENTS OF THE TAILINGS WATER MANAGEMENT SYSTEM AND GENERAL MINE SITE LAYOUT

DATE	95-12-08	DWN.	WMG	CHKD.	AFR	FILE NO.	11509M03C

FIGURE 2



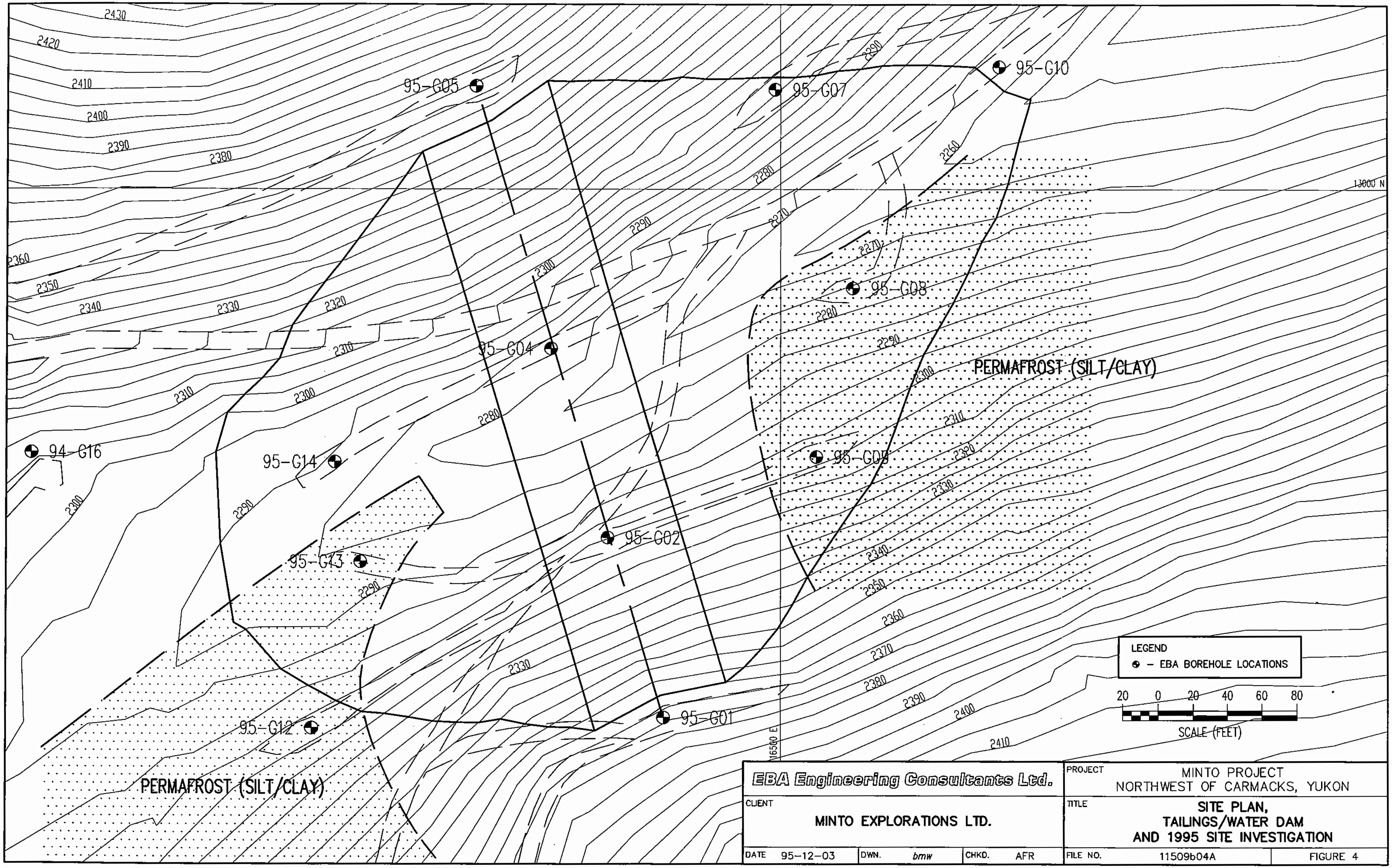
EBA Engineering Consultants Ltd.

PROJECT
MINTO PROJECT
NORTHWEST OF CARMACKS, YUKON

CLIENT
MINTO EXPLORATIONS LTD.

TITLE
SITE PLAN
AND
BOREHOLE LOCATIONS

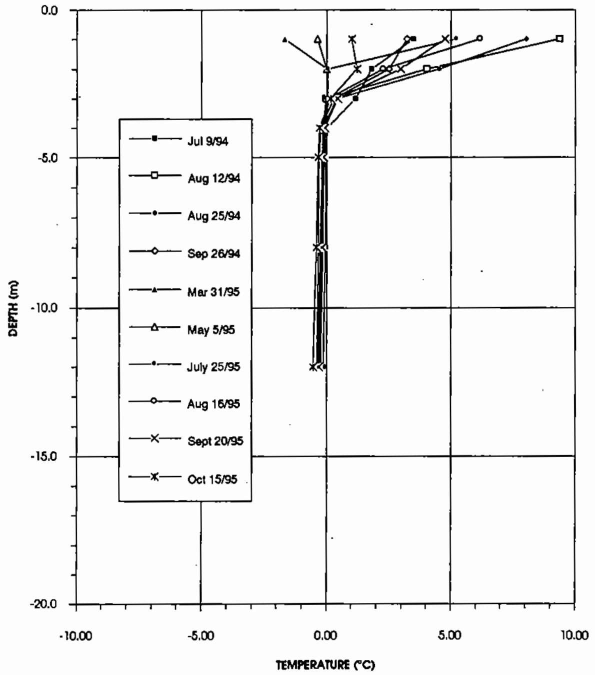
DATE	95-12-03	DWN.	bmw	CHKD.	KWJ	FILE NO.	11509M07B	FIGURE 3



EBA Engineering Consultants Ltd.

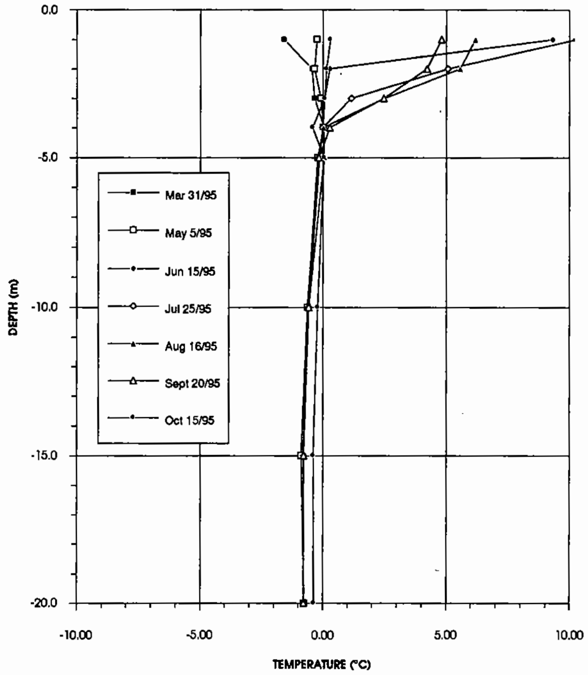
PROJECT	MINTO PROJECT NORTHWEST OF CARMACKS, YUKON
CLIENT	MINTO EXPLORATIONS LTD.
TITLE	SITE PLAN, TAILINGS/WATER DAM AND 1995 SITE INVESTIGATION
DATE	95-12-03
DWN.	bmw
CHKD.	AFR
FILE NO.	11509b04A
	FIGURE 4

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



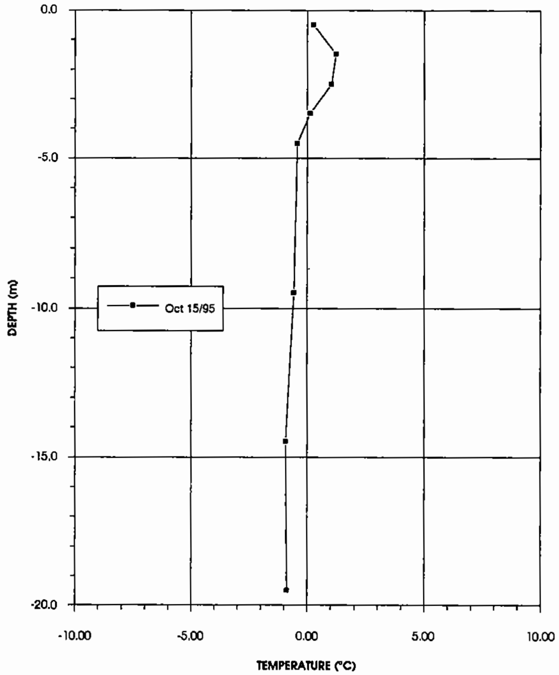
GROUND TEMPERATURE PROFILE
MINTO PROJECT - TAILINGS POND
LOWER SITE (BH 94-G11, El.=724.17 m)

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.

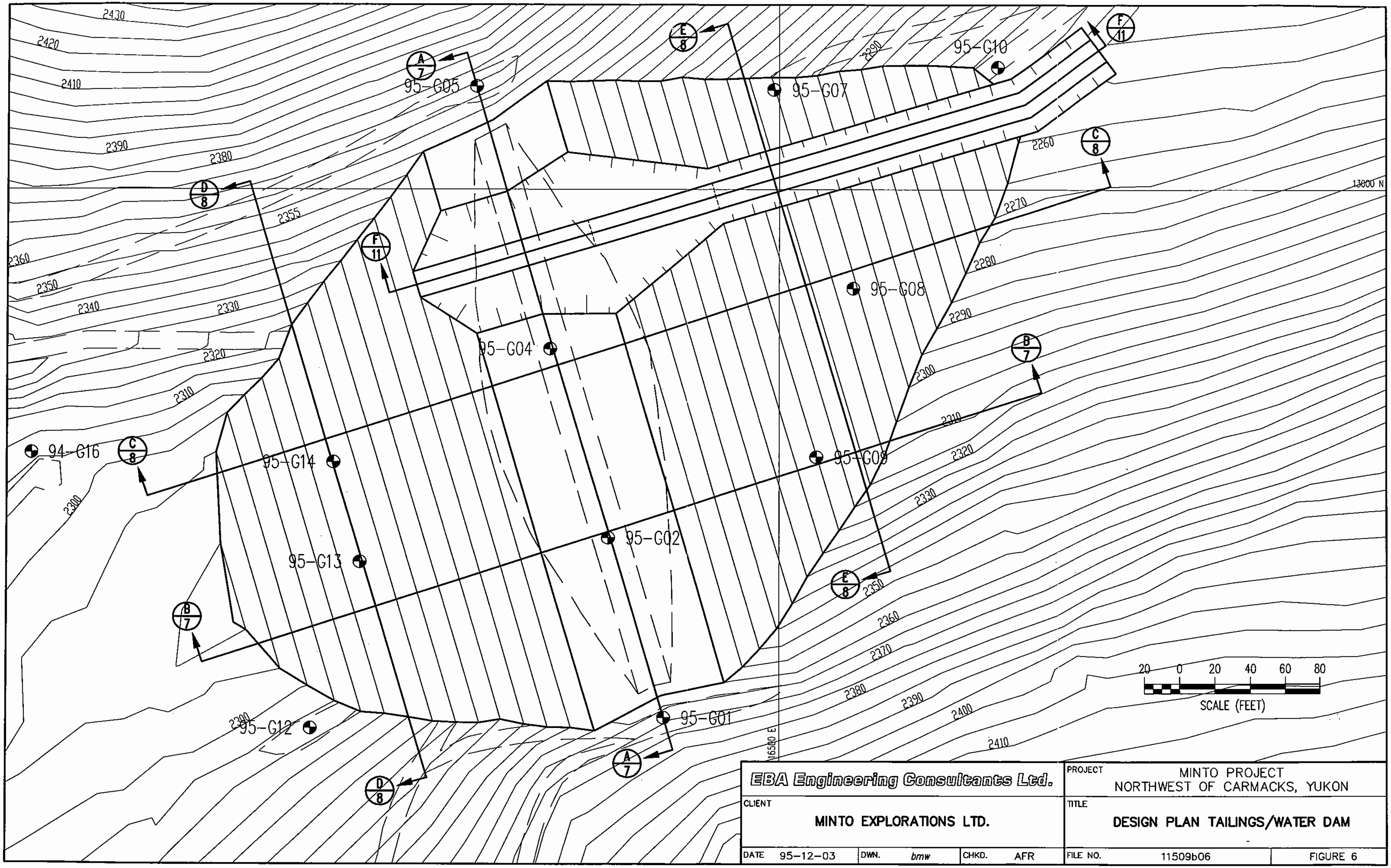
CLIENT
MINTO EXPLORATIONS LTD.

DATE 95-12-18
DWN. DRG
CHKD. KWJ

PROJECT
MINTO PROJECT
NORTHWEST OF CARMACKS, YUKON

TITLE
GROUND TEMPERATURES
TAILINGS AREA

FILE NO. 201-11509
FIGURE 5



EBA Engineering Consultants Ltd.

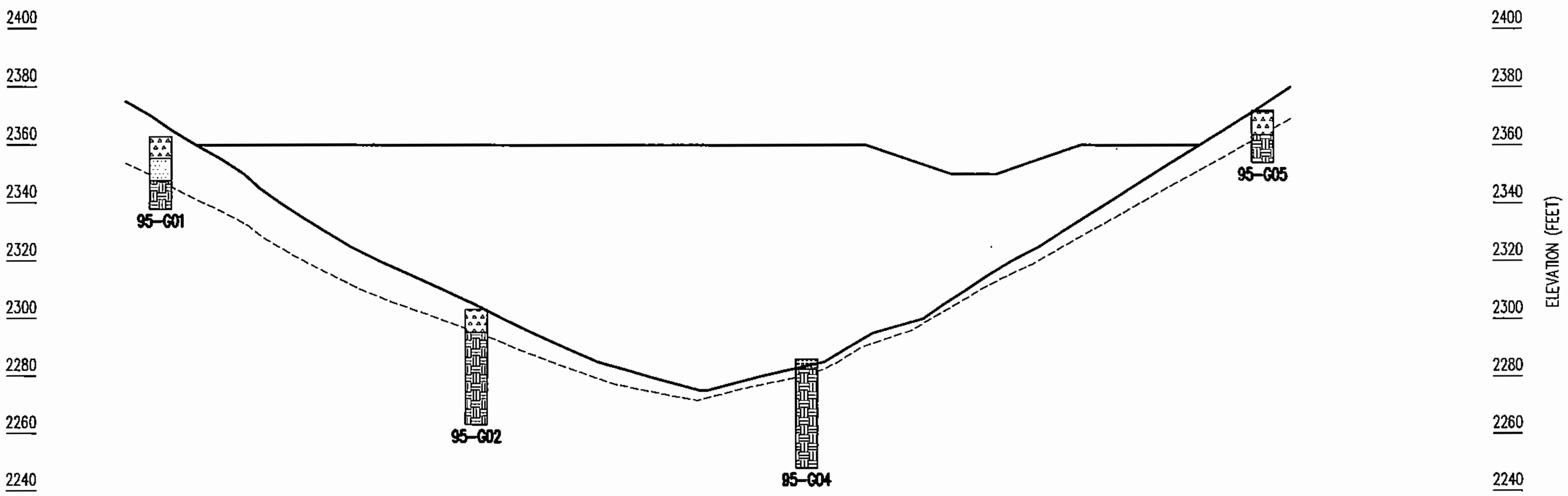
CLIENT
MINTO EXPLORATIONS LTD.

PROJECT
MINTO PROJECT
NORTHWEST OF CARMACKS, YUKON

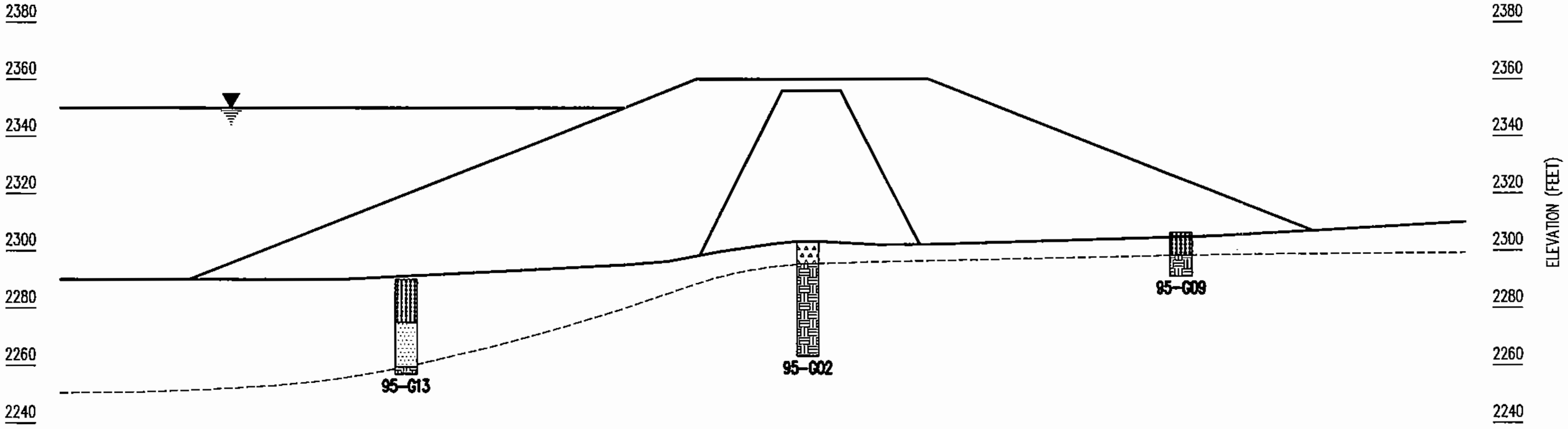
TITLE
DESIGN PLAN TAILINGS/WATER DAM

DATE 95-12-03
DWN. bmw
CHKD. AFR
FILE NO. 11509b06
FIGURE 6

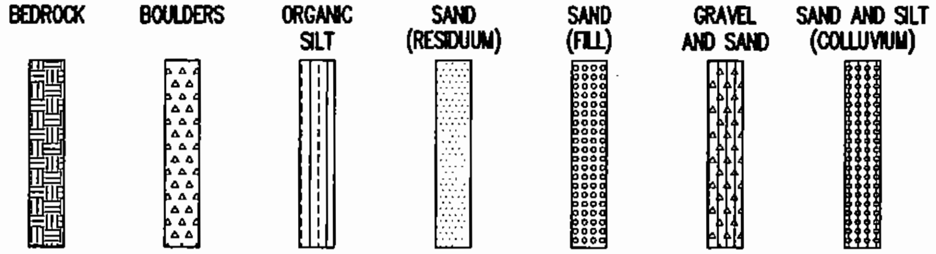
SECTION A/6

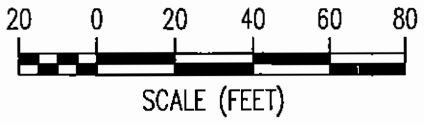


SECTION B/6



LEGEND





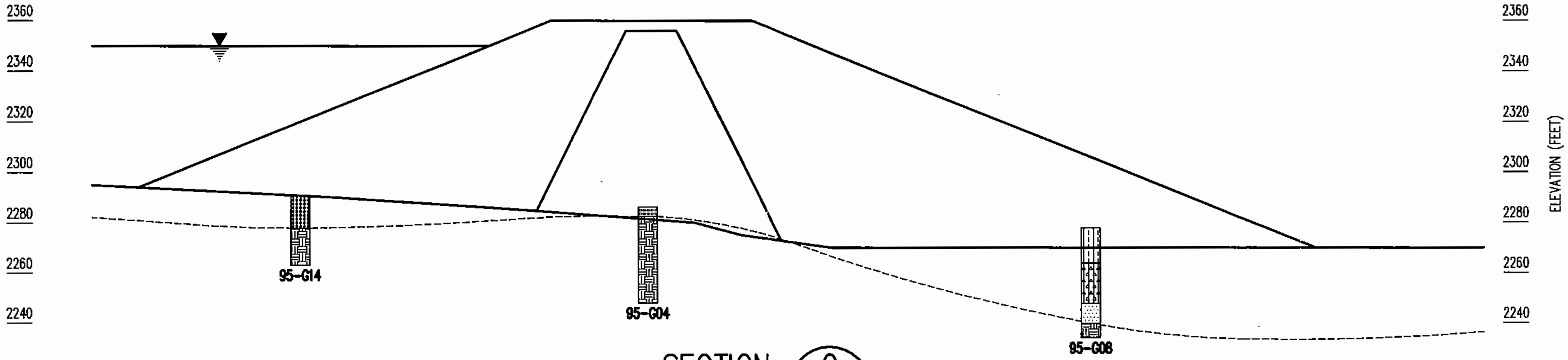
EBA Engineering Consultants Ltd.

PROJECT
MINTO PROJECT
NORTHWEST OF CARMACKS, YUKON

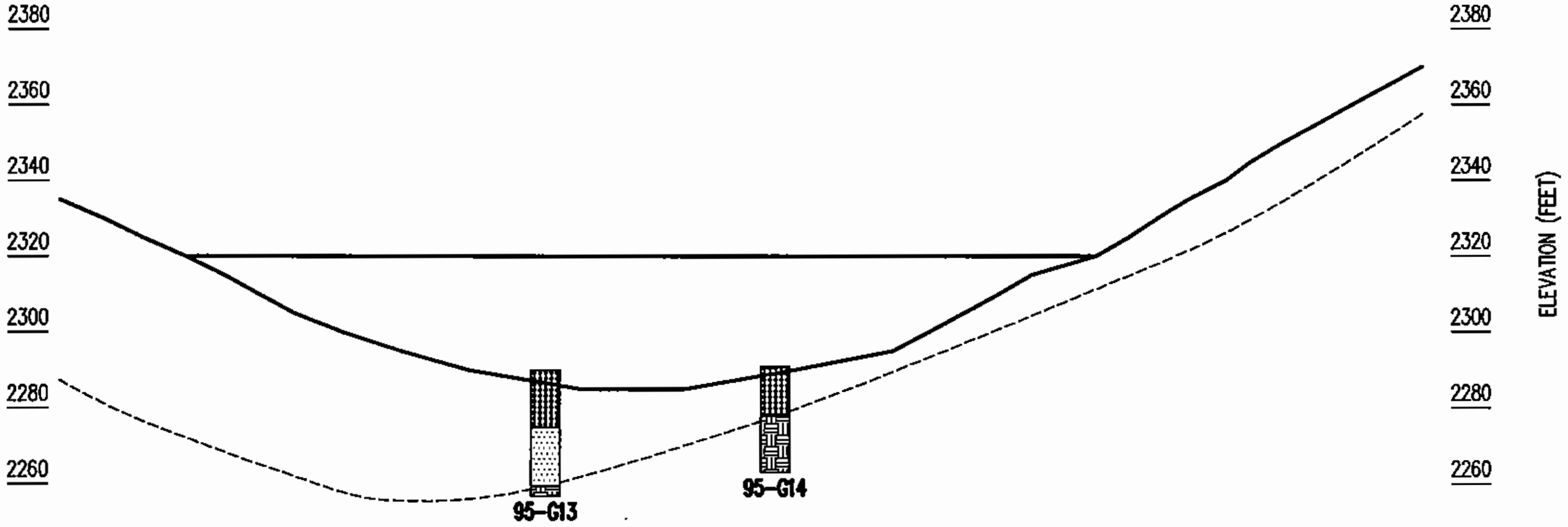
CLIENT
MINTO EXPLORATIONS LTD.

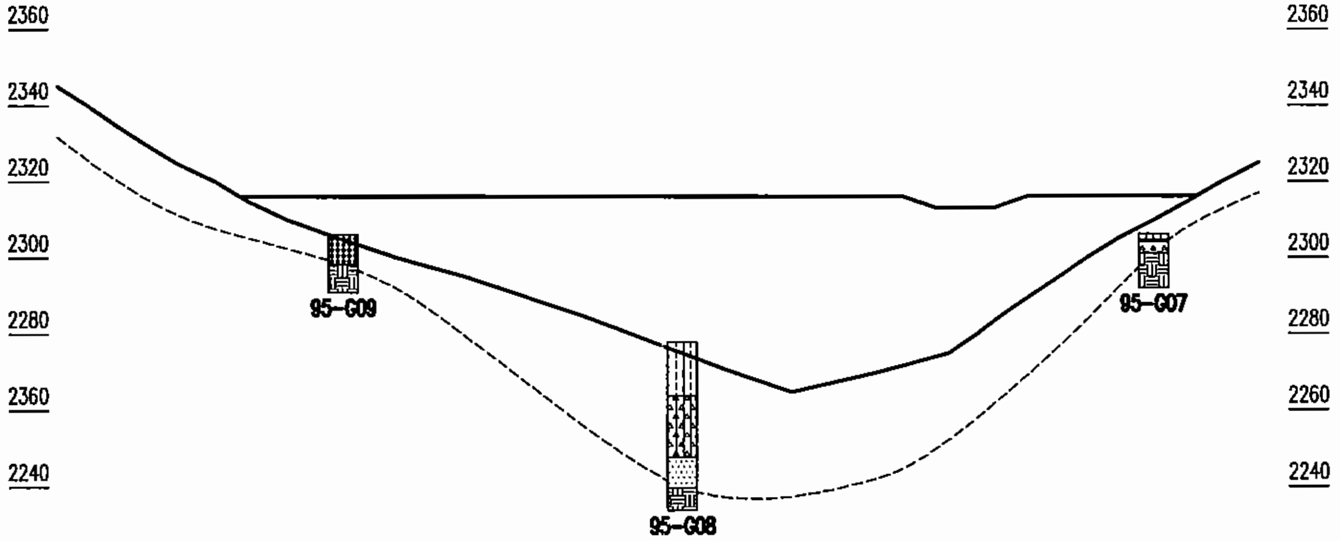
TITLE
CROSS SECTIONS A & B

DATE	95-12-03	DWN.	bmw	CHKD.	KWJ	FILE NO.	11509b07	FIGURE 7



SECTION C/6

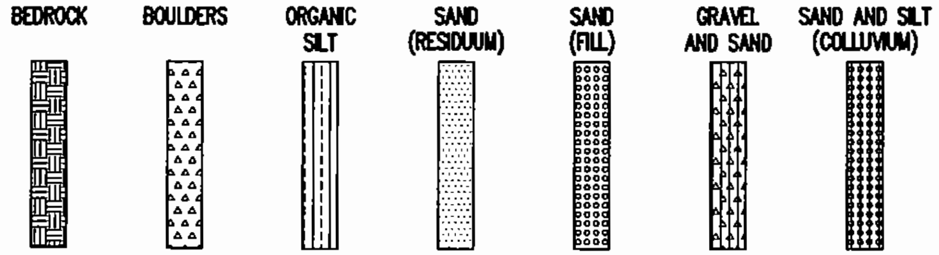


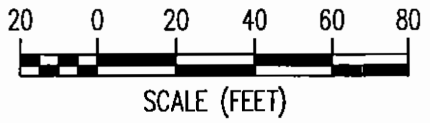


SECTION D/6

SECTION E/6

LEGEND



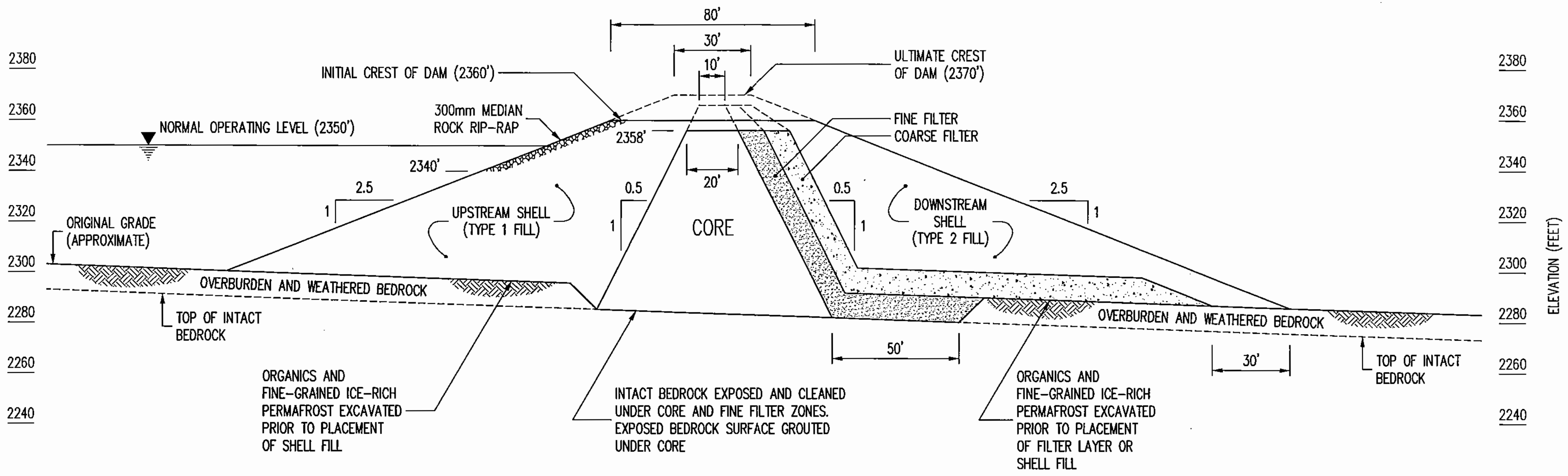


EBA Engineering Consultants Ltd.

CLIENT	MINTO EXPLORATIONS LTD.
PROJECT	MINTO PROJECT NORTHWEST OF CARMACKS, YUKON
TITLE	CROSS SECTIONS C, D, E

DATE	95-12-03	DWN.	bmw	CHKD.	KWJ	FILE NO.	11509b08

FIGURE 8



	FILL TYPE	DESCRIPTION
1)	UPSTREAM SHELL	REWORKED RESIDUUM AND WEATHERED BEDROCK
2)	CORE	SELECT SANDY, SILTY CLAY
3)	DOWNSTREAM SHELL	SHOT ROCK (FROM OPEN PIT)

SCALE (FEET)

EBA Engineering Consultants Ltd.

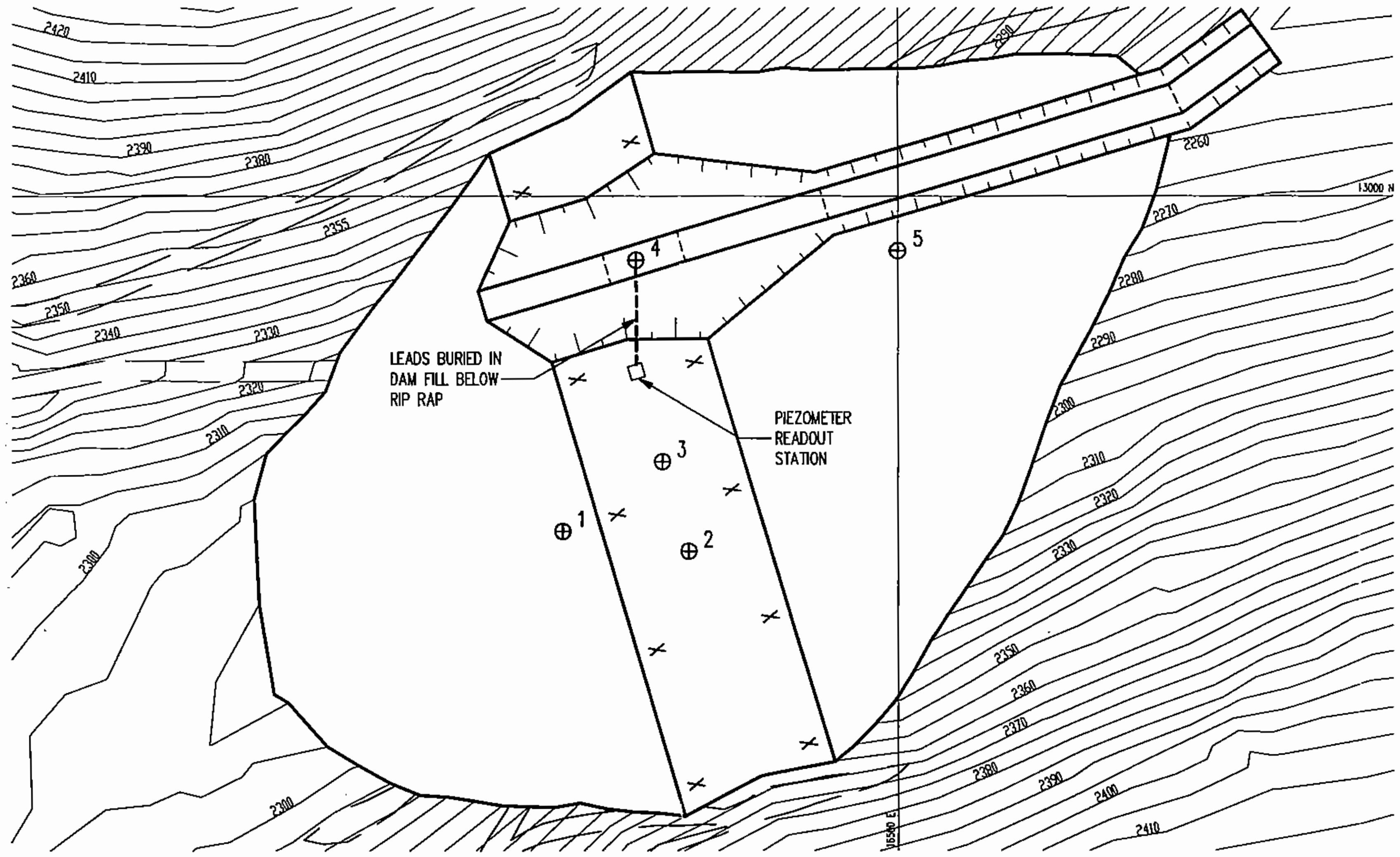
PROJECT
MINTO PROJECT
NORTHWEST OF CARMACKS, YUKON

CLIENT
MINTO EXPLORATIONS LTD.

TITLE
TYPICAL TAILINGS/WATER DAM SECTION
INITIAL AND ULTIMATE DESIGN

DATE 95–12–03	DWN. bmw	CHKD. KWJ	FILE NO. 11509b09B

FIGURE 9

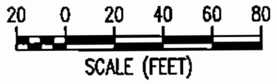


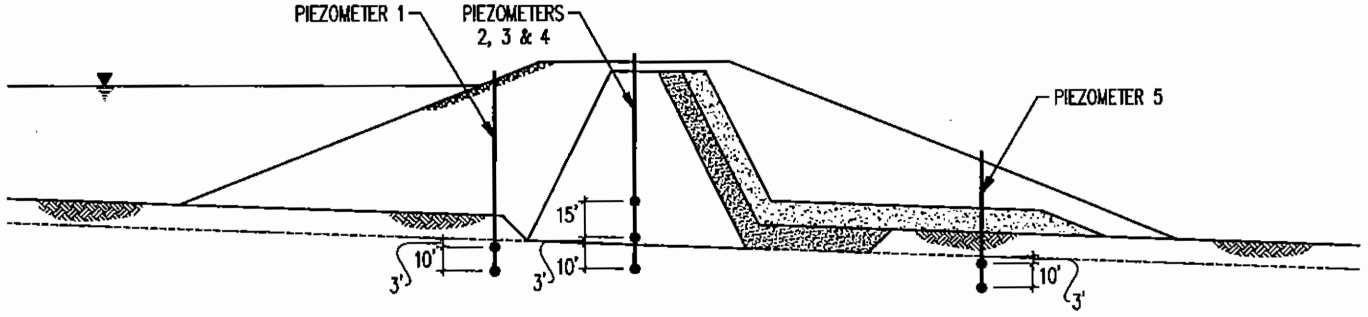
LEGEND

⊕ PNEUMATIC PIEZOMETER

× SETTLEMENT / SURVEY POINT

□ PIEZOMETER READOUT BOX

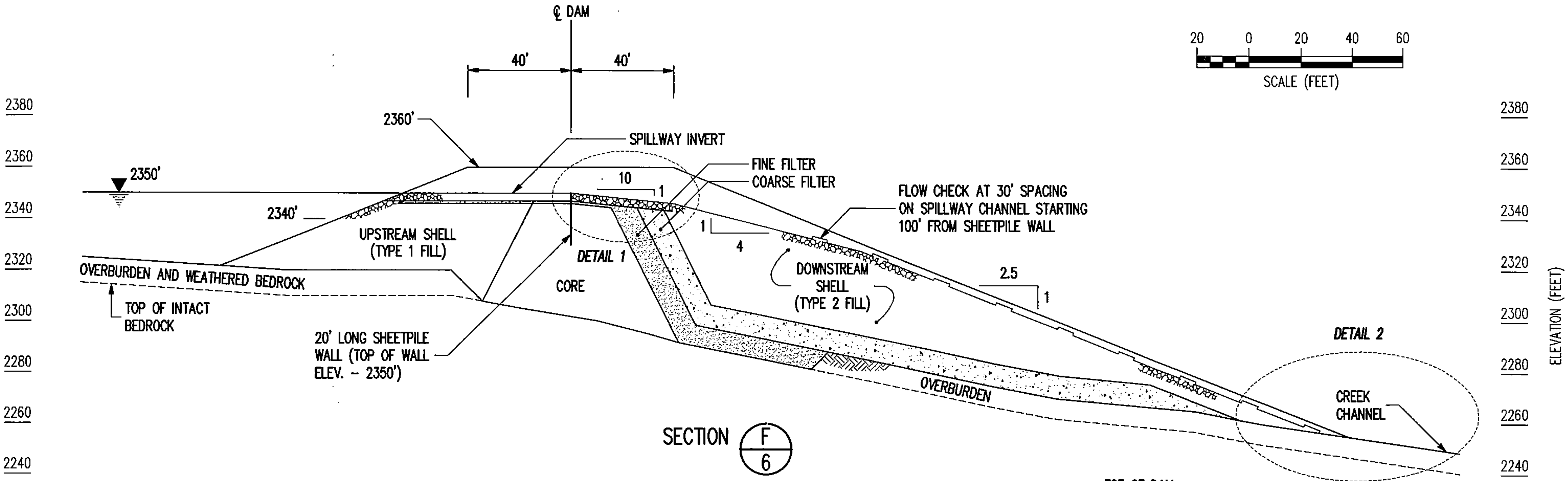




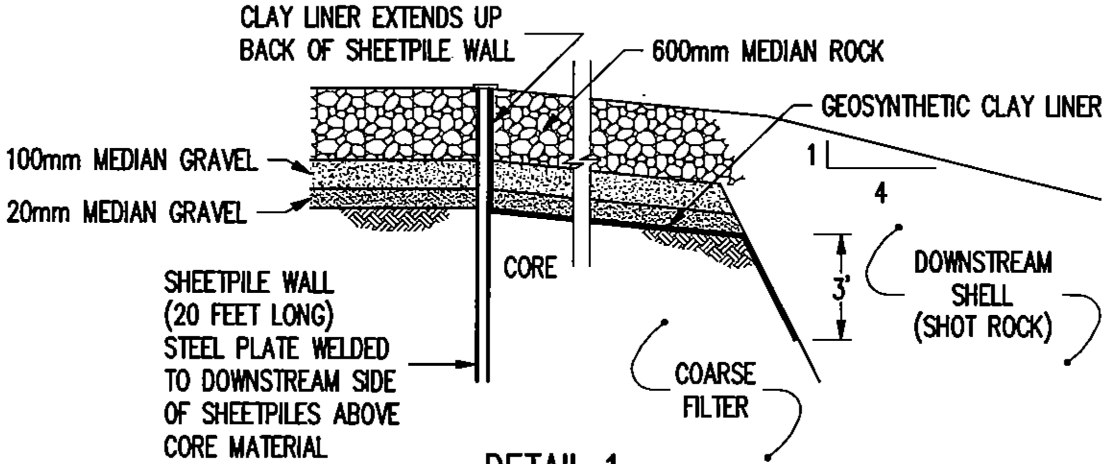
NOTE: ALL DEPTHS RELATIVE TO SURFACE OF COMPETENT BEDROCK

EBA Engineering Consultants Ltd.	PROJECT MINTO PROJECT NORTHWEST OF CARMACKS, YUKON
CLIENT **MINTO EXPLORATIONS LTD.**	TITLE **INSTRUMENTATION LAYOUT**

DATE	95-12-03	DWN.	bmw	CHKD.	AFR	FILE NO.	11509b10C	FIGURE 10

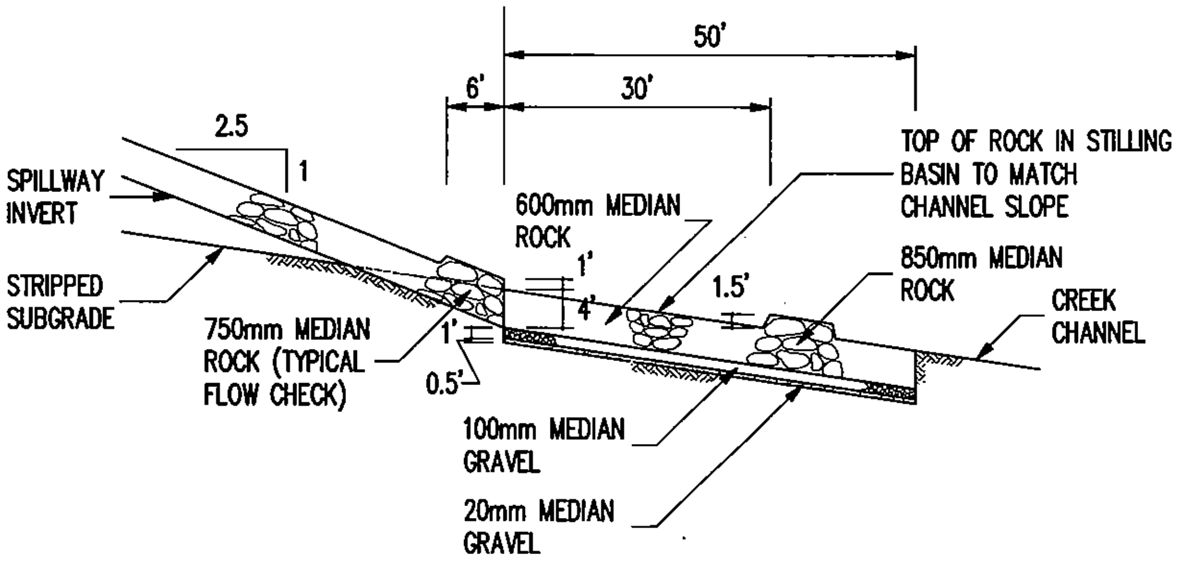


SECTION F/6



DETAIL 1

N.T.S.

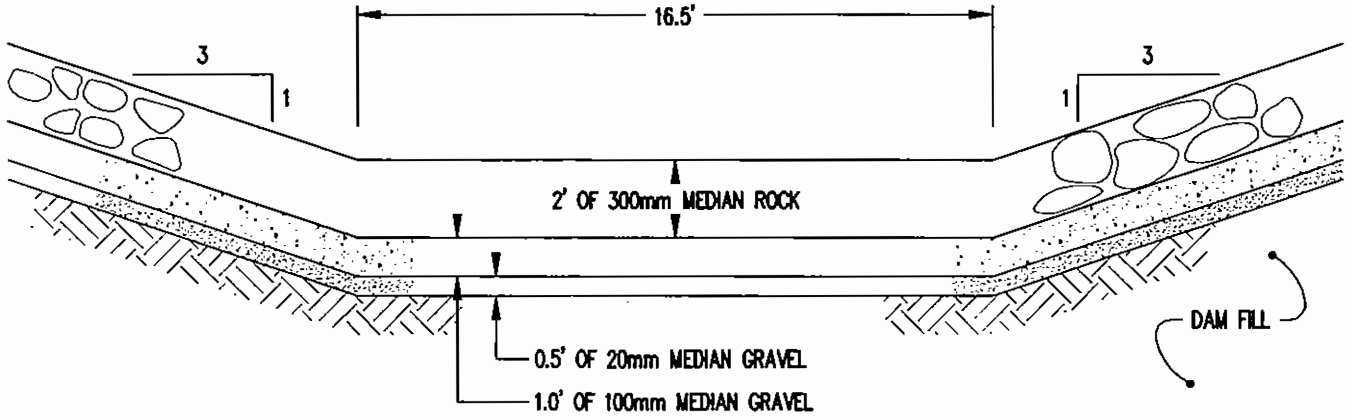


DETAIL 2

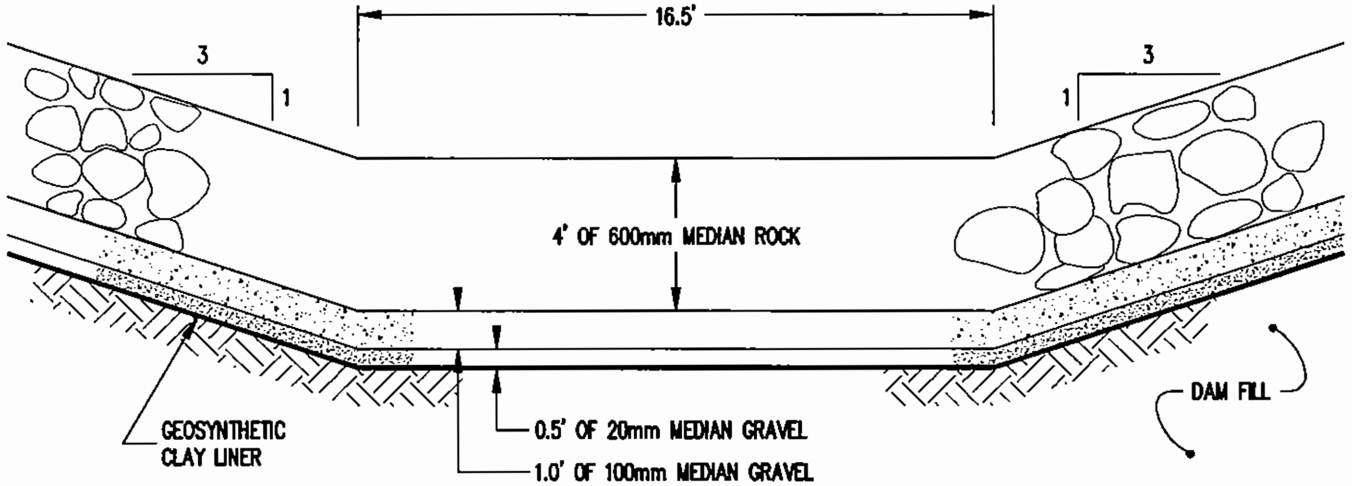
N.T.S.

EBA Engineering Consultants Ltd.	PROJECT MINTO PROJECT NORTHWEST OF CARMACKS, YUKON
CLIENT **MINTO EXPLORATIONS LTD.**	TITLE **SPILLWAY PROFILE**
DATE 95–12–03 DWN. bmw CHKD. KWJ	FILE NO. 11509b11C FIGURE 11

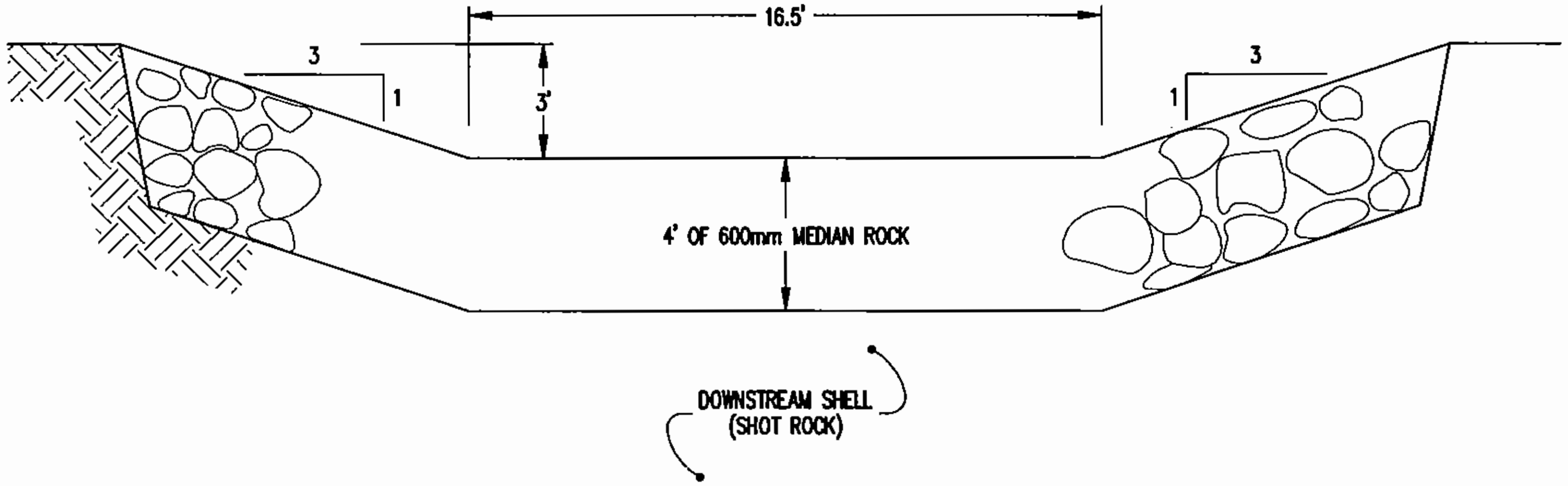
TYPICAL SPILLWAY SECTION AT CREST OF DAM UPSTREAM OF SHEETPILE CUTOFF

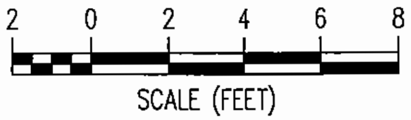


TYPICAL SPILLWAY SECTION AT CREST OF DAM DOWNSTREAM OF SHEETPILE CUTOFF



TYPICAL SPILLWAY SECTION ON DOWNSTREAM FACE OF DAM





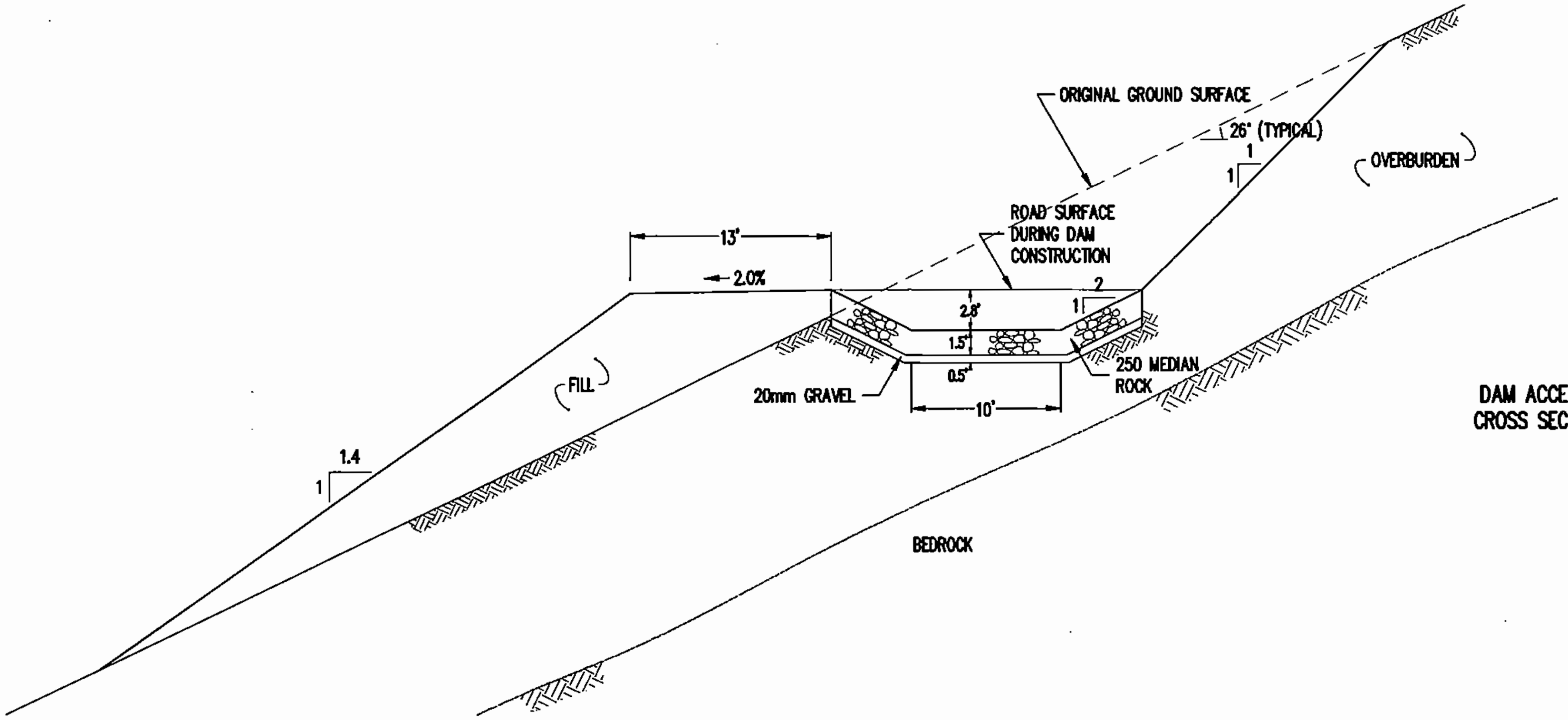
EBA Engineering Consultants Ltd.

CLIENT
MINTO EXPLORATIONS LTD.

PROJECT
MINTO PROJECT
NORTHWEST OF CARMACKS, YUKON

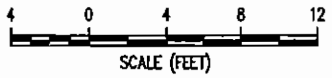
TITLE
TYPICAL SPILLWAY SECTIONS

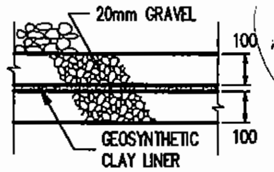
DATE	95-12-03	DWN.	bmw	CHKD.	KWJ	FILE NO.	11509b12B	FIGURE 12



DAM ACCESS ROAD AND DIVERSION DITCH CROSS SECTION – NONPERMAFROST AREAS

SECTION A/2

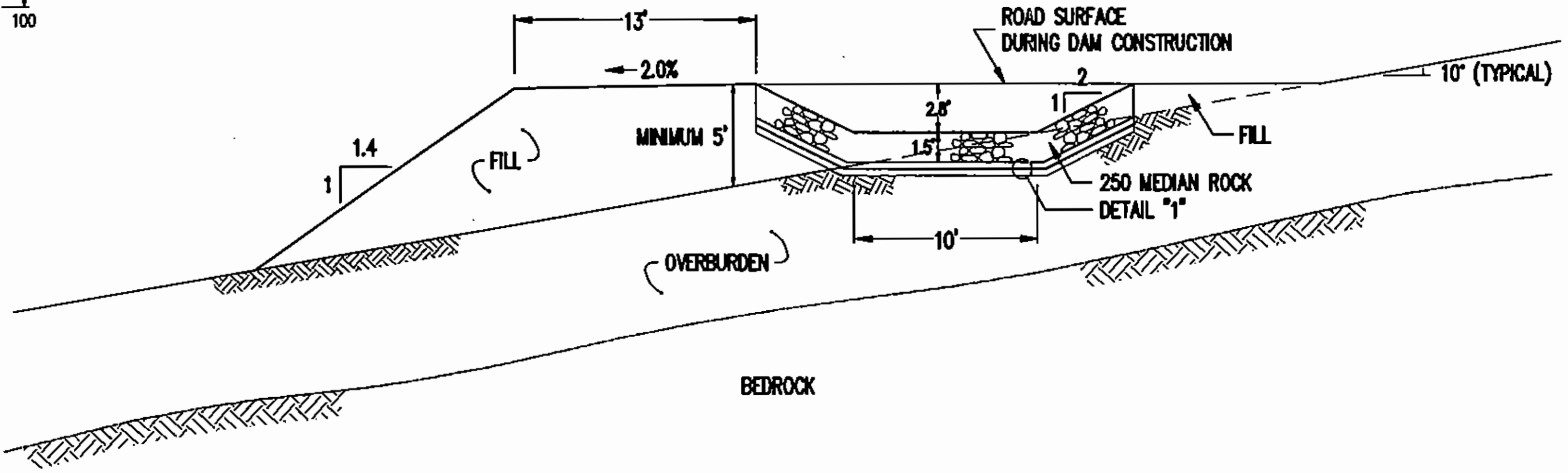




(min 4"?)

DETAIL 1

N.T.S.



DAM ACCESS ROAD AND DIVERSION DITCH CROSS SECTION – PERMAFROST AREAS

SECTION B/2

EBA Engineering Consultants Ltd.				PROJECT	MINTO PROJECT NORTHWEST OF CARMACKS, YUKON
CLIENT	MINTO EXPLORATIONS LTD.			TITLE	DAM ACCESS ROAD AND DIVERSION DITCH CROSS SECTIONS
DATE 95-12-03	DWN. bmw	CHKD. KWJ		FILE NO. 11509b13D	FIGURE 13

APPENDIX A.1
EBA 1995 BOREHOLE LOGS
TAILINGS/WATER DAM AREA

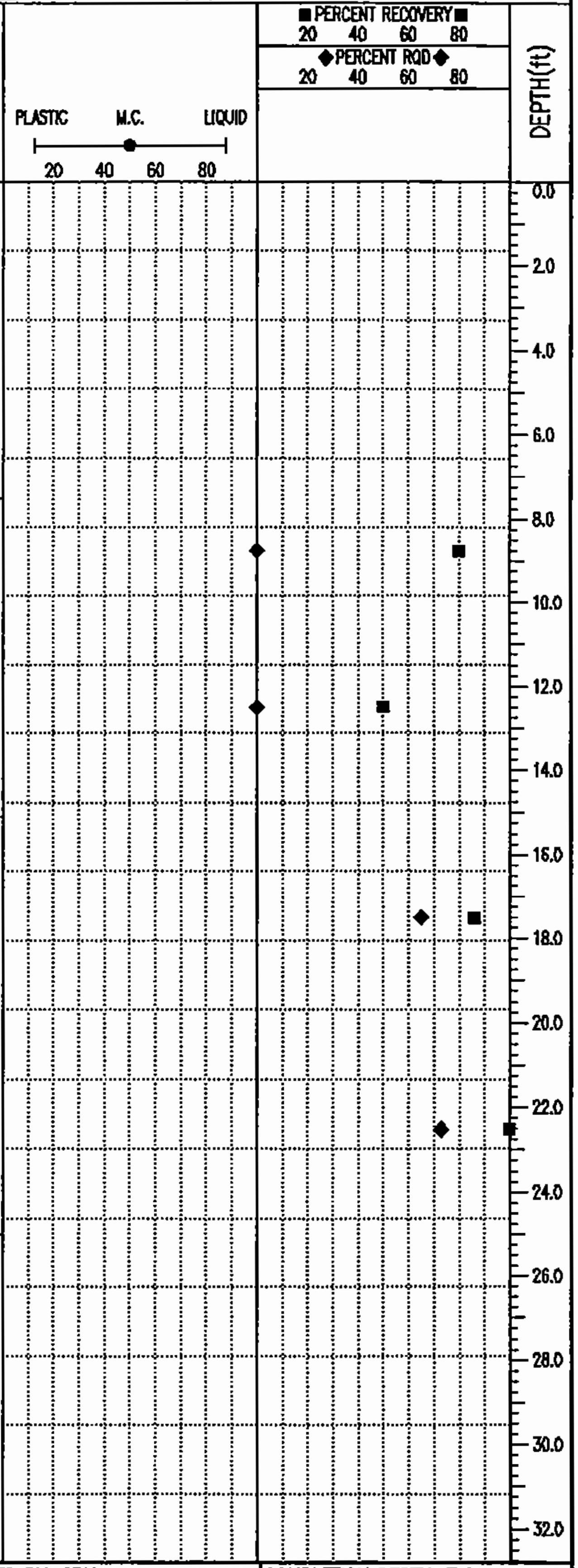
DETAILED GEOTECHNICAL DESIGN	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 95-G01
PROPOSED TAILINGS DAM – MINTO PROJECT	DRILL: LONGYEAR 38, C/W NQ DRILL RODS	PROJECT NO: 0201-95-11509
NEAR MINTO CREEK, YUKON	UTM ZONE: 8 N6945332 E386653	ELEVATION: 720.20 (m)

SAMPLE TYPE ■ GRAB SAMPLE ◪ NO RECOVERY ☒ NQ CORE ☰ 75 mm SPOON ◫ CRREL BARREL

DEPTH(m)	SAMPLE TYPE	SAMPLE NO	SPT(N)	USC	SOIL SYMBOL	SOIL DESCRIPTION	DEPTH(ft)
0.0				GP		BOULDERS (COLLUVIUM) – some sand, some gravel, trace of silt; clast supported; coarse angular boulders and cobbles; coarse angular sand and gravel; moderately weathered; brown; dry – casing set to 2.3 m; no recovery above 2.3 m	0.0
				SW		SAND (RESIDUUM) – trace of gravel, trace of silt; coarse angular sand; highly weathered; brown; dry – becomes less weathered with depth	
				BR		GRANODIORITE (BEDROCK) – moderately weathered; fractured – less weathered with depth	
						END OF DRILLHOLE @ 7.6 m – 0 to 2.3 m logged by observation of cut bank exposure adjacent to hole – all USC's are estimated, based on visual classification and field testing of recovered samples MINE GRID COORDINATES (IMPERIAL UNITS) Northing – 12694.0 Easting – 16433.0 Elevation – 2363.0	
10.0							32.0

Depth (m): 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0

Depth (ft): 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0, 28.0, 30.0, 32.0



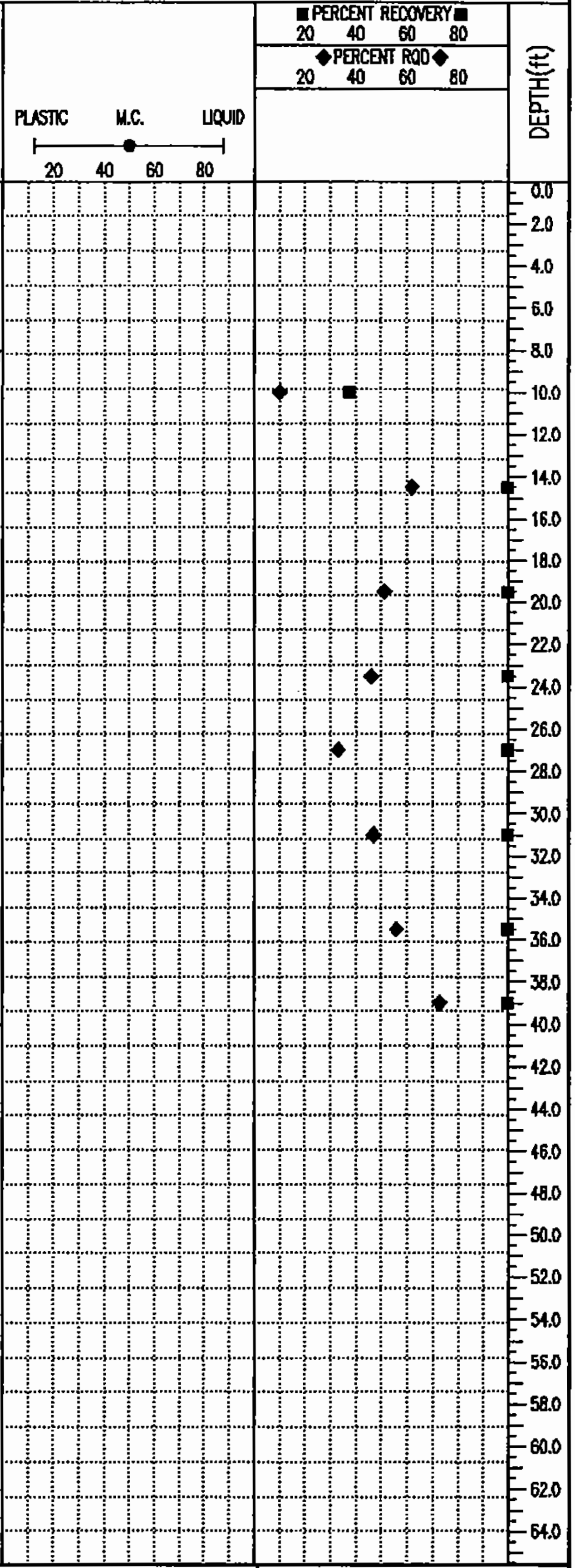
EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 7.6 m
	REVIEWED BY: CRH	COMPLETE: 95/09/25
	Fig. No:	Page 1 of 1

95/11/28 11:42AM (RECKD010)

DETAILED GEOTECHNICAL DESIGN	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 95-G02
PROPOSED TAILINGS DAM – MINTO PROJECT	DRILL: LONGYEAR 38, C/W NQ DRILL RODS	PROJECT NO: 0201-95-11509
NEAR MINTO CREEK, YUKON	UTM ZONE: 8 N6945364 E386645	ELEVATION: 702.00 (m)

SAMPLE TYPE ■ GRAB SAMPLE ◿ NO RECOVERY ☒ NQ CORE ☰ 75 mm SPOON ▯▯ CRREL BARREL

DEPTH(m)	SAMPLE TYPE	SAMPLE NO	SPT(N)	USC	SOIL DESCRIPTION
0.0				GP	BOULDERS AND COBBLES (COLLUVIUM) – some sand, trace of silt; coarse, angular, moderately weathered boulders & cobbles; coarse, angular, highly weathered sand; clast supported; brown – casing set to 2.4 m; no recovery above 2.4 m
3.4				BR	GRANODIORITE (BEDROCK) – slightly weathered; highly fractured
12.2					END OF DRILLHOLE @ 12.2 m – 0 to 2.4 m logged from observations of cut slope adjacent to drillhole – constant head permeability tests completed in drillhole – static water level approximated at 693.4 m – all USC's are estimated, on visual classification and field testing of recovered samples MINE GRID COORDINATES (IMPERIAL UNITS) Northing – 12798.0 Easting – 16401.0 Elevation – 2303.0

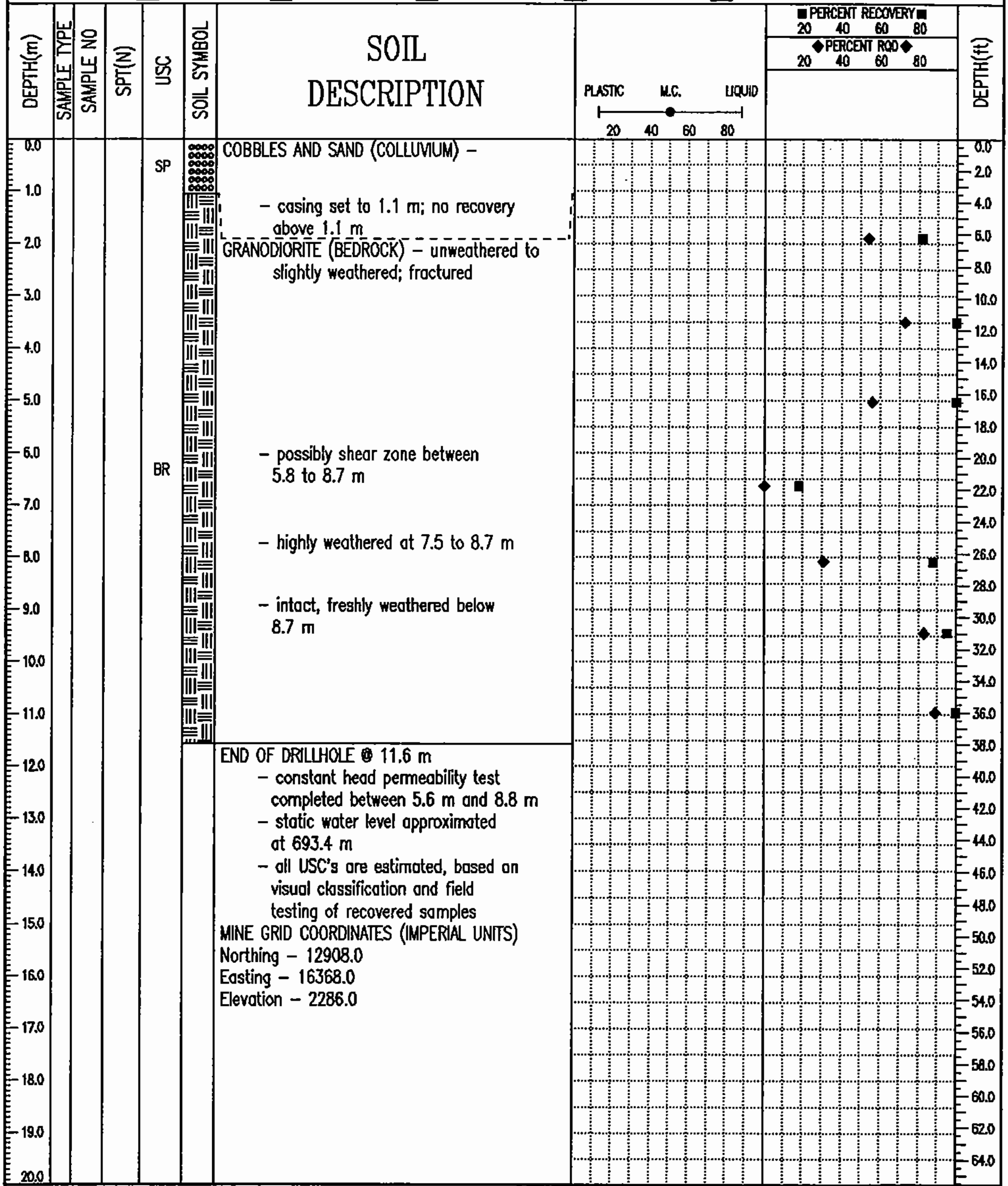


EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 12.2 m
	REVIEWED BY: CRH	COMPLETE: 95/09/26
	Fig. No:	Page 1 of 1

95/11/28 11:42AM (RECRO020)

DETAILED GEOTECHNICAL DESIGN	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 95-G04
PROPOSED TAILINGS DAM – MINTO PROJECT	DRILL: LONGYEAR 38, C/W NQ DRILL RODS	PROJECT NO: 0201-95-11509
NEAR MINTO CREEK, YUKON	UTM ZONE: 8 N6945398 E386636	ELEVATION: 696.80 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ NQ CORE ☰ 75 mm SPOON ▥ CRREL BARREL



COBBLES AND SAND (COLLUVIUM) –

– casing set to 1.1 m; no recovery above 1.1 m

GRANODIORITE (BEDROCK) – unweathered to slightly weathered; fractured

– possibly shear zone between 5.8 to 8.7 m

– highly weathered at 7.5 to 8.7 m

– intact, freshly weathered below 8.7 m

END OF DRILLHOLE @ 11.6 m
- constant head permeability test completed between 5.6 m and 8.8 m
- static water level approximated at 693.4 m
- all USC's are estimated, based on visual classification and field testing of recovered samples

MINE GRID COORDINATES (IMPERIAL UNITS)
Northing – 12908.0
Easting – 16368.0
Elevation – 2286.0

EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 11.6 m
	REVIEWED BY: CRH	COMPLETE: 95/09/27
	Fig. No:	Page 1 of 1

95/11/28 02:01PM (REC0020)

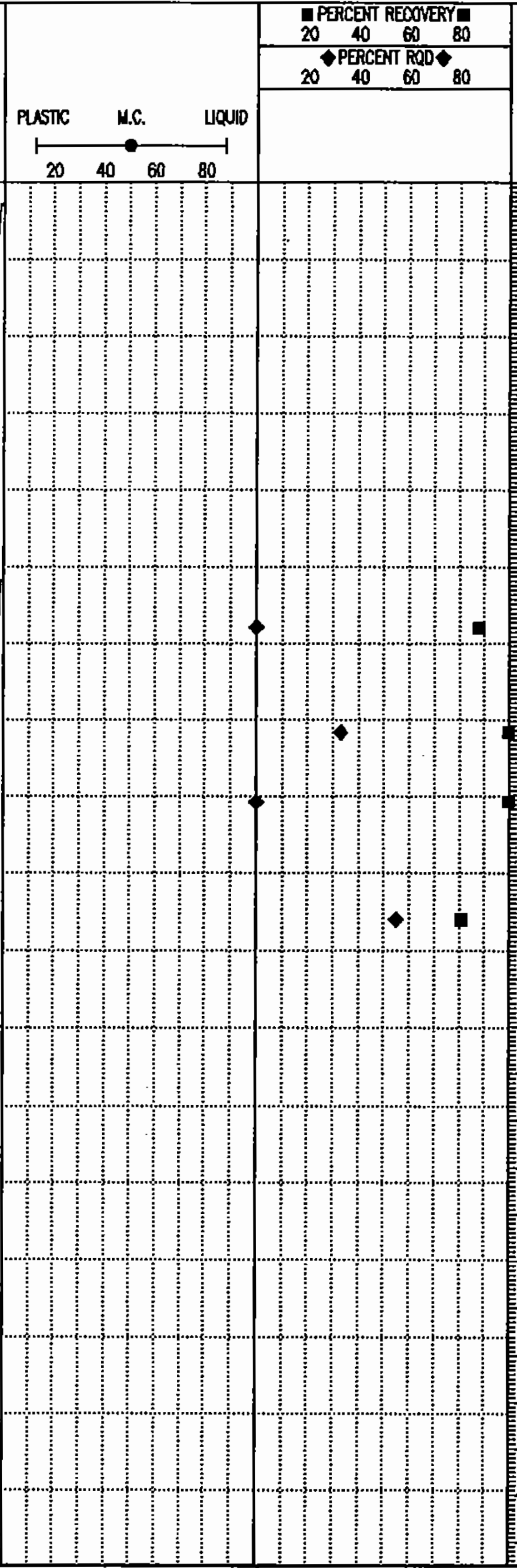
DETAILED GEOTECHNICAL DESIGN	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 95-G05
PROPOSED TAILINGS DAM – MINTO PROJECT	DRILL: LONGYEAR 38, C/W NQ DRILL RODS	PROJECT NO: 0201-95-11509
NEAR MINTO CREEK, YUKON	UTM ZONE: 8 N6945444 E386624	ELEVATION: 723.00 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ NQ CORE ☰ 75 mm SPOON ◫ CRREL BARREL

DEPTH(m)	SAMPLE TYPE	SAMPLE NO	SPT(N)	USC	SOIL SYMBOL	SOIL DESCRIPTION	DEPTH(ft)
0.0				OL		ORGANIC SAND & SILT – numerous fine roots; loose; brown; dry	0.0
				GW		GRAVEL AND SAND (COLLUVIUM) – some silt; frequent boulders and cobbles; occasional roots; angular well graded gravel and cobbles, moderately weathered; boulders to 0.6 m; matrix supported; dense; dry; brown – casing set to 1.2 m; no recovery above 1.2 m – salt deposits on underside of aggregates from 0.6 m to 1.8 m – becomes coarser with depth – clast supported, trace to some sand or silt by 1.8 m	2.0
3.0				BR		GRANODIORITE (BEDROCK) – slightly weathered, intensely broken – more competent below 4.1 m – difficult drilling	10.0
5.5						END OF DRILLHOLE @ 5.5 m – overburden profile logged from cut slope adjacent to hole – all USC's are estimated, based on visual classification and field testing of recovered samples MINE GRID COORDINATES (IMPERIAL UNITS) Northing – 13059.0 Easting – 16325.0 Elevation – 2372.0	18.0

Depth scale (m): 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0

Depth scale (ft): 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0, 28.0



EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH REVIEWED BY: CRH Fig. No:
COMPLETION DEPTH: 5.5 m COMPLETE: 95/09/29	Page 1 of 1

95/11/28 11:43AM (REC/R009)

DETAILED GEOTECHNICAL DESIGN	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 95-G07
PROPOSED TAILINGS DAM – MINTO PROJECT	DRILL: LONGYEAR 38, C/W NQ DRILL RODS	PROJECT NO: 0201-95-11509
NEAR MINTO CREEK, YUKON	UTM ZONE: 8 N6945442 E386677	ELEVATION: 702.90 (m)

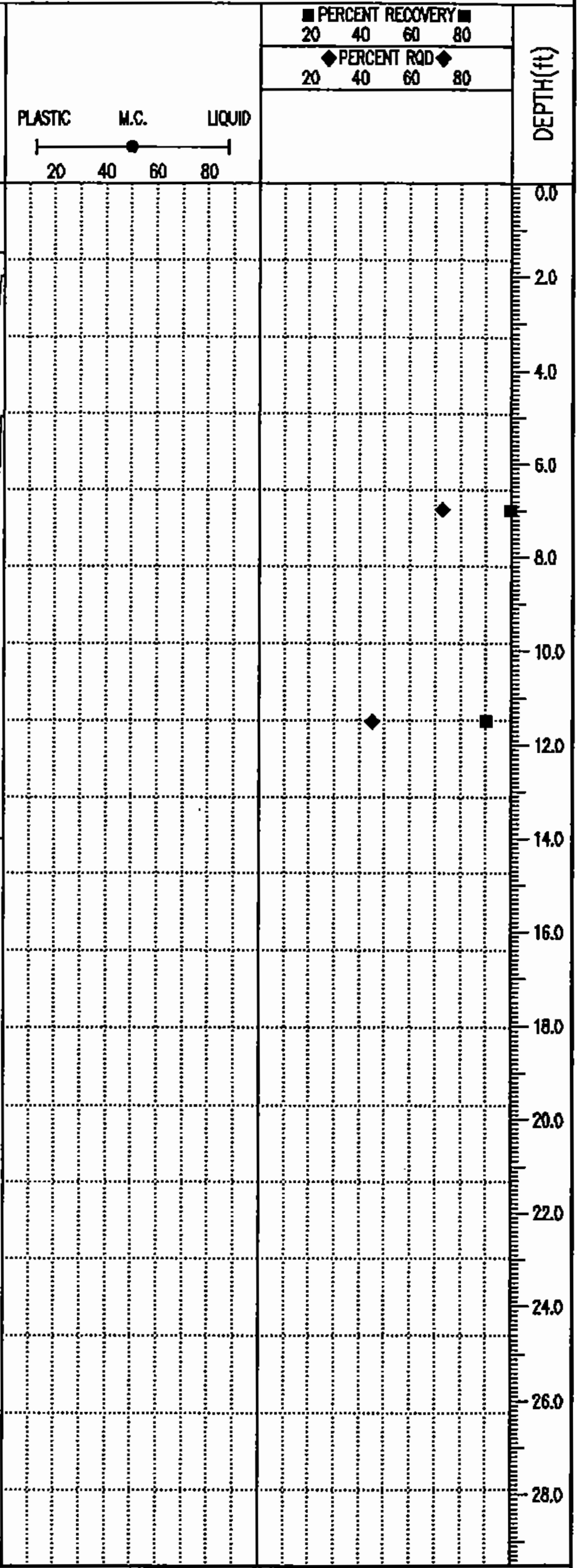
SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ NQ CORE ☰ 75 mm SPOON ▯ CRREL BARREL

USC	SOIL DESCRIPTION
OL	ORGANIC SILT – some sand, numerous roots, occasional gravel; brown
SP	SAND – some silt to silty, numerous roots; angular, coarse sand; grey-brown
GW	GRAVEL AND SAND (COLLUVIUM) – trace of silt, frequent cobbles, occasional roots; medium to coarse, angular, sand; angular gravel – becomes coarse with depth – casing set to 1.5 m; no recovery above 1.5 m
BR	GRANODIORITE (BEDROCK) – freshly weathered only on fracture/joint faces; moderate fractured with occasional broken zones

END OF DRILLHOLE @ 4.3 m

- overburden profile logged from cut slope adjacent to hole; bedrock in cut face approximately 3.0 m to 3.7 m where as at 1.5 m in drillhole
- all USC's are estimated, based on visual classification and field testing of recovered samples

MINE GRID COORDINATES (IMPERIAL UNITS)
Northing – 13057.0
Easting – 16497.0
Elevation – 2306.0



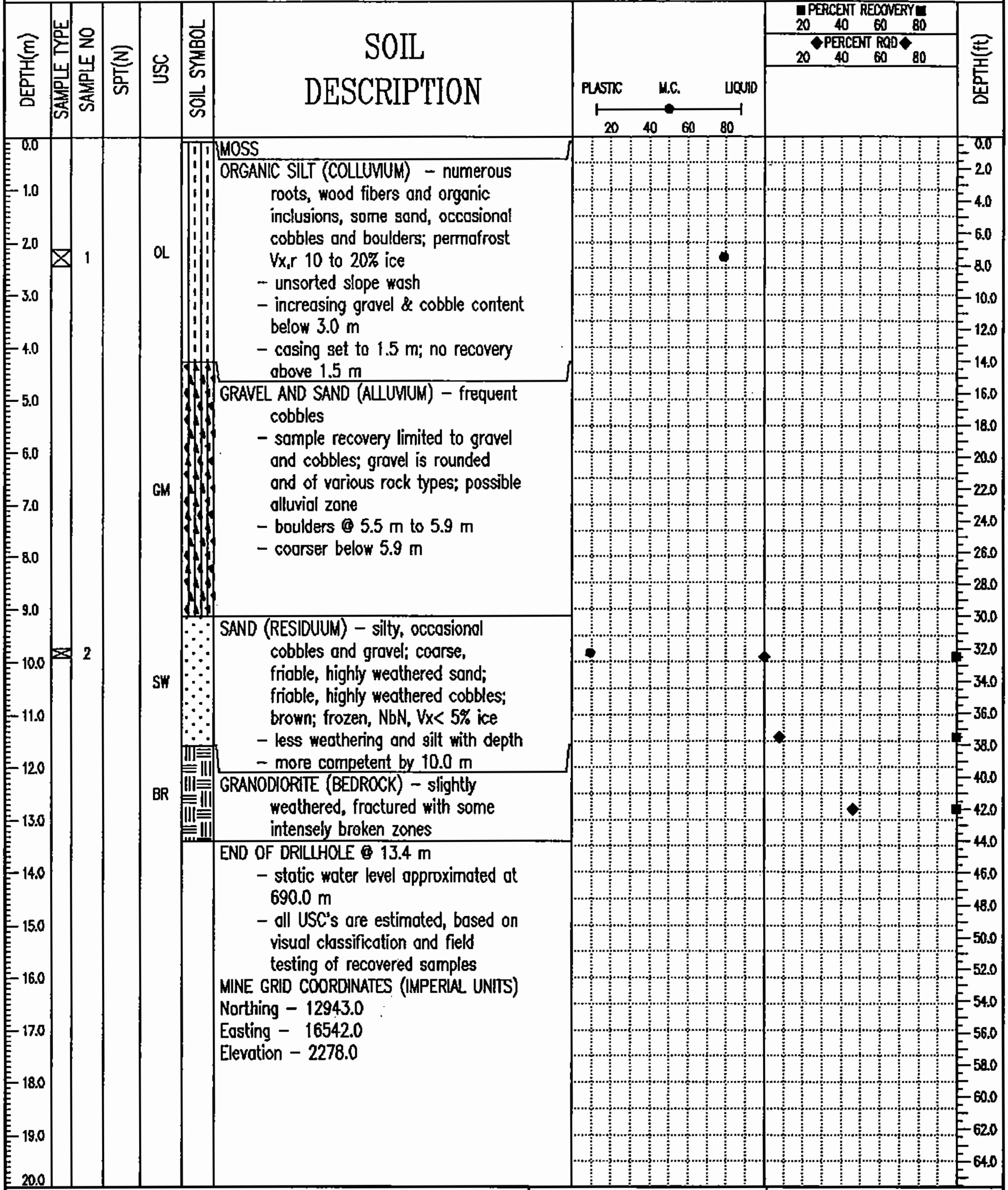
DEPTH(m): 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0

EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH REVIEWED BY: CRH Fig. No:
COMPLETION DEPTH: 4.3 m COMPLETE: 95/09/30	Page 1 of 1

95/11/28 11:44AM (REC/RQD)

DETAILED GEOTECHNICAL DESIGN	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 95-G08
PROPOSED TAILINGS DAM – MINTO PROJECT	DRILL: LONGYEAR 38, C/W NQ DRILL RODS	PROJECT NO: 0201-95-11509
NEAR MINTO CREEK, YUKON	UTM ZONE: 8 N6945407 E386689	ELEVATION: 694.30 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ NQ CORE ☰ 75 mm SPOON ▯ CRREL BARREL



MOSS

OL ORGANIC SILT (COLLUVIUM) – numerous roots, wood fibers and organic inclusions, some sand, occasional cobbles and boulders; permafrost Vx,r 10 to 20% ice
- unsorted slope wash
- increasing gravel & cobble content below 3.0 m
- casing set to 1.5 m; no recovery above 1.5 m

GM GRAVEL AND SAND (ALLUVIUM) – frequent cobbles
- sample recovery limited to gravel and cobbles; gravel is rounded and of various rock types; possible alluvial zone
- boulders @ 5.5 m to 5.9 m
- coarser below 5.9 m

SW SAND (RESIDUUM) – silty, occasional cobbles and gravel; coarse, friable, highly weathered sand; friable, highly weathered cobbles; brown; frozen, NbN, Vx< 5% ice
- less weathering and silt with depth
- more competent by 10.0 m

BR GRANODIORITE (BEDROCK) – slightly weathered, fractured with some intensely broken zones

END OF DRILLHOLE @ 13.4 m
- static water level approximated at 690.0 m
- all USC's are estimated, based on visual classification and field testing of recovered samples

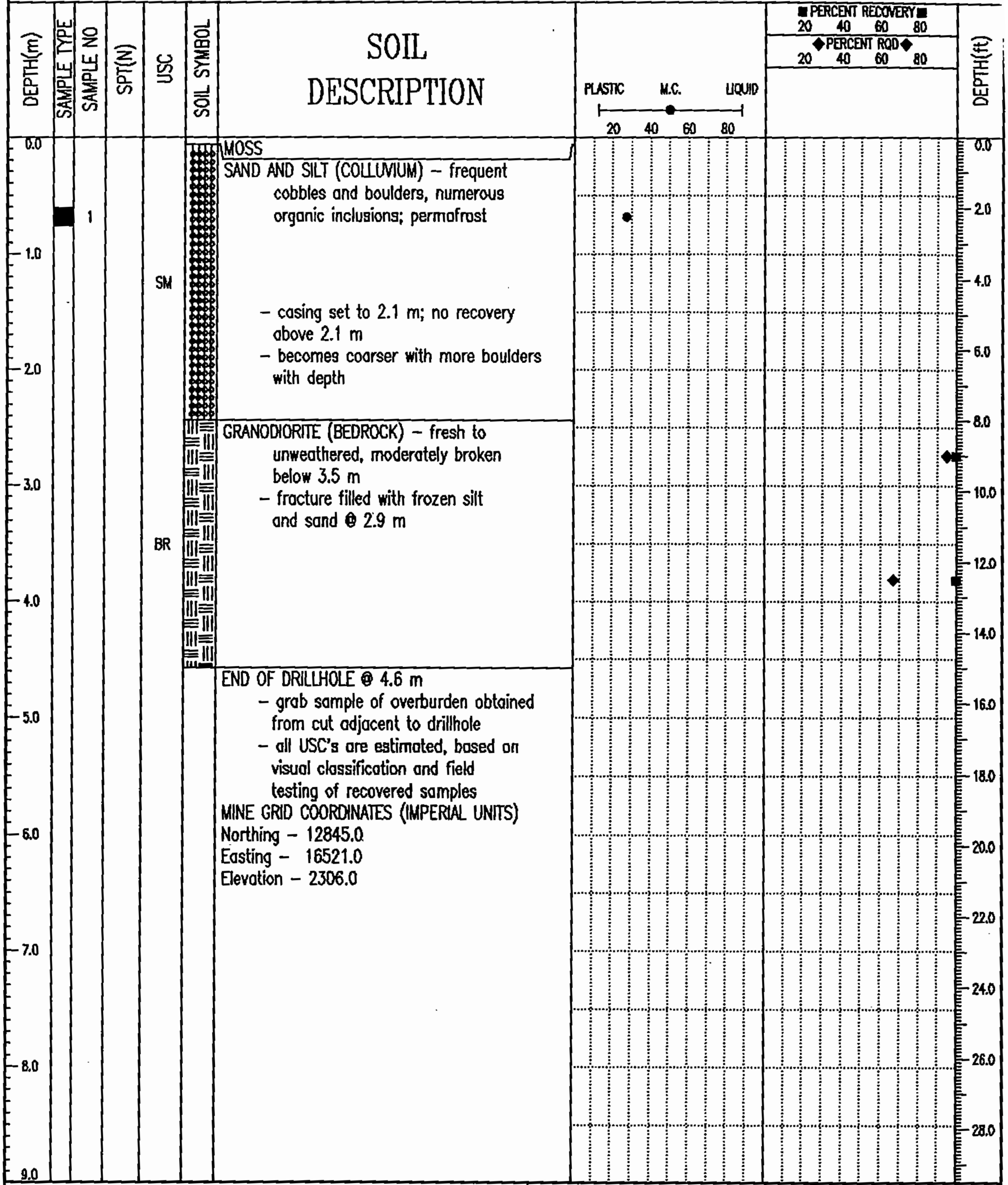
MINE GRID COORDINATES (IMPERIAL UNITS)
Northing – 12943.0
Easting – 16542.0
Elevation – 2278.0

EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 13.4 m
	REVIEWED BY: CRH	COMPLETE: 95/09/29
	Fig. No:	Page 1 of 1

95/11/28 02:02PM ([illegible])

DETAILED GEOTECHNICAL DESIGN	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 95-G09
PROPOSED TAILINGS DAM – MINTO PROJECT	DRILL: LONGYEAR 38, C/W NQ DRILL RODS	PROJECT NO: 0201-95-11509
NEAR MINTO CREEK, YUKON	UTM ZONE: 8 N6945377 E386682	ELEVATION: 702.90 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ NQ CORE ☰ 75 mm SPOON ▯ CRREL BARREL



MOSS

SAND AND SILT (COLLUVIUM) – frequent cobbles and boulders, numerous organic inclusions; permafrost

- casing set to 2.1 m; no recovery above 2.1 m
- becomes coarser with more boulders with depth

GRANODIORITE (BEDROCK) – fresh to unweathered, moderately broken below 3.5 m

- fracture filled with frozen silt and sand @ 2.9 m

END OF DRILLHOLE @ 4.6 m

- grab sample of overburden obtained from cut adjacent to drillhole
- all USC's are estimated, based on visual classification and field testing of recovered samples

MINE GRID COORDINATES (IMPERIAL UNITS)

Northing – 12845.0

Easting – 16521.0

Elevation – 2306.0

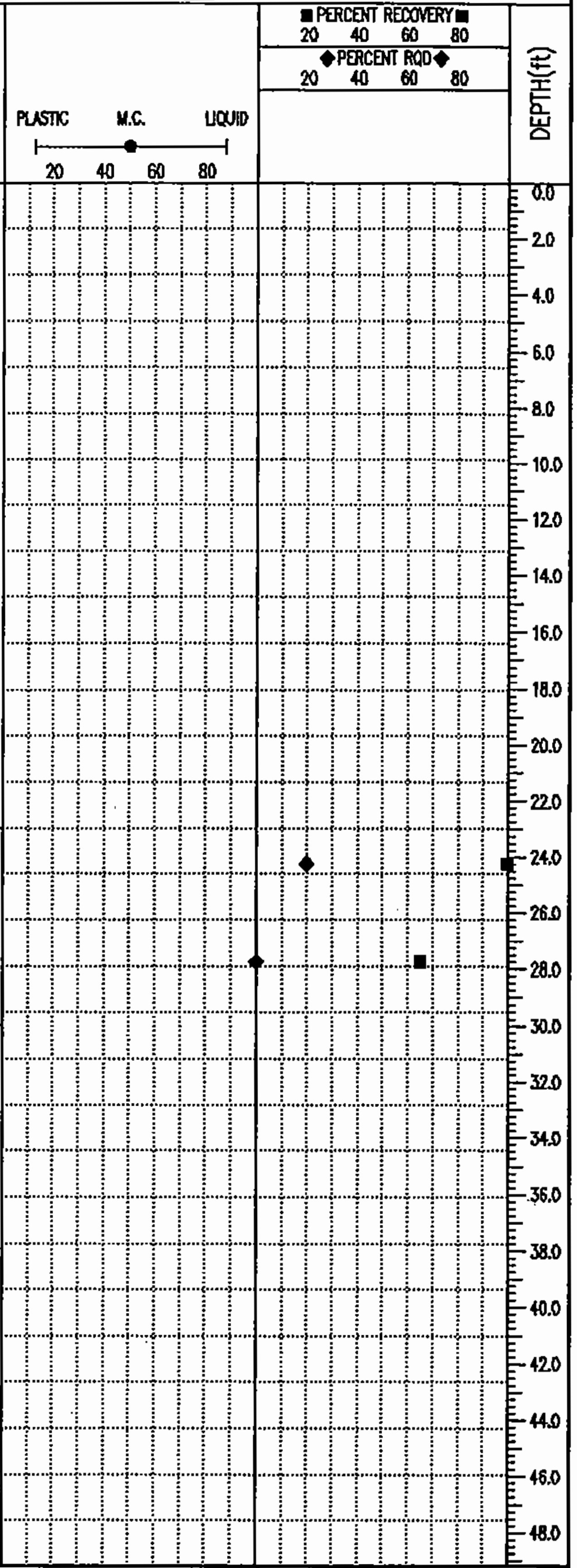
EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 4.6 m
	REVIEWED BY: CRH	COMPLETE: 95/09/28
	Fig. No:	Page 1 of 1

95/11/28 11:43AM (REC/RQ09)

DETAILED GEOTECHNICAL DESIGN	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 95-G10
PROPOSED TAILINGS DAM – MINTO PROJECT	DRILL: LONGYEAR 38, C/W NQ DRILL RODS	PROJECT NO: 0201-95-11509
NEAR MINTO CREEK, YUKON	UTM ZONE: 8 N6945445 E386716	ELEVATION: 690.70 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ NQ CORE ☰ 75 mm SPOON ‖ CRREL BARREL

DEPTH(m)	SAMPLE TYPE	SAMPLE NO	SPT(N)	USC	SOIL SYMBOL	SOIL DESCRIPTION
0.0				SP		SAND (COLLUVIUM) – some gravel, some silt, frequent cobbles and boulders; well graded, angular, friable sand; friable, angular, weathered gravel; brown; compact – casing set to 1.5 m; no recovery above 1.5 m – more boulders with depth – recovery limited to cobbles and gravel
7.0				BR		GRANODIORITE (BEDROCK) – moderately to slightly weathered; intensely broken; fractures up to 51 mm filled with decomposed sand and gravel (granodiorite)
9.1						END OF DRILLHOLE @ 9.1 m – static water level approximated at 687.3 m – all USC's are estimated, based on visual classification and field testing of recovered samples MINE GRID COORDINATES (IMPERIAL UNITS) Northing – 13070.0 Easting – 16626.0 Elevation – 2266.0



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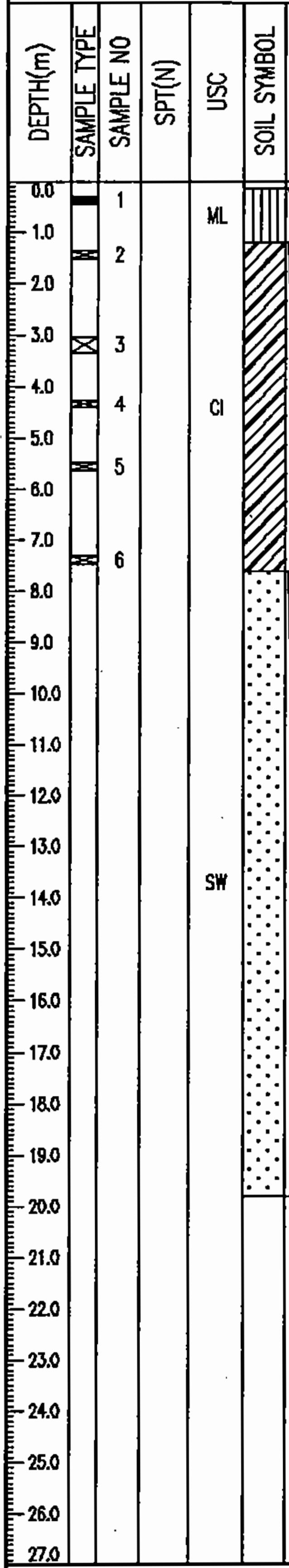
LOGGED BY: CRH	COMPLETION DEPTH: 9.1 m
REVIEWED BY: CRH	COMPLETE: 95/09/30
Fig. No:	Page 1 of 1

95/11/28 11:46AM (RECRD015)

DETAILED GEOTECHNICAL DESIGN	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 95-G11
PROPOSED TAILINGS DAM – MINTO PROJECT	DRILL: LONGYEAR 38, C/W NQ DRILL RODS	PROJECT NO: 0201-95-11509
NEAR MINTO CREEK, YUKON	UTM ZONE: 8 N6945281 E386622	ELEVATION: 724.80 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ NQ CORE ☰ 75 mm SPOON ▥ CRREL BARREL



SOIL DESCRIPTION

MOSS, ROOTS

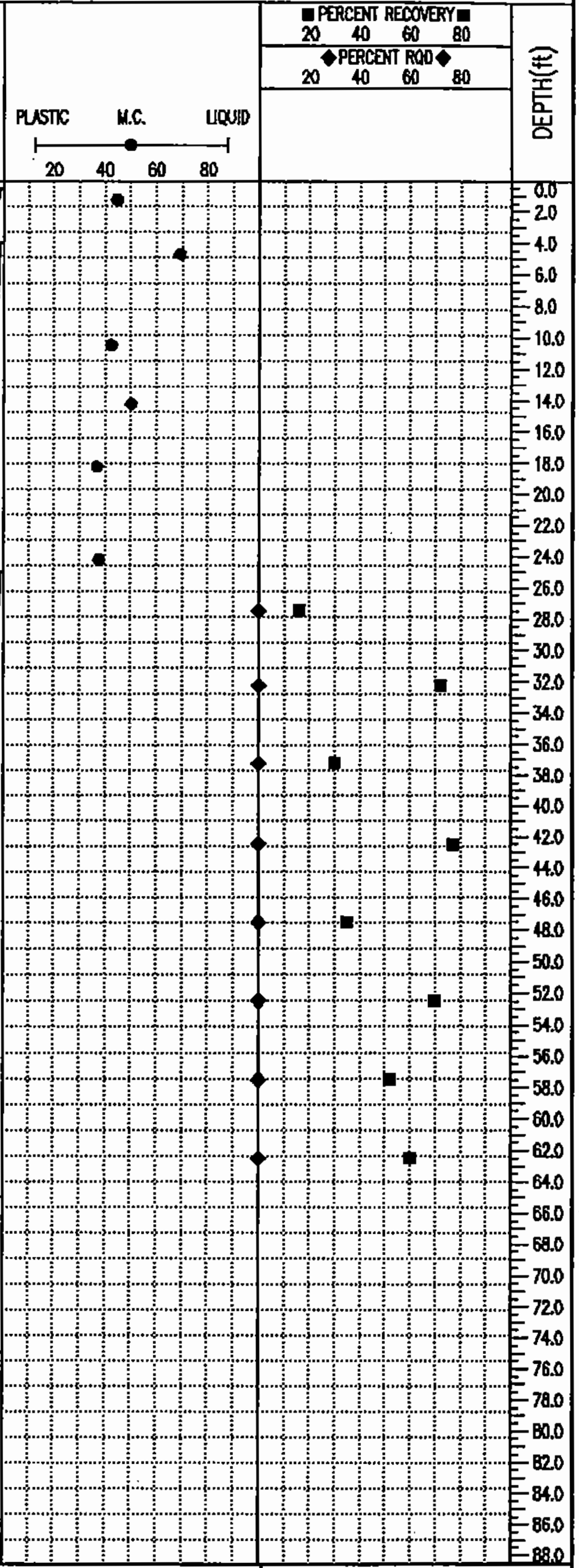
SILT – some fine sand, numerous organics; wet; firm to soft; mottled brown with black
- frozen by 0.9 m

CLAY AND SILT – medium plastic; wet when thawed; occasional organic fibres; dark grey
- permafrost; Vs, Vx up to 40% ice, ice in thin layers or lens
- becomes lighter grey; Vr,Vx 10 to 20% ice
- temperature = – 0.14 C at 2.1 m
- temperature = – 0.29 C at 4.3 m
- becomes less plastic, olive grey, with varved bedding (1 to 2 mm), Vx, 10%< ice
- temperature = –0.26 C at 5.5 m

SAND (RESIDUUM) – some silt, occasional gravel; highly weathered, friable, angular coarse sand; friable gravel; rusty brown, frozen; NbN

END OF DRILLHOLE @ 19.8 m
- thermister string (EBA #945) installed to 19.5 m below ground surface
- all USC's are estimated, based on visual classification and field testing of recovered samples

MINE GRID COORDINATES (IMPERIAL UNITS)
Northing – 12524.0
Easting – 16335.0
Elevation – 2378.0



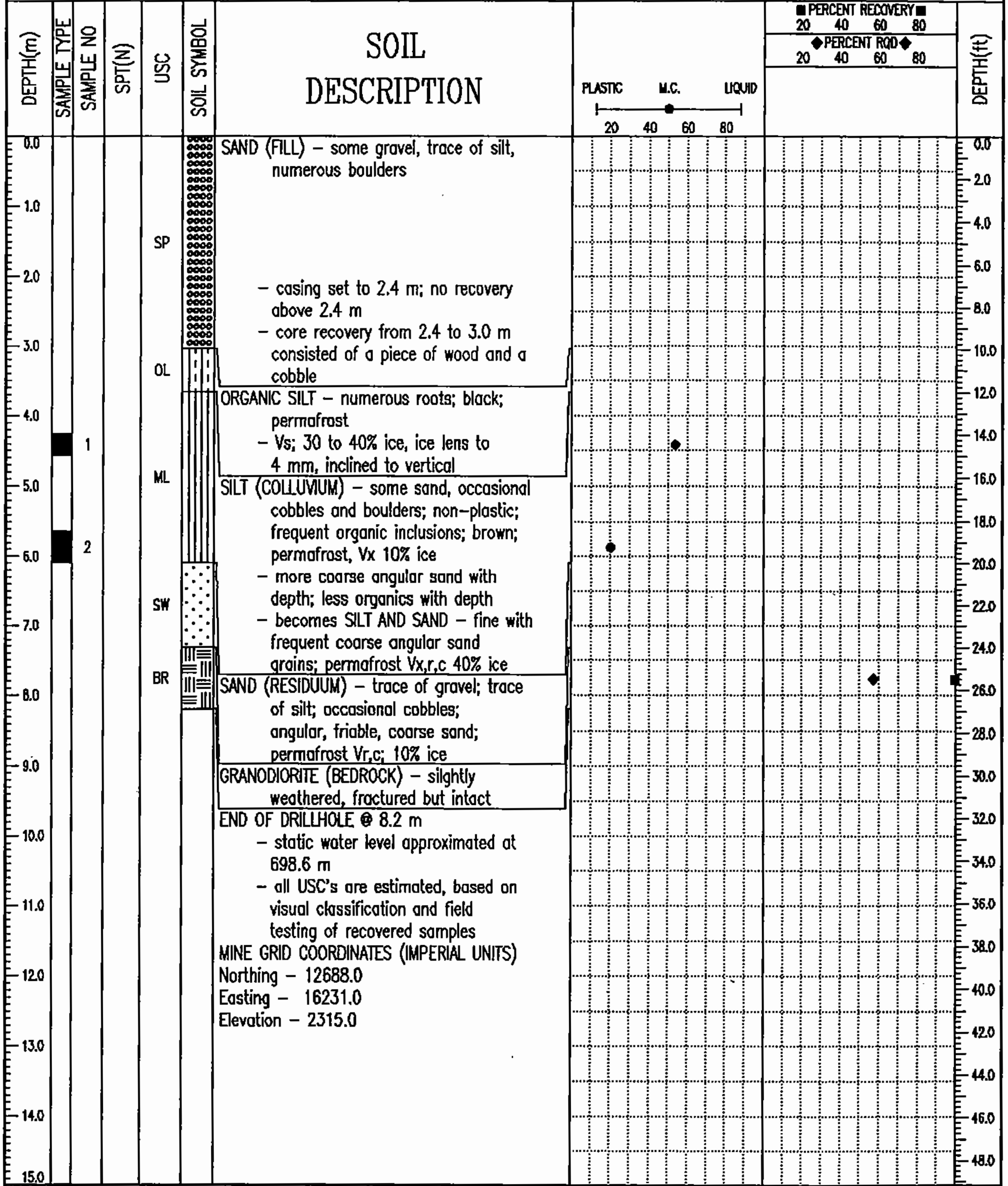
EBA Engineering Consultants Ltd.
Whitehorse, Yukon

LOGGED BY: CRH	COMPLETION DEPTH: 19.8 m
REVIEWED BY: CRH	COMPLETE: 95/09/25
Fig. No:	Page 1 of 1

95/11/28 11:47AM (REC#Q027)

DETAILED GEOTECHNICAL DESIGN	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 95-G12
PROPOSED TAILINGS DAM – MINTO PROJECT	DRILL: LONGYEAR 38, C/W NQ DRILL RODS	PROJECT NO: 0201-95-11509
NEAR MINTO CREEK, YUKON	UTM ZONE: 8 N6945332 E386592	ELEVATION: 705.60 (m)

SAMPLE TYPE ■ GRAB SAMPLE ◪ NO RECOVERY ☒ NQ CORE ☰ 75 mm SPOON ▥ CRREL BARREL



SOIL DESCRIPTION

SAND (FILL) – some gravel, trace of silt, numerous boulders

- casing set to 2.4 m; no recovery above 2.4 m
- core recovery from 2.4 to 3.0 m consisted of a piece of wood and a cobble

ORGANIC SILT – numerous roots; black; permafrost

- Vs; 30 to 40% ice, ice lens to 4 mm, inclined to vertical

SILT (COLLUVIUM) – some sand, occasional cobbles and boulders; non-plastic; frequent organic inclusions; brown; permafrost, Vx 10% ice

- more coarse angular sand with depth; less organics with depth
- becomes SILT AND SAND – fine with frequent coarse angular sand grains; permafrost Vx,r,c 40% ice

SAND (RESIDUUM) – trace of gravel; trace of silt; occasional cobbles; angular, friable, coarse sand; permafrost Vr,c; 10% ice

GRANODIORITE (BEDROCK) – silghtly weathered, fractured but intact

END OF DRILLHOLE @ 8.2 m

- static water level approximated at 698.6 m
- all USC's are estimated, based on visual classification and field testing of recovered samples

MINE GRID COORDINATES (IMPERIAL UNITS)
Northing – 12688.0
Easting – 16231.0
Elevation – 2315.0

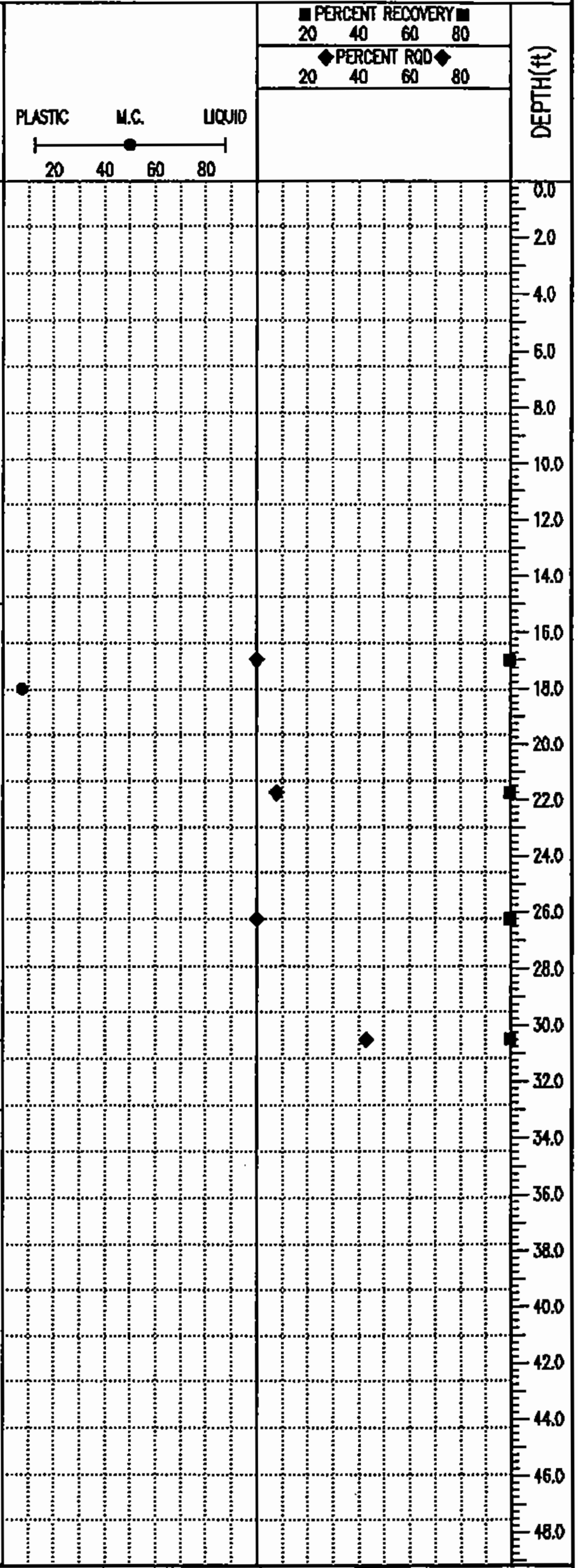
EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 8.2 m
	REVIEWED BY: CRH	COMPLETE: 95/09/28
	Fig. No:	Page 1 of 1

95/11/28 01:46PM (RECRD015)

DETAILED GEOTECHNICAL DESIGN	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 95-G13
PROPOSED TAILINGS DAM – MINTO PROJECT	DRILL: LONGYEAR 38, C/W NQ DRILL RODS	PROJECT NO: 0201-95-11509
NEAR MINTO CREEK, YUKON	UTM ZONE: 8 N6945361 E386601	ELEVATION: 698.00 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ NQ CORE ☰ 75 mm SPOON ◫ CRREL BARREL

DEPTH(m)	SAMPLE TYPE	SAMPLE NO	SPT(N)	USC	SOIL SYMBOL	SOIL DESCRIPTION
0.0				SM		GRAVEL AND SAND (ALLUVIUM) – some silt; numerous cobbles and boulders – casing set to 1.8 m; no recovery above 1.8 m; below 1.8 m recovery limited to gravel and cored cobbles/boulders – some rounded gravel recovered; various rock types observed in the recovery
4.5		1		SW		SAND – (RESIDUUM) – trace of silt; coarse, angular, friable, highly weahtered sand; frozen Vx, Vc, 10% < ice – Nbn below 5.8 m (or unfrozen) – zones of less weathering @ 5.8 to 6.4 m and 8.5 to 8.8 m
9.3				BR		GRANODIORITE (BEDROCK) – freshly weathered, intact bedrock
10.1						END OF DRILLHOLE @ 10.1 m – possible fault or shear zone – static water level approximated at 695.2 m – all USC's are estimated, based on visual classification and field testing of recovered samples MINE GRID COORDINATES (IMPERIAL UNITS) Northing – 12784.0 Easting – 16259.0 Elevation – 2290.0



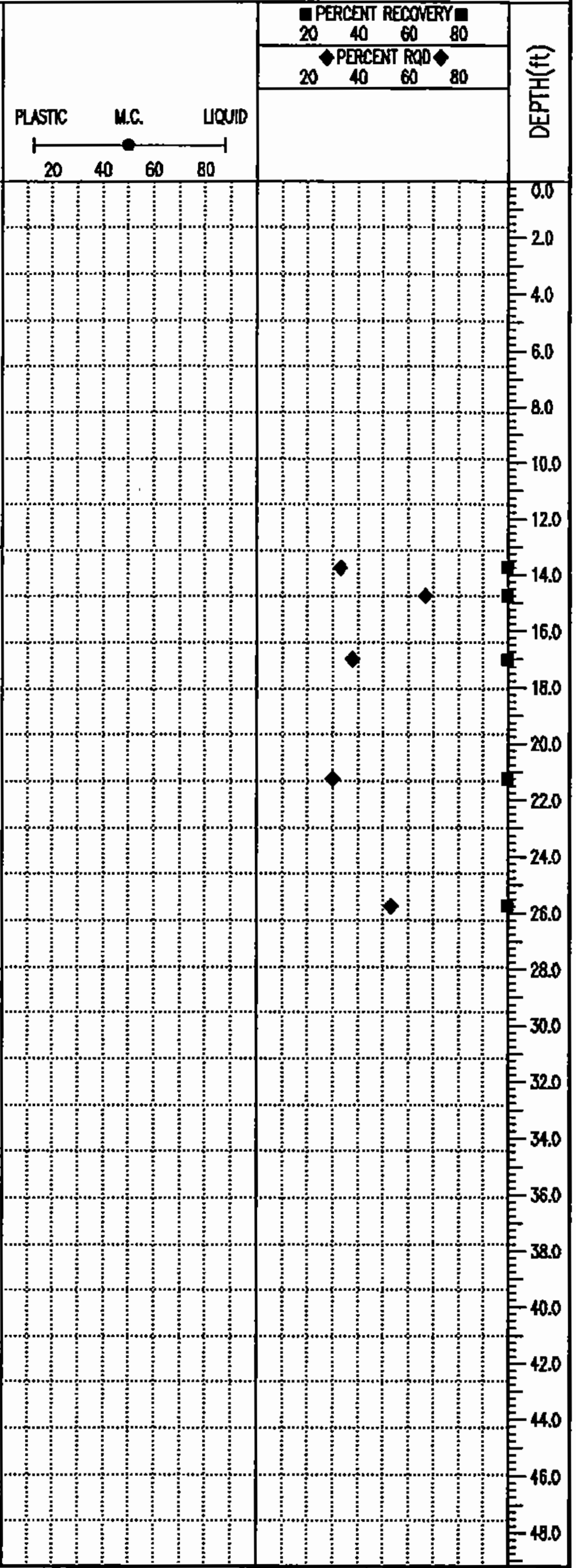
EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 10.0 m
	REVIEWED BY: CRH	COMPLETE: 95/09/28
	Fig. No:	Page 1 of 1

95/11/28 01:47PM (RECRD015)

DETAILED GEOTECHNICAL DESIGN	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 95-G14
PROPOSED TAILINGS DAM – MINTO PROJECT	DRILL: LONGYEAR 38, C/W NQ DRILL RODS	PROJECT NO: 0201-95-11509
NEAR MINTO CREEK, YUKON	UTM ZONE: 8 N6945379 E386597	ELEVATION: 698.30 (m)

SAMPLE TYPE ■ GRAB SAMPLE ▨ NO RECOVERY ☒ NQ CORE ☰ 75 mm SPOON ▥ CRREL BARREL

DEPTH(m)	SAMPLE TYPE	SAMPLE NO	SPT(N)	USC	SOIL DESCRIPTION
0.0				SP/GP	SAND (COLLUVIUM) – numerous boulders and cobbles, trace of gravel, trace of silt; angular, weathered sand; angular, weathered gravel, cobbles and boulders – casing set to 1.8 m; no recovery above 1.8 m; poor recovery above 4.0 m – below 3.0 m; possible alluvial sand and gravel, rounded gravel present in recovery
4.0				BR	GRANODIORITE (BEDROCK) – fresh to unweathered, shattered throughout
8.5					END OF DRILLHOLE @ 8.5 m – constant head permeability test completed from 5.9 to 8.5 m – static water level approximately 695.0 to 696.5 m – all USC's are estimated, base on visual classification and field test of recovered samples MINE GRID COORDINATES (IMPERIAL UNITS) Northing – 12842.0 Easting – 16244.0 Elevation – 2291.0



LOGGED BY: CRH	COMPLETION DEPTH: 8.5 m
REVIEWED BY: CRH	COMPLETE: 95/09/27
Fig. No:	Page 1 of 1

EBA Engineering Consultants Ltd.
Whitehorse, Yukon

95/11/28 01:48PM (BEB0015)

APPENDIX A.2
EBA 1994 BOREHOLE LOGS
TAILINGS/WATER DAM AREA

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

DEPTH(m): 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0, 17.0, 18.0, 19.0, 20.0, 21.0, 22.0, 23.0, 24.0, 25.0, 26.0, 27.0, 28.0, 29.0, 30.0

SAMPLE TYPE	SAMPLE NO	SPT(N)	USC
	1		
☒	2	7	
	3		
▤	4		
▤	5		
	6		
	7		
▤	8		
☒	9	70/120	SM
	10		
	11		

SOIL DESCRIPTION

PEAT – Fibrous; wet; soft; dark brown

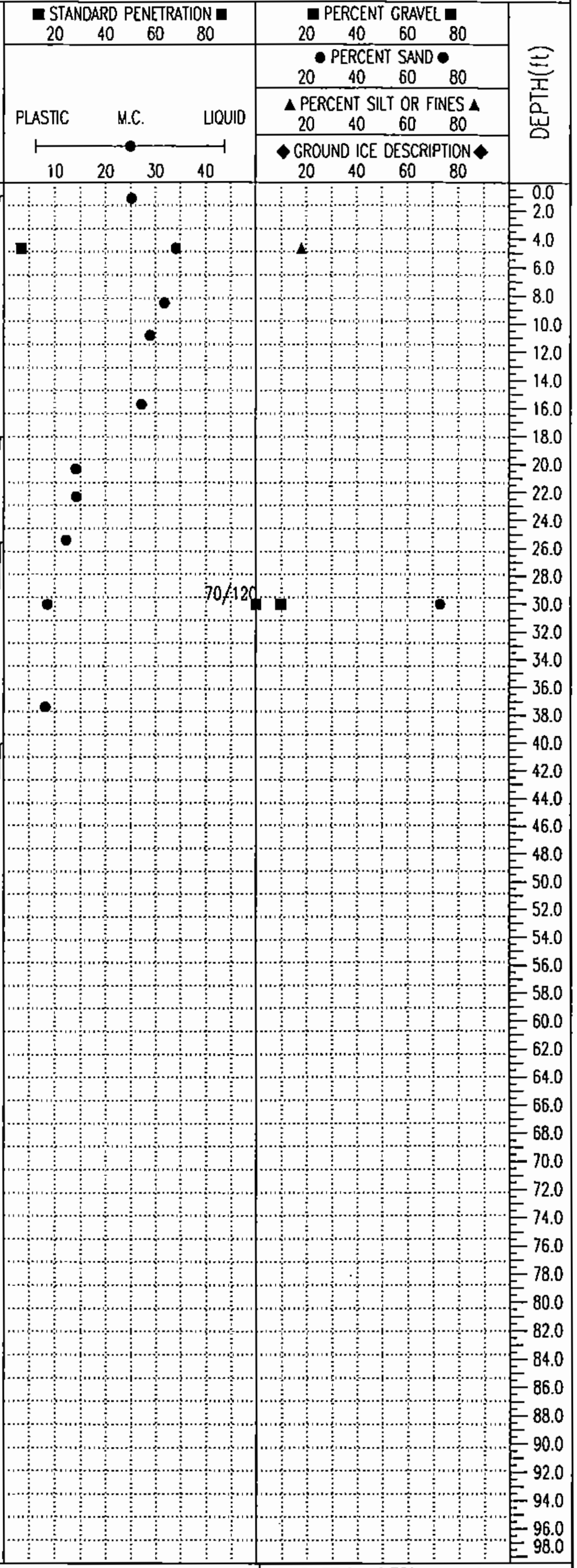
ORGANIC SILT (COLLUVIUM) – clayey to some clay, trace of sand, trace of gravel; frequent peat inclusions, occasional cobbles; wet; soft; dark grey
- permafrost below 3.1 m; Nbe with Vx<5%, some Vr 10% ice in Sample No. 4
- becomes cobbly with depth

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

95/06/27 05:04PM (0201-30)

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
4.2		1			
4.7	☒	2	55		
6.2	☒	3	40/150		
7.7	☒	4	50/40	SM	

SOIL DESCRIPTION

0.0 m

ORGANIC SILT – some sand, numerous roots; occasional 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

– water table @ 4.1 m

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

– slow, hard drilling, 45 seconds for 25 mm

END OF BOREHOLE @ 7.7 m

– water table @ 4.1 m

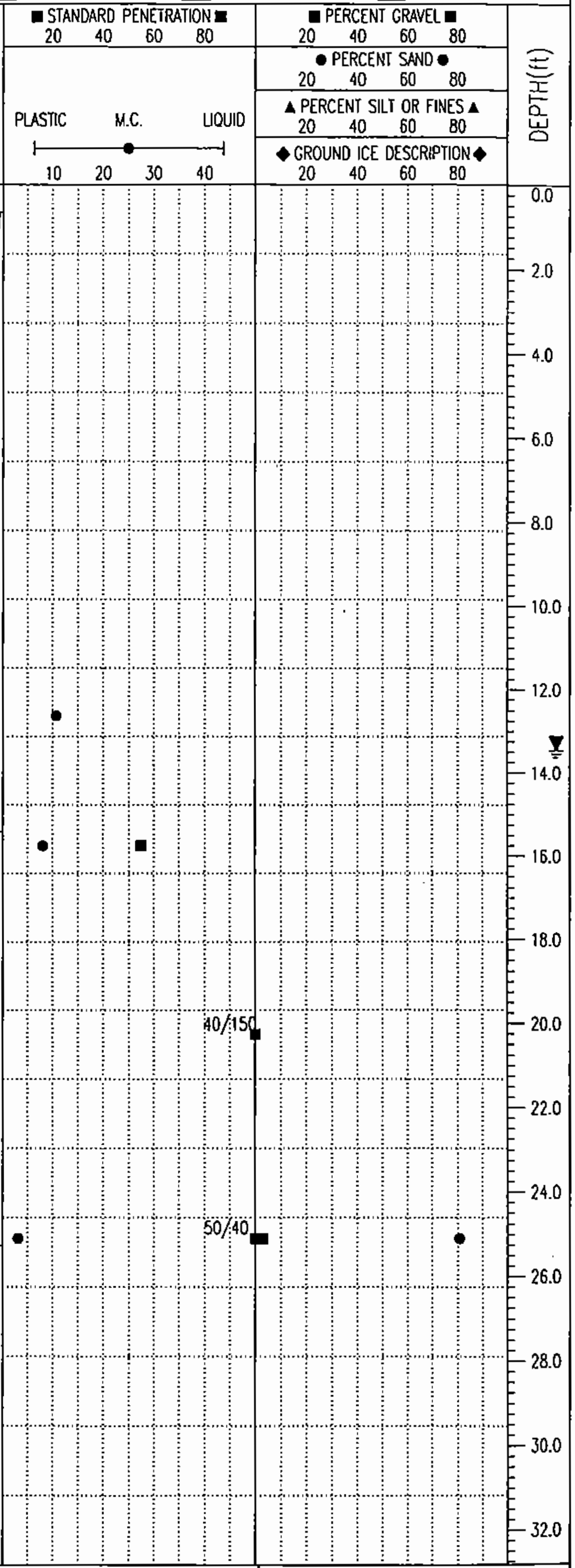
MINE GRID COORDINATES (IMPERIAL UNITS)

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-G12
TAILINGS DAM (NORTH ABUTMENT)	DRILL: CME-75 C/W HOLLOW STEM AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6949280 E388727	ELEVATION: 759.44 (m)

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

SAMPLE TYPE	SAMPLE NO	SPT(N)
	1	
☒	2	43/150
☒	3	
☒	4	40
☒	5	50/60

SOIL DESCRIPTION

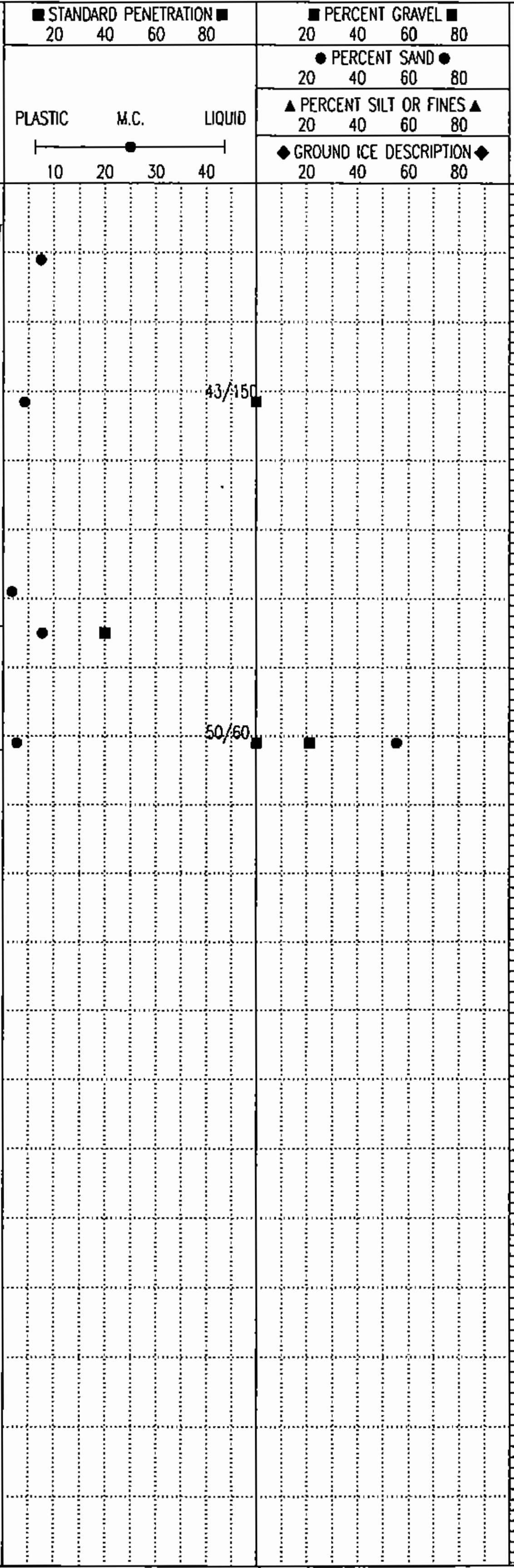
ORGANIC SAND – silty, some gravel; moist; loose; dark brown,
- frequent root fibers

SAND (COLLUVIUM) – some gravel; some silt; frequent cobbles; angular, quartz and mica rich sand; angular friable gravel; damp; dense; rusty brown
- becomes light grey-brown below 1.5 m
- difficult, rough drilling 1.8 to 2.4 m

SAND (RESIDUUM) – some gravel
- rough, hard drilling
- drilling refusal @ 4.1 m

END OF BOREHOLE @ 4.1 m

MINE GRID COORDINATES (IMPERIAL UNITS)
Northing – 11915.79
Easting – 14429.77
Elevation – 2491.60
EBA BOREHOLE NO: 11509-BH14



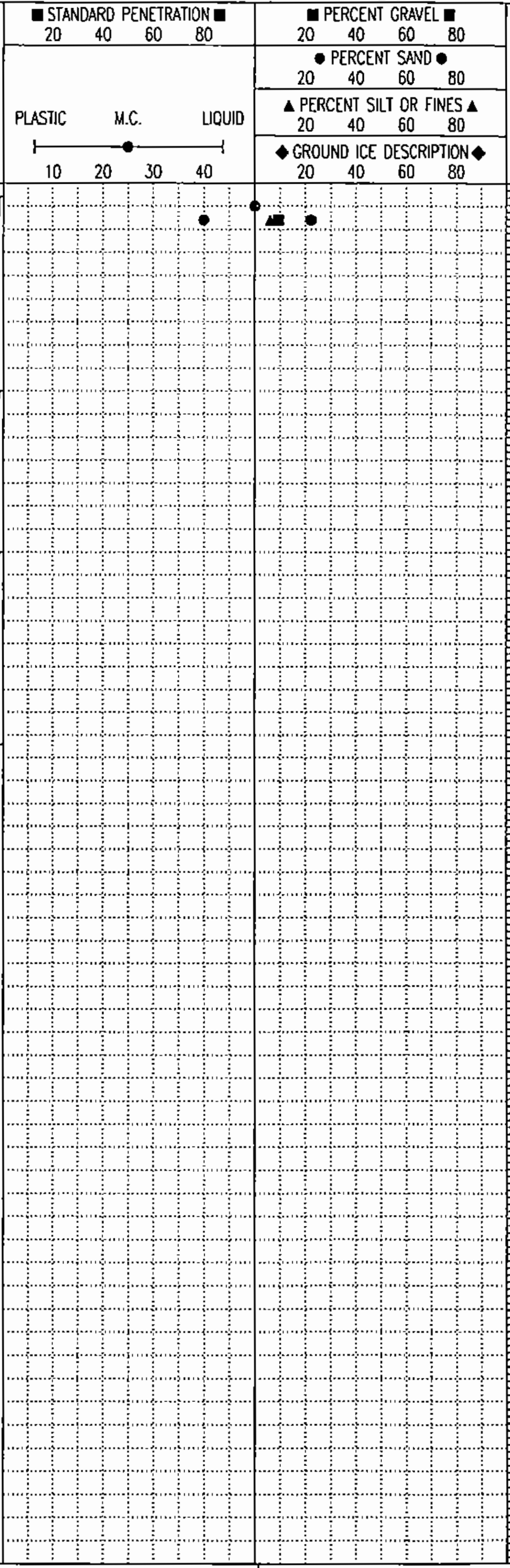
EBA ENGINEERING CONSULTANTS LTD.	LOGGED BY: CRH	COMPLETION DEPTH: 4.1 m
Whitehorse, Yukon	REVIEWED BY: CRH	COMPLETE: 94/06/26
	Fig. No:	Page 1 of 1

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

PROPOSED COPPER MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 94-G13
WATER RETENTION DAM (SOUTH ABUTMENT)	DRILL: LONGYEAR 38, 3 7/8 TRICONE, HW	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6949376 E389101	ELEVATION: 714.85 (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		1 2				SURFACE - willows, alders, moss and organics (driller noted clear ice @ base of organics)
2.0		3				SILT (COLLUVIUM) - sandy, trace of organics, olive brown, frozen - easy drilling - all cuttings washed out - sampling not possible
5.0		4				SAND (RESIDUUM) - trace of silt and organics, olive brown to brownish - all cuttings washed out - sampling not possible grey, frozen
8.0						BEDROCK - grandorite - grinding @ 8.0 m - lost circulation from top of casing (washed out from below) - intact bedrock @ 8.5 m - continued drilling to 12.2 m
12.2						END OF BOREHOLE @ 12.2 m NOTE: hole @ toe of solifluction lobe MINE GRID COORDINATES (IMPERIAL UNITS) Northing - 12186.02 Easting - 15667.50 Elevation - 2345.30 EBA BOREHOLE NO: 11509-BH17



DEPTH(ft) 0.0 – 98.0

EBA ENGINEERING CONSULTANTS LTD. Whitehorse, Yukon	LOGGED BY: JRT	COMPLETION DEPTH: 12.2 m
	REVIEWED BY: CRH	COMPLETE: 94/08/22
	Fig. No:	Page 1 of 1

95/06/27 05:07PM (0201-30)

PROPOSED COPPER MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 94-G14
WATER RETENTION DAM (CENTRE)	DRILL: CME-75 C/W HOLLOW STEM AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YT	UTM ZONE: 8 N6949427 E389062	ELEVATION: 708.45 (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
0.8		1			
1.7	☒	2	9		
3.3	☒	3	16		
4.6	☒	4	67		
5.7		5			

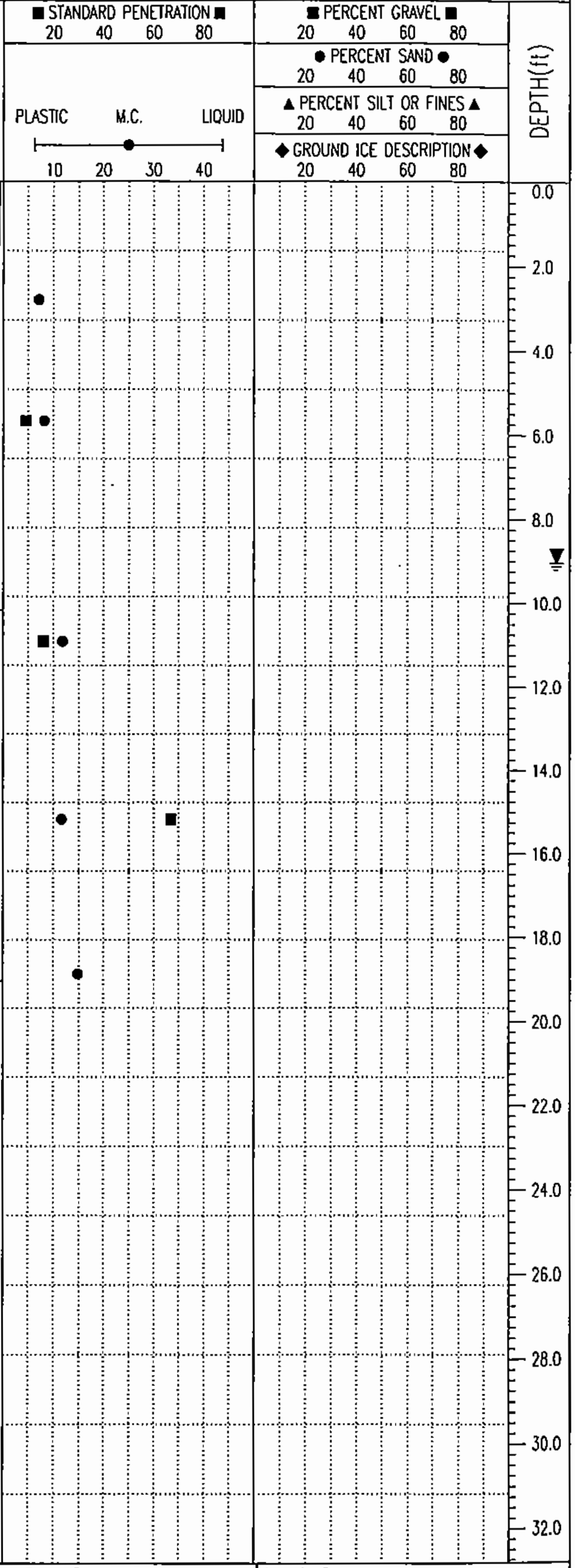
SOIL DESCRIPTION

ORGANIC SILT – 100 mm thick
cobbles; unsorted; matrix supported; angular to subangular well graded sand; fine to coarse angular to subangular gravel; angular to subangular cobbles; moist; loose; brown
SAND – gravelly, some silt, frequent
- becomes moister with depth
- cobbles or boulders from 2.0 to 3.0 m
- water table @ 2.75 m

- SAND (RESIDUUM) – some gravel, trace to some silt, occasional silt inclusions; unsorted; angular well graded sand; angular friable fine gravel; quartz and mica rich; moist to wet; very dense; rusty brown
- drilling much harder from 3.1 m to 4.5 m
- very hard slow drilling from 4.6 m to end of hole (60 seconds+ per 25 mm)

END OF BOREHOLE @ 5.8 m
- no sloughing
- water @ 2.75 m

NOTE BH: in cut bench 0.5 m deep
MINE GRID COORDINATES (IMPERIAL UNITS)
Northing – 12357.83
Easting – 15544.19
Elevation – 2324.30
EBA BOREHOLE NO: 11509-BH11



EBA ENGINEERING CONSULTANTS LTD. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 5.8 m
	REVIEWED BY: CRH	COMPLETE: 94/06/24
	Fig. No:	Page 1 of 1

95/06/27 05:08PM (0201-10)

PROPOSED COPPER MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 94-G15
WATER RETENTION DAM (NORTH ABUTMENT)	DRILL: CME-75 C/W HOLLOW STEM AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6949477 E389034	ELEVATION: 724.05 (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
		1			
	☒	2	66	SM	▨
	☒	3	30/75		
		4			
		5			
		6			
	▨	7	30		

SOIL DESCRIPTION

SAND (RESIDUUM) – gravelly, some silt, occasional cobbles; well graded angular sand; fine angular gravel; unsorted; compact; olive grey

- becomes dense and siltier with depth
- gravelly or cobbly zone from 1.8 to 2.4 m
- centre bit coated in rock powder @ 4.5 m
- from 4.6 to 6.1 m drilling very slow (10 to 20 seconds per 25 mm)
- 6.1 to 7.6 m, very slow hard drilling (10 to 15 s per 25 mm), some rough sections

END OF BOREHOLE @ 7.7 m

- no sloughing
- no water
- no permafrost

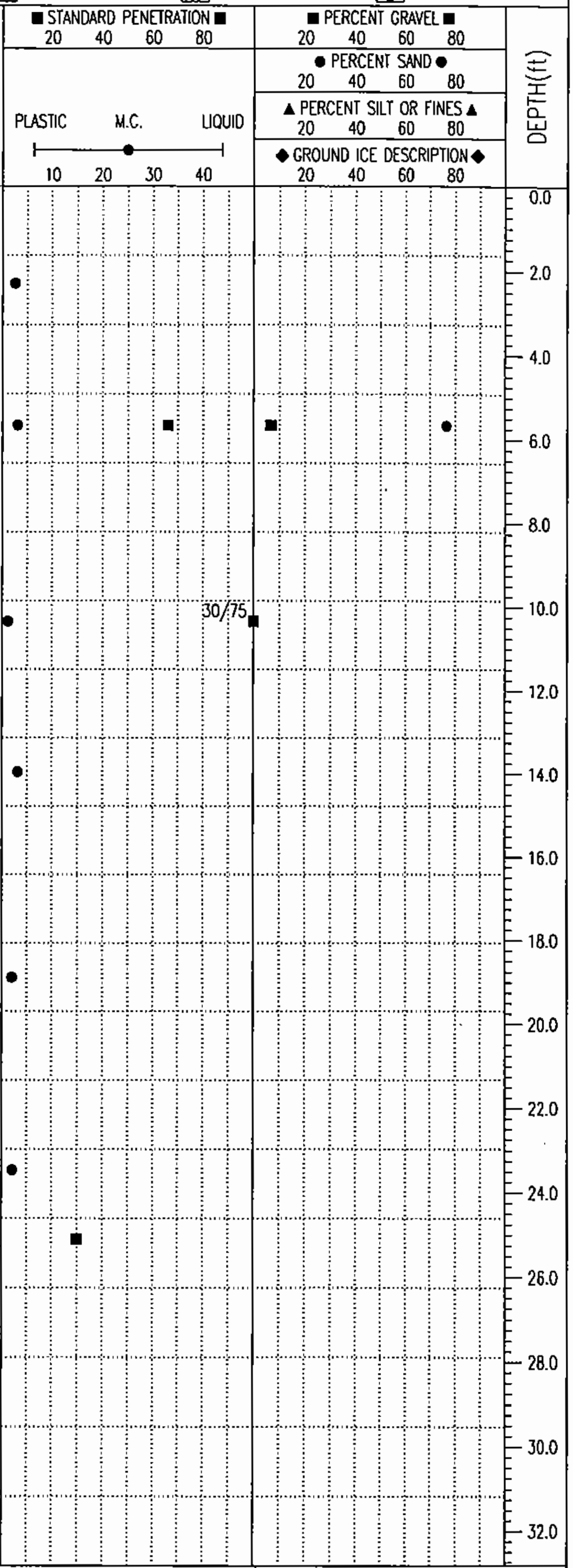
NOTE: BH located on a cut bench roughly 2 m below natural ground;

MINE GRID COORDINATES (IMPERIAL UNITS)

Northing – 12525.58

Easting – 15458.62

Elevation – 2375.50



Depth (m) scale: 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0

EBA ENGINEERING CONSULTANTS LTD. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 7.7 m
	REVIEWED BY: CRH	COMPLETE: 94/06/24
	Fig. No:	Page 1 of 1

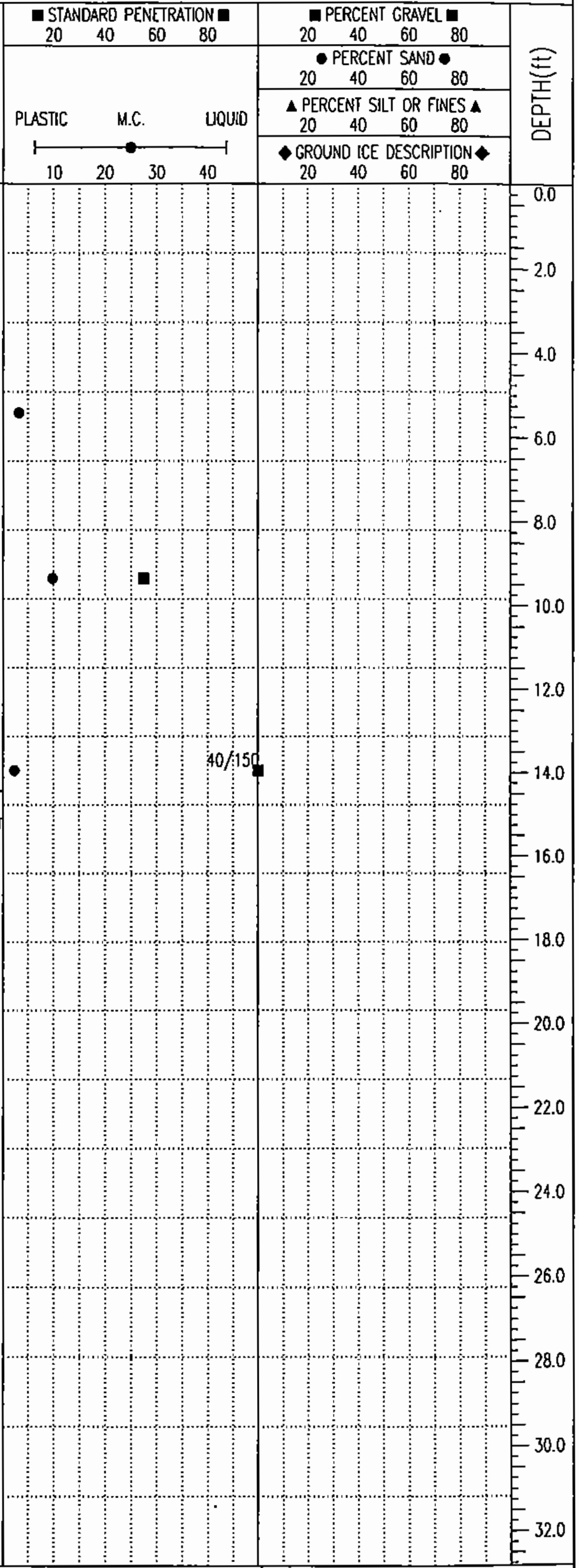
95/06/27 05:09PM (0201-10)

PROPOSED COPPER MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 94-G16
ALT. RETENTION DAM (NORTH CENTRE)	DRILL: CME-75 C/W HOLLOW STEM AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YUKON	UTM ZONE: 8 N6949582 E389217	ELEVATION: 705.15 (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						SAND – gravelly, silty, numerous cobbles; angular to subangular well graded sand; angular to subangular gravel; unsorted; moist to wet; loose; dark brown – less cobbles below 1.2 m
		1				
						– becomes darker brown below 2.4 m; some ice crystals Nbe
		2	55			SAND (RESIDUUM) – some fine gravel, some to trace of silt; angular, fine gravel; unsorted; damp; compact; light brown – becomes very dense by 4.0 m
		3	40/150			
						GRANODIORITE (BEDROCK) – hard REFUSAL @ 4.6 – minor seepage @ 4.6 – no well installed
						END OF BOREHOLE @ 4.6 m MINE GRID COORDINATES (IMPERIAL UNITS) Northing – 12847.49 Easting – 16069.55 Elevation – 2313.50 EBA BOREHOLE NO: 11509-BH16

DEPTH(m): 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0



EBA ENGINEERING CONSULTANTS LTD.
Whitehorse, Yukon

LOGGED BY: CRH	COMPLETION DEPTH: 4.6 m
REVIEWED BY: CRH	COMPLETE: 94/06/27
Fig. No:	Page 1 of 1

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

PROPOSED COPPER MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: 94-G17
ALTERNATE RETENTION DAM (SOUTH ABUTMENT)	DRILL: LONGYEAR 38, 3 7/8 TRICONE, HW	PROJECT NO: 0201-11509
(SOUTH ABUTMENT) MINTO CREEK, YUKON	UTM ZONE: 8 N6949491 E389265	ELEVATION: 713.81 (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
0.0					
1.0		1			
2.0					
3.0		2			
4.0					
5.0					
6.0					
7.0					
8.0					
9.0					
10.0					
11.0					
12.0					
13.0					
14.0					
15.0					
16.0					
17.0					
18.0					
19.0					
20.0					
21.0					
22.0					
23.0					
24.0					
25.0					
26.0					
27.0					
28.0					
29.0					
30.0					

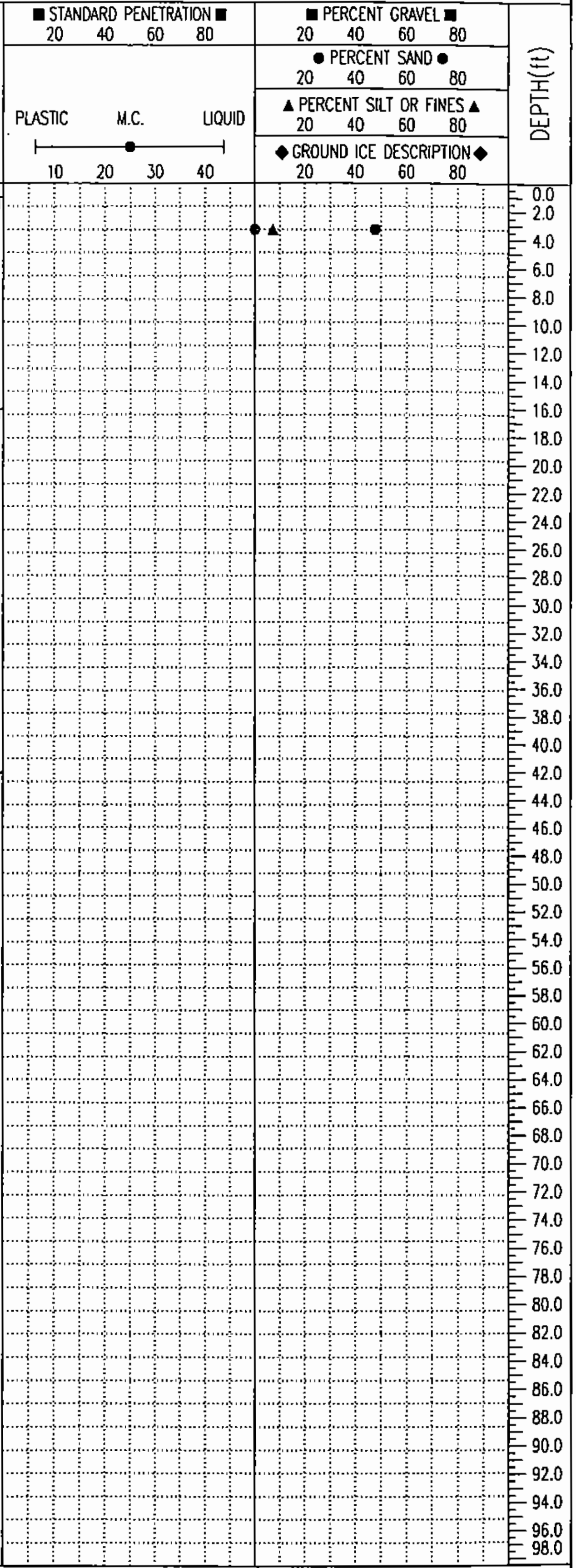
SOIL DESCRIPTION

MOSS AND ORGANICS – black
– permafrost @ 0.2 m

SAND – silty, trace of quartz gravel, sizes to 75 mm diameter, Vs, Vr 25%
– occasional organic seams and pockets throughout
– organics throughout, frozen
– cobble or boulder @ 4.0 m

SAND – lighter colour (to light brown) at 4.9 m
– no sampling possible below 4 m depth
– difficult drilling to 9.8 m
– silty sand and gravel on bit at 9.8 m (frozen sandy gravel)
– put on new bit, drill to 12.8 m
– still frozen, some gravel
– hole abandoned due to difficult drilling

END OF BOREHOLE @ 12.8 m
MINE GRID COORDINATES (IMPERIAL UNITS)
Northing – 12545.57
Easting – 16219.65
Elevation – 2341.90
EBA BOREHOLE NO: 11509-BH18



EBA ENGINEERING CONSULTANTS LTD.
Whitehorse, Yukon

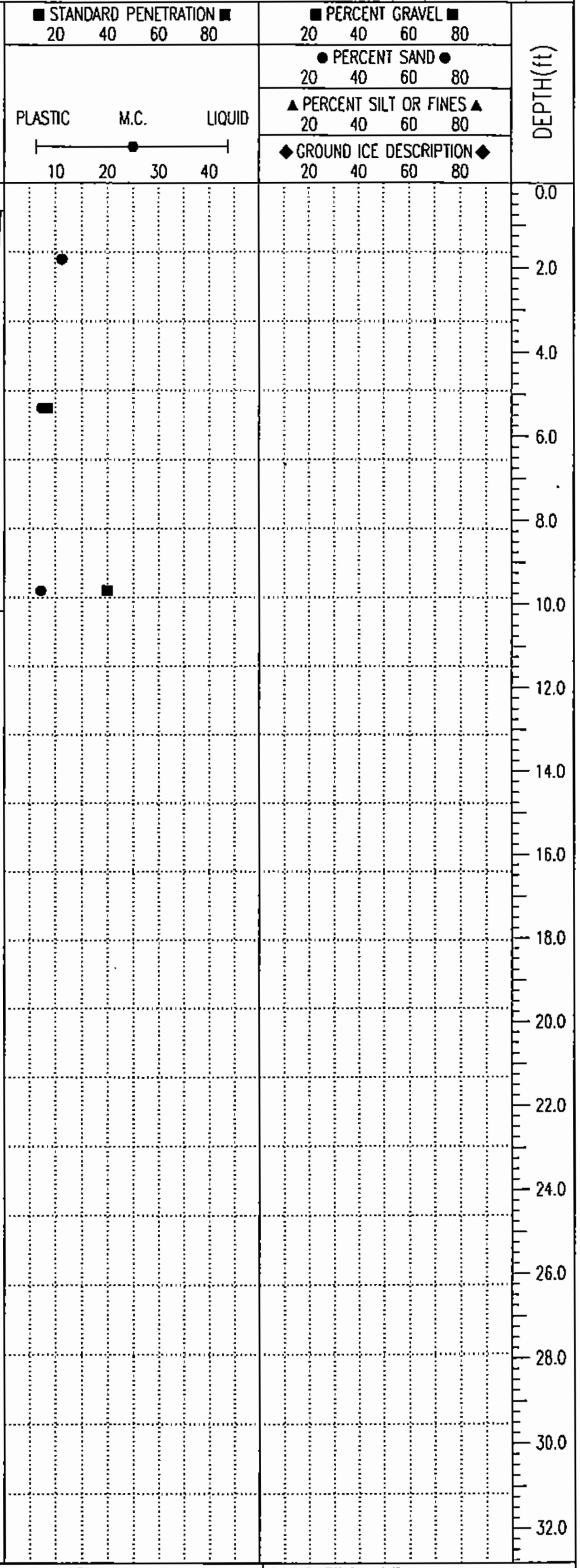
LOGGED BY: JRT	COMPLETION DEPTH: 12.8 m
REVIEWED BY: CRH	COMPLETE: 94/08/22
Fig. No:	Page 1 of 1

95/06/27 05:11PM (0201-30)

PROPOSED COPPER MINE DEVELOPMENT	CLIENT: MINTO EXPLORATIONS LTD.	BOREHOLE NO: GH 94-20
TAILINGS DAM CENTRE HOLE	DRILL: CME-75 C/W HOLLOW STEM AUGERS	PROJECT NO: 0201-11509
MINTO CREEK, YT	UTM ZONE: 8 N - E -	ELEVATION:

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		1				ORGANIC SILT – some sand, numerous roots, occasional cobbles and boulders; damp; Blah; brown
	☒	2	17			SAND (COLLUVIUM) – some silt; some gravel; occasional cobbles; unsorted; well graded, angular sand, angular friable gravel; damp; compact; brown – becomes olive grey
3.0	☒	3	40			
						END OF BOREHOLE @ 3.1 m – boulder @ 3.1 m – drilling refusal @ 3.1 m



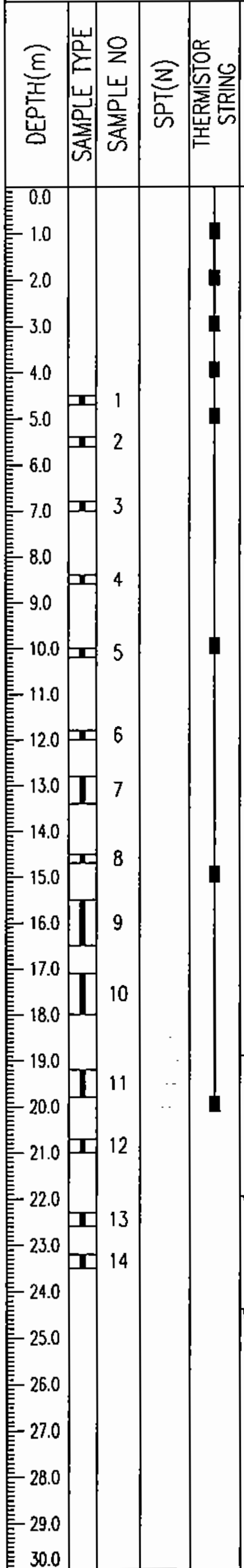
EBA ENGINEERING CONSULTANTS LTD. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 3.1 m
	REVIEWED BY: CRH	COMPLETE: 94/06/24
	Fig. No:	Page 1 of 1

95/06/27 05:12PM (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 (COLLUVIUM) – silty, some sand, some gravel, some cobbles, trace of clay; angular gravel and sand; low plastic; unsorted; frozen Nbe; wet; dark brown/grey

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

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

– clear ice lenses

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

– trace of sand, trace of clay, 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

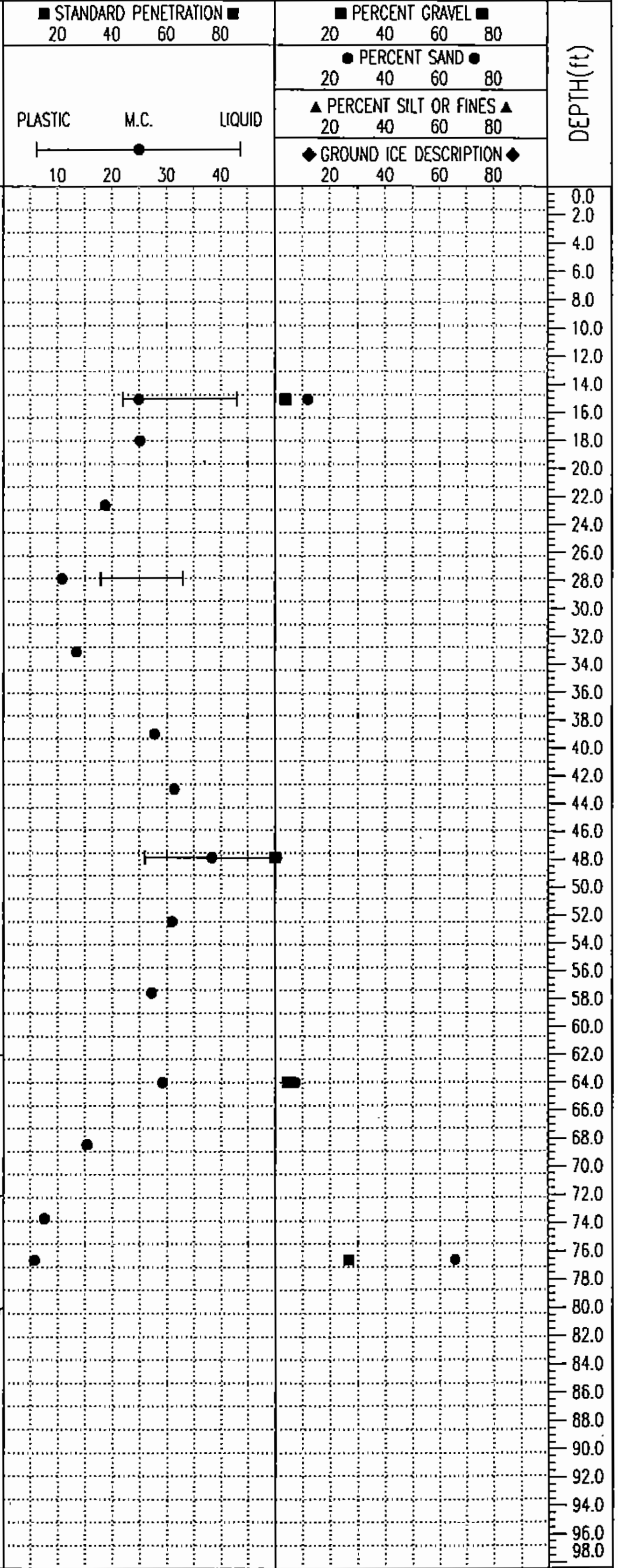
MINE GRID COORDINATES (IMPERIAL UNITS)

Northing – 11350.36

Easting – 14714.81

Elevation – 2468.60

EBA BOREHOLE NO: 11509-BH19

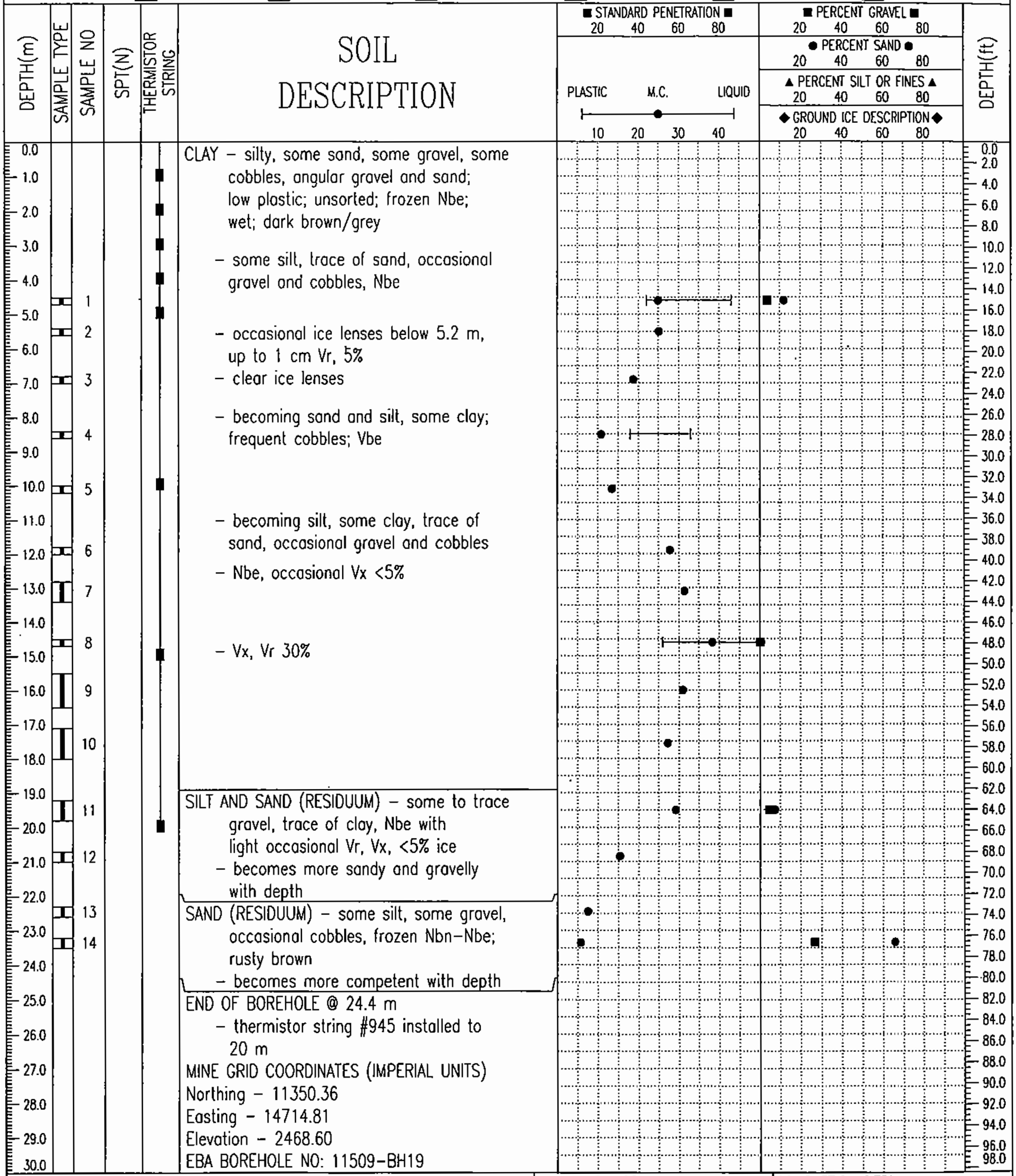


EBA ENGINEERING CONSULTANTS LTD. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 24.4 m
	REVIEWED BY: CRH	COMPLETE: 94/08/22
	Fig. No:	Page 1 of 1

95/06/27 05:13PM (0201-30W)

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



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

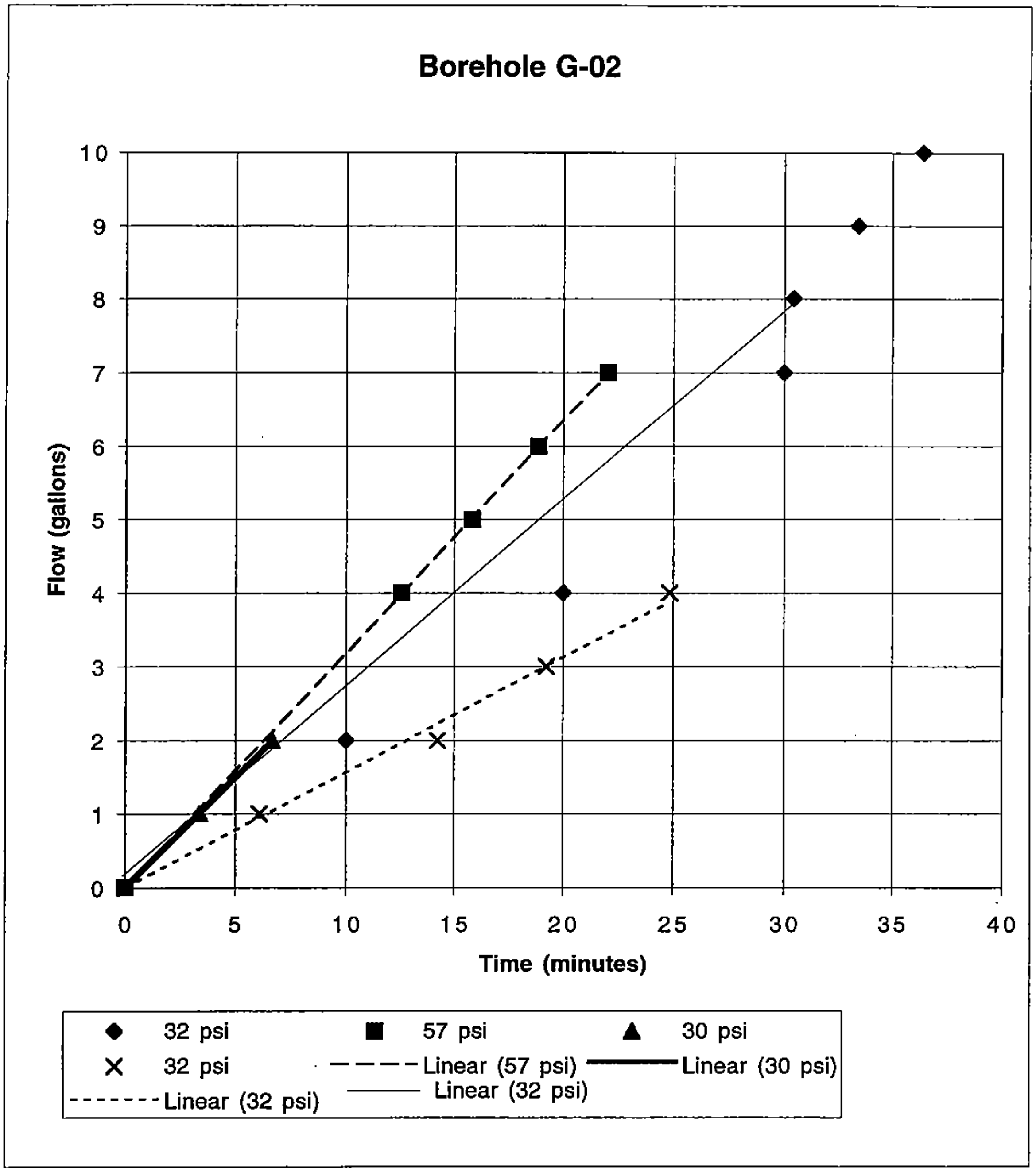
- thermistor string #945 installed to 20 m

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

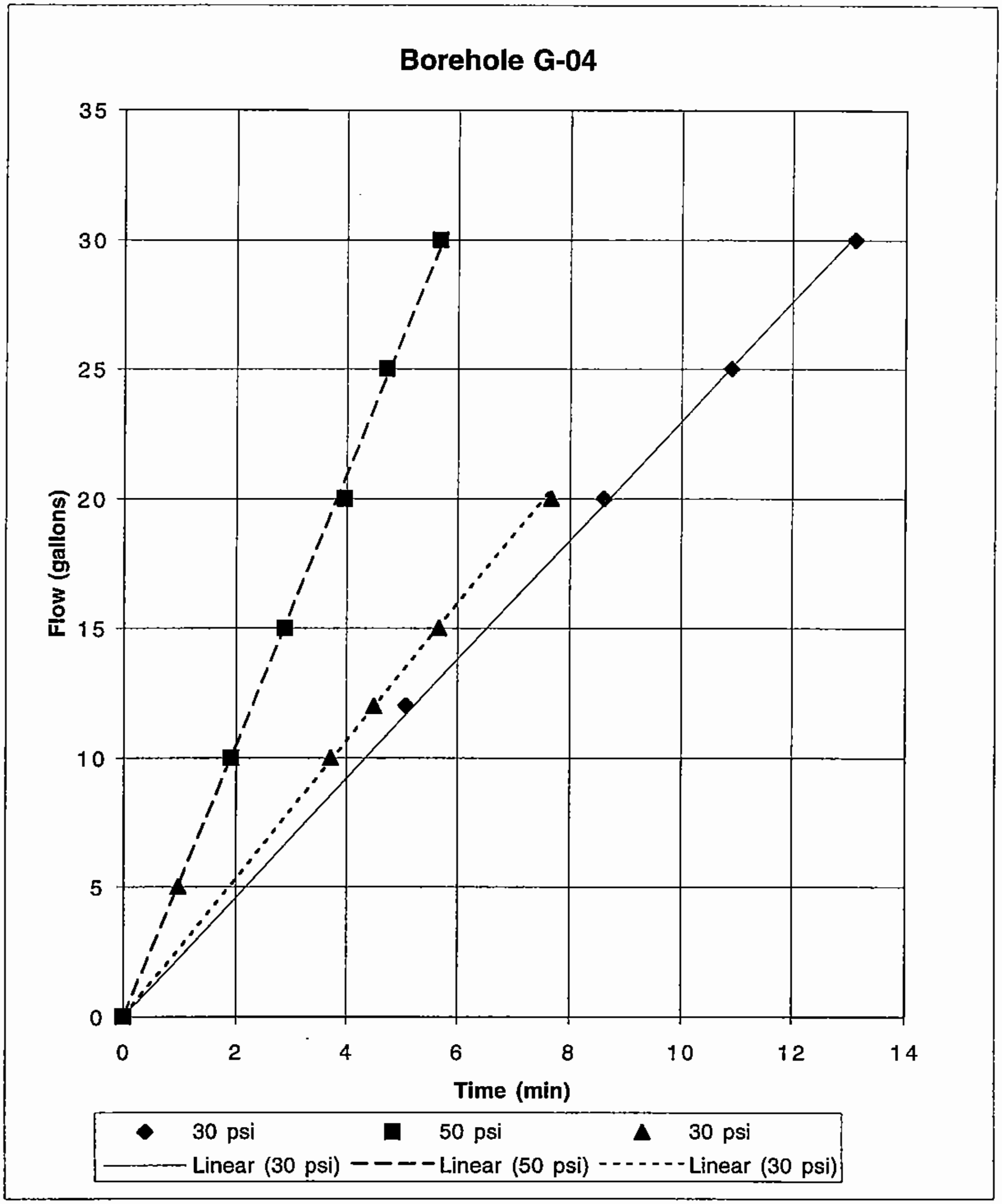
EBA Engineering Consultants Ltd. Whitehorse, Yukon	LOGGED BY: CRH	COMPLETION DEPTH: 24.4 m
	REVIEWED BY: CRH	COMPLETE: 94/08/22
	Fig. No:	Page 1 of 1

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

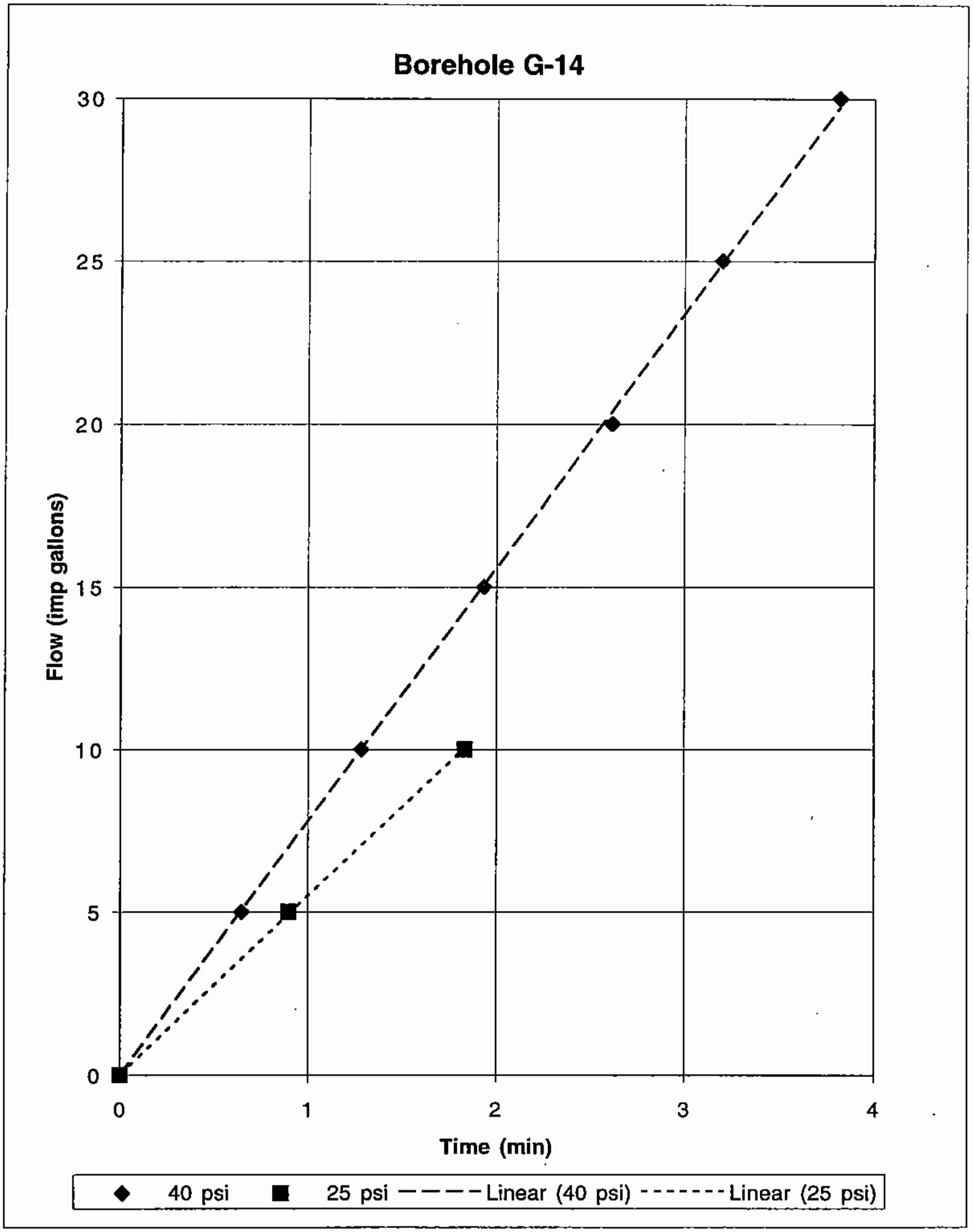
APPENDIX A.3
EBA 1995 PACKER TESTS
TAILINGS/WATER DAM



Pressure (psi)	Q (imp gal/min)	Q (usgpm)	he (m H2O)	L (m)	k (m/s)	Interval Tested (m)
32	0.22	0.27	31.2	3.35	1.8E-07	7.5-10.8
57	0.32	0.38	48.8	3.35	1.6E-07	7.5-10.8
30	0.30	0.36	29.8	3.35	2.5E-07	7.5-10.8
32	0.16	0.19	31.2	3.35	1.3E-07	5.0-8.4



Pressure (psi)	Q (imp gal/min)	Q (usgpm)	he (m H2O)	L (m)	k (m/s)	Interval Tested (m)
30	2.23	2.68	24.6	3.35	2.3E-06	5.6-9.0*
50	5.22	6.27	38.7	3.35	3.4E-06	5.6-9.0*
30	2.64	3.18	24.6	3.35	2.7E-06	5.6-9.0*

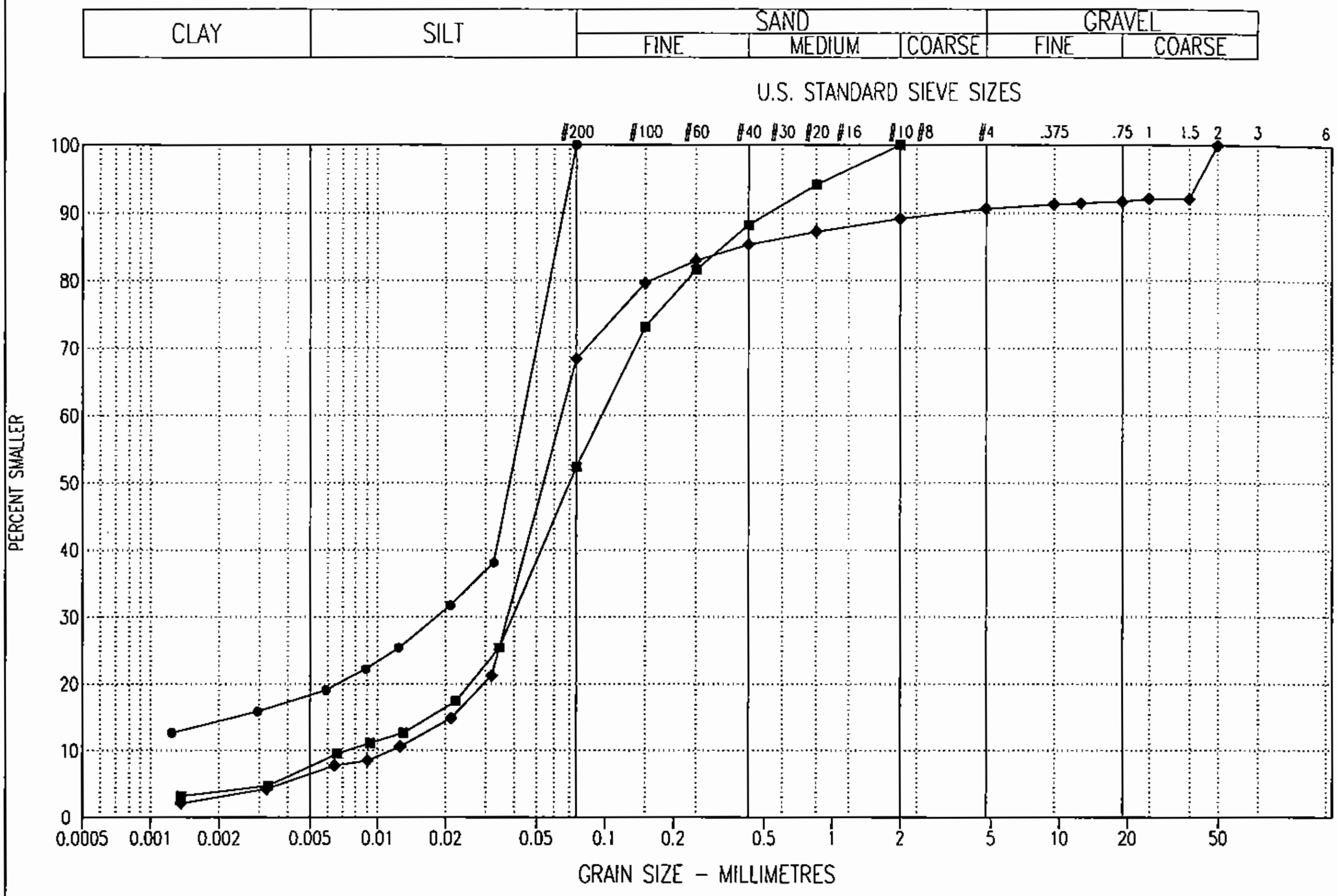


Pressure (psi)	Q (imp gal/min)	Q (usgpm)	he (m H2O)	L (m)	k (m/s)	Depth Interval (m)
40	7.79	9.36	31.5	2.90	7.2E-06	5.6-8.5
25	5.47	6.57	21	2.90	7.6E-06	5.6-8.5

APPENDIX B.1
LABORATORY TEST RESULTS
COLLUVIUM

EBA Engineering

PARTICLE SIZE – ANALYSIS OF SOILS



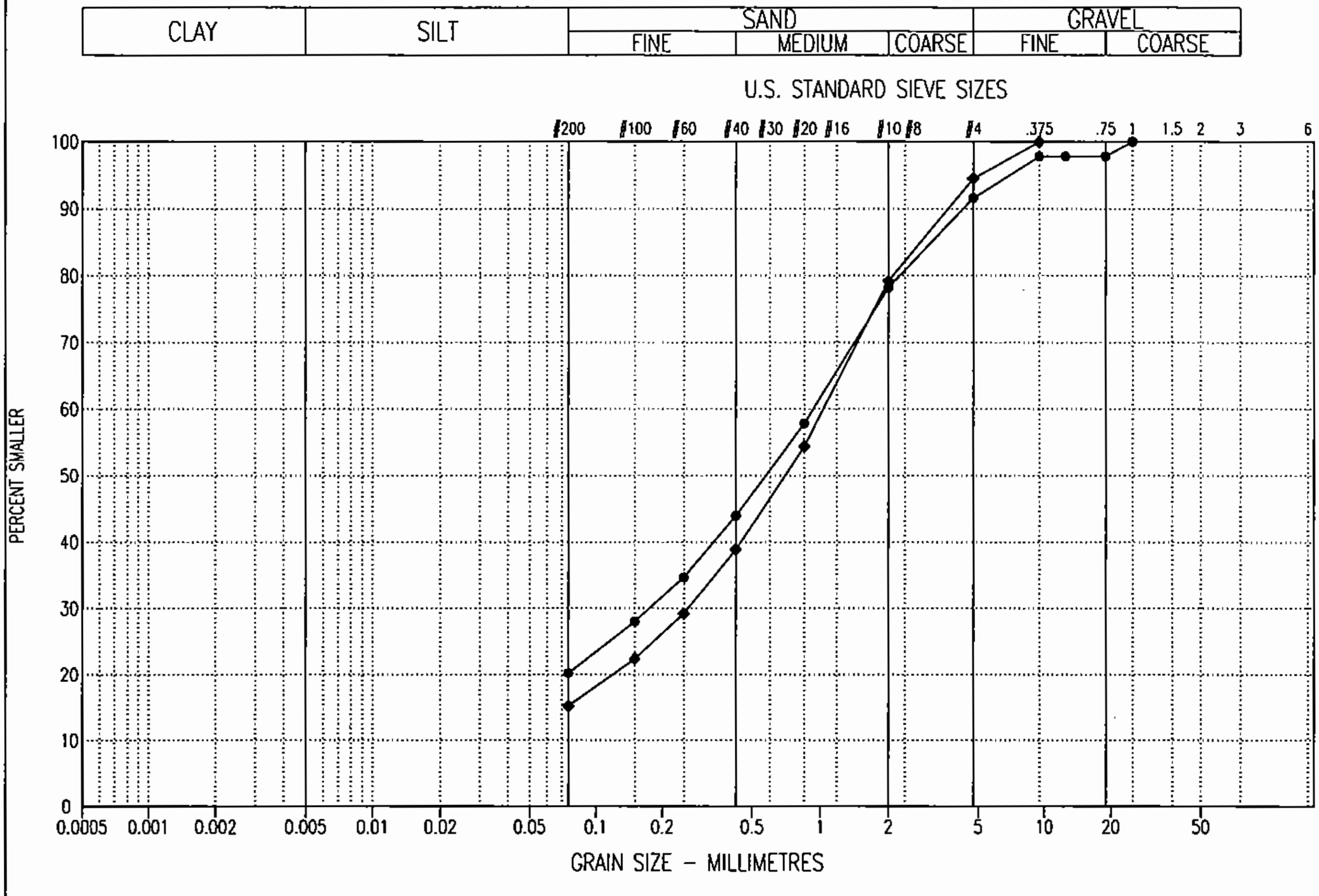
SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION				Cu	Cc	U.S.C
			CLAY %	SILT %	SAND %	GRAVEL %			
●——●	94-G11	1.20 – 1.65	18.0	82.0	0.0	0.0	–	–	
◆——◆	94-G13	0.70 – 0.90	6.2	62.2	22.2	9.4	5.8	2.0	
■——■	94-G17	0.90 – 1.10	7.2	45.1	47.7	0.0	13.9	2.3	

SILTY COLLUVIUM

Project: 0201-11509 Date Tested: 94/08/05 BY: FRS

Tested in accordance with ASTM D422 unless otherwise noted.

PARTICLE SIZE - ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION			Cu	Cc	U.S.C
			CLAY & SILT %	SAND %	GRAVEL %			
●——●	94-G04	2.60 - 2.90	20.1	71.4	8.5	26.1	0.9	SM
◆——◆	94-G06	2.60 - 3.00	15.2	79.3	5.5	22.5	1.3	SM

SANDY COLLUVIUM

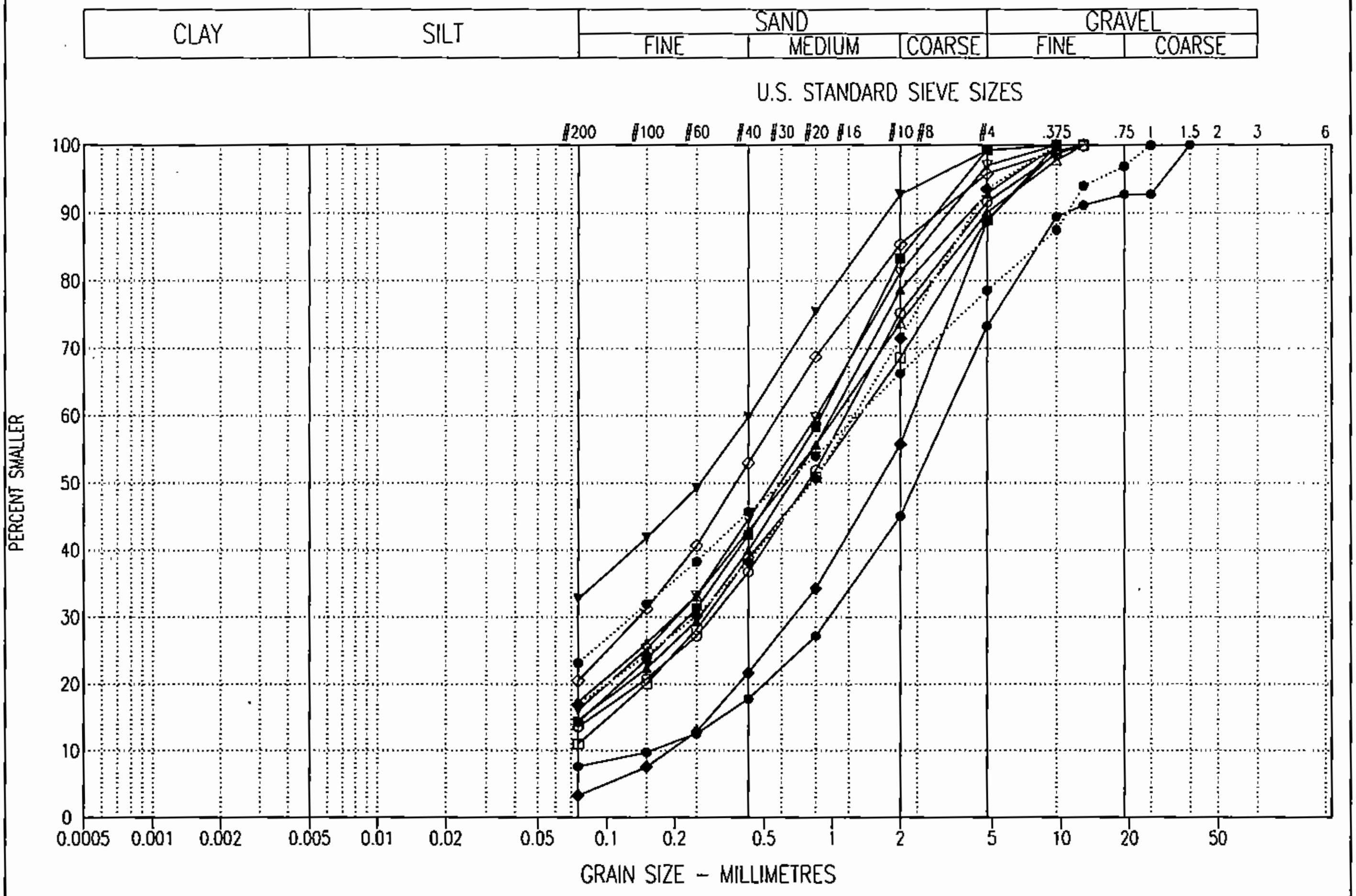
Project: 0201-11509 Date Tested: 94/06/20 BY: FRS

Tested in accordance with ASTM D422 unless otherwise noted.

APPENDIX B.2
LABORATORY TEST RESULTS
NATURAL RESIDUUM

EBA Engineering

PARTICLE SIZE – ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION			Cu	Cc	U.S.C
			CLAY & SILT %	SAND %	GRAVEL %			
●——●	94-21	23.20 – 23.50	7.6	65.7	26.7	21.9	1.9	SW-SM
◆——◆	94-G01	0.40 – 0.80	3.2	85.6	11.2	12.0	1.1	SW
■——■	94-G02	4.50 – 5.00	14.3	85.0	0.7	17.6	1.1	SM
▲——▲	94-G05	6.95 – 7.40	14.5	78.4	7.1	20.7	1.2	SM
▼——▼	94-G06	10.40 – 10.50	32.8	66.3	0.9	18.7	0.5	SM
⊙——⊙	94-G07	4.40 – 4.85	13.6	77.9	8.5	22.6	1.3	SM
◇——◇	94-G08	9.10 – 9.20	20.5	75.3	4.2	16.8	0.9	SM
⊡——⊡	94-G09	1.30 – 1.80	11.0	78.0	11.0	21.1	0.8	SP-SM
△——△	94-G11	9.00 – 9.30	17.3	72.7	10.0	25.9	0.9	SM
▽——▽	94-G11A	7.60	16.2	80.8	3.0	18.6	1.1	SM
●·········●	94-G12	4.00 – 4.10	23.1	55.4	21.5	43.6	0.4	SM
◆·········◆	94-G15	1.50 – 1.95	17.0	76.5	6.5	30.9	1.0	SM

NATURAL RESIDUUM

Project: 0201-11509

Date Tested: 94/09/22

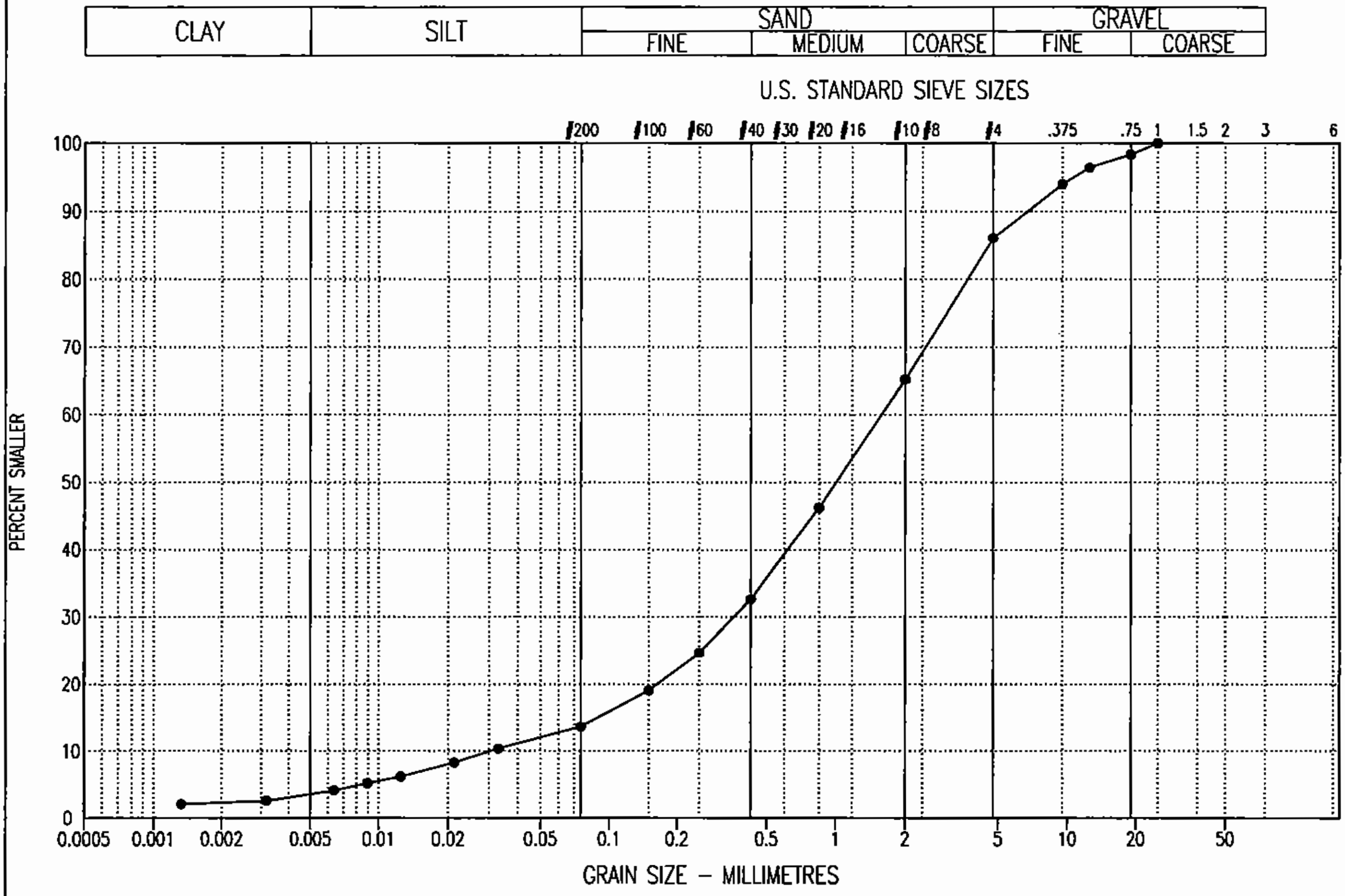
BY: ATM

Tested in accordance with ASTM D422 unless otherwise noted.

APPENDIX B.3
LABORATORY TEST RESULTS
COMBINED RESIDUUM SAMPLES

EBA Engineering

PARTICLE SIZE - ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION				Cu	Cc	U.S.C
			CLAY %	SILT %	SAND %	GRAVEL %			
●——●	2187	0.00	3.4	10.2	72.4	14.0	54.5	2.6	SM

Project: 201-11509

Date Tested: 94/11/29

BY: IS

Tested in accordance with ASTM D422 unless otherwise noted.

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MOISTURE-DENSITY RELATIONSHIP
(ASTM Designation D 698, D 1557)

Project: MINTO COPPER MINE

Address: MINTO CREEK, YUKON

Project No.: 201-11509

Date Tested: 94 11 24

Client: MINTO EXPLORATIONS

Attention: MR. LUTZ KLINGMANN

Sample No.: 2187

Date Sampled: UNKNOWN

Sample Location:

Sample Description: SAND, SOME SILT, GRAVEL (25mm MAX), LIGHT BROWN

Maximum Dry Density: 2125 kg/m³

Optimum Moisture Content: 9.0 %

Natural Moisture Content: 3.4 %

☒ Standard Proctor (ASTM D 698)

☐ Modified Proctor (ASTM D 1557)

Hammer Weight: 2.494 kg

Hammer Drop: 304.8 mm

No. of Layers: 3

No. of Blows/Layer: 56

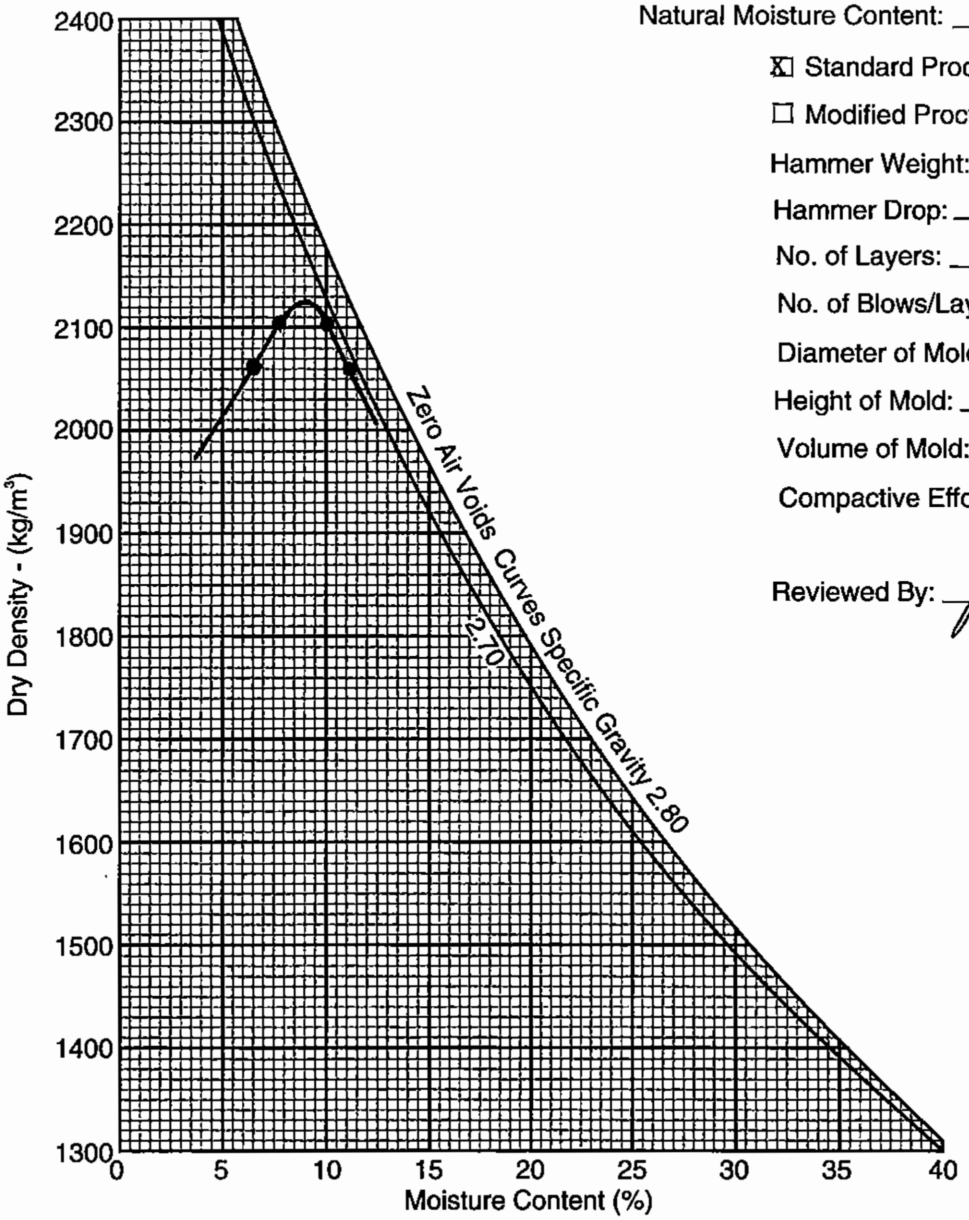
Diameter of Mold: 152.3 mm

Height of Mold: 116.5 mm

Volume of Mold: 0.00212 m³

Compactive Effort: 590.3 kJm³

Reviewed By: A. Ruban P.Eng.



2059.CDR

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Direct Shear Test

Project No.: 0201-11509
Date Tested: 95-01-18

Test Hole No.: Sa.#2187
Depth (m):
Test Number: DS-1

Initial Sample Conditions

Moisture Content (%): 10.0
Wet Density (Mg/m3): 2.011
Dry Density (Mg/m3): 1.828

Horiz. Disp. (mm)	Vert Disp. (mm)	Shear Stress (kPa)	Horiz. Disp. (mm)	Vert Disp. (mm)	Shear Stress (kPa)
0.00	0.000	0.0	7.43	-0.165	335.5
0.04	-0.002	31.1	7.70	-0.164	335.3
0.13	-0.012	60.9	7.97	-0.166	337.9
0.24	-0.024	81.5	8.23	-0.167	341.8
0.34	-0.042	101.2	8.50	-0.169	346.5
0.64	-0.074	133.8	8.76	-0.171	349.6
0.78	-0.091	154.7	9.03	-0.173	352.2
0.92	-0.112	175.0	9.30	-0.174	355.3
1.07	-0.130	192.0	9.60	-0.177	358.4
1.21	-0.146	205.3	9.87	-0.179	362.2
1.36	-0.159	217.5	10.14	-0.181	363.8
1.54	-0.173	230.6	10.42	-0.181	366.0
1.78	-0.186	245.1	10.69	-0.181	368.7
2.04	-0.195	257.6	10.97	-0.181	370.0
2.29	-0.201	266.4	11.27	-0.181	372.3
2.55	-0.203	275.9	11.54	-0.180	373.5
2.80	-0.204	283.5	11.85	-0.178	374.8
3.06	-0.205	290.2	12.14	-0.175	377.2
3.35	-0.203	297.1	12.41	-0.172	376.4
3.62	-0.202	301.3	12.68	-0.168	376.7
3.91	-0.199	307.1	12.95	-0.163	376.5
4.18	-0.196	311.5	13.26	-0.159	373.4
4.44	-0.192	314.4	13.53	-0.156	372.5
4.71	-0.189	316.7	13.80	-0.152	372.8
4.97	-0.186	317.6	14.08	-0.148	370.6
5.24	-0.184	319.6	14.35	-0.145	369.5
5.51	-0.181	320.4	14.62	-0.142	369.4
5.80	-0.178	322.3	14.90	-0.140	367.4
6.06	-0.175	325.4	15.21	-0.139	365.8
6.33	-0.171	328.8	15.49	-0.139	363.4
6.60	-0.169	330.8			
6.88	-0.167	333.2			
7.15	-0.166	333.2			

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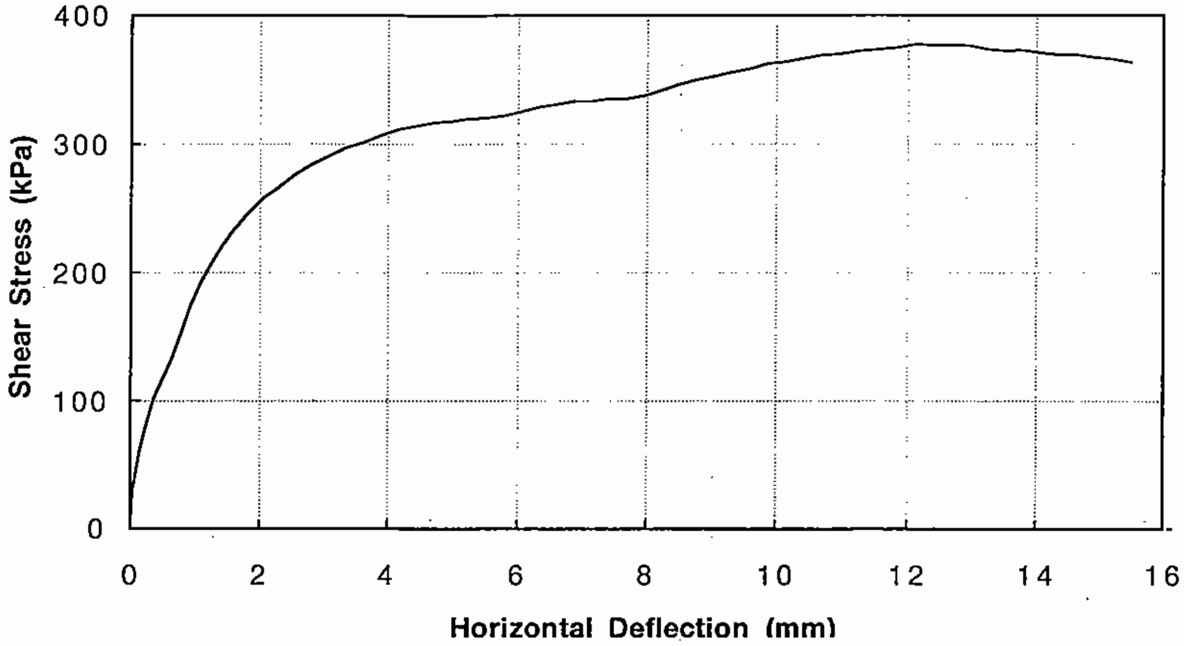
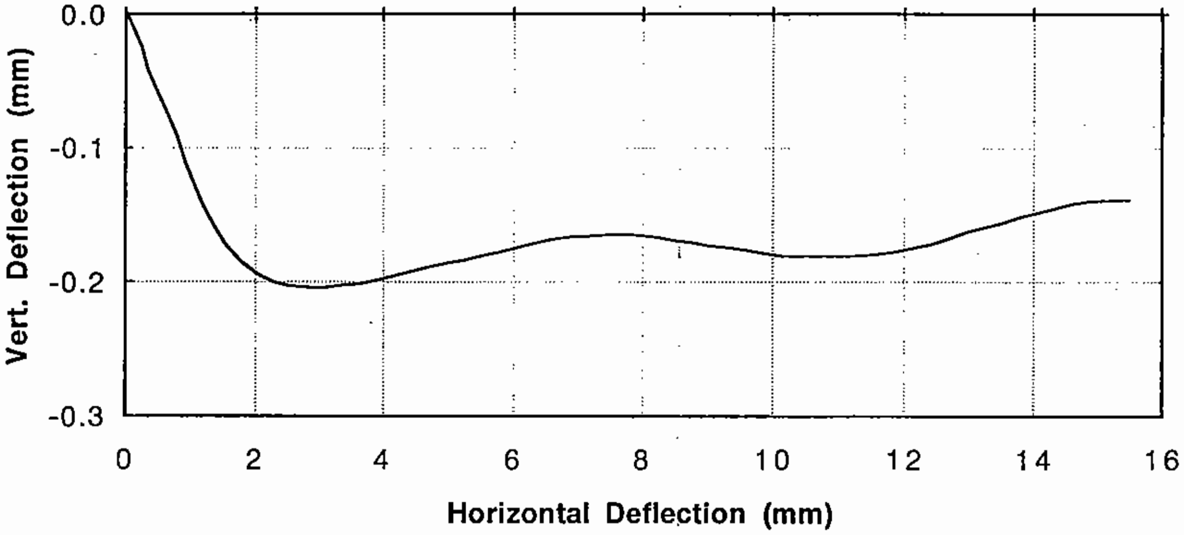
Direct Shear Test

Peak Stress= 377 kPa





Test Hole Number: Sa.#2187
Depth:
Normal Stress(kPa): 480
Displ. Rate(mm/min.):0.24
Test No.: DS-1

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EBA Engineering Consultants Ltd.

Direct Shear Test

Project No.: 0201-11509
Date Tested: 95-01-19

Test Hole No.: Sa.#2187
Depth (m):
Test Number: DS-2

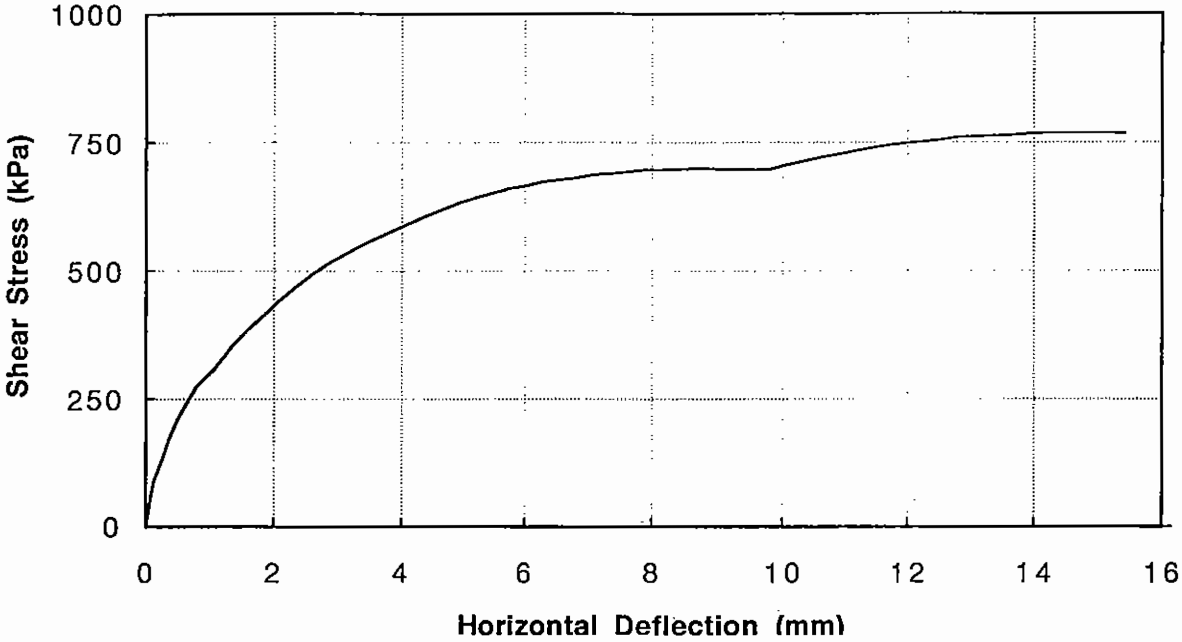
Initial Sample Conditions

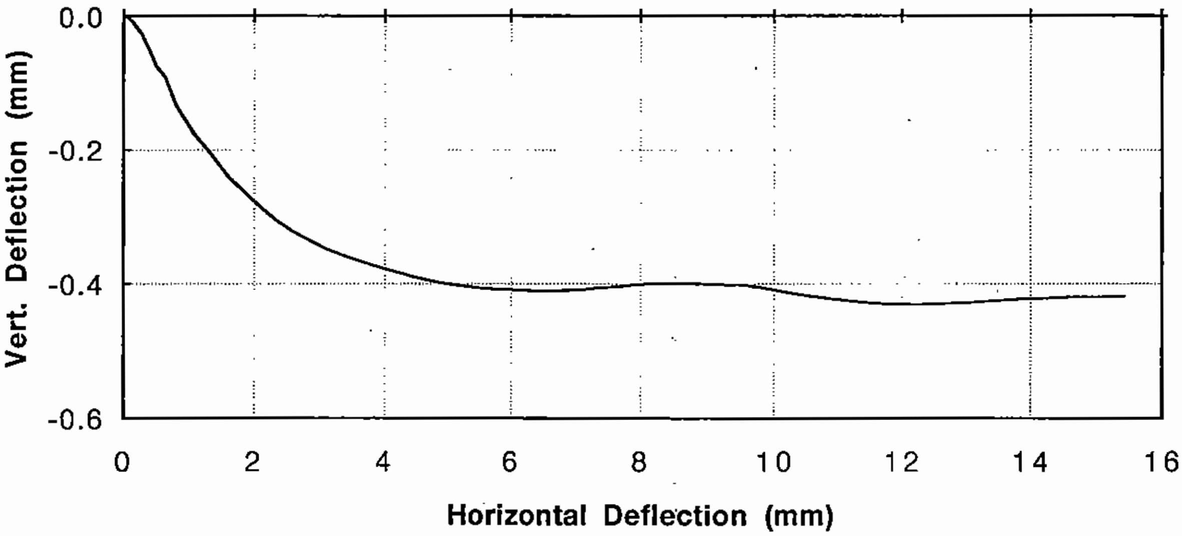
Moisture Content (%): 9.9
Wet Density (Mg/m3): 1.974
Dry Density (Mg/m3): 1.795

Horiz. Disp. (mm)	Vert Disp. (mm)	Shear Stress (kPa)
0.00	0.000	0.0
0.07	-0.002	46.3
0.13	-0.007	87.4
0.28	-0.027	134.4
0.38	-0.046	172.3
0.51	-0.075	209.8
0.64	-0.091	239.3
0.81	-0.133	274.6
1.09	-0.176	309.1
1.34	-0.206	349.9
1.60	-0.240	384.0
1.85	-0.263	412.4
2.10	-0.286	442.4
2.35	-0.306	468.9
2.60	-0.322	493.4
2.86	-0.336	513.6
3.11	-0.348	532.1
3.38	-0.359	549.9
3.64	-0.367	565.8
3.90	-0.375	580.3
4.16	-0.383	593.9
4.42	-0.390	607.4
4.68	-0.395	620.2
4.95	-0.400	632.4
5.23	-0.404	642.9
5.50	-0.407	651.9
5.76	-0.409	659.9
6.03	-0.410	665.3
6.30	-0.410	672.5
6.56	-0.410	677.2
6.82	-0.410	680.5
7.11	-0.409	686.2
7.38	-0.407	689.5
7.65	-0.404	693.0
7.92	-0.402	696.2
8.18	-0.400	696.3
8.44	-0.400	697.6
8.71	-0.400	698.9
8.99	-0.401	698.0
9.25	-0.402	698.4
9.52	-0.402	697.0
9.79	-0.406	697.2
10.05	-0.411	705.9
10.32	-0.415	713.6
10.59	-0.419	720.6
10.88	-0.423	727.1
11.15	-0.426	733.0
11.44	-0.429	739.4
11.71	-0.430	744.6
11.99	-0.431	747.7
12.25	-0.431	751.2
12.54	-0.431	754.7
12.81	-0.430	759.1
13.08	-0.428	760.6
13.35	-0.427	761.5
13.62	-0.425	763.4
13.95	-0.423	766.6
14.29	-0.422	767.7
14.65	-0.420	768.0
14.86	-0.420	767.6
15.14	-0.420	767.6
15.42	-0.419	767.4

Direct Shear Test

Peak Stress= 768 kPa





Test Hole Number: Sa.#2187
Depth:
Normal Stress(kPa): 960
Displ. Rate(mm/min.): 0.24
Test No.: DS-2

EBA Engineering Consultants Ltd.

Direct Shear Test

Project No.: 0201-11509
Date Tested: 95-01-20

Test Hole No.: Sa.#2187
Depth (m):
Test Number: DS-3

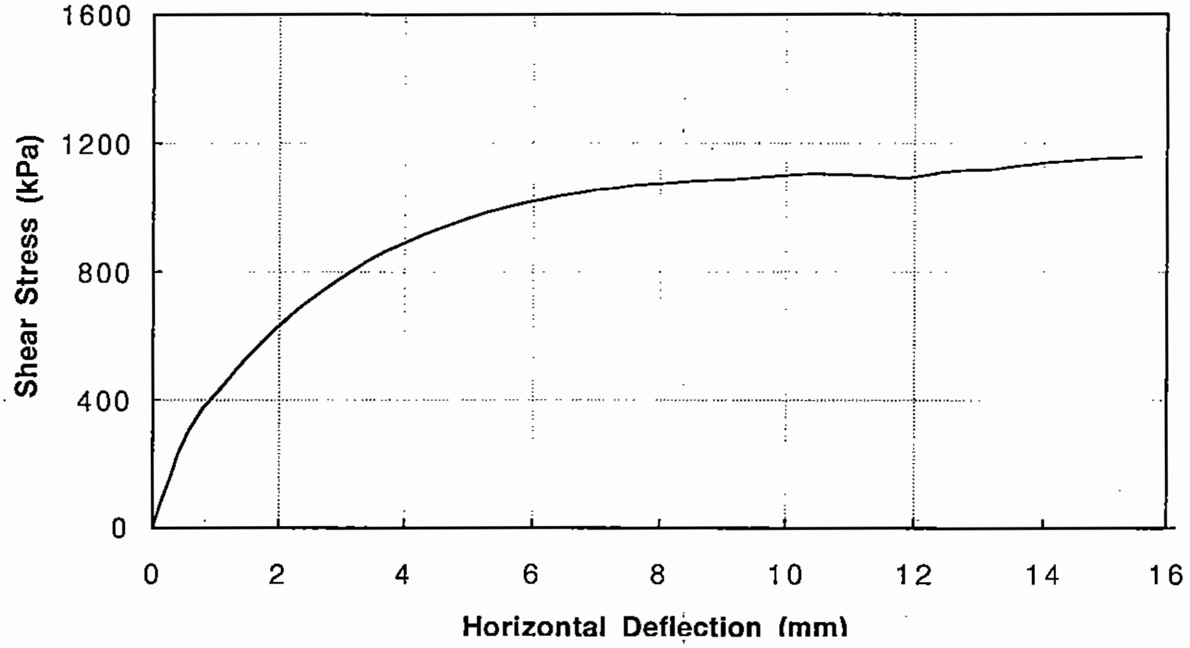
Initial Sample Conditions

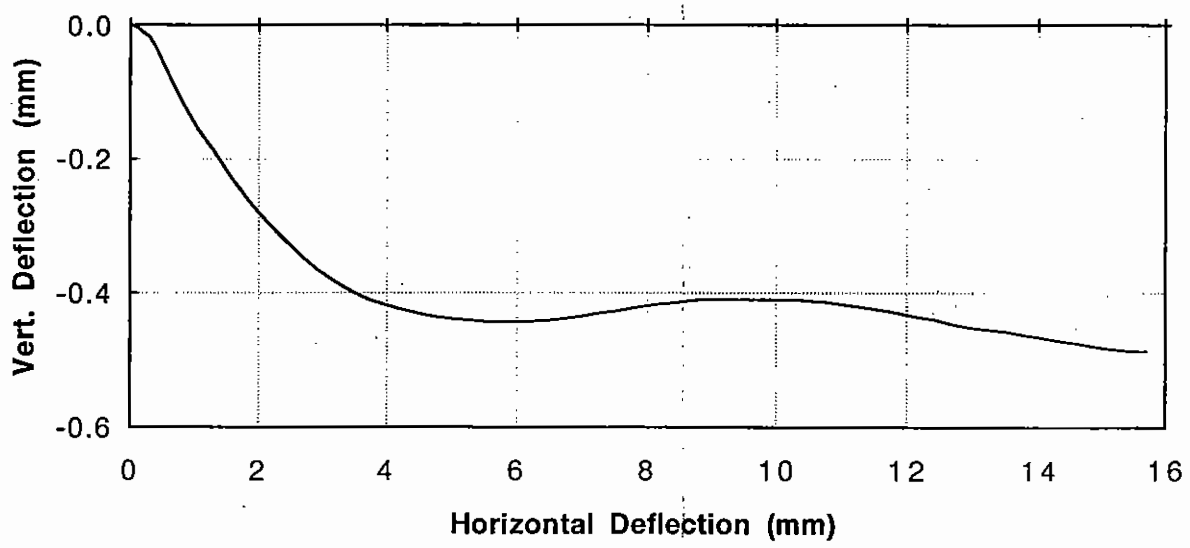
Moisture Content (%): 10.1
Wet Density (Mg/m3): 1.982
Dry Density (Mg/m3): 1.800

Horiz. Disp. (mm)	Vert Disp. (mm)	Shear Stress (kPa)
0.00	0.000	0.0
0.13	-0.004	78.4
0.31	-0.018	167.1
0.41	-0.033	230.4
0.58	-0.069	302.2
0.80	-0.111	371.5
1.07	-0.156	430.5
1.30	-0.187	486.6
1.55	-0.223	542.9
1.87	-0.264	606.7
2.13	-0.294	654.7
2.38	-0.320	696.4
2.67	-0.346	737.1
2.92	-0.365	770.7
3.16	-0.382	803.0
3.42	-0.397	834.1
3.70	-0.410	865.2
3.97	-0.418	886.7
4.26	-0.426	912.9
4.50	-0.431	931.2
4.76	-0.436	949.0
5.07	-0.440	969.8
5.32	-0.442	986.4
5.60	-0.444	1000.9
5.88	-0.444	1014.4
6.15	-0.444	1025.6
6.43	-0.442	1037.6
6.71	-0.439	1045.6
6.99	-0.435	1055.4
7.28	-0.431	1059.5
7.54	-0.428	1066.7
7.80	-0.423	1069.9
8.12	-0.418	1074.9
8.34	-0.416	1077.8
8.60	-0.413	1082.6
8.87	-0.410	1084.3
9.16	-0.410	1086.8
9.42	-0.411	1090.1
9.69	-0.411	1095.5
9.95	-0.411	1099.7
10.22	-0.411	1102.8
10.49	-0.412	1104.3
10.76	-0.415	1102.0
11.06	-0.418	1101.0
11.33	-0.422	1097.9
11.60	-0.425	1093.9
11.87	-0.430	1090.1
12.19	-0.437	1099.9
12.40	-0.441	1109.9
12.70	-0.448	1115.2
12.96	-0.453	1116.1
13.23	-0.455	1118.1
13.50	-0.458	1126.2
13.77	-0.463	1132.2
14.03	-0.467	1138.1
14.31	-0.471	1143.3
14.60	-0.476	1146.7
14.88	-0.480	1150.8
15.15	-0.484	1153.3
15.43	-0.487	1155.2

Direct Shear Test

Peak Stress= 1155 kPa





Test Hole Number:	Sa.#2187
Depth:	
Normal Stress(kPa):	1440
Displ. Rate(mm/min.):	0.24
Test No.:	DS-3

CONSTANT HEAD PERMEABILITY TEST

Job Number: 0201-11509

Test Hole: Sa.#2187 Depth:

Date: 95-02-14

Test No: P-9

Time	Buret (cc)	Elap. (min)	Outflow (cc)
10:36	40.6	0	0.0
10:47	45.4	11	4.8
10:58	49.7	22	9.1
11:10	54.2	34	13.6
11:28	61.0	52	20.4
11:42	66.3	66	25.7
12:04	74.1	88	33.5
12:30	83.0	114	42.4
12:59	92.7	143	52.1
13:29	81.7	173	63.1
13:56	72.7	200	72.1
14:27	62.4	231	82.4
14:54	53.3	258	91.5
15:22	44.2	286	100.6

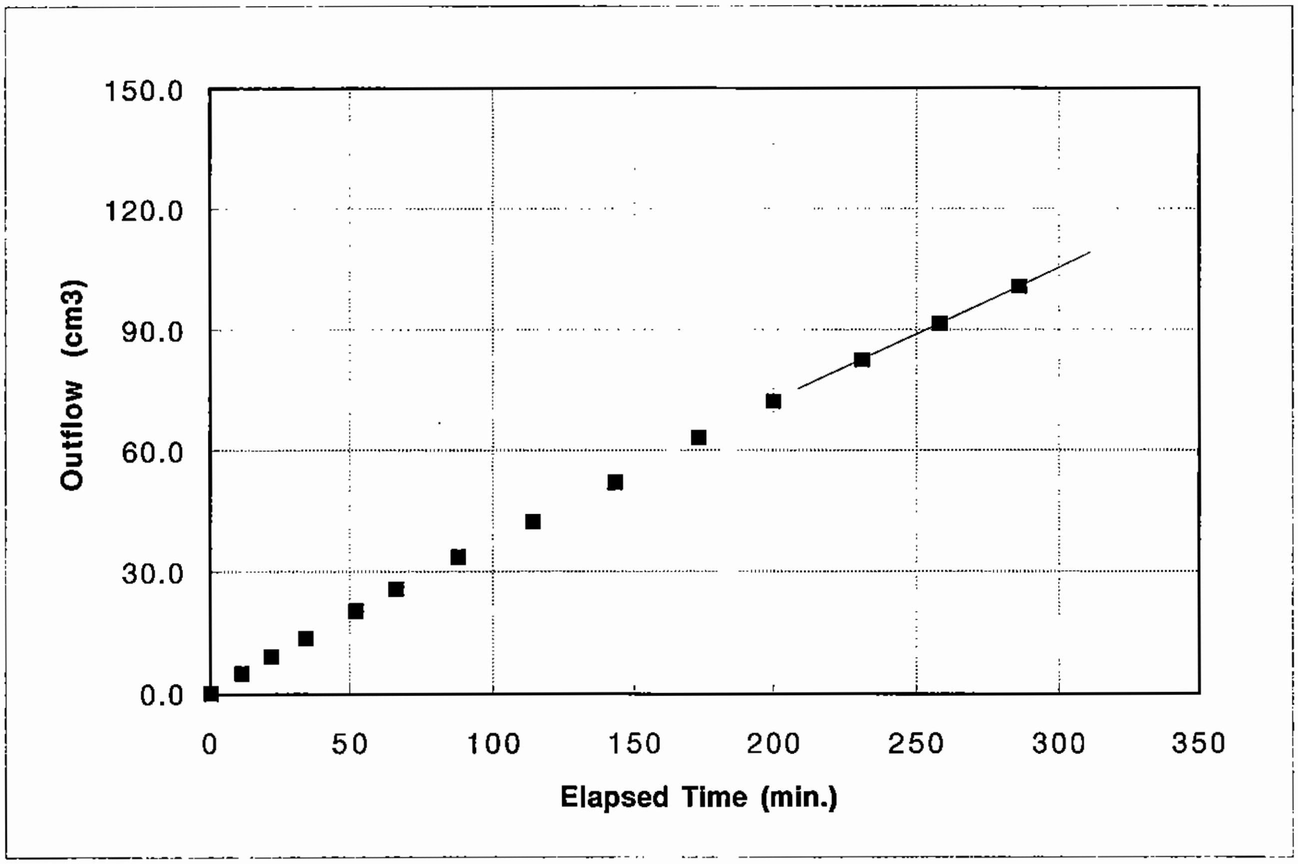
Diameter=	89.7	mm
Height=	72.5	mm
Volume=	458.16	cm3
Head Diff.=	3.9	psi

Q= 0.0055152 cm3/sec

i= 37.84

A= 63.19 cm2

K= 2.31E-06 cm/sec



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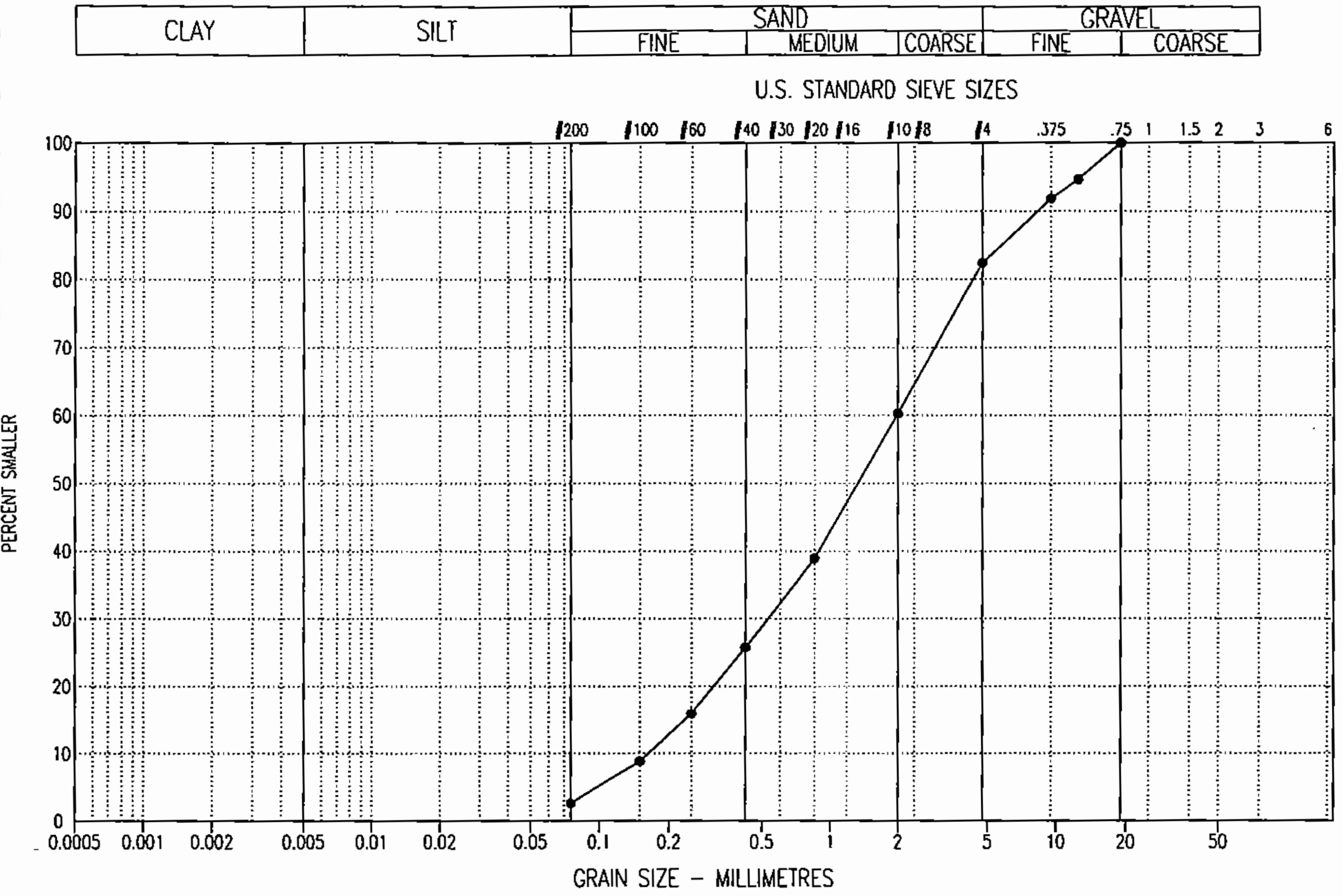
PARTICLE SIZE – ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION			Cu	Cc	U.S.C
			CLAY & SILT %	SAND %	GRAVEL %			
●——●	S-2187	0.00	2.6	79.8	17.6	12.0	1.0	SP
	WASHED RESIDUUM							

Project: 201-11509 Date Tested: 95/02/17 BY: IS

Tested in accordance with ASTM D422 unless otherwise noted.

CONSTANT HEAD PERMEABILITY TEST

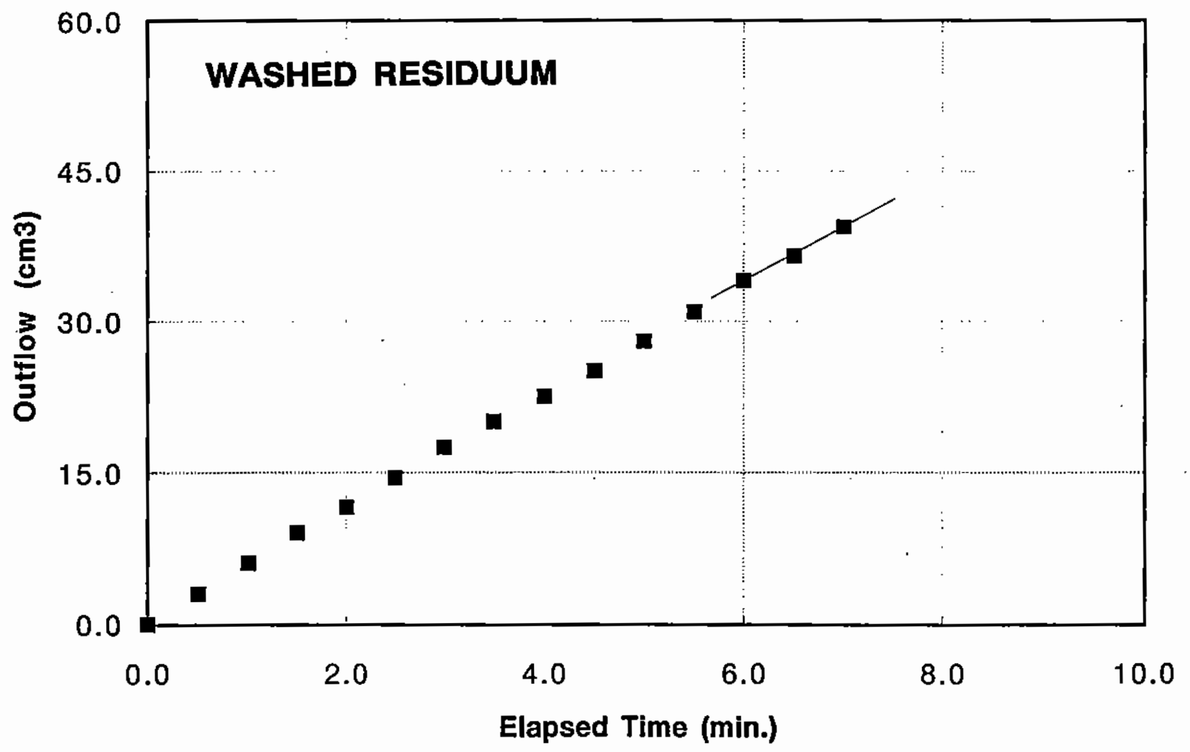
Job Number:	0201-11509		Date:	95-02-16	
Test Hole:	Sa.#2187	Depth:	Test No:	P-10	

Time	Buret (cc)	Elap. (min)	Outflow (cc)
14:32	7.5	0.0	0.0
14:32	10.5	0.5	3.0
14:33	13.5	1.0	6.0
14:33	16.5	1.5	9.0
14:34	19.0	2.0	11.5
14:34	22.0	2.5	14.5
14:35	25.0	3.0	17.5
14:35	27.5	3.5	20.0
14:36	30.0	4.0	22.5
14:36	32.5	4.5	25.0
14:37	35.5	5.0	28.0
14:37	38.5	5.5	31.0
14:38	41.5	6.0	34.0
14:38	44.0	6.5	36.5
14:39	47.0	7.0	39.5

Diameter=	89.7	mm
Height=	62.1	mm
Volume=	392.43	cm3
Head Diff.=	0.47	psi

Q= 0.1 cm3/sec
i= 5.32
A= 63.19 cm2

K= 2.97E-04 cm/sec



APPENDIX B.4
LABORATORY TEST RESULTS
SEMI-IMPERVIOUS CORE MATERIALS

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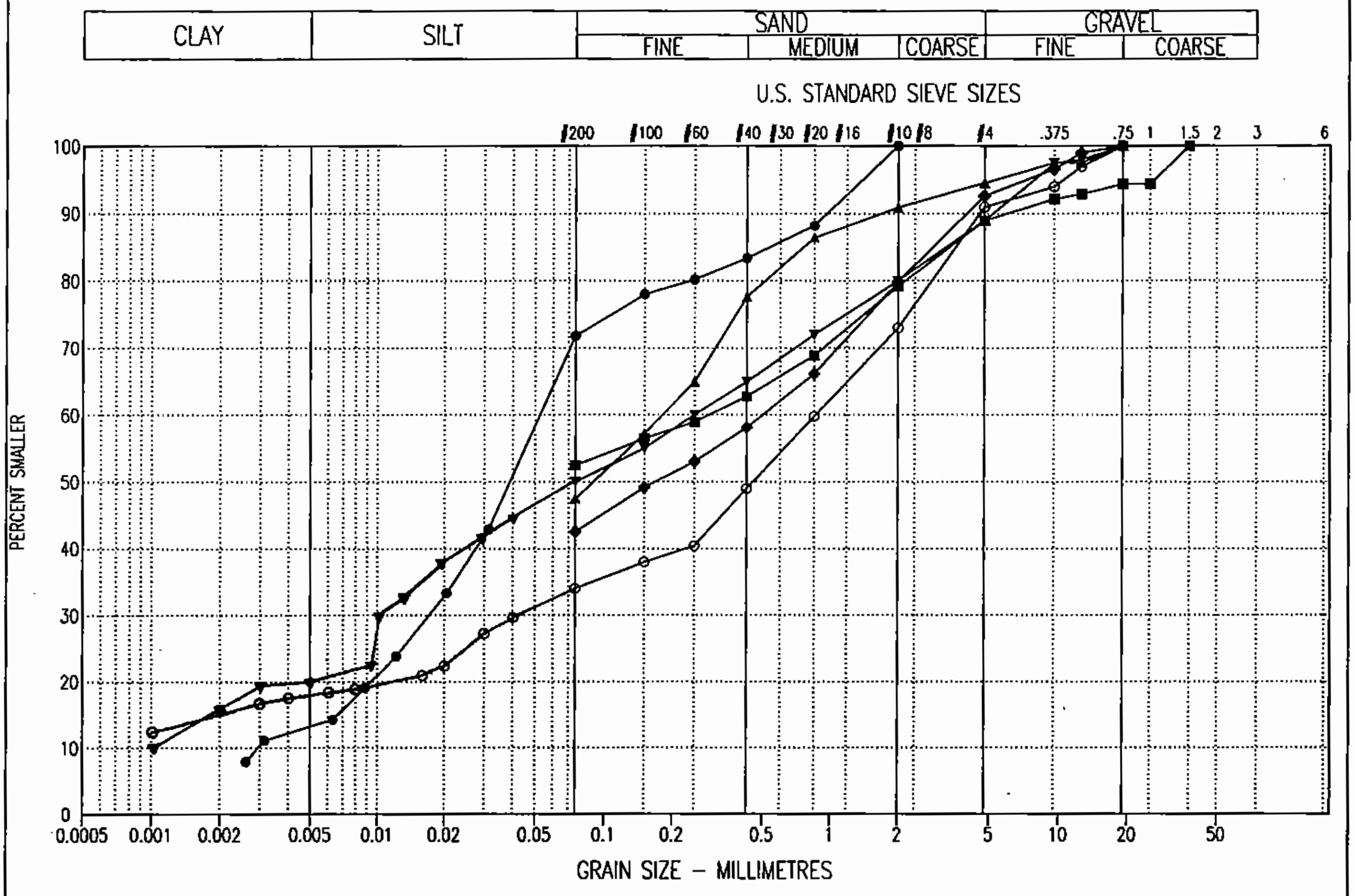
PARTICLE SIZE - ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY %	SILT %	SAND %	GRAVEL %	Cu	Cc	U.S.C
●	1	0.50	12.9	58.8	28.3	0.0	19.4	1.8	
◆	2	0.50	42.5		50.0	7.5	12.6	0.2	SM
■	3	0.50	52.5		36.4	11.1	7.5	0.3	
▲	4	0.50	47.4		47.1	5.5	4.6	0.5	SM
▼	GOLDERCLAY1	0.00	50.0		39.0	11.0	6.2	0.3	
○	GOLDERCLAY2	0.00	34.0		57.0	9.0	19.6	0.1	SM

POTENTIAL IMPERVIOUS CORE MATERIALS - CLAY

Project: 0201-11509

Date Tested: 95/08/24

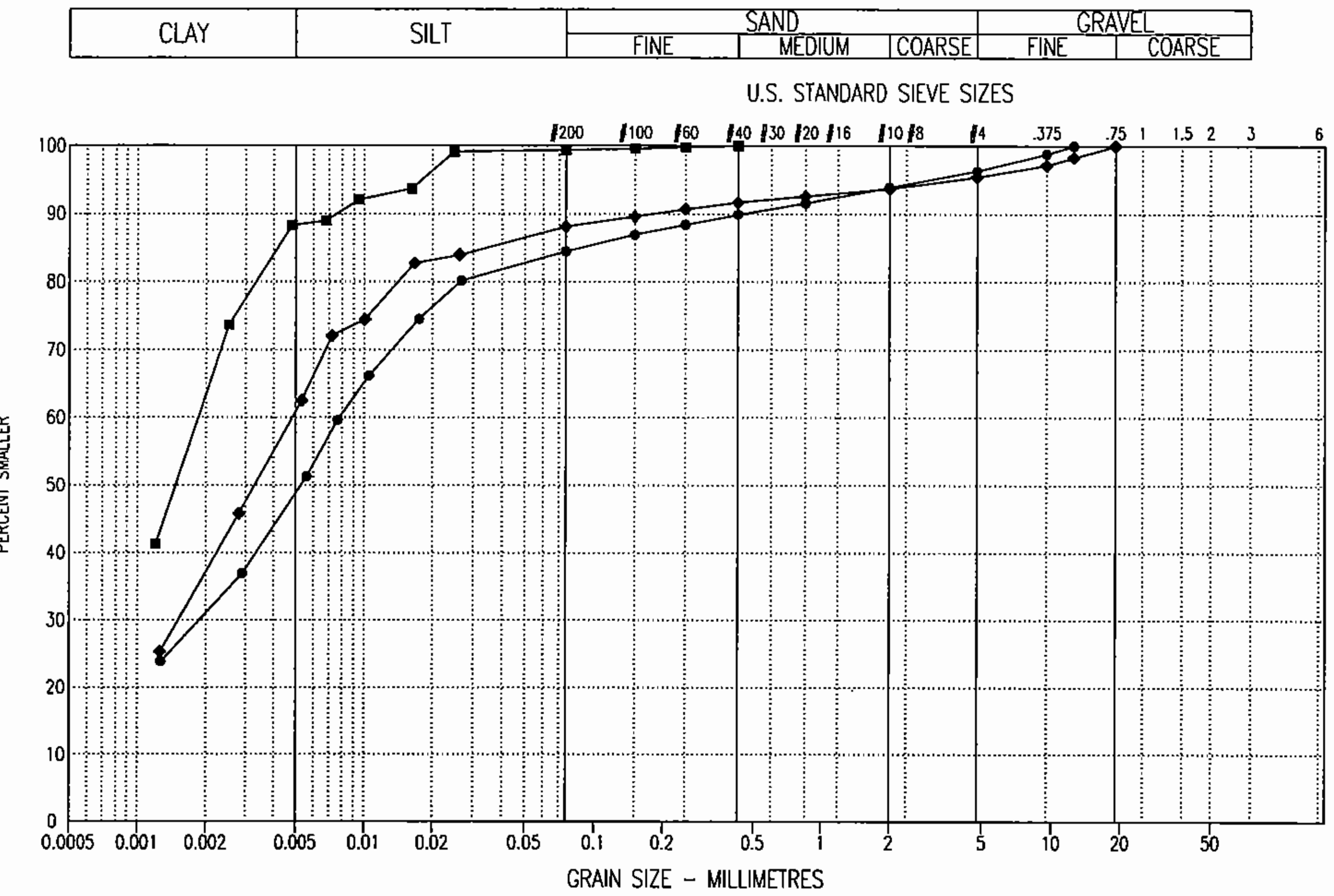
BY: JSB

Tested in accordance with ASTM D422 unless otherwise noted.

APPENDIX B.5
LABORATORY TEST RESULTS
CLAY MATERIALS

EBA Engineering

PARTICLE SIZE - ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY %	SILT %	SAND %	GRAVEL %	Cu	Cc	U.S.C
●—●	G21#1	4.60	48.1	36.3	11.9	3.7	–	–	
◆—◆	G21#11	19.20 – 19.80	60.3	27.8	7.3	4.6	–	–	
■—■	G21#8	14.30 – 14.60	88.3	11.1	0.6	0.0	–	–	

Project: 0201-11509

Date Tested: 94/12/12

BY: IS

Tested in accordance with ASTM D422 unless otherwise noted.

MOISTURE-DENSITY RELATIONSHIP
(ASTM Designation D 698, D 1557)

Project: Minto Copper Mine
Address: Minto, YT
Project No.: 201-11509
Date Tested: 94 12 19
Client: Minto Exploration Ltd.
Attention: Mr. Lutz Klingmann, P.ENG.

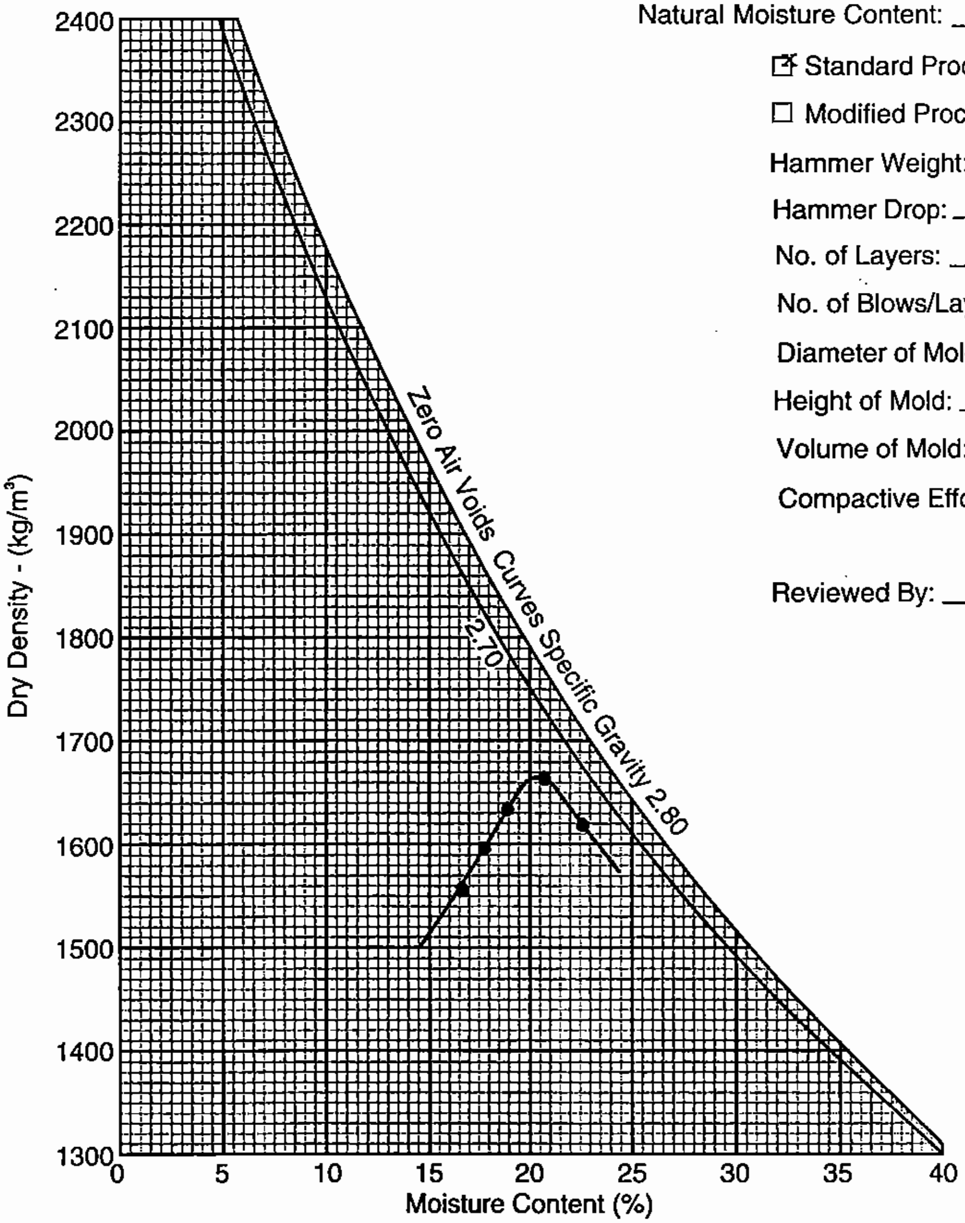
Sample No.: G21
Date Sampled:
Sample Location: Combined samples
Sample Description: Clay, silty, light brownish grey

Maximum Dry Density: 1665 kg/m³
Optimum Moisture Content: 20.7 %
Natural Moisture Content: n/a %

☑ Standard Proctor (ASTM D 698)
☐ Modified Proctor (ASTM D 1557)

Hammer Weight: 2.494 kg
Hammer Drop: 304.8 mm
No. of Layers: 3
No. of Blows/Layer: 25
Diameter of Mold: 101.4 mm
Height of Mold: 116.3 mm
Volume of Mold: 0.00093 m³
Compactive Effort: 593.5 kJm³

Reviewed By: ________________ P.Eng.



Multi-Stage Consolidated Undrained Triaxial Test

STAGE 1

Project No.: 0201-11509

Date Tested: 95-01-03

Test Hole No.: G21

Depth (m):

Test Number: CU-1

	Initial	Final
Moisture Content (%):	19.3	19.5
Wet Density (Mg/m3):	1.908	2.378
Dry Density (Mg/m3):	1.599	1.989

Strain (%)	σ1–σ3 (kPa)	Excess PP (kPa)	Parameter a	σ1/σ3	(σ1–σ3)/2 (kPa)	(σ1+σ3)/2 (kPa)
0.00	0.0	0.0	0.00	1.00	0.0	240.0
0.14	59.4	23.8	0.40	1.27	29.7	245.9
0.29	108.3	50.9	0.47	1.57	54.2	243.3
0.43	125.8	67.1	0.53	1.73	62.9	235.8
0.74	137.5	89.3	0.65	1.91	68.7	219.4
1.06	144.0	104.0	0.72	2.06	72.0	208.1
1.38	149.8	115.1	0.77	2.20	74.9	199.7
1.71	153.7	123.3	0.80	2.32	76.9	193.5
1.96	155.6	127.9	0.82	2.39	77.8	190.0
2.37	158.8	132.4	0.83	2.48	79.4	187.0
2.70	160.9	135.5	0.84	2.54	80.5	185.0
3.12	163.9	137.5	0.84	2.60	81.9	184.4
3.28	164.7	138.0	0.84	2.62	82.4	184.3
3.45	165.6	138.6	0.84	2.63	82.8	184.2
3.77	167.5	139.4	0.83	2.67	83.7	184.3
3.93	168.7	139.6	0.83	2.68	84.4	184.8
4.09	169.9	139.6	0.82	2.69	85.0	185.4
4.25	171.0	139.7	0.82	2.70	85.5	185.8
4.58	172.3	139.7	0.81	2.72	86.1	186.4
4.74	172.9	139.7	0.81	2.72	86.5	186.8
4.90	173.6	139.6	0.80	2.73	86.8	187.2
5.23	174.8	139.5	0.80	2.74	87.4	188.0
5.40	175.4	139.4	0.79	2.74	87.7	188.4
5.72	176.9	139.2	0.79	2.75	88.4	189.2
5.88	177.5	139.1	0.78	2.76	88.8	189.7
6.04	178.1	139.0	0.78	2.76	89.1	190.1
6.37	179.3	138.8	0.77	2.77	89.7	190.8
6.53	180.0	138.8	0.77	2.78	90.0	191.2
6.85	181.2	138.6	0.77	2.79	90.6	191.9
7.01	181.6	138.6	0.76	2.79	90.8	192.2
7.25	182.0	138.6	0.76	2.80	91.0	192.4

Test Hole No.: G21 Test Number: CU-1 STAGE 2
Depth:

Strain (%)	σ1−σ3 (kPa)	Excess PP (kPa)	Parameter a	σ1/σ3	(σ1−σ3)/2 (kPa)	(σ1+σ3)/2 (kPa)
7.25	0.0	0.0	0.00	1.00	0.0	478.8
7.32	63.4	29.1	0.46	1.14	31.7	481.4
7.41	105.9	51.2	0.48	1.25	52.9	480.6
7.49	153.0	76.4	0.50	1.38	76.5	479.0
7.58	180.1	97.9	0.54	1.47	90.1	471.0
7.66	195.0	109.5	0.56	1.53	97.5	466.8
7.83	217.1	126.5	0.58	1.62	108.6	460.8
8.01	239.3	144.5	0.60	1.72	119.6	453.9
8.35	257.3	165.1	0.64	1.82	128.6	442.3
8.52	264.7	176.1	0.67	1.87	132.4	435.1
8.69	272.3	182.2	0.67	1.92	136.1	432.8
8.87	279.5	188.2	0.67	1.96	139.7	430.4
9.04	285.2	194.9	0.68	2.00	142.6	426.5
9.38	295.3	205.4	0.70	2.08	147.7	421.1
9.55	300.8	209.8	0.70	2.12	150.4	419.4
9.72	304.5	212.9	0.70	2.15	152.3	418.1
9.90	307.1	215.4	0.70	2.17	153.6	417.0
10.07	309.5	217.8	0.70	2.19	154.8	415.8
10.42	313.8	221.1	0.70	2.22	156.9	414.6
10.59	315.5	222.3	0.70	2.23	157.7	414.3
10.77	318.0	223.2	0.70	2.24	159.0	414.6
10.94	319.5	224.1	0.70	2.25	159.7	414.5
11.12	320.6	224.7	0.70	2.26	160.3	414.4
11.47	322.6	225.9	0.70	2.28	161.3	414.2
11.64	323.9	226.3	0.70	2.28	162.0	414.5
11.82	325.3	226.5	0.70	2.29	162.7	415.0
12.00	326.4	226.7	0.69	2.29	163.2	415.3
12.18	327.5	226.9	0.69	2.30	163.7	415.6
12.53	329.8	227.1	0.69	2.31	164.9	416.6
12.71	330.8	226.8	0.69	2.31	165.4	417.4
12.89	331.8	226.8	0.68	2.32	165.9	417.9
13.04	332.8	226.9	0.68	2.32	166.4	418.3
13.22	333.8	226.8	0.68	2.32	166.9	418.9
13.58	336.1	226.6	0.67	2.33	168.1	420.3
13.76	337.1	226.5	0.67	2.34	168.6	420.9
13.94	338.5	226.4	0.67	2.34	169.2	421.6
14.11	339.7	226.3	0.67	2.34	169.8	422.4

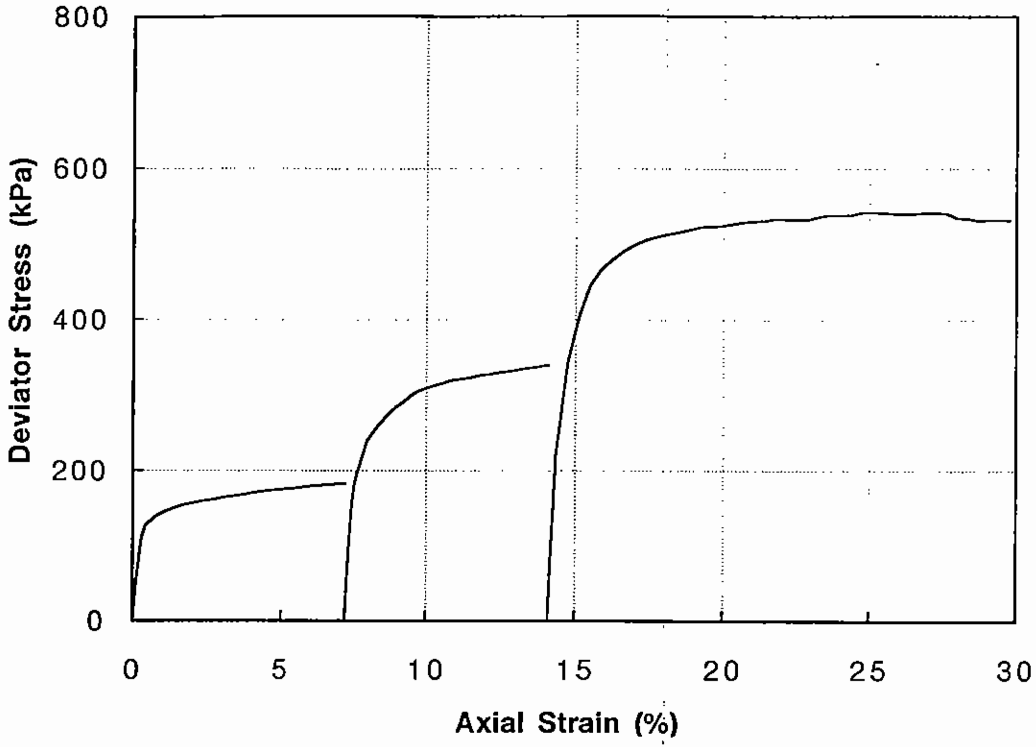
Test Hole No.: G21 Test Number: CU-1 STAGE 3

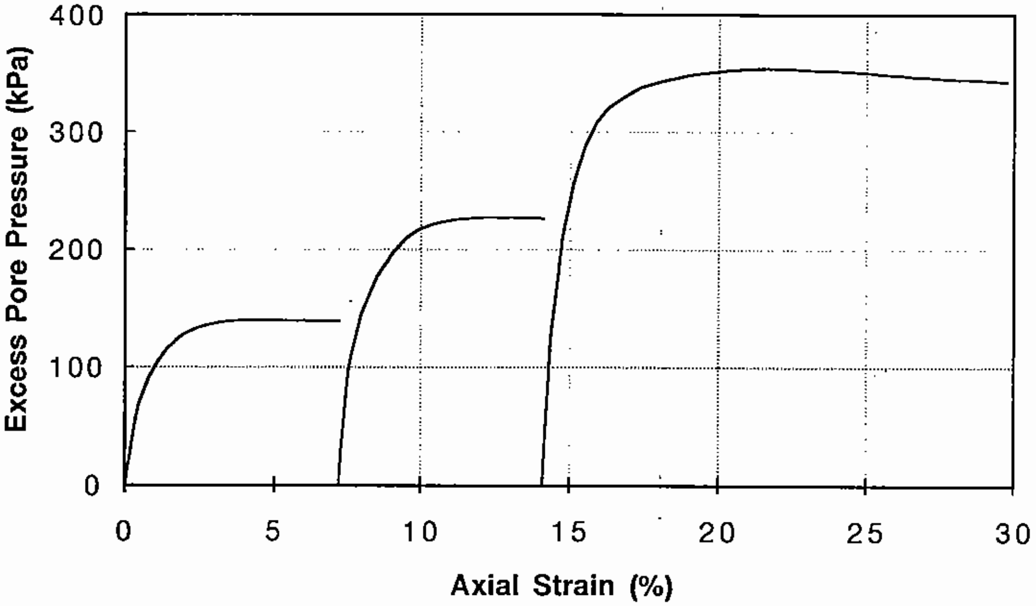
Depth:

Strain (%)	σ1−σ3 (kPa)	Excess PP (kPa)	Parameter a	σ1/σ3	(σ1−σ3)/2 (kPa)	(σ1+σ3)/2 (kPa)
14.11	0.0	0.0	0.00	1.00	0.0	802.3
14.19	82.6	46.0	0.56	1.11	41.3	797.6
14.29	148.4	82.2	0.55	1.21	74.2	794.2
14.38	220.7	124.1	0.56	1.33	110.3	788.5
14.76	342.3	210.1	0.61	1.58	171.2	763.3
15.13	403.2	256.6	0.64	1.74	201.6	747.2
15.50	444.7	287.0	0.65	1.86	222.4	737.6
15.88	466.4	307.3	0.66	1.94	233.2	728.1
16.25	478.8	319.8	0.67	1.99	239.4	721.9
16.63	489.7	326.4	0.67	2.03	244.9	720.8
17.00	498.1	332.6	0.67	2.06	249.1	718.7
17.37	505.0	337.8	0.67	2.09	252.5	717.0
17.75	509.3	340.8	0.67	2.10	254.7	716.2
18.12	513.3	343.3	0.67	2.12	256.6	715.6
18.49	515.8	345.8	0.67	2.13	257.9	714.3
18.86	519.2	347.6	0.67	2.14	259.6	714.3
19.23	522.2	349.4	0.67	2.15	261.1	714.0
19.60	523.0	350.6	0.67	2.16	261.5	713.1
19.97	524.3	351.6	0.67	2.16	262.2	712.8
20.34	526.2	352.5	0.67	2.17	263.1	712.9
20.70	529.2	353.3	0.67	2.18	264.6	713.6
21.07	529.8	353.8	0.67	2.18	264.9	713.4
21.44	530.9	354.1	0.67	2.18	265.4	713.6
21.81	533.0	354.5	0.67	2.19	266.5	714.3
22.18	532.6	354.3	0.67	2.19	266.3	714.3
22.54	532.6	354.0	0.66	2.19	266.3	714.6
22.91	532.9	353.5	0.66	2.19	266.5	715.3
23.28	535.5	353.0	0.66	2.19	267.8	717.1
23.65	538.4	352.5	0.65	2.20	269.2	719.0
24.01	538.3	352.3	0.65	2.20	269.2	719.1
24.38	538.8	351.5	0.65	2.20	269.4	720.2
24.74	542.0	351.0	0.65	2.20	271.0	722.3
25.11	541.9	350.3	0.65	2.20	270.9	722.9
25.47	541.5	349.7	0.65	2.20	270.7	723.4
25.83	540.5	348.9	0.65	2.19	270.2	723.6
26.19	540.0	348.2	0.64	2.19	270.0	724.1
26.55	540.1	347.5	0.64	2.19	270.1	724.8
26.91	540.9	347.1	0.64	2.19	270.5	725.6
27.27	541.3	346.3	0.64	2.19	270.6	726.6
27.63	540.3	345.8	0.64	2.18	270.1	726.6
27.99	534.3	345.3	0.65	2.17	267.2	724.2

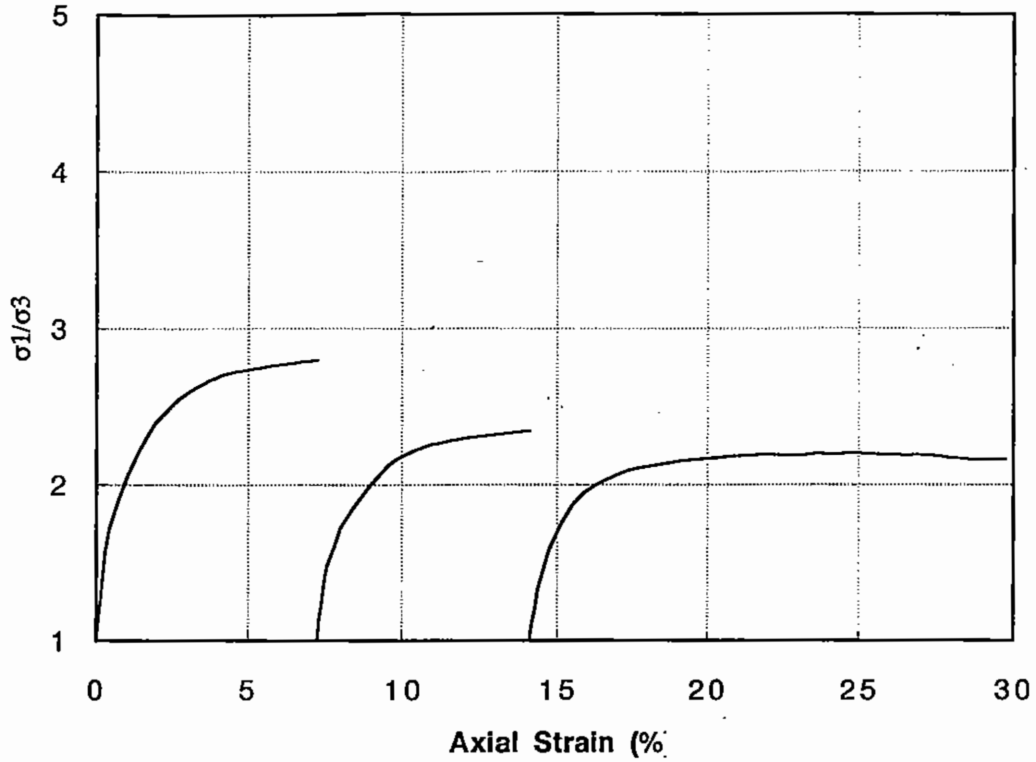
Test Hole No.: G21 Test Number: CU-1 STAGE 3
Depth:

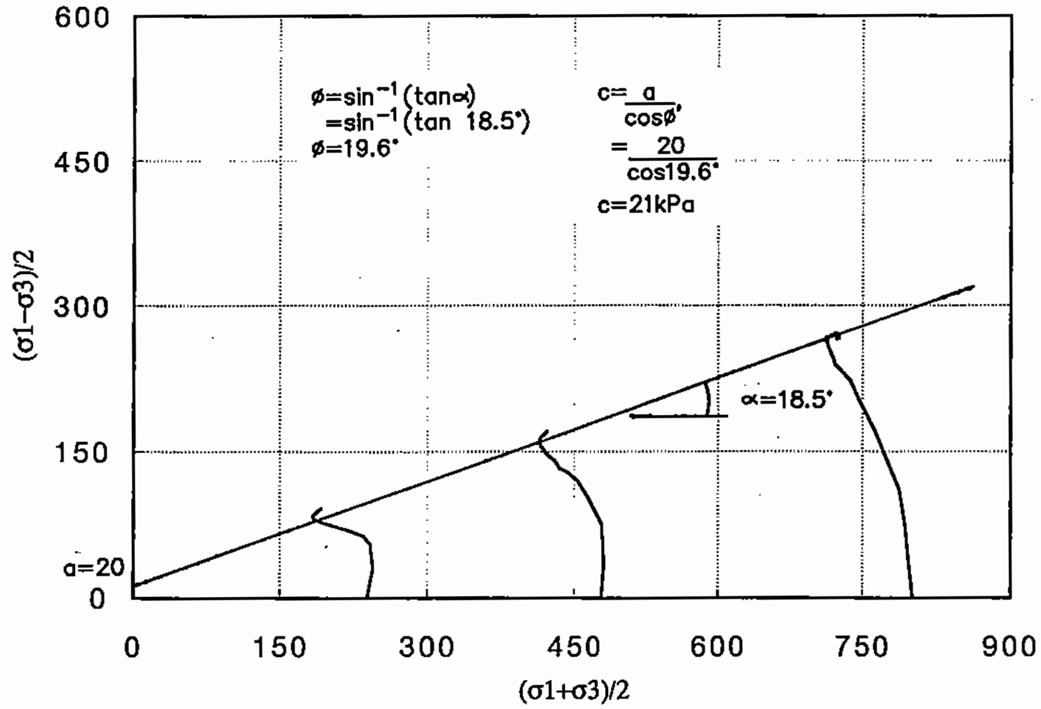
Strain (%)	σ1–σ3 (kPa)	Excess PP (kPa)	Parameter a	σ1/σ3	(σ1–σ3)/2 (kPa)	(σ1+σ3)/2 (kPa)
28.35	533.4	344.8	0.65	2.17	266.7	724.1
28.71	530.7	344.4	0.65	2.16	265.3	723.3
29.07	531.5	343.8	0.65	2.16	265.7	724.2
29.43	531.7	343.2	0.65	2.16	265.8	724.9
29.76	532.1	342.7	0.64	2.16	266.0	725.6





Test Hole: G21
Effective Stress: 240/480/800 kPa
Strain Rate: 0.004 %/min.
Test No.: CU-1





Test Number: CU-1

CONSTANT HEAD PERMEABILITY TEST

Job Number: 0201-11509

Test Hole: G21 Depth:

Date: 95-01-13

Test No: P-1

Time	Buret (cc)	Elap. (min)	Outflow (cc)
8:22	13.2	0	0.0
10:22	13.5	120	0.3
13:02	14.0	280	0.8
15:32	14.5	430	1.3
17:46	14.9	564	1.7
8:32	17.5	1450	4.3
12:57	18.3	1715	5.1
10:05	21.7	2983	8.5
15:52	20.7	3330	9.5
7:49	18.2	4287	12.0
13:02	17.3	4600	12.9
16:57	16.7	4835	13.6
7:50	14.4	5728	15.8
12:59	13.6	6037	16.7

Diameter= 70.82 mm

Height= 25.24 mm

Volume= 99.42 cm3

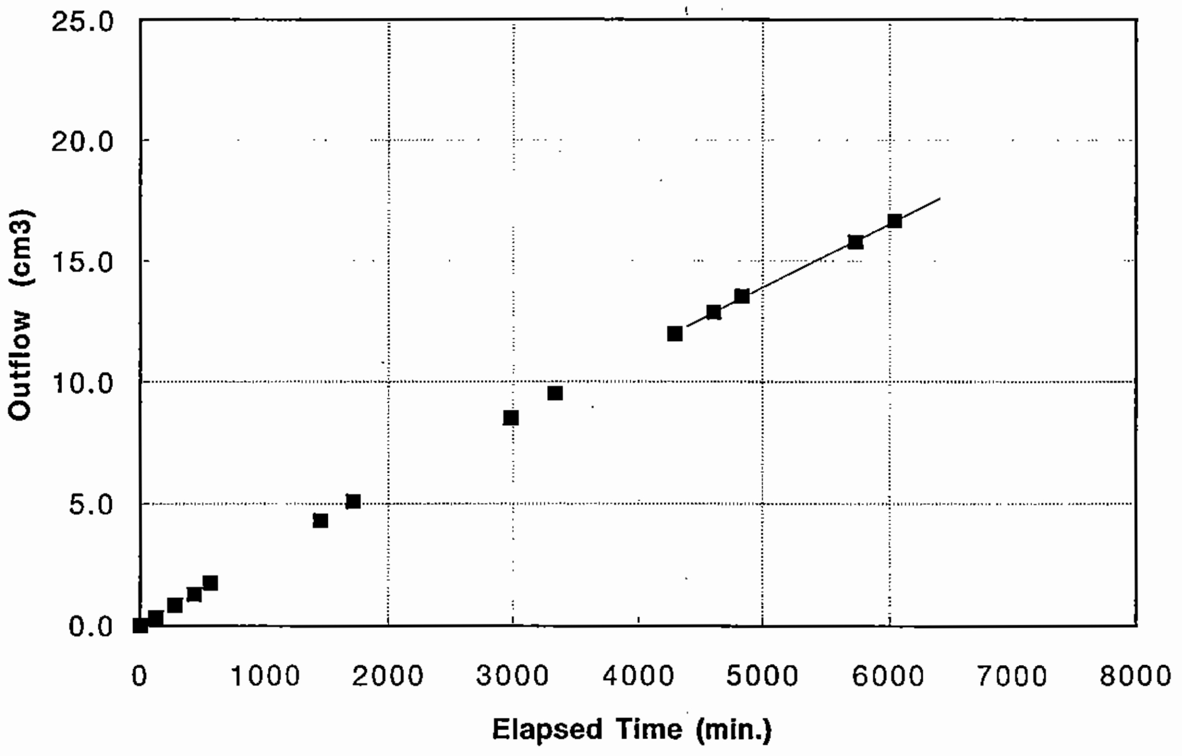
Head Diff.= 5 psi

Q= 4.349E-05 cm3/sec

i= 139.34

A= 39.39 cm2

K= 7.92E-09 cm/sec



APPENDIX C
DAM STABILITY ANALYSIS

APPENDIX C
DAM STABILITY ANALYSES

C.1 INTRODUCTION

The base of the dam will be founded on intact bedrock beneath the central core and on residuum or weathered bedrock beneath the upstream and downstream shell of the dam. These are all considered to be relatively competent strata with no major planes of weakness which could contribute to a potential failure plane. Therefore the performance of the dam will be dictated primarily by the fill materials used to construct the core and shell of the dam. The other major factor is the development of a phreatic surface which will be created over time due to water seepage through the core.

One other major factor is the phreatic surface which will be developed in the downstream shell as water will be continually spilled over the crest of the dam and permitted to flow through the downstream shell. Due to the relatively low predicted summer flows (0.04 m^3/sec), it is calculated that all the water which is spilled over the crest will flow through the coarse filter on the downstream side of the core.

C.2 MATERIAL CHARACTERISTICS

It has been assumed that an adequate quantity of sandy, silty clay for constructing the core will be obtained from the proposed borrow source along the main access road at the east edge of the lease boundary. It has also been assumed that the clay will have similar properties to the clay obtained from Borehole 94-G21. Laboratory tests have been undertaken to determine the bulk unit weight and strength properties of the clay in a remolded or reworked condition. The laboratory testing for clay borrow was conducted on material which was finer grained than the current borrow source. Therefore the strength parameters utilized in the analyses are considered to be conservative for the currently proposed borrow material.

The upstream outer shell of the dam will be constructed with a combination of coarse grained residuum and weathered bedrock from a borrow pit located upstream of the dam in the base of the valley. Laboratory testing has been conducted to determine the bulk unit weight, permeability and strength properties of the residuum in a remolded condition.

The downstream shell will be constructed from waste rock obtained from the open pit overburden. This will be a well graded shot rock with a maximum top size of approximately

600mm. Laboratory testing on the shot rock is not possible at this stage, therefore, conservative parameters have been assumed for this material.

For the native residuum and weathered bedrock layer, bulk unit weights and strength parameters were assumed to be the same as the reworked residuum. Parameters for the filter materials were assumed to be the same as the recompacted residuum used for the upstream shell, which is considered to be conservative. The underlying, intact granodiorite bedrock was assumed to be a very hard competent strata which would not be penetrated by any potential failure planes. A typical cross section through the centre of the dam illustrating the various physical parameters of the soil strata and embankment fill materials used in the stability analyses is presented in Figure C-1, attached.

In all cases it was assumed that a minimum density equivalent to 95 percent of Standard Proctor maximum dry density would be achieved for any compacted fill materials. Bulk unit weights and effective strength parameters adopted for the analyses are summarized as follows:

Soil Type	Bulk Density (kg/m^3)/(pcf)	c' (kPa/psf)	Ø'
Clay Core	1890/118	0	20°
Residuum (Upstream Shell)	2080/130	0	35°
Shot Rock (Downstream Shell)	2080/130	0	40°
Filters	2080/130	0	35°
Weathered Bedrock	2080/130	0	35°

C.3 PORE PRESSURES

To determine the location of the phreatic surface which would develop through the dam, a seepage analysis was conducted using a finite element model. Details of the seepage analysis are presented in the main text of the report and in Appendix D. The results of the seepage analysis predicted a significant decrease in the phreatic surface passing through the central core. This phreatic surface is depicted on Figure C-2. The pore pressure grid generated by the seepage analysis was input into the slope stability computer program and used in the stability analyses.

Analyses were also conducted to evaluate the stability of the dam immediately after construction assuming that the core material would have a B of 0.5. The underlying native soils and dam shell fill materials are coarse grained, relatively free draining and will not develop any pore pressures during construction.

As water will be continually spilled over the crest of the dam and permitted to flow through the downstream shell, a phreatic surface will be generated due to average summer flow conditions. Due to the relatively low predicted summer flows (0.04 m^3/sec), it is estimated that all the water will flow within the coarse filter on the downstream side of the core. In the event of a design flood event (5.0 m^3/sec), a higher phreatic surface will temporarily develop in the downstream side of the dam.

If any drawdown within the reservoir were to occur, it would be governed by the capacity of the pumps that will be pumping the water up to the mill. This is assumed to be a relatively slow process, which would take weeks or months to occur, rather than days. Based on the anticipated water requirements calculated by Minto Explorations Ltd., the water level will be drawndown in the reservoir by a maximum of 1.5 m (5 feet) over the winter months (5 month period). A rapid drawdown of the dam is not considered possible and therefore has not been considered in the analysis.

C.4 STABILITY ANALYSES

Stability analyses were conducted using a computer program (SLOPEW) which utilizes limit equilibrium theory to solve for the factor of safety. The analyses assumed a two dimensional analysis, which is considered to be conservative given the steep-walled valley slopes in the vicinity of the dam.

The initial case evaluated in the slope stability analysis was the dam in a 'dry' condition with no seepage through or beneath the dam, which is representative of conditions at the end of construction assuming there are pore pressures developed during construction. These analyses indicate a factor of safety of 2.12, with the critical failure surfaces being relatively shallow slip planes parallel to the downstream face of the dam. Assuming pore pressures are developed in the core during construction, yielded the same factor of safety of 2.12. In both these analyses the critical failure surface is a relatively shallow slip plane close to the surface of the downstream shell.

Analyses were also conducted for the full impoundment condition using pore pressures derived from the seepage analysis, which is considered to be representative of the steady state seepage conditions with maximum reservoir storage. This analysis yielded a factor of safety of 1.83 for failures at the downstream toe of the dam. Similar analyses for failure surfaces which extend through the centre of the dam indicate a factor of safety of 1.97. The minimum factor of safety recommended by the Dam Safety Guidelines prepared by the CDSA is 1.5 for the steady state seepage condition. A typical section illustrating the shape of the critical slip surfaces for the conditions discussed above is presented in Figure C-2.

Analyses were conducted for the upstream face of the dam which will be submerged under water most of the time. As discussed previously, a rapid drawdown of the water in the reservoir is not possible and therefore has not been analyzed. The minimum factor of safety for a condition with an upstream submerged face is 1.77.

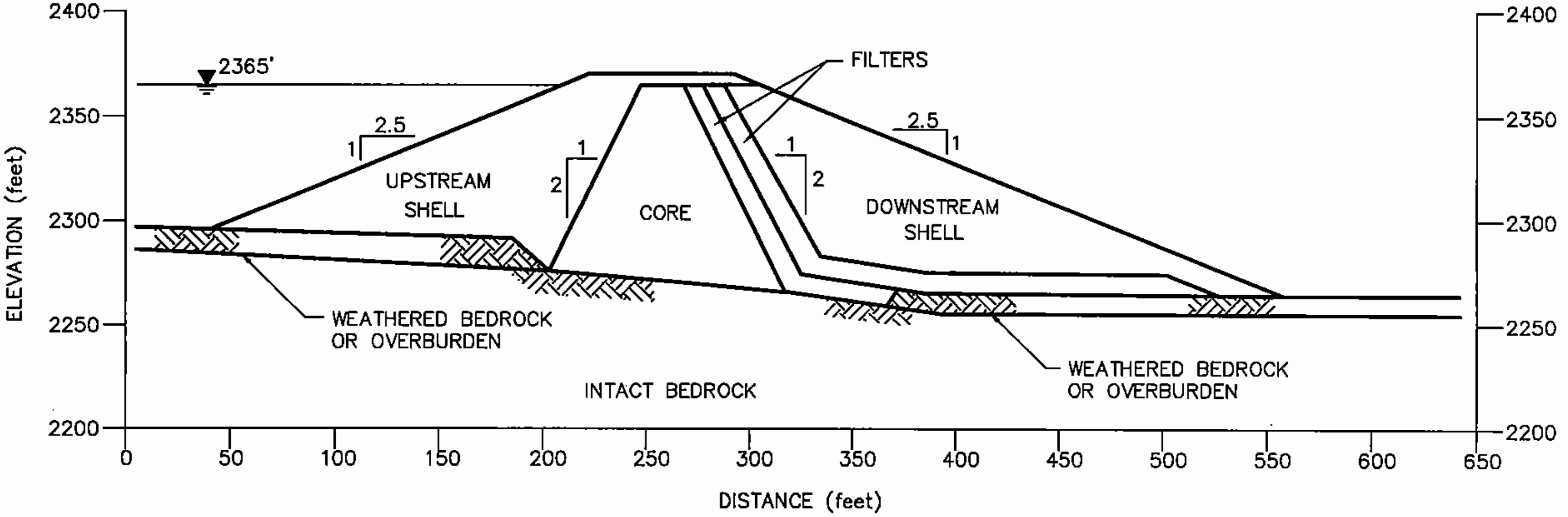
The final condition analyzed involved a design flood event over the tailings dam creating an elevated phreatic surface in the downstream shell. This analysis determined the factor of safety to be 1.50 for a deep seated slide and 1.09 for a localized slide at the downstream toe of the dam. This is considered to be an acceptable factor of safety for a deep seated failure. If problems were to develop at the downstream toe, it would be feasible to access this area and surcharge the toe with a berm or possibly some oversized rip rap.

C.5 SEISMIC ANALYSES

A series of analyses were conducted to evaluate the stability of the dam subjected to seismic loading. The general practice for evaluating the seismic stability of dams has been the use of pseudo-static analysis. This procedure simulates seismic activity by applying a horizontal force to the centroid of each slice in the computer analysis. Although this method has limitations when analyzing structures built with loose cohesionless soils, the analysis offers a reasonable means for evaluating behaviour of embankments built of clay or dense cohesionless soils.

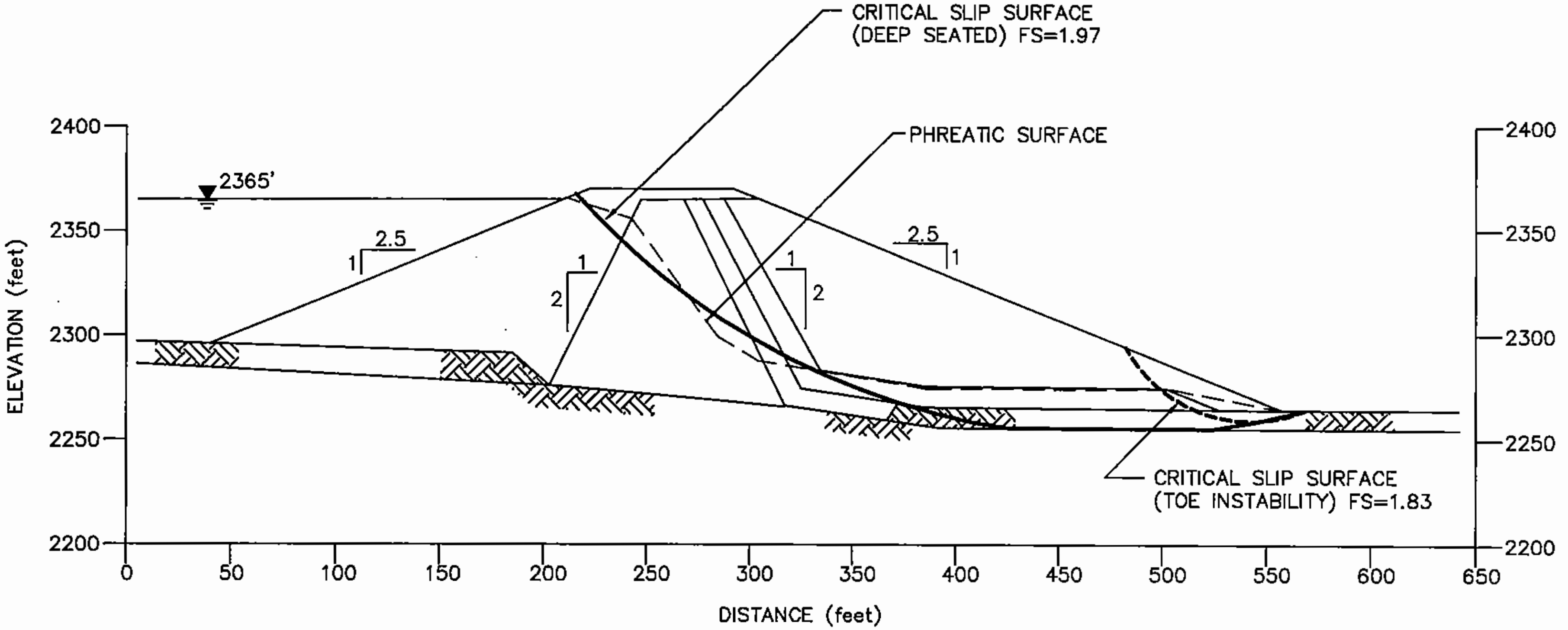
CDSA Dam Safety Guidelines recommend a benchmark level (annual probability of exceedance of 1/100 to 1/475) for Low Consequence dams. As outlined in the main text, at the Minto mine site, this corresponds to a design earthquake peak horizontal acceleration of 0.083g. With the removal of any ice-rich silt in the foundation soils beneath the dam, the native residuum and bedrock (both weathered and intact) is not considered to be liquifiable nor will any excess pore pressures be generated due to seismic events.

A pseudo-static stability analysis was performed by applying a series of seismic loads equivalent to 0.03 g, 0.06 g and 0.083 g. Assuming a long term phreatic surface under normal flow conditions the minimum factors of safety for the dam were determined to be 1.67, 1.53 and 1.43, respectively. These critical slip surfaces were determined to be localized toe failures. The factors of safety for slip surfaces extending through the main dam for the three seismic loading conditions were calculated to be 1.79, 1.63 and 1.53. The minimum factor of safety typically adopted for stability under seismic loading conditions is 1.2.



SOIL TYPE	DENSITY (pcf)	c' (psf)	ø
Clay Core	118	0	20°
Residuum (Upstream Shell)	130	0	35°
Shot Rock (Downstream Shell)	130	0	40°
Filters	130	0	35°
Weathered Bedrock	130	0	35°

EBA Engineering Consultants Ltd.	PROJECT MINTO PROJECT NORTH OF CARMACKS, YUKON
CLIENT **MINTO EXPLORATIONS LTD.**	TITLE **TYPICAL SECTION AND SOIL PARAMETERS USED FOR STABILITY ANALYSIS**
DATE 95–12–20 DWN. DRG CHKD. AFR	FILE NO. 11509D03B FIGURE C–1



NOTES:
1. SOIL STRATIGRAPHY AND PARAMETERS AS SHOWN ON FIGURE C–1.
2. ANALYSIS BASED ON LONG TERM SEEPAGE DEVELOPED THROUGH CORE OF DAM; NO SEISMIC LOADS.
3. FS – FACTOR OF SAFETY.

EBA Engineering Consultants Ltd.

PROJECT
MINTO PROJECT
NORTH OF CARMACKS, YUKON

CLIENT
MINTO EXPLORATIONS LTD.

TITLE
TYPICAL STABILITY ANALYSIS
LONG TERM SEEPAGE CONDITION

DATE 95–12–21
DWN. DRG
CHKD. AFR
FILE NO. 11509D04B
FIGURE C–2

APPENDIX D
DAM SEEPAGE ANALYSES

To evaluate the seepage of water through and beneath the dam due to the impoundment of tailings and water, an analysis was conducted using a finite element computer program (SEEP/W). Permeability (or hydraulic conductivity) of the soils was determined based on the results of laboratory testing on residuum for the upstream dam shell. Values for the native residuum were assumed to be similar to the permeability obtained in the laboratory on the reconstituted residuum.

Detailed laboratory testing has not been conducted on the proposed core material from the new borrow area located along the access road at the eastern edge of the lease. Therefore the results of the laboratory testing on the clay identified in the 1994 field investigation were used to estimate the permeability parameters of the proposed clay core material. The original laboratory tests indicated the clay had a permeability of less than 1 x 10^{-8} cm/sec. For the new proposed clay borrow, the permeability was increased one order of magnitude to 1 x 10^{-7} cm/sec.

Field testing conducted by EBA in 1995 measured the in situ permeability of the weathered and intact bedrock under the dam as discussed in Section 5.2.3 of the main report.

The following presents a summary of the permeabilities which were input into the computer model for the various soil types. All soils were assumed to be isotropic with ratios of horizontal to vertical permeabilities equal to unity.

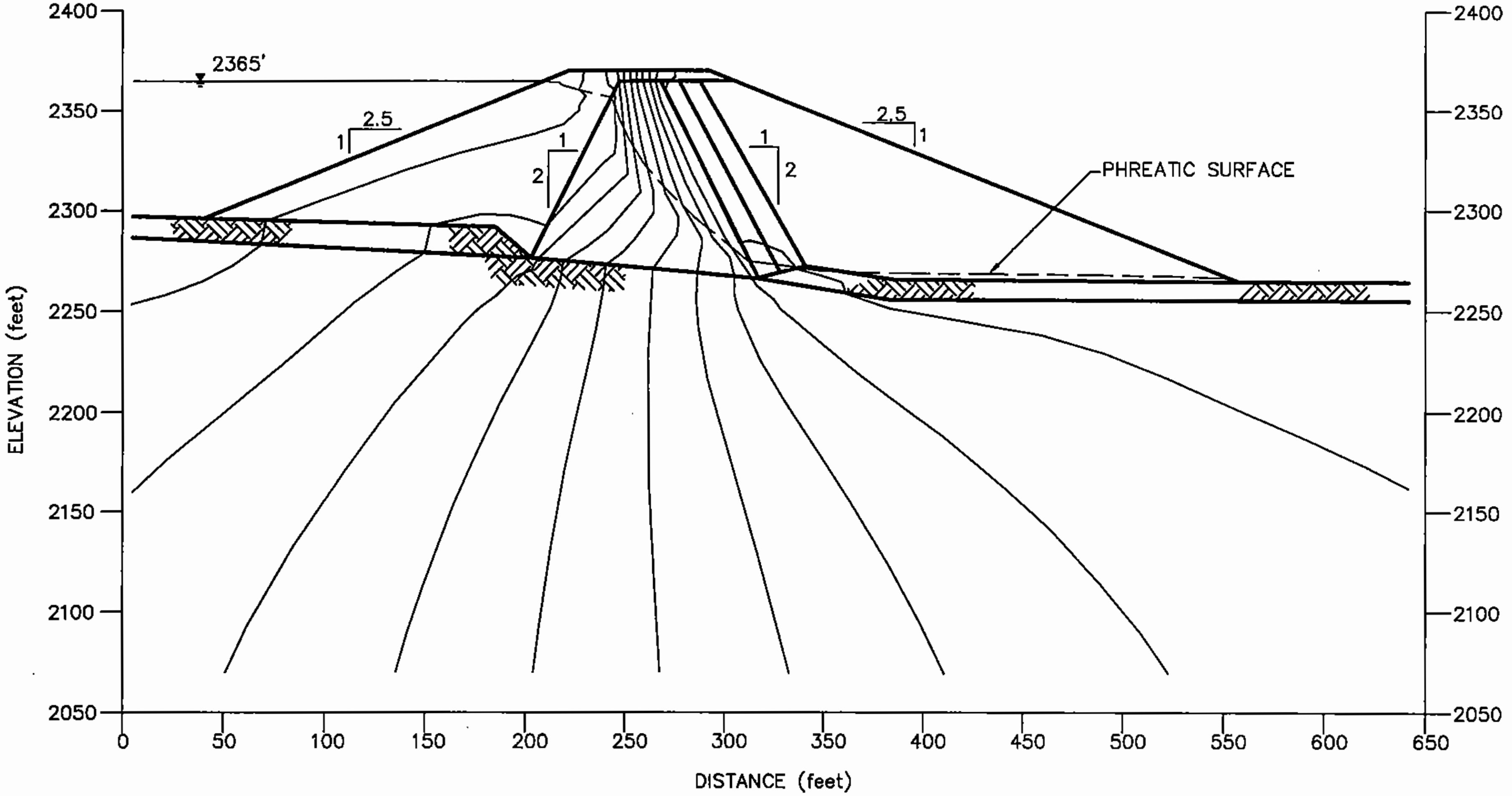
Soil Type	Permeability (cm/sec)
Residuum (in situ)	4 x 10^{-6}
Upstream Shell	4 x 10^{-6}
Downstream Shell	1 x 10^{-2}
Semi- Impervious Core	1 x 10^{-7}
Weathered Bedrock	1 x 10^{-4}
Intact Bedrock	1 x 10^{-5}

A seepage analysis was undertaken to evaluate the shape of the phreatic surface through the dam utilizing the above stated values under long term conditions. A simplified section illustrating the phreatic surface of the flow net is presented on Figure D.1. Output from this seepage analysis produced an estimate of the anticipated flow through and beneath the dam and a pore pressure grid which was used in the stability analysis.

The seepage analysis assumed an upstream water level in the reservoir of 2365 feet and a crest elevation of 2370 feet, which corresponds to the ultimate values for the dam. A 10 foot thick layer of fractured, weathered bedrock with a relatively high permeability (1×10^{-4} cm/sec) was assumed to extend under the upstream shell of the dam. This is considered to be a conservative assumption, which reduces the length of the seepage path and increases the predicted seepage loss.

Results of the analysis indicate that the seepage rate through and under the dam equates to approximately 14.3 m^3 (500 ft^3) per day, which is less than 0.5 % of the average daily flow in Minto Creek. Assuming that all the bedrock under the dam was highly fractured and had an average permeability of 1×10^{-4} cm/sec the estimated seepage loss is approximately 113 m^3 (4,000 ft^3) per day. This is considered to be an absolute worse case for seepage loss. The value of 14.3 m^3 (500 ft^3) per day is considered to be a more realistic estimate of the seepage loss which will likely occur.

Based on this analysis it was determined that almost no seepage occurs through the core, but that the majority of the seepage occurs through the foundation beneath the dam. Relatively high seepage gradients occur immediately downstream of the core. To control seepage and decrease the possibility of piping at this location it was decided to overexcavate the weathered bedrock for a distance of 50 feet beyond the downstream toe of the core and replace it with the fine filter aggregate.



EBA Engineering Consultants Ltd.	PROJECT MINTO PROJECT NORTH OF CARMACKS, YUKON
CLIENT **MINTO EXPLORATIONS LTD.**	TITLE **TYPICAL SEEPAGE SECTION**

DATE	95-12-19	DWN.	DRG	CHKD.	AFR	FILE NO.	11509D02A	FIGURE D-1

APPENDIX E
THERMAL ANALYSIS OF NORTH-FACING SLOPE

APPENDIX E
THERMAL ANALYSES OF NORTH-FACING SLOPE

E.1 GEOTHERMAL MODEL

Geothermal analyses were carried out to estimate the thermal regime following full impoundment of the Minto tailings pond.

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. The heat exchange at the ground surface is modelled with an energy balance equation considering air temperatures, wind speed, snow depth and solar radiation.

E.2 INPUT PARAMETERS

E.2.1 Climatic Data

No climatic data was available from the site. The meteorological station closest to the site is Pelly Ranch, situated about 40 km northeast of the site. Other nearby stations include Carmacks and Fort Selkirk. Figure E.1 presents a plot showing the mean monthly air temperatures measured at several of the nearby meteorological stations. Comparison of the mean monthly air temperatures from the three stations show that they are similar. The average monthly air temperatures from the three stations were calculated. However, all three stations are located at a lower elevation than the Minto mine site. Air temperatures are expected to be cooler at the higher elevation of the Minto site. Johnston (1981) states that climatologists typically assume a 6°C decrease in temperature for every kilometre increase in elevation. Since the minesite is located approximately 260 m (850 ft) higher than the weather stations, 1.6°C was subtracted from the mean monthly air temperatures. These values were input as the mean air temperatures for the site. Wind speed for the site was estimated by averaging wind speeds from four meteorological stations in the Yukon: Burwash, Mayo, Watson Lake and Whitehorse. The mean monthly wind speed ranged between 87 and 12 km/h. The mean snow depth was estimated from snow cover data from Pelly Ranch. Solar radiation values were taken from the average measured values at Whitehorse. Table E.1 presents a summary of the climatic data from selected stations near the Minto Site. Table E.2 summarizes the climatic data used in the thermal analyses.

E.2.2 Soil Properties

The worst case thermal condition on the north-facing valley slope will exist when the dam has little or no tailings on its upstream slope and water is impounded to its full depth in the main water storage pond. To evaluate this effect, a section of the north-facing valley slope was analyzed at the location of EBA Boreholes 94-G16 and 94-G17. This section is located slightly upstream of the dam and also at a location where ice-rich frozen silts and sands were found to exist on the valley slope. The ground temperatures measured in EBA Borehole 94-G11 are thought to be representative of ground temperatures near the valley bottom while those in boreholes 94-G21 and 95-G11 would be representative of temperatures further up slope. These temperature profiles have therefore been used as the modelled initial ground temperatures along this section of the valley slope. The geothermal analyses have been carried out using EBA's proprietary geothermal analysis program GEOTHERM. For the two-dimensional cross section analysis, the sand layer was assumed to overlay bedrock. Material properties used in the thermal analyses are listed in Table E.2. These thermal properties were calculated from the soil index properties.

E.3 CALIBRATION OF THERMAL MODEL

EBA installed two borehole thermistor strings in the summer of 1994. They are in Boreholes G21 situated at an elevation 752 m (2465 feet), and G11, located about 5 m (16 feet) above the creek at an elevation of approximately 724 m (2375 feet).

One-dimensional analyses were conducted for each borehole to calibrate the thermal model. The generalized soil stratigraphy modelled was interpreted from Boreholes G16 and G17. The measured ground temperatures were input as the initial temperature profile in the thermal model. Climatic conditions were applied to the ground-air surface nodes and the model was then run for a 20 year period to permit the temperatures to equilibrate. Both boreholes are on a slope, and less snow cover is therefore expected compared to that measured at the meteorological station, which is on a level surface. Parametric analyses were carried out varying snow thickness until the measured and computed ground temperatures matched. The variation in snow thickness was used as input for the two-dimensional cross section analysis.

E.4 TAILINGS IMPOUNDMENT

A two-dimensional analysis was conducted using the simplified soil profile cross section shown in Figure E.2. An initial ground temperature of -0.5°C was assigned to the entire section. Figure E.2 also shows the variation in snow depth cover, as determined from the one-dimensional borehole temperature calibrations. The snow depth factor refers to the multiplication factor by which monthly snow thicknesses are multiplied to account for expected increases or decreases in snow cover resulting from drifting.

Climatic boundary conditions were applied to the surface nodes. The model was run for a period of 15 years to allow temperatures to equilibrate. Figure E.2 shows the estimated ground temperature regime prior to impoundment. The base of the valley is warmer than along the slope because of increased snow cover and because the sand transfers heat much more readily than the wetter silt cover.

Full impoundment to an elevation of approximately 72 m (2365) was assumed to occur on May 1. A constant temperature of +10°C was then applied to all water-impounded surface boundaries. Lake water temperature data in northern climates is limited, but the value of +10°C is conservative compared to lake temperature measurements in the central and eastern N.W.T. (mean annual water temperature below +5°C). Snow thickness variations along the slope above the water level remained the same as prior to impoundment for the ground-air surface nodes.

The model was run for a 20 year period to allow temperatures to equilibrate. Figure E.3 shows the progression of the 0°C isotherm over the 20 year period following full impoundment. The silt underlying the water has fully thawed by the fifth year. Upslope from the water, the silt thaws more slowly; after twenty years, thawing of the silt layer has extended about 12 m from the edge of the water.

TABLE E.1: MONTHLY METEOROLOGICAL DATA USED IN THERMAL ANALYSES

Month	Air Temperature (°C)	Wind Speed (km/h)	Snow Depth (cm)	Daily Solar Radiation (W/m^2)
January	-30.5	8	30	15.1
February	-22.2	9.5	36.5	46.6
March	-13.7	11	33	107.1
April	-1.8	12	16	183
May	5.7	12.5	2	227.8
June	11.3	11.5	0	244.7
July	13.3	10.5	0	218
August	10.9	10.5	0	174.2
September	5	10.5	0	104.9
October	-3.8	10.5	4	50.7
November	-17.3	10.5	14.5	18.8
December	-27.3	10.5	23	8.6
Mean Annual	-5.9			

TABLE E.2: PHYSICAL PROPERTIES USED IN THERMAL ANALYSES

Material	Moisture Content (%)	Dry Density (Mg/m³)	Total Density (MG/m³)	Frozen Thermal Conductivity (W/m°C)	Unfrozen Thermal Conductivity (W/m°C)	Frozen Specific Heat (kJ/kg-°C)	Unfrozen Specific Heat (kJ/kg-°C)	Latent Heat (MJ/m³)
Ice-rich silt	25	1.59	1.99	2.44	1.49	1.03	1.42	-125
Sand and silt	15	1.90	2.18	2.64	1.76	0.91	1.18	-95
Sand	10	2.10	2.30	2.67	1.99	0.86	1.05	-70
Bedrock	0	2.65	2.65	3.00	3.00	0.73	0.73	0

Snow thermal conductivity = 0.30 W/m°C.
Snow emissivity = 0.90, snow absorptivity = 0.30
Ground emissivity = 0.90, ground absorptivity = 0.80
30% quartz content assumed

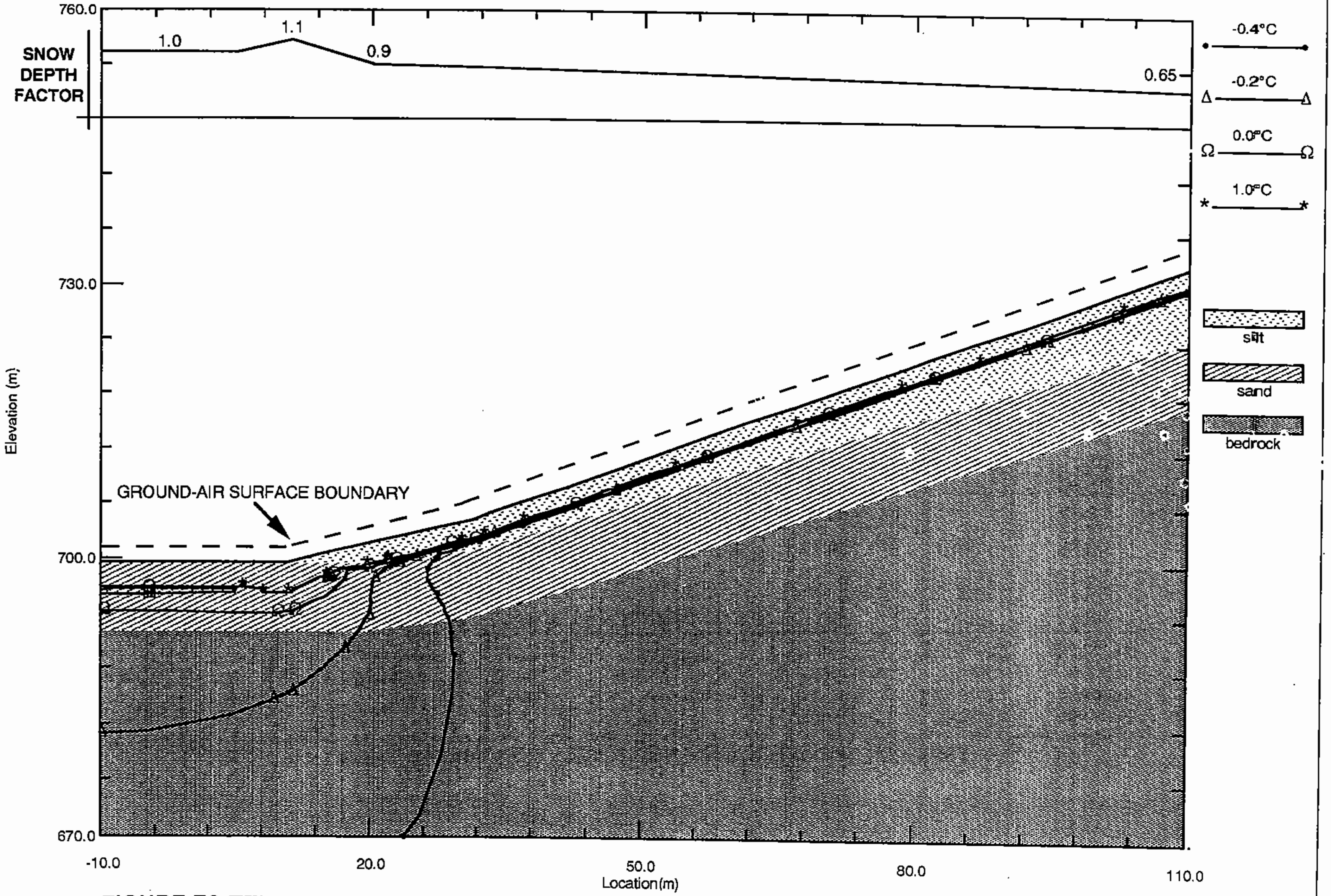


FIGURE E2 TEMPERATURE DISTRIBUTION OF VALLEY CROSS SECTION PRIOR TO IMPOUNDMENT

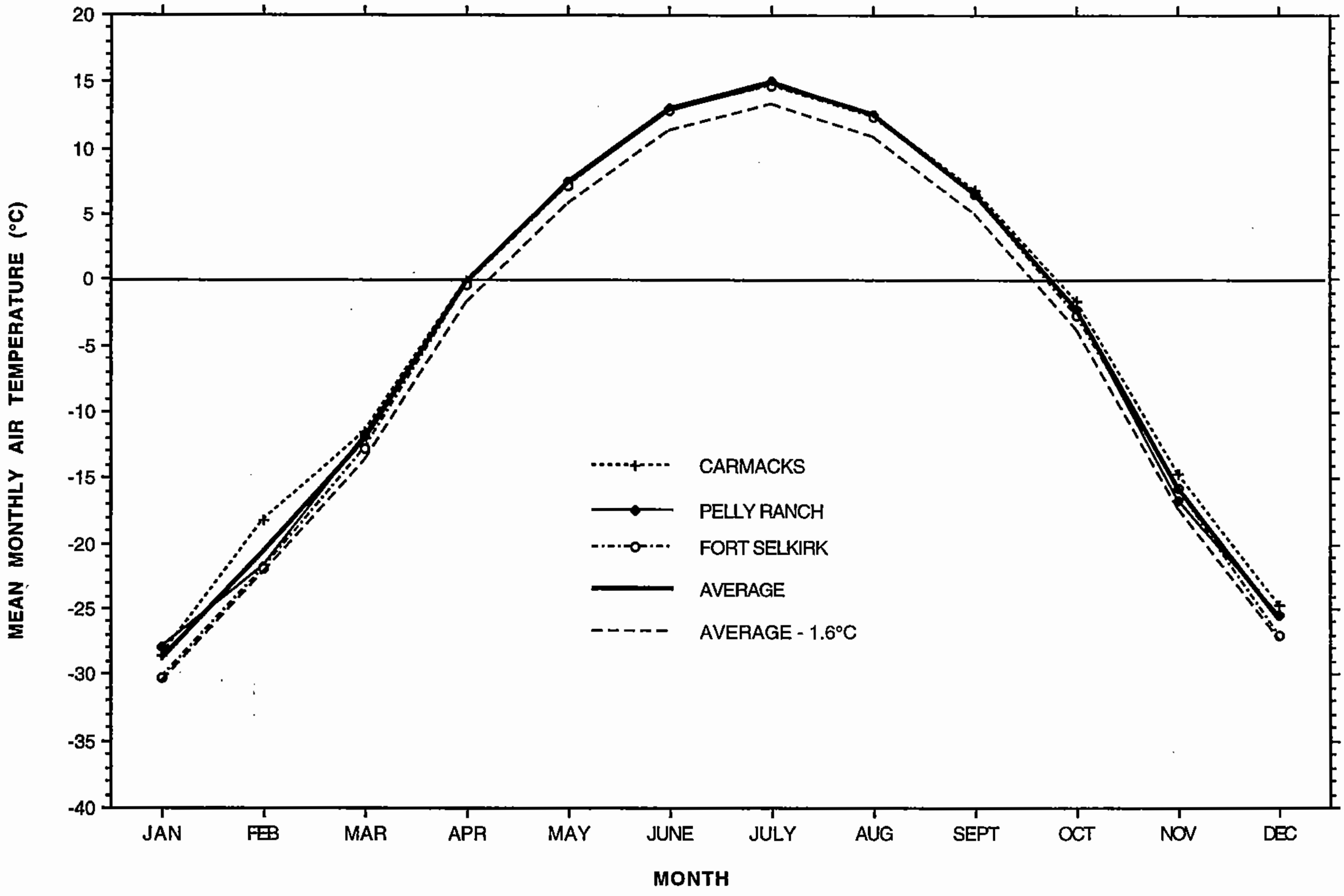


FIGURE E.1: MEAN MONTHLY TEMPERATURES FROM STATIONS NEAR THE MINESITE

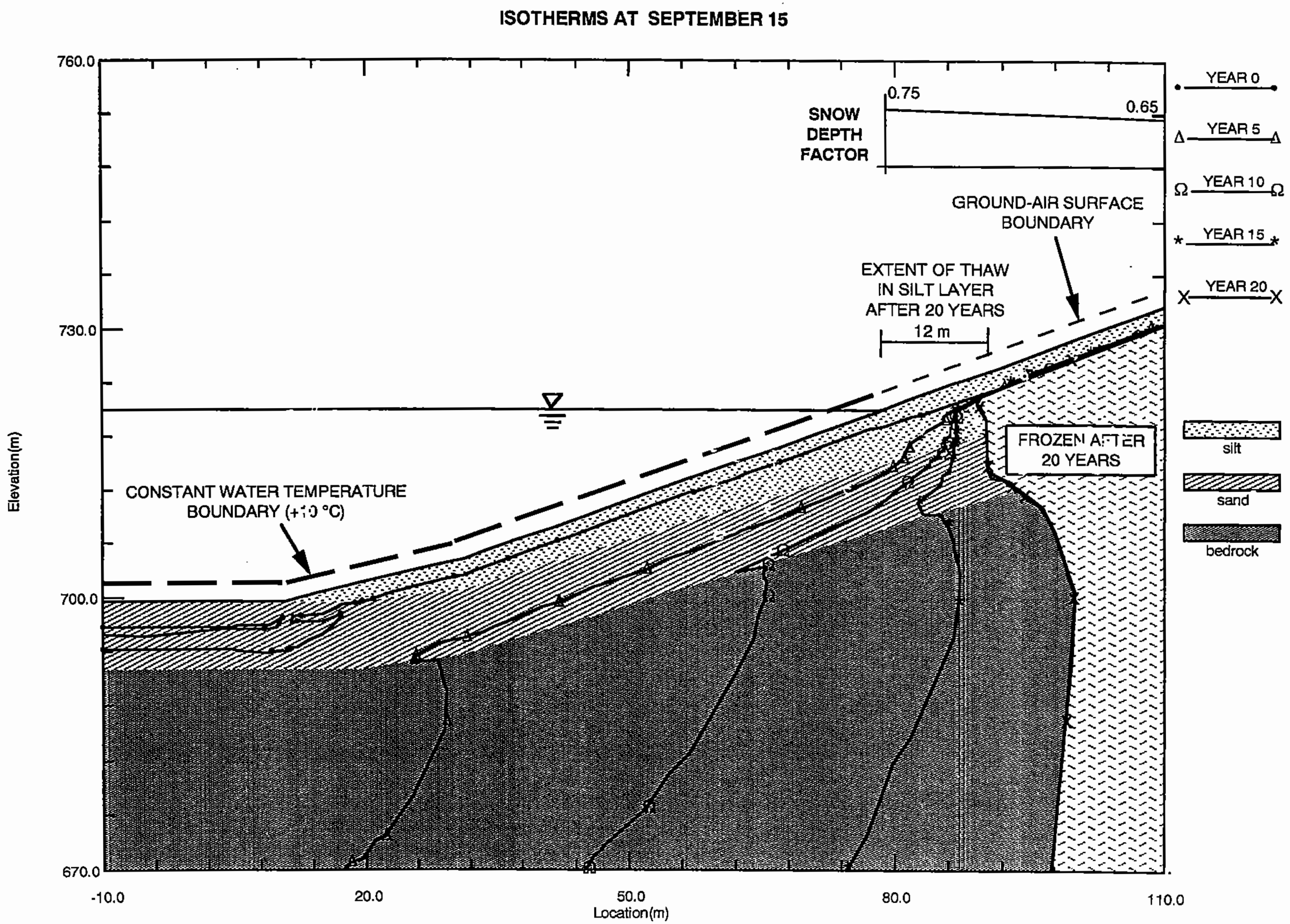


FIGURE E3 POSITIONS OF 0 °C ISOTHERM FOLLOWING FULL IMPOUNDMENT

APPENDIX F
SPILLWAY AND DIVERSION DITCH HYDROLOGY

December 18, 1995 Your Project: 201 - 95 - 11509

EBA Engineering Consultants Ltd. Our Project: 28
14535 - 118 Avenue
Edmonton, Alberta
T5L 2M7

Attention: Kevin Jones, P.Eng.
Project Director, Frontier Division

Re: **The Minto Project - Yukon**
Spillway and Diversion Ditch Design

Dear Kevin Jones:

As discussed in our meeting on November 23, 1995, this letter provides design recommendations for the Minto Project Spillway and Diversion Ditch.

Background Material

Background material used in the design calculations included the following:

1. Report; *The Minto Project Yukon - Tailings Disposal & Water Management*, Minto Explorations Ltd. (Provided background on diversion ditch)
2. Several drawings and sketches indicating spillway plan and profile on dam. (Used to compute flow profile within spillway channel)
3. Particle size analysis report of native material (Used for sizing filter material)
4. Verbal data provided by EBA Engineering Consultants Ltd. at the November 23, 1995 meeting and during subsequent telephone conversations. Information included:
    a. Dam crest elevation of 2360 ft.
    b. Full Supply Level of reservoir of 2350 ft.
    c. 1:200 year design flow for spillway and diversion ditch design is 5.0 m^3/s.
    d. Maximum allowable rise in reservoir level of about 1.5 m for 1:200 year design flow.
    e. A sheetpile cutoff wall will be inserted into the impervious dam core to prevent seepage of flow through the riprap material used to line the spillway channel. The top of the sheetpile wall will match the reservoir Full Supply Level.
    f. Upstream and downstream slope of dam at 2.5H:1V.
    g. Wide range of rock size is available for riprap.

B.K. Hydrology Service
5610 - 56A Street, Beaumont, Alberta, T4X 1A7
Phone (403) 929 8325 Fax (403) 929 5985

h. Large size shot rock (D_{15} greater than 100 mm) will be used to construct the portion of the dam downstream of the dam core.

i. Riprap protection on upstream face of dam to be designed for a 2.0 ft high design wave.

Spillway Channel Located on Downstream Face of Dam

The spillway channel will be constructed on the crest and downstream face of the dam. The recommended spillway channel cross section is a trapezoidal shape with a 3H:1V side slopes and a 5.0 m bottom. A vertical sheet pile cutoff wall will be placed on the dam core to prevent seepage flow through the rock riprap during periods of little or no flow. The top of the sheetpile wall will be set to match the Full Supply Level of 2350 ft. The channel slope varies along the spillway profile. Upstream of the sheetpile wall the channel bottom will be horizontal and will extend about 65 ft (20 m) to the upstream face of the dam. Downstream of the sheetpile wall, three different channel slopes are used; 10H:1V, 4H:1V and 2.5H:1V (See Figure 11, main report). For these different channel slopes, computed maximum channel velocities, flow depths and required median rock riprap size to prevent erosion are listed in Table 1. Channel flow calculations are based on a Manning's n ranging from 0.050 to 0.075. Channel depths and velocities were computed using the HEC-2 program to compute the water profile along the spillway.

TABLE 1
Spillway Channel Velocities and Median Rock Riprap Sizes

Channel Slope (m/m)	Velocity (m/s)	Depth (m)	Median Rock Riprap Size (mm)	Median Rock Riprap Weight (kg)
0.0	1.9	0.86	300	35
0.10	2.7	0.43	n/a	n/a
0.25	3.6	0.33	n/a	n/a
0.40	4.2	0.25	600	300

To simplify the design and provide an additional factor of safety for the less steep channel sections near the crest of the dam, the following riprap sizes are specified:

1. The spillway downstream of the sheetpile cutoff wall should be lined using the 600 mm median size riprap.

2. The first 5 m of spillway upstream of the sheetpile cutoff wall should be lined using the 600 mm median size riprap.

3. The 300 mm riprap along the horizontal section of channel is also oversized based on channel flow velocities. This 300 mm size was chosen to match the rock riprap size required on the upstream dam face to prevent wave erosion (see riprap for wave protection section).

At intervals along the spillway channel, flow checks should be constructed to reduce flow velocities. Flow check spacing along the channel is shown on the schematic in Figure 11 in the main report. These checks should be constructed using rock that is about 1.2 times greater than the median size rock. The flow check will rise about 250 mm above the channel bottom, and extend between 1 to 2 m along the channel.

Along the horizontal portion of the spillway channel, the channel depth will be 10 ft (about 3.0 m). Since maximum flow depths are less than 1.0 m, this provides a channel freeboard of over 2.0 m which is more than adequate.

The channel should be designed with a 0.5 metre freeboard on the sloped sections of the spillway. This results in a maximum channel depth of about 1.0 metre. This 1.0 m depth should be used along the entire spillway channel located downstream of the cutoff wall. The rough channel bottom and high channel velocities will result in significant turbulence in the channel flow. Water depths will also be increased in the vicinity of the flow checks. The recommended freeboard should contain this turbulent flow within the spillway channel.

Velocities at the spillway exit will be less than 4.2 m/s. Therefore, rock riprap along the creek channel should only be required for a distance of about 15 m beyond the spillway exit. A flow check should be located at the spillway exit and another flow check should be located about 5 m from the end of the rock riprap protection in the creek channel (See Detail 2, Figure 11, main report).

Flow Conditions at Spillway Entrance

The spillway entrance should provide the design flow of 5.0 m^3/s while limiting the rise in reservoir water level to less than about 1.5 m. Based on this design criteria, I recommend a spillway entrance with the same configuration as the spillway channel. For this configuration, the reservoir level will rise less than 0.88 m above the Full Supply Level for the design flow 5.0 m^3/s. These easily meets the above reservoir rise criteria.

This rise in reservoir depth was computed using the HEC-2 program. The water surface profile along the channel was computed by assuming that critical flow occurs at the sheetpile cutoff wall.

Riprap for Wave Protection

The design wave height is 2.0 ft. A double layer of 300 mm median size rock riprap is required to prevent erosion for this 2.0 ft wave.

Diversion Ditch

The recommended diversion ditch cross section is a trapezoidal shape with a 3 m bottom and 2H:1V side slopes. The diversion ditch design flow is set to 5.0 m^3/s. The average channel slope is about 3.8% and was assumed to vary from 3.0% to 4.5%. For a flow of 5.0 m^3/s, channel velocities and depths, are listed in Table 2. Channel flow calculations are based on a Manning's n of 0.05.

TABLE 2
Diversion Ditch Velocity and Depth for Design Flow of 5.0 m^3/s

Slope	Velocity (m/s)	Depth (m)
3.0%	2.0	0.60
3.8%	2.2	0.56
4.5%	2.4	0.54

Based on the channel velocities, a median rock riprap size of about 250 mm is required to prevent channel erosion. A previous report indicates that only a limited channel freeboard is required, since any channel overflow will flow into the tailings impoundment. Based on this, a 0.25 m freeboard is recommended resulting in a channel depth of 0.85 m.

Rock Riprap Gradation and Placement

Various median size rock riprap has been recommended in previous sections. Gradations for these median rock riprap sizes are listed in Tables 3.

TABLE 3
Rock Riprap Gradation (mm) and Rock Weight (kg)

% Passing	250 mm Median Size	300 mm Median Size	600 mm Median Size
Rock Size (mm)			
100	400	450	1000
40 - 80	300	350	700
20 -50	250	300	600
<15	150	200	350
Rock Weight (kg)			
100	90	125	1400
40 - 80	40	60	475
20 - 50	20	40	300
<15	5	10	60

The rock riprap should be placed to a thickness of twice the median rock riprap size. The rock should be durable (Specify an L.A. Abrasion Test or a Sodium Sulphate test) and should have a minimum specific gravity of 2.65.

725 mm and 850 mm size rock are specified for the flow checks on the spillway and at the spillway exit. Rocks should be identified in the field which meet these specifications as close as possible and stockpiled for construction of the flow checks. These rocks should also meet the other criteria listed above for rock riprap.

Filter Layers

Filter layers are required to prevent the removal of the native material or fill material from beneath the rock riprap. For rock riprap with a median size of 300 mm or less, a single filter layer is required. For rock riprap with a median size greater than 300 mm, a double filter layer is required. Required filter gradation and minimum filter thickness are listed in Table 4.

TABLE 4
Filter Gradation

% Passing and Minimum Filter Thickness	Filter 1 (mm)	Filter 2 (mm)
100%	40	200
60% - 85%	30	150
25% - 50%	20	100
<10%	10	75
Thickness	150	300

Based on the above, a single layer filter is required under the diversion ditch and under the rock riprap for wave protection. A double filter layer should be used under all sections of the spillway channel which are not located over shot rock. No filter is required under the spillway channel for the section which is located over the shot rock on the downstream face of the dam.

Closure

I appreciate the opportunity to undertake this work for you. If you have any questions about the above the above material, please give me a call.

Sincerely,

PROFESSIONAL ENGINEER ALBERTA
BERND KALLENBACH

Dec 18/95

Bernie Kallenbach, M.Eng., P.Eng.
President

APPENDIX G
EMBANKMENT CONSTRUCTION RECOMMENDATIONS

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The first stage of embankment construction will commence with stripping of the organics and deleterious materials on the base of the valley. Under both the upstream and downstream shells, stripping will also be extended to include any ice-rich fine-grained permafrost. Coarse grained frozen soils such as residuum or weathered bedrock will not be overexcavated. Within the limits of the core and where the downstream fine filter comes into contact with the bedrock, the overburden soils and weathered bedrock will all be excavated to expose sound, intact bedrock.

This exposed bedrock surface will be thoroughly cleaned using high pressure air or water. Loose blocks will be removed and all knobs or overhangs will be removed by barring and wedging or by light blasting.

Material filling cracks and joints will be excavated (usually to a depth of not less than three times their width at the surface), using air and water, or other tools as necessary to completely remove soil or weathered rock that may be subject to erosion and to ensure a good bond of concrete or grout to the rock. Such joints and cracks should then be filled with concrete or grout. Wherever possible, a pipe should be set to the bottom of the joint or crack and grout pumped in until the joint or crack is completely filled. Grout should then be broomed and brushed across the top of the joint to ensure that the contact with the core material will be tight and nonerodible. Grout used for this purpose should be highly plastic and of buttery consistency. The maximum aggregate size used in the grout for filling cracks should not exceed one-third the width of the crack to be filled.

Depressed areas, holes and other irregularities should be filled with a plastic mix of concrete vibrated into place. Small ribs and similar irregularities should be filleted with concrete to produce slopes not steeper than about 1H:1V. Larger ribs or protrusions should be removed or trimmed to produce a gently sloping surface. The final rock surface should have gentle contours against which soil can be compacted by heavy equipment. Hand compaction with light, air-powered tampers will not provide adequate compactive effort.

Where the bedrock surface is irregular, it is preferable to use extensive concrete fills. The objective is to reduce hand labour using light compaction equipment which may not be capable of achieving the specified density. Care must be taken to ensure that joints under the concrete are properly cleaned and treated.

Surface treatment as described above may be difficult to accomplish on steeply sloping abutments. In this case, gunite may be used for filling depressions after the cracks and joints have been cleaned and sealed. If there is extensive jointing, adequate sealing of joints may require construction of a concrete slab which is dowelled to the rock followed by grouting through the slab. If shotcrete or gunite is used, care must be taken to remove all rebound material before placing of the core material. Shotcrete tends to give a rough surface along which seepage could develop. Accordingly, the finish coat should be gunite with sand aggregate. Shotcrete and gunite must be placed as several thin coats, usually 50 mm (2 inches) maximum; otherwise the gunite could sag away from the rock.

The depth of excavation necessary in weathered rock is difficult to establish during design. The depth of weathering is usually very irregular, being controlled by minor variations in joint spacing and rock type. Abrupt changes in elevation of the surface of the bedrock will be encountered. There may be deeply weathered zones extending well below the line of general excavation. Tentatively it has been assumed that an average depth of overexcavation of approximately 3.0m (10 feet) will be required beneath the core and fine filter on the downstream shell of the dam. Deeper excavation including some excavation of sound rock, may be more economical to reduce dental work.

During early stages of excavation, careful examination and supervision will be undertaken to confirm with field personnel a common understanding as to the definition of sound rock. This will establish which materials should be removed and which may stay in place. Requirements for removal in the lower foundations of the dam will likely be more stringent, where seepage forces are greater.

For the first lift of fill over the cleaned and grouted rock surface, it is preferable to select the most plastic fill available. Gravel exceeding 50mm (2 inches) in diameter should be removed from the material placed in this first lift over the rock to improve compaction at the contact. The surface on which it is placed should be moist but free of standing water and the fill should be placed wet of optimum.

Initial lifts for the impervious core on rock foundations must be placed and compacted by methods that will assure proper compaction without damaging the rock surface. One method is to use a small dozer to push a thicker than normal lift (approximately 50% greater than specified) over the foundation rock. This initial lift can then be compacted with heavily loaded trucks or other suitable pneumatic equipment. Rolling should be continued until density tests indicate that the specified compaction is achieved at the top of the rock, as the "top-of-rock" density is critical from both shear strength and seepage control standpoints. Prior to placing the next lift, the surface of the initial lift must be scarified to assure good bonding with the next lift. Where the foundation rock has an undulating surface, several lifts compacted with pneumatic equipment may be required before switching to an approved sheepsfoot roller.

Surface preparation in the shell areas will commence with removal and disposal of trees, brush, organic soils, debris and other unsuitable material. Topsoil should be stripped and stockpiled for possible later use, if required. Areas which contain ice-rich fine-grained permafrost within the limits of the shell areas will also be excavated and removed off site. The exposed subgrade should then be scarified to a depth of 150 mm (6 inches), moisture conditioned and compacted to the specified density.

Special effort is required for the fill against abutments, as poorly compacted fill at these locations can be the source of seepage and piping problems. These problems are usually caused by the inability of self-propelled compactors to compact the material within 0.3 to 0.6 m (1 to 2 feet) of steep abutments. Compaction in these restricted areas should therefore be conducted with hand held tampers. These tampers can only compact thin lifts and their production rates are slow. In some instances good compaction against abutments may be achieved by rolling parallel to steep abutments with the front tires of loaded, front-end loaders. The tires can rub against the abutment without damaging the rock or concrete. Maintaining good quality control in these areas is critical to minimizing the possibility of settlement, seepage or piping problems.

Materials used in the upstream shell will be primarily coarse grained residuum and weathered bedrock. Compaction of these soils will be best achieved using steel drum vibratory rollers. Similarly, the rockfill used for the downstream shell will be compacted most effectively using a (10 ton minimum) steel drum vibratory roller. Due to difficulties measuring densities of rockfill, a procedural specification is generally adopted requiring 4 to 6 passes per lift. Typical lift thicknesses for rockfills should be in the order of 1.0 m (3 feet). Stability of rockfills and resistance to seepage forces improves significantly when they have been compacted compared to being end dumped. This is particularly important for rockfills utilized as a "flow through" or built-in spillway.

For rockfill zones where free drainage is desired, it is important to ensure that an excessive percentage of fines (less than 25 mm or 1 inch) is not incorporated in the quarry-run material. Therefore it is critical that a screening operation with a large, strong, vibrating screen (with 25 mm square openings) be incorporated at the pit.

APPENDIX H
CONSTRUCTION QUALITY ASSURANCE REQUIREMENTS

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H.1 SITE CLEARING/FOUNDATION PREPARATION

Site clearing and foundation preparation will be required in the footprint of the dam as well as in some adjacent areas and the borrow pits. The site clearing and foundation preparation should be carried out as noted in the following:

1. Remove all trees shrubs and bushes and stockpile in the chosen disposal area as approved by the Engineer.

2. Excavate surficial organic materials including all moss, peat and organic soils from under the dam footprint. Also excavate these materials along the access road and diversion ditch route with the exception of the areas where permafrost soils exist. Under no circumstances should the organic material be removed or disturbed during the construction of the access road in the permafrost areas. Dispose of these materials in the chosen disposal area as approved by the Engineer.

3. Remove all ice rich frozen soils from the dam shell foundation areas as directed by the Engineer. Dense, ice poor frozen soils may be remain in place outside of the area of the dam core. Final determination of materials to be removed will be at the discretion of the Engineer.

4. Foundation preparation under the dam core must involve removal of all organic soils, colluvium, residuum and weathered bedrock as directed by the Engineer. The bedrock surface must be thoroughly cleaned and grout or concrete used to seal fractures which daylight at the surface of the competent bedrock as directed by the Engineer.

H.2 BORROW MATERIALS

All earthfill materials used in the construction of the dam should conform to the following requirements:

1. Supply Type 1 dam shell material consisting of native sand granodiorite residuum and weathered bedrock. The material should conform to the following gradation limits:

SIZE (mm)	PERCENT PASSING BY MASS
50	100%
5	70-100%
1	20-70%
.075	<30%

2. Supply Type 2, shot rock material for the construction of the downstream shell comprised of competent non weathered granodiorite with a maximum size of 600 mm (24 inches).

SIZE (mm)	PERCENT PASSING BY MASS
600	100%
300	40-80%
100	20-50%
50	<5%

3. Supply dam core material consisting of native silty sandy clay. The material should conform to the following gradation limits:

SIZE (mm)	PERCENT PASSING BY MASS
20	100%
2	80-100%
.075	30-100%
.005	15-70%

4. Supply coarse filter material comprised of competent crushed or screened granodiorite based gravel which conforms to the following gradation limits:

SIZE (mm)	PERCENT PASSING BY MASS
40	100%
30	60-85%
20	25-50%
10	<10%

5. Supply fine filter material comprised of competent crushed or screened granodiorite based gravel which conforms to the following gradation limits:

SIZE (mm)	PERCENT PASSING BY MASS
10	100%
5	85-100%
2.5	65-100%
1.25	40-80%
0.315	5-40%
0.16	0-20%
0.08	0-3%

6. Supply 20 mm rip rap and GCL bedding material comprised of competent crushed or screened granodiorite based gravel which conforms to the following gradation limits:

SIZE (mm)	PERCENT PASSING BY MASS
40	100%
30	60-85%
20	25-50%
10	<10%

7. Supply 100 mm rip rap bedding material comprised of competent crushed or screened granodiorite based gravel which conforms to the following gradation limits:

SIZE (mm)	PERCENT PASSING BY MASS
200	100%
150	60-85%
100	25-50%
75	<10%

H.3 EMBANKMENT CONSTRUCTION

All earthfill materials used in the construction will be placed in accordance with the following recommendations:

1. Place Type 1 dam shell and core materials in near horizontal lifts not exceeding a compacted lift thickness of 200 mm (8 inch).

2. Compact Type 1 dam shell and core materials to a minimum of 95 % standard Proctor maximum dry density as determined by ASTM D698.

3. Dry or add water as necessary to ensure that core materials achieve moisture contents above optimum moisture content as determined by ASTM D698. Materials can be moisture conditioned by blading, rolling or otherwise working the material with a grader or dozer.

4. Place Type 2 shot rock fill in near horizontal lifts not exceeding a compacted lift thickness of 1.0 m (3 feet).

5. Compact Type 2 shot rock fill using a procedural approach developed in conjunction with the engineer. This will generally involve making 4 to 6 passes with a large smooth drum vibratory roller.

H.4 DAM CONSTRUCTION MONITORING

Monitoring of dam construction should be undertaken by a competent geotechnical and materials testing Engineering company under the direction of a Geotechnical Engineer and technicians as appropriate. Quality assurance testing during construction should include the following at a minimum:

1. Obtain a sample of each of the manufactured coarse and fine filter materials and 20 mm and 100 mm rip rap bedding materials during manufacture for each 500 m^3 produced or from each days production. Determine the particle size distribution of each sample to ensure compliance with the specified gradation.

2. Obtain a sample of the natural residuum to be used as Type 1 fill for each 1000 m^3 produced. Determine the particle size distribution of each sample to ensure compliance with the specified gradation.

2. Obtain a sample of the silty sandy clay fill to be used in construction of the core for each 500 m^3 produced. Determine the particle size distribution of each sample to ensure compliance with the specified gradation.

3. Undertake compaction testing on all placed filter materials, bedding materials, core and Type 1 fills at a rate of 1 test per 250 m^3 placed.

H.5 EROSION PROTECTION

Rip rap is required for erosion protection along the overflow spillway, upstream dam face near water level and along the diversion ditch. This rip rap material should conform to the following criteria and be installed in accordance with the following recommendations:

1. Supply 750 mm rip rap comprised of competent crushed granodiorite which conforms to the following gradation limits:

SIZE (mm)	PERCENT PASSING BY MASS
1200	100%
850	40-80%
750	20-50%
450	<15%

2. Supply 600 mm rip rap comprised of competent crushed granodiorite which conforms to the following gradation limits:

SIZE (mm)	PERCENT PASSING BY MASS
1000	100%
700	40-80%
600	20-50%
350	<15%

3. Supply 300 mm rip rap comprised of competent crushed granodiorite which conforms to the following gradation limits:

SIZE (mm)	PERCENT PASSING BY MASS
450	100%
350	40-80%
300	20-50%
200	<15%

3. The GCL can only be placed on a surface of and covered with material free of sharp rocks or debris.

4. Placement of the GCL materials should commence from the downstream end of the ditch or spillway such that each subsequent joint overlap will be on top of the previously placed downstream portion. Each overlapping joint should be a minimum of 400 mm (1.3 feet) wide. Overlapped joints should be treated with the addition of powdered bentonite both between and along the edges of the joint.

5. All GCL material must be covered by all of the rip rap and bedding material within 48 hours of placement.