MOUNT NANSEN RISK ASSESSMENT, CONCEPTUAL CLOSURE PLAN AND COST ESTIMATION

Prepared for the Government of Yukon

Prepared by EBA Engineering Consultants Ltd.

Project # 1200081

May, 2004

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Submitted To:

GOVERNMENT OF YUKON

Prepared By:

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EXECUTIVE SUMMARY

EBA Engineering Consultants Ltd. (EBA) was retained by the Government of Yukon, Energy, Mines and Resources to complete a risk assessment, conceptual closure plan and order-of-magnitude cost estimation for closure of the tailings facility at the mine site formerly operated by B.Y.G. Natural Resources Inc. (Mount Nansen Mine Site), 60 km west of Carmacks, Yukon. The assessment was to consider the current condition and physical stability of the earthfill tailings dam, stability under extreme events, alternative scenarios for closure and cost estimation for each scenario. As requested by the Government of Yukon, this evaluation considers both the current state of these facility, the projected condition in 2008 (five years in the future), and, for a longer time frame, closure of the facility.

This assessment has been completed in accordance with generally accepted geotechnical practice and engineering judgement has been used in the development of conclusions and recommendations.

The Mount Nansen tailings facility currently consists of a tailings impoundment with a water reclaim/pump causeway, a tailings dam, diversion channels, a reclaim pond formed by a cross valley seepage control dyke located below the main dam, and an emergency spillway. The impoundment area is roughly 7 ha in area with rough dimensions of 250 m (north-south) by 280 m (east-west). The volume of tailings within the impoundment is estimated to be in the order of 283 500 m^3 including both subaqueous and beach tailings. Surface water stored within the impoundment varies seasonally but typical ranges from 40 000 m^3 to 60 000 m^3 occupying a surface area of about 4.5 ha.

From 1999 to present, the operation of the impoundment has consisted of the seasonal treatment and release of surface water, and the continuous collection and pump back into the impoundment of seepage collected by the seepage control dyke. Treated water is ultimately released into Dome Creek below the mill site and flows through the Dome Creek diversion into the spillway and beyond the facility.

In 1999, EBA and Klohn Crippen Design Consultants Ltd. (Klohn) were jointly commissioned to complete a preliminary dam safety assessment. The results of the preliminary study showed no evidence of imminent failure of the dam but the long-term performance of the structure was still unknown. The foundation soils were clearly thawing, organics and loose sand were suspected to exist within the thawed foundation soils and possibly within the dam fill, and seepage was well above design levels. The liquefaction potential of thawed foundation soil and of any poorly compacted zones of the dam was not determined but considered to reflect a future risk. Based on this assessment, two upgrading/repair programs were completed to replace the seepage control dyke in autumn 2000, and upgrading and repairs to the emergency spillway in the autumn 2000 and summer 2001.

A dam safety assessment completed by EBA in 2002 and reviewed as part of the current study indicates that the dam and spillway must be upgraded to ensure long-term safety. The addition of reasonable closure options has addressed the need to reduce or eliminate long-term water treatment.

In order to assist in the risk assessment, stability analyses was completed on the current dam, the 5-year window (2008) and the preferred closure of the facility. Results of this analysis showed that the dam is currently stable under static conditions but that an extreme earthquake event would cause liquefaction of some soils and likely result in dam failure. An extreme flood event would also likely result in failure.

Our review of risk of the existing facility indicates the dam and spillway do not currently satisfy the high to very high consequence classification. To achieve acceptable levels on the short and long-term static and seismic stability, a number of remedial measures would be required including lowering the phreatic level within the dam and reducing groundwater and surface water within and flowing into the facility.

Several scenarios have been proposed for "conceptual" closure plans of the Mt. Nansen Tailings Facility. These scenarios include;

1. Removal of tailings to the excavated open pit and closure of facilities,
2. Removal of tailings to a new facility and closure of facilities,
3. Closure of current tailings facility with long-term water management and dam stabilization.

This assessment has identified proper closure of the current tailings facility as the preferred plan based on current conditions, health and safety of the general public, environmental protection and cost implications. The existing facility should be strengthened, stabilized and made effectively water tight to provide long-term security under all conditions. To finalize the design of the proposed closure plan, a number of activities and analyses will be required as outlined in this report.

Prior to final design and costing of the preferred option, EBA completed an order-of-magnitude cost for three closure scenarios. It was estimated that the preferred option would cost about $3.8 million while the other options range in cost from $4.4 to 6.2 million.

1.0 INTRODUCTION

1.1 Project Description

EBA Engineering Consultants Ltd. (EBA) was retained by the Government of Yukon, Energy, Mines and Resources to complete a risk assessment, conceptual closure plan and order-of-magnitude cost estimation for closure of the tailings facility at the mine site formerly operated by B.Y.G. Natural Resources Inc. (Mount Nansen Mine Site), 60 km west of Carmacks, Yukon. The assessment was to consider the current condition and physical stability of the earthfill tailings dam, stability under extreme events, alternative scenarios for closure and cost estimation for each scenario. As requested by the Government of Yukon, this evaluation considers both the current state of these facility, the projected condition in 2008 (five years in the future), and, for a longer time frame, closure of the facility.

During the course of this assessment, reviews of available geotechnical instrumentation data were completed. Details of recent activities are reported in two previous EBA reports, "Dam Safety Assessment, Mount Nansen Tailings Facility Near Carmacks, Yukon" dated May 2002 and "Mount Nansen Summary Data Report" dated September 2002.

This assessment has been completed in accordance with generally accepted geotechnical practice and engineering judgement has been used in the development of conclusions and recommendations. This assessment encompasses most but not all of the elements of a more comprehensive "Dam Safety Review" as defined by the Canadian Dam Association in the 1999 Dam Safety Guidelines.

Authorization to proceed with this assessment was provided by Mr. Hugh Copland, P.Eng., Government of Yukon, in January 2004.

1.2 Scope of Work

The scope of work for this assessment was outlined in EBA's proposal of January 2004, submitted to Hugh Copland with the Government of Yukon. As outlined in that document, the proposal was prepared to address four areas of interest that had been identified and other issues identified in subsequent discussions with Mr. Hugh Copland. The four areas of interest were:

- Complete a risk assessment to identify risk levels associated with the occurrence of extreme events over the implementation time frame to 2008 and beyond.
- Determine most practical and cost effective conceptual closure plan for the tailings facility considering overall stability of the tailings facility in terms of the static and seismic cases.
- Complete an order of magnitude cost estimate for upgrading the impoundment for final closure.
- Description of additional work required to finalize a closure plan for the tailings facility.

Three potential tailings facility closure plans were reviewed and the above criteria were applied to each scenario. These three scenarios include; 1) removal of tailings to a new impoundment and closure, 2) removal of tailings to the exiting open pit and closure, and 3) closure of the current facility.

The work scope included using pre-determined seismic hazard information and cone penetration test results to characterize the embankment fill and the thawed foundation soils. Using the seismic hazard criteria and the soil characteristics determined from the CPT testing, the liquefaction potential of fill and native soils was determined previously by EBA. Also critical to the conceptual closure plan was the estimation of fill volumes required to complete grade-to-drain slopes and phreatic levels after filling with subsequent soil capping and revegetation.

Using the previous results of the CPT program, the liquefaction assessment, the known phreatic levels and the known and predicted thaws depths underneath the dam, static and dynamic stability analyses were completed for the current facility, over the next 5 years and for conceptual closure.

This report excludes a conceptual closure plan for water treatment of any continuing seepage from the tailings facility.

1.3 Available Information

During the course of this assessment, EBA and/or its subconsultant B.K. Hydrology Services (BKH) had access to numerous documents and reports relating to the design, licensing, construction, and operation of the tailings facility. These documents included:

- Dam Safety Assessment, Mount Nansen Tailings Facility Near Carmacks, Yuko" by EBA dated May 2002
- Mount Nansen Summary Data Report by EBA dated September 2002.
- Design reports prepared by Klohn Crippen Consultants Ltd. (Klohn)
- Water Use application documents prepared by B.Y.G. Natural Resources Inc.
- Water Licence QZ94-004 issued by the Yukon Territorial Water Board.
- Tailings Dam Construction report prepared by Klohn.
- Site Visit reports prepared by Geo-Engineering.
- Instrumentation Installation Report and internal memoranda prepared by EBA.
- Spillway upgrading reports prepared by Vista Engineering, and
- Project Data Review reports prepared by Klohn and EBA.

Full references to these documents presented in the References following this report.

2.0 MOUNT NANSEN TAILINGS FACILITY

2.1 Facility Description

As shown in Figure 1, the Mount Nansen tailings facility currently consists of a tailings impoundment with a water reclaim/pump causeway, a tailings dam, diversion channels, a reclaim pond formed by a cross valley seepage control dyke located below the main dam, and an emergency spillway. The impoundment area is roughly 7 ha in area with rough dimensions of 250 m (north-south) by 280 m (east-west). The volume of tailings within the impoundment is estimated to be in the order of 283 500 m^3 including both subaqueous and beach tailings[1]. Surface water stored within the impoundment varies seasonally but typical ranges from 40 000 m^3 to 60 000 m^3 occupying a surface area of about 4.5 ha.

A topographic site plan of the facility including the impoundment, tailings dam, and seepage dyke (but excluding the spillway) is presented as Figure 2. Figure 2 is based on as-built topographic surveys of the tailings dam, tailings impoundment, and seepage control dyke including the changes resulting from the upgrading work completed in the autumn of 2000.

As shown on Figure 2, the Mount Nansen tailings impoundment is formed by a 270 metre long dam which runs (north-south) across the Dome Creek Valley. The dam, which is located approximately 1.5 km downstream from the Mount Nansen mill site, is an earthfill structure consisting of a main embankment of about 160 m in length with a low abutment dyke extending another 110 m across a terrace feature on the north abutment. The main embankment section of the dam has a maximum height of 21.5 m, whereas the northern dyke or terrace section has a maximum height of about 6 m with a typical height of about 4 m.

To accommodate the dam and the impoundment, Dome Creek was rerouted around the impoundment into a diversion channel that runs along the north side of the valley. Runoff control ditches running along the western perimeter of the impoundment join into the diversion near the northwest corner of the impoundment. No diversion channels have been constructed on the south side of the impoundment.

The diversion channel runs at a gentle slope until it just passes the dam centreline. At that point the channel enters into a steep spillway channel that runs from an elevation of 1152 m down to 1121 m, over a distance of 315 m. At the end of the spillway the flow exits back into the original channel of Dome Creek.

To account for possible overflow from the impoundment, an emergency spillway channel runs from the northeast corner of the impoundment into the diversion spillway channel joining the spillway about 60 m downstream from the dam centre line. This emergency channel has an invert of 1150.6 m.

Control of water levels within the impoundment is accomplished primarily by diverting the flow of Dome Creek around the impoundment and by intercepting surface runoff

[1] Based on surveys completed by Yukon Engineering Services Ltd. in October 2001.

from the western perimeter. Flow that enters the impoundment can only be removed by seepage through the dam and its abutments, by overflow through the emergency spillway, or by pumping out of impoundment up to the water treatment plant located at the mill. To facilitate pumping from the impoundment, a causeway leading to a pump building is located on the north side of the impoundment roughly 70 m upstream of the dam.

A final element of the tailings facility is a downstream reclaim pond. The pond is formed by a seepage control dyke that is located across the former channel of Dome Creek, 40 metre downstream from the toe of the tailings dam. This dyke structure was rebuilt during autumn 2000 and now consists of a 50 metre long, 4 metre high earthfill dyke that incorporates a PVC liner keyed about 2 m into the permafrost. The key trench was designed to refreeze through the use of horizontal thermosyphons. Details of the design and construction of the rebuilt seepage dyke are documented in a report entitled "Mount Nansen Seepage Dyke Design and Spillway Upgrading Construction Report" dated May 2002. Much of the seepage passing through the dam and its abutments is captured in the reclaim pond and pumped back up into the main impoundment. Some seepage is known to bypass the pond by flowing through unfrozen zones in the north terrace and into Dome Creek downstream of the seepage control pond. Monitoring of the water quality of Dome Creek is conducted by Water Resources at points downstream of the reclaim pond.

For facility design, construction and previous operating conditions for the facility, refer to EBA's report on "Dam Safety Assessment, Mount Nansen Tailings Facility Near Carmacks, Yukon".

2.2 Facility Status, 1999 to 2003

The Federal Department of Indian and Northern Affairs (DIAND/Responsible Authority) assumed management of the facility after operations were suspended in the summer of 1999.

From 1999 to present, the operation of the impoundment has consisted of the seasonal treatment and release of surface water, and the continuous collection and pump back into the impoundment of seepage collected by the seepage control dyke. The seasonal treatment and release of surface water from the main impoundment is conducted by pumping surface water from the tailings impoundment up to the water treatment plant at the former mill site.

Treated water is ultimately released into Dome Creek below the mill site and flows through the Dome Creek diversion into the spillway and beyond the facility. During the shutdown phase the pond water level has ranged from 1148.6 m to 1150.1 m, with an average recorded level of 1149.6 m.

In addition to the environmental site maintenance, the Responsible Authority (RA) has commissioned several evaluations of the impoundment and has managed two significant repair/upgrading programs associated with the seepage dyke and emergency spillway components of the facility. The evaluations commissioned by the RA, included a bathometric survey of the tailings pond, a preliminary dam safety assessment, conceptual site decommissioning studies, tailings and water quality studies, and the dam safety assessment reported herein.

The bathometric survey was completed on August 4, 1999 when the impoundment water level was at Elev. 1150.0 m. The survey showed a maximum water depth of 2.6 m and estimated the stored water volume at 53 000 m^3. Based on the reservoir storage curve provided by Klohn in 1995, this would suggest that at least 253 000 m^3 of subaqueous tailings are present within the impoundment. An important observation from the bathometry was that the deepest portion of the pond was located just upstream (west) of the upstream face of the dam.

For the preliminary dam safety assessment, EBA and Klohn were jointly commissioned to complete this work in the fall of 1999. This assessment was based on a site visit in September 1999, followed by the evaluation of all available construction and instrumentation data. Klohn and EBA completed this review in January 2000. The results of the preliminary study were that there was no evidence of imminent failure of the dam but the long-term performance of the structure was still unknown. The foundation soils were clearly thawing, organics and loose sand were suspected to exist within the thawed foundation soils and possibly within the dam fill, and seepage was well above design levels. The liquefaction potential of thawed foundation soil and of any poorly compacted zones of the dam was not determined.

CANMET completed a chemical stability assessment of the impounded tailings in 2002. Their report concluded that the tailings appear to represent a relatively stable system from a chemical perspective. Only CNS and NH4-N will remain parameters of major concern for short-term. Laboratory testing suggested potential As and Zn release with changing environmental conditions.

EBA is not aware of the status or findings of any other studies (decommissioning, tailings and water quality). The findings of the current dam safety assessment are presented within this report.

The two upgrading/repair programs directed by the RA during the shutdown phase have included the complete replacement of the seepage control dyke in autumn 2000, and upgrading and repairs to the emergency spillway in the autumn 2000 and summer 2001. As already indicated, details regarding these programs are reported separately.

2.3 Consequence Classification and Extreme Event Criteria

In order to complete a risk assessment of the Mount Nansen tailings impoundment, it was necessary to utilize a consequence classification previously selected by EBA. The consequence classification represents the potential incremental impacts (in terms of loss of life and/or economic and environmental losses) associated with the failure of a dam or of its various components. For a given classification, extreme events, such as floods and earthquakes, that could trigger a failure are selected based the Dam Safety Guidelines of the Canadian Dam Association (1999, CDA). Because the dam and spillway are considered high risk facilities, the extreme event criterion for this facility includes Probable Maximum Flood (PMF) and the Maximum Credible Earthquake (MCE).

3.0 TAILINGS RISK ASSESSMENT

EBA's mandate to assess risk to the tailings facility included the review of the previous stability analysis and expansion of the analysis to include extreme events and conceptual closure plans.

Assessment of risk with respect to the Mt. Nansen Tailings Facility has been reviewed with respect to:

a. Stability of facility under current, long-term and extreme event conditions,
b. health and safety of the general public,
c. environmental protection, and
d. cost estimation.

A probabilistic approach to assess risk was evaluated for determining the extent of risk on the current facility and suggested closure scenarios.

Several risk levels were defined for assessing the probability of an extreme event. These levels are defined as;

Low Risk = probability of occurrence is <20%.
Moderate Risk = probability of occurrence is < or = 50%
High Risk = probability of occurrence is > 50%.

Two main extreme events for consideration are seismic and flooding over a period of one to 1,000 years. Available data from references suggests the probability of these events occurring is shown in Table 1;

Table 1 Event Probability

RETURN EVENT PERIOD (years)	SEISMIC	FLOODING
5	Low	Low
20	Low	Moderate
100	Moderate	Moderate
200	Moderate	High
1000	High	High

In assessing risk, it was necessary to review the performance of the facility as detailed by previous work, specifically the performance in terms of permafrost thaw, pond levels, and phreatic levels within the dam, seepage, and settlement. Additional risk issues are related to potential environmental contamination as it relates to the possible release of high levels of CNS, NH4-N, As and Zn from tailings pore water.

3.1 Facility Performance

Detailed work has been completed previously by EBA to evaluate the performance of the dam. This report provides a review of this previous work and expands the review to the entire facility. For a more detailed description of the dam performance, refer to EBA's report, "Dam Safety Assessment, Mount Nansen Tailings Facility Near Carmacks, Yukon", dated May 2002.

Significant issues, excerpted from different parts of the report are highlighted below;

- *Thawing of permafrost underneath the dam is considered to be one of the most significant performance parameters for this dam. Thawing of the permafrost could lead to relatively large total and differential settlements. It would also increase the amount of seepage underneath the structure. Excess pore pressures that could develop within thawing permafrost could also impact the stability of the dam. Finally, thawing of frozen sand zones could represent a potential stability hazard should they be loose enough to liquefy during a seismic event.*

- *Based on a review of the data from these sources EBA concluded that the depth of permafrost thaw underneath the dam is highly variable and appears to be a function of the original aspect of the native ground, the concentration of seepage over or through the ground, and the amount of stripping completed during construction. Three different thaw zones were identified underneath the dam. These consist of the south abutment and valley base, the north abutment, and the north terrace.*

- *The depth of thaw into the original permafrost underneath the south abutment and valley base ranges from nil to as much as 4.5 m. However, the typical range based on the thermistors and the CPT test data is 1.5 m to 2.5 m.*

- *The control of seepage and phreatic levels within a tailings dam is a critical aspect of the dam's overall performance. High phreatic levels and/or high seepage flows ultimately increase the potential for slope failures and/or piping. Moreover, seepage of contaminants can also be an environmental liability if it is not properly collected and treated.*

- *The average pond level has been roughly Elev. 1149.6 m, which is close to the end of mining predicted level of 1149.7 m.*

- *The high pond level recorded early in the life of impoundment also meant that the volume of water stored within the impoundment greatly exceeded the design assumptions. The excess of stored water was in the range of 130 000 m^3 during the first year of operation. This extra water was present prior to significant tailings deposition. The tailings were required to act as a seepage barrier and insulating layer for thermal protection.*

- *Depending on the pond level, the average beach width approaches 35 m to 40 m, with a minimum level over at the north end of the main span of the dam of less than 20 m.*

- *The bathometry survey shows that the slope of the submerged tailings is relatively steep resulting in water depths of over 2.5 m near the north abutment of the dam. This area of relatively deep water also happens to be adjacent to the minimum width of the tailings beach and the area of greatest permafrost thaw.*

- *The actual phreatic surface across the dam crest varies considerable but is generally in excess of Elev. 1140 m across the main embankment. Across the north terrace section, the phreatic level is not known; however, test pitting and probe hole drilling along the downstream toe of the north terrace section suggests that the phreatic level is in the order of 1 m ±0.5 m above the permafrost table. This would suggest that it ranges from Elev. 1149.4 m at the emergency spillway channel to Elev. 1143 m near where the main embankment begins.*

- *The difference in the phreatic level across the main embankment (Elev. 1144 m to Elev. 1141 m) may be related to the distribution of tailings within the impoundment and the depth of thaw of the foundation soils underneath the dam.*

- *At the downstream toe berm crest, the phreatic level seems to level out to a typical elevation of about 1137 m across the main embankment, although there is still a small drop from south to north (about 0.5 m).*

- *The performance of the Mount Nansen Dam in terms of seepage has been poor. High seepage pressures associated with high pond levels led to sand boils at the toe of the dam and slope failures along the north (natural) abutment slope above the seepage pond in July 1997.*

- *Settlement of the dam crest was identified in the design process as a likely occurrence due to the thawing of permafrost foundation soils.*

- *Cumulative settlements (1999 – 2001) on the downstream face of the dam were typically in the range of 10 mm to 40 mm.*

- *Visual evidence of deformation and cracking of the dam has also been observed. Subsidence and cracking of dam fill materials has been observed on the downstream face of the dam near the edge of the south abutment. The deformation consists of* *depressions ranging up to 1.2 m in depth and extensive cracking around and near the depressions. This area of deformation was not observed until after the construction of the emergency toe berm and crest access road in the summer and fall of 1997.*

- *Overall, the magnitude of the settlement of the dam to date cannot be conclusively determined; however, it seems that the settlement may be less than was anticipated by the Designer. In addition, deformation of the downstream slope of the dam is occurring particularly on the south abutment area that is known to have high phreatic levels.*

3.2 Liquefaction and Stability Assessment

To evaluate the stability of the Mount Nansen tailings facility it was necessary to consider all of the factors that would affect the stability both in the present, in the 5 year window that was being considered for this assessment, extreme events, and conceptual closure. Factors for stability assessment included the dam geometry, the amount of thaw underneath the foundation of the facility, the condition of the thawed soils, the pore pressures developed by those thawed soils, the phreatic level within the facility, the seismic hazard or seismic loading that could be anticipated, the liquefaction potential, the residual strength of the liquefied soils, and the strength parameters for the fill and native soil materials.

3.2.1 Seismic Hazard

The tectonic setting of the region is defined by three major faults that could pose a significant seismic threat to the mine site: the Fairweather fault (254 km away in the Southwest), the Denali fault (125 km away in the Southwest), and the Tintina fault (132 km away in the Northwest). Using this tectonic setting both probabilistic analysis and deterministic analysis were completed for the seismic hazard assessment of the mine site. The results of the probabilistic assessment are summarized in Table 2. The results of the deterministic analysis are shown in Table 3.

Table 2 Results of Probabilistic Seismic Hazard Analysis

RETURN PERIOD (YEARS)	475	1,000	10,000
Peak Horizontal Ground Acceleration (g)	0.096	0.119	0.27
Peak Horizontal Ground Velocity (m/s)	0.218	0.265	0.61

Table 3 Results of Deterministic Seismic Hazard Analysis

FAULT	DISTANCE TO SITE (km)	MAXIMUM MAGNITUDE	PGA
Fairweather	254	8.7	0.131 g
Denali	125	7.3	0.125 g
Tintina	132	7.3	0.117 g

Based on these results and the recommended procedures of the Canadian Dam Association, the MDE for the Mt. Nansen dam site would have a probabilistically determined Peak Horizontal Ground Acceleration (PGA) of 0.27g. This level of PGA was associated with a local magnitude 7.5 seismic event (extreme event).

Assessment of liquefaction was previously completed by EBA. Evaluation included the use of seismic hazard information and cone penetration testwork.

The liquefaction analysis showed;

- Thin zones of native foundation soils at the south end of the dam are marginally liquefiable under a severe earthquake event.
- The dam fills are, in general, compacted and non-liquefiable. The risk associated with liquefaction of the dam fill and the native foundation soil is considered very low.

- At the toe berm, the native foundation soils are also considered liquefiable under the MDE event.
- At the north side native ground, some of the thin zones of native soils are considered marginally susceptible to soil liquefaction under a severe earthquake event.

3.2.2 Stability Analyses

Results of limit equilibrium analyses for dam slope stability under both static and seismic conditions are presented for current, extreme events and conceptual closure. For this analysis, EBA has assumed that the maximum facility height cross section (centre of main embankment) was the critical section to be evaluated for stability. The location of this cross section is shown on Figure 2. The modeled cross section is presented on Figure 3. The following different scenarios were analyzed in the stability assessment:

- Static stability under current thawing condition of the foundation soils.
- Static seismic stability under current thawing condition of the foundation soils.
- Static stability under 5-year thawing condition of the foundation soils.
- Seismic stability under 5-year thawing condition of the foundation soils.
- Static stability under extreme events.
- Static and seismic stability for conceptual closure.

Limit equilibrium analyses were conducted for both circular and specified non-circular failure surfaces using two methods of limit equilibrium analyses (the Bishop method for circular surface and the Janbu method for specified non-circular surface). The limit equilibrium analyses were conducted using the computer programs Slope/W and XSTABL.

<u>Assumptions</u>

The following assumptions were used for analysis as previously defined by EBA and reviewed for this evaluation;

- thawed depth of foundation soil = 2.5 m for current conditions,

- thawed depth of foundation soil = 3.0 m for 5 year window, and
- thawed depth of foundation soil = 3.5 m for closure.

Soil parameters include;

Soil Units	Bulk Unit Weight (γ) (kN/m3)	Frictional Strength (ϕ) (Degrees)	Cohesion (kPa)	Foundation R_u Value	Residual Strength (kPa)
Tailings	18.6	28	0		9.0
Compacted Dam Fill	19.5	34	0		-
Native Foundation Soil	19.0	28 to 30	0	0.10	14.4

The phreatic surface within the facility is about 10 m below the ground surface (est. Elevation 1141 m) near the crest of the dam and slopes within 1.5 m to 2.0 m of the toe berm crest (est. Elevation 1138 m).

High groundwater level was assumed at 5 m below the ground surface at the dam crest (Elevation 1146 m) and at 0.5 m to 1.0 below the ground surface at the toe berm (Elevation 1139 m).

After closure, the phreatic level has been estimated to decrease by an average of 5 metres from current typical levels. This decrease will be a direct result of proper drainage from the installed capping, limiting infiltration from precipitation and upgrading the diversion channel to prevent leakage into the facility, groundwater and surface water input from the west is controlled by a collection drain at the upstream side of the facility.

The foundation soil was assumed to have excess pore water pressure equal to 10% of the total overburden stress, i.e., R_u =10%.

Residual strengths proposed by Idriss (1998) have been used as the basis for the selection of residual strengths of liquefied soil for the Mt. Nansen tailings dam assessment. A residual strength of 9 kPa was selected for the liquefied tailings with an assumed SPT blow count of $(N_1)_{60}$ = 8. A residual strength of 14.4 kPa was used for the liquefied foundation soil based on $(N_1)_{60}$ = 11. $(N_1)_{60}$ values in the range of 8 to 10 were assumed for the thawed foundation sands and for the tailings in the stability analysis for foundation liquefaction completed by Klohn in 1995.

3.2.3 Results of Stability Analyses

Factors of safety of the facility at current conditions, in 2008, and for conceptual closure are summarized in Table 5 for the static condition and in Table 6 for the seismic condition.

Table 5 Results of Stability Analyses (Previous and New) – Static

Cases	Variation in Soil / Groundwater Parameters		Static Minimum Factor of Safety
	Foundation Soil Friction Angle (□)	Level of Phreatic Surface	
Current			
1	30	Typical level	1.61
2	30	High level (EE)	1.44
3	29	Typical level	1.56
4	29	High level (EE)	1.40
5	28	Typical level	1.52
6	28	High level (EE)	1.36
7	28	High level (EE)	1.67 [3]
Year 2008			
8	30	Typical level	1.59
9	30	High level (EE)	1.43
10	28	High level (EE)	1.34
11	28	Slope breakout	1.23
Closure			
12	28	Typical levels	1.75
13	28	High levels	1.42

EE is Extreme Event
See Section 4.0 for discussion of closure.

Table 6 Results of Stability Analyses – Seismic

Year	Post Liquefaction Static Factor of Safety	Post Liquefaction Pseudo Static Factor of Safety (0.27g) – Extreme Event
Current	0.70	< 0.7
5-Year Window Year 2008	0.70	< 0.7
Closure	1.1	1.0

Based on the results of stability analyses, it is therefore concluded that

- The factor of safety of the critical dam section varies from 1.52 to 1.61 under current observed level of phreatic surface (groundwater level within the dam). This range of factor of safety is considered adequate under static conditions for dam stability.
- The factor of safety under the high level of phreatic surface could decrease to 1.36 and is considered adequate for dam stability under permanent condition. The groundwater level at the toe berm is critical to the dam stability.
- The perspective of dam stability for the 5-year window (to 2008) can be viewed as similar or the same as for the current condition. Moreover, the worse case "extreme event" phreatic level scenario (slope breakout at Elev. 1135 m) was considered for the 2008 condition and was found to decrease the factor of safety from 1.34 to 1.23.
- Closure of the current facility could result in a factor of safety from 1.42 to 1.75 depending on the level of which the phreatic surface and pore water pressures can be lowered.
- Under the design seismic condition (MDE event), the risk of dam failure for the current configuration along a liquefied foundation soil is considered to be high. The post liquefaction static factor of safety was calculated to be about 0.70 indicating generally unstable slope conditions. By lowering the

phreatic surface and resultant pore water pressures within the dam and foundation, the factor of safety can be increased to greater than 1.0 at closure.

The above conclusions with regard to the stability of the facility are based on assumed soil strength parameters. Actual parameters are likely to vary above or below those used in this assessment, although the range of values for the native sand is supported by empirical correlations to cone penetration resistance. It should also be noted that the analysis using the "slope break out" phreatic case does not account for any seasonal refreezing of the thawed foundation soils. As always in limit equilibrium analyses, the factor of safety has some undefined level of uncertainty.

3.3 Stability Conclusions

Our review of risk of the existing facility indicates the dam and spillway do not currently satisfy the high to very high consequence classification. The dam and spillway could fail under a severe earthquake or flood. As a result of this conclusion, we recommend that a safe closure plan be developed. The following section discusses optional plans.

4.0 TAILINGS CONCEPTUAL CLOSURE PLAN

The primary objectives for closure of the tailings facility are described as follows (modified from "Guidelines for Abandonment and Restoration Planning for Mines in the Northwest Territories"):

- To ensure tailings are closed in such a manner that the requirements for long-term maintenance, monitoring and subsequent costs are minimized.
- To prevent additional contamination to the environment.
- To identify and prevent acid mine drainage.
- To return affected areas to a state compatible with the original undisturbed conditions, giving due consideration to practical factors including economics, aesthetics, future productivity and future use.

Several scenarios have been proposed for "conceptual" closure plans of the Mt. Nansen Tailings Facility. These scenarios include;

1. Removal of tailings to the excavated open pit and closure of facilities,
2. Removal of tailings to a new facility and closure of facilities,
3. Closure of current tailings facility with long-term water management and dam stabilization.

Each scenario has been reviewed from a stability, health and safety, environmental protection and cost perspective.

Specific closure issues for the Mt. Nansen Tailings Facility are;

- Ensure stability of the facility under extreme loading conditions.
- Ensure water quality meets regulatory requirements.
- Choose the most cost-effective scenario for closure.

5.0 SCENARIOS FOR CLOSURE

5.1 Removal of Tailings

Removal of tailings will require dredging and piping of saturated tails or pumping of water out of the facility and conventional excavation. Depending on the extent of saturation, dredging is the preferred mechanism for removal of tailings.

An estimated 95% of tailings can be removed from the current facility. The remaining 5% would be incorporated into the closure of the current facility.

5.1.1 New Impoundment

The removal of tailings from the current facility into a nearby new facility will require the construction of a new impoundment designed and constructed to industry standards. This new facility will require closure along with closure of the remnants of the old facility, if any.

Upon closure, the surfaces of both facilities must be capped with a suitable impervious cover material to control wind and water erosion and provide a growth medium for vegetation.

Stability analysis of the new facility must be conducted along with the design of the impoundment.

This scenario is considered to have a low risk to health and safety and be the highest cost alternative to closure.

5.1.2 Deposition in Open Pit

The removal of tailings from the current facility into the nearby abandoned open pit will require a groundwater evaluation and monitoring system for the open pit.

This scenario is considered to have a moderate risk to health and safety and high cost but less than the tailings dam alternative. Long-term costs may be higher because of the necessary monitoring program.

5.2 Closure of Current Facility

Closure of the current tailings facility will require the placement of a cover material that will consolidate the tailings, divert surface runoff and restrict precipitation infiltration to the tailings.

The key to successful closure to the current facility will be to minimize and reduce current water in the impoundment. This can be achieved by installing a proper soil horizon (cap) over the facility and successful re-vegetation. However, it may be necessary to include a process for more rapid consolidation of the saturated tailings to facilitate reduction in pore volumes and provide overall drainage. Wick drains would accomplish this task and would ensure rapid and long-term consolidation of the tailings. A permeable layer would be placed below the capping soil and above the tailings to capture excess pore water during consolidation. After consolidation, this layer would be sealed to prevent the reverse effect of bringing outside water into the tailings.

The cost of wick drains would add approximately $450,000 to the cost of closure. Because of this cost is significant and appropriate, care will be required to ensure successful wicking of the saturated tailings by adequate surface drainage as the tailings gradually consolidate. A staged filling and capping design should be considered including the placement of a 300 mm thick sand layer located below the capping fill to serve as a drain during compaction.

The permeability of the tailings would be reduced by the capping fill resulting in a lowered water table and reduced seepage losses to meet environmental quality standards.

At the upstream end of the tailings, a cutoff drainage trench and French drain would be installed to collect ground and surface water and divert them around the facility to minimize infiltration into the tailings. The drain would be approximately 0.6 metres wide by 2 metres deep below the 1 metre trench/swale.

We anticipate that a suitable capping material can be identified within a reasonable haulage distance.

The current diversion channel will need to be upgraded. This will require a concrete channel for long-term life and ensure proper water diversion away from the tailings area with subsequent reduction in flow of water into the facility.

5.2.1 Long Term Water Management

For this option, water treatment would be ongoing but reduced over time. Dam stabilization would be required similar to the closure of the existing facility option. There is little advantage to this option since the stabilization costs would be similar to the ongoing maintenance and water treatment would be more expensive than capping the existing facility.

6.0 COST ESTIMATIONS FOR CLOSURE

An estimate of costs for each conceptual closure plan has been prepared to an order-of-magnitude level. The intent of this cost estimation is to help review the comparison of scenarios and present some conceptual costs for tailings closure.

The estimated costs were developed from comparisons to closure costs incurred at other mine sites and our understanding of site conditions and construction costs in the area.

Costs are based on using an external contractor, engineer and manager for the required design and construction activities.

Cost estimation for each scenario is presented in Appendix A. In summary, the costs for each option are presented below;

Table 7 Closure Scenario Costs

CLOSURE SCENARIO	COST ($Cdn)
Removal of Tailings, In-pit Disposal	4,376,000
Removal of Tailings, New Impoundment	6,158,000
Upgrading and Closure of Current Facility	3,776,000

7.0 CONCLUSIONS AND RECOMMENDATIONS

The risk assessment completed by EBA in 2002 and reviewed as part of the current study indicates that the dam and spillway must be upgraded to ensure long-term safety. The closure options reviewed in this report have addressed the need to reduce or eliminate long-term treatment.

This assessment of the Mount Nansen Tailings Impoundment has identified the current tailings facility as the preferred choice for closure based on current conditions, health and safety of the general public, environmental protection and cost implications.

Reducing the pore water volume and phreatic surface within the dam are critical requirements. Diverting runoff and seepage are also a necessity.

The proposed closure plan envisions reducing the phreatic load with in the dam using wick drains and an effective preload fill composed of impermeable material, for reducing precipitation infiltration overlying a sand drain to initially allow for tailings to consolidate and the pore water to dissipate. A cutoff drain and trenched French drain around the upstream edge of the tailings will further reduce groundwater flow volumes through the tailings.

The greatest hazard to the structure would be the occurrence of a significant seismic or flood event. The proposed upgrading of the facility would minimize this risk.

7.1 Recommendations

We recommend that the existing facility be strengthened, stabilized and made effectively water tight to provide long-term security under all conditions (Figure 4). It is understood that a decision to either upgrade the facility to an acceptable closure condition or to fully decommission the facility will be implemented by 2005. A comprehensive plan for this closure is required.

Based on the recommended choice of the various conceptual closure scenarios, the following additional work is recommended to finalise a closure plan;

- Investigate and complete an engineering evaluation for cover thickness, grades, wick drain and water quality requirements for final closure design of the current facility.
- Identify a nearby source for impervious neutral capping material.
- Estimate settlement of cap material and provide a final design to ensure long-term protection of the tailings facility.
- Complete a seepage evaluation to estimate long-term phreatic levels and seepage losses. This would also address any potential changes to seepage water quality.
- Detailed review of tailings water quality – historical, current and projected.
- If necessary, collect further water quality data.
- Complete an accurate closure cost estimate.

8.0 CLOSURE

EBA trusts that this report meets with your approval. Please do not hesitate to contact the undersigned should you have any questions or comments.

Respectfully submitted,

EBA ENGINEERING CONSULTANTS LTD.

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	"Keith Robinson"
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Senior Engineer	Principal Geotechnical Consultant

9.0 REFERENCES

1. EBA 2002, “Dam Safety Assessment, Mount Nansen Tailings Facility Near Carmacks, Yukon”, May.
2. EBA 2002 “Mount Nansen Summary Data Report”, September.
3. EBA 2002. “Summary Data Report”, May.
4. EBA 2002. “Mount Nansen Seepage Dyke and Spillway Upgrading Construction Report”, May.
5. BYG 1998. “1997 Annual Report - Mount Nansen Mine”, February.
6. BYG 1999. “1998 Annual Report - Mount Nansen Mine”.
7. CDA 1999. “Dam Safety Guidelines”, Canadian Dam Association, January.
8. EBA 1998. “Instrumentation Installation – Mount Nansen Mine, North West of Carmacks”, April 24.
9. Klohn 2000. “BYG Tailings Dam, Mount Nansen, YT – Project Data Review Report”, January 12.
10. EBA 1999a. “Geotechnical Data Review Report – Mount Nansen Tailings Dam Safety Evaluation”, Draft, December.
11. EBA 1999b. “Summary of 1997 Toe Berm Construction – Mount Nansen Tailings Dam”, Memo, Photographs and Photograph Logs, December 17 and 18.
12. EBA 1999c. “Review of Seepage Records – Mount Nansen Tailings Dam”, Memo, December 18.
13. EBA 1999d. “Review of Settlement Pin Data – Mount Nansen Tailings Dam”, Memo, December 18.
14. Geo-Engineering 1997. “Mt. Nansen – BYG Mine, Tailings Pond Performance”, August 22.

15. Klohn-Crippen 1995. “Tailings Impoundment – Final Design Report”, August 10.

16. Klohn-Crippen 1996. “Mount Nansen Tailings Facility – Construction Report May to October 1996”, December 12.

17. Klohn-Crippen 1997. “Mount Nansen Tailings Facility – Site Inspection”, June 4.

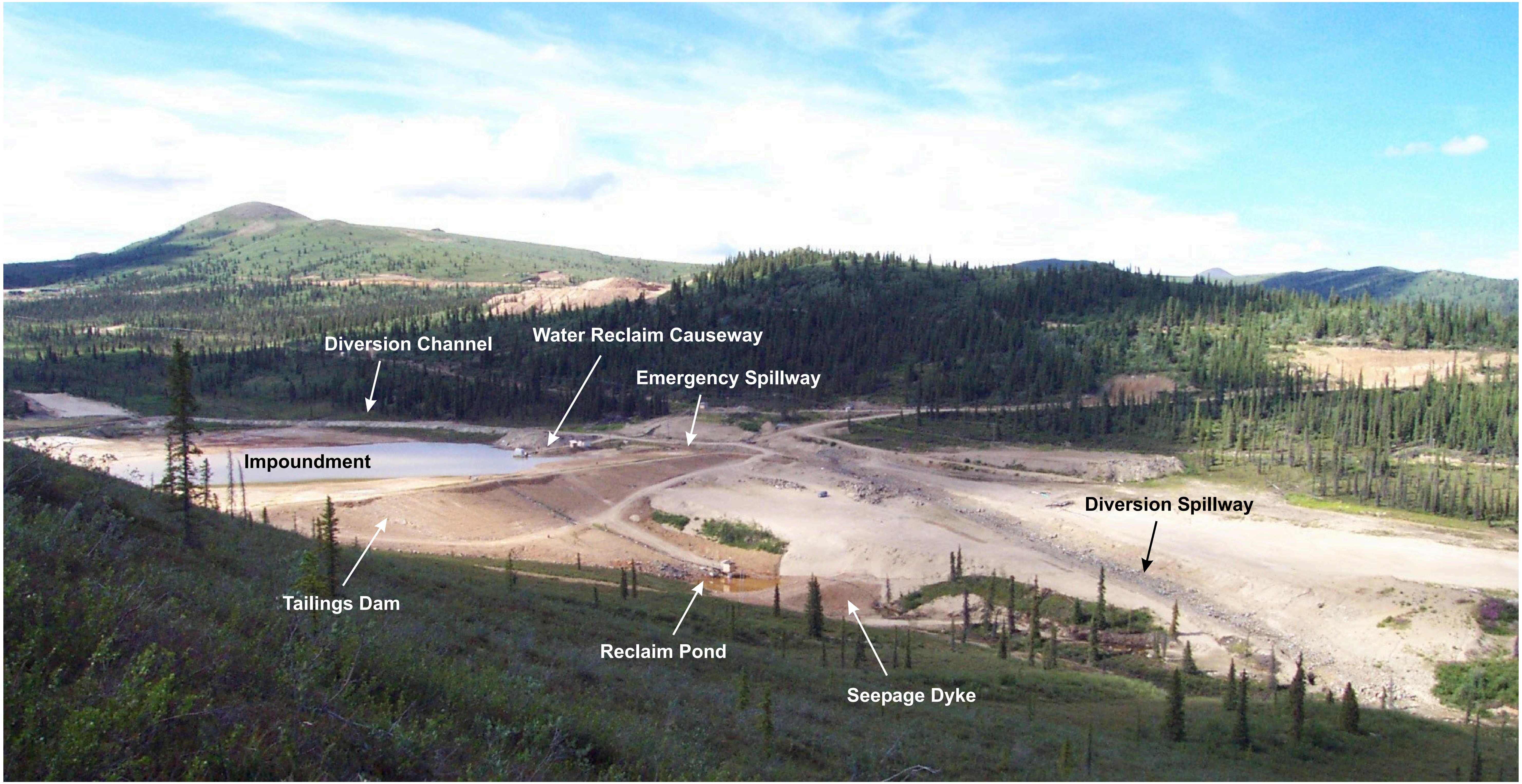
18. Klohn-Crippen 1999. “BYG Tailings Dam, Mount Nansen, YT – Site Visit Report”, October 19.

19. Vista 1997. “Spillway & Diversion Ditch Engineering Analysis”, July 28.

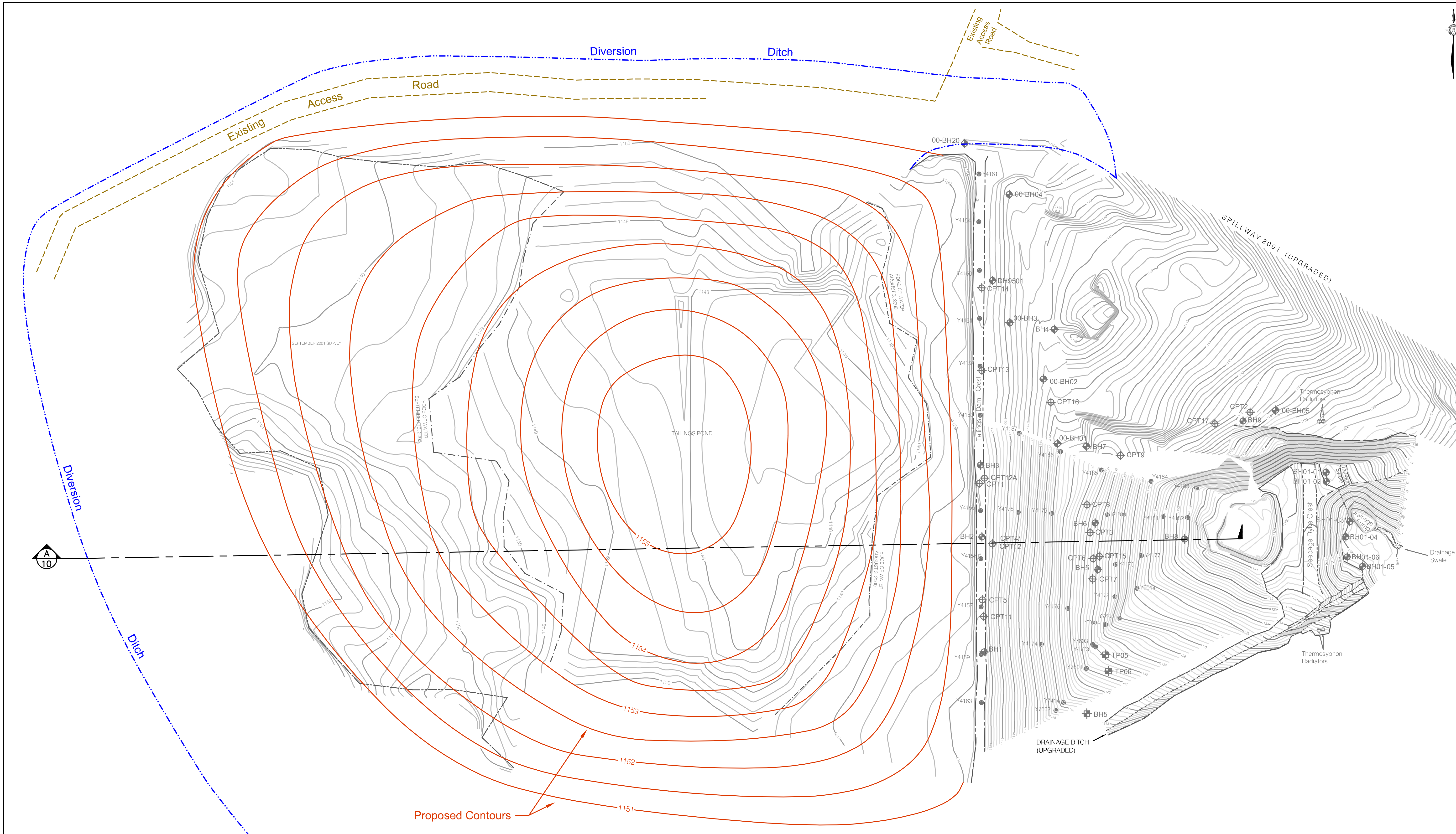
20. Vista 1998. “Tailings Impoundment Drainage Control Evaluation”, February 24.

21. YES 1999. “Report on Mt. Nansen Tailings Dam Monitoring Survey”, Yukon Engineering Services, December 17.

22. Youd, T.L. & Idriss, I.M., 1997. "Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils", Report No. NCEER-97-0022, Multidisciplinary Center for Earthquake Engineering Research.



EBA Engineering Consultants Ltd.	PROJECT: MOUNT NANSEN DAM SAFETY ASSESSMENT
CLIENT: GOVERNMENT OF YUKON ENERGY, MINES & RESOURCES	TITLE: TAILINGS IMPOUNDMENT FACILITY
DATE: May, 2004 DWN: JSB CHKD: CRH	FILE NO.: 1200081 DWNG: FIGURE 1 REVISION:



NOTES:

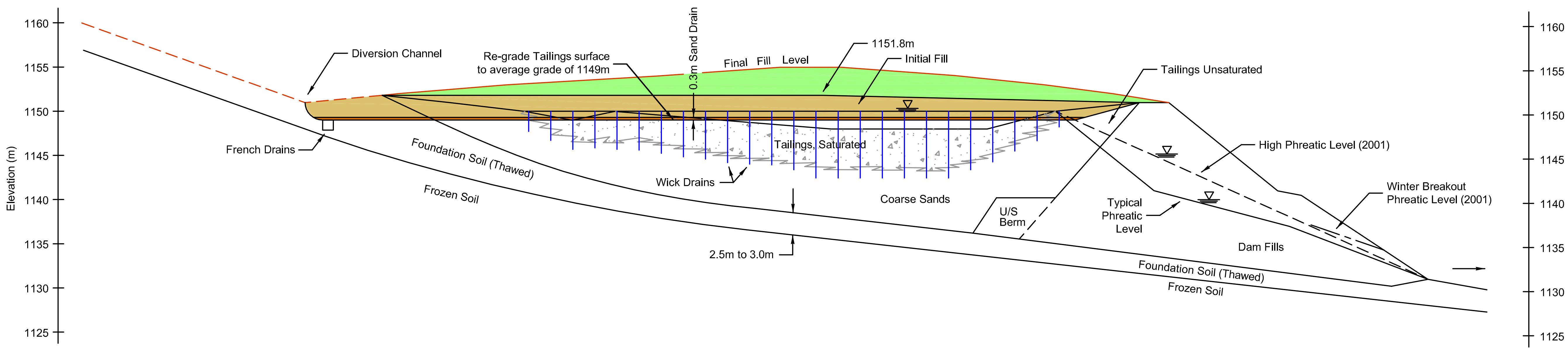
1. Base data from Yukon Engineering Services, 2001

2. Contours are existing grades based on 2001 sureys and bathimetric soundings of the pond

SCALE 1:1500

10 0 10 30 60m

EBA Engineering Consultants Ltd. eba		PROJECT	MT. NANSEN TAILING IMPOUND ASSESSMENT
CLIENT GOVERNMENT OF YUKON ENERGY, MINES & RESOURCES		TITLE	CONCEPTUAL SITE PLAN SHOWING RECLAIMED TAILING IMPOUNDMENT
DATE 2004/04/04	DWN. JAB / CHKD. EF	FILE NO. 0201-1200081	FIGURE 2



SECTION A 3

SUMMARY OF SOIL PARAMETERS USED IN LIMIT EQUILIBRIUM ANALYSES

Soil Units	Bulk Unit Weight (kN/m3)	Frictional Strength (degree)	Cohesion (kPa)	Foundation Ru Value	Residual Strength (kPa)
Tailings	18.6	28	0		9.0
Compacted Dam Fill	19.5	34	0		
Native Foundation Soil	19.0	28-30	0	0.10	14.4

SUMMARY OF FACTORS OF SAFETY FROM STABILITY ANALYSES

Year	Static Minimum Factor of Safety	Post Liquefacation Static Factor of Safety	Post Liquefacation Pseudo Static Factor of Safety (0.27g)
Current Year 2000	1.36 - 1.61	0.70	<< 0.7
5 Year Window Year 2008	1.23 - 1.59	0.70	<< 0.7
Closure	1.42 - 1.75	1.1	<< 1.1

HORIZONTAL SCALE 1:1500
10 0 10 30 60m

VERTICAL SCALE 1:500
5 0 5 10 20m

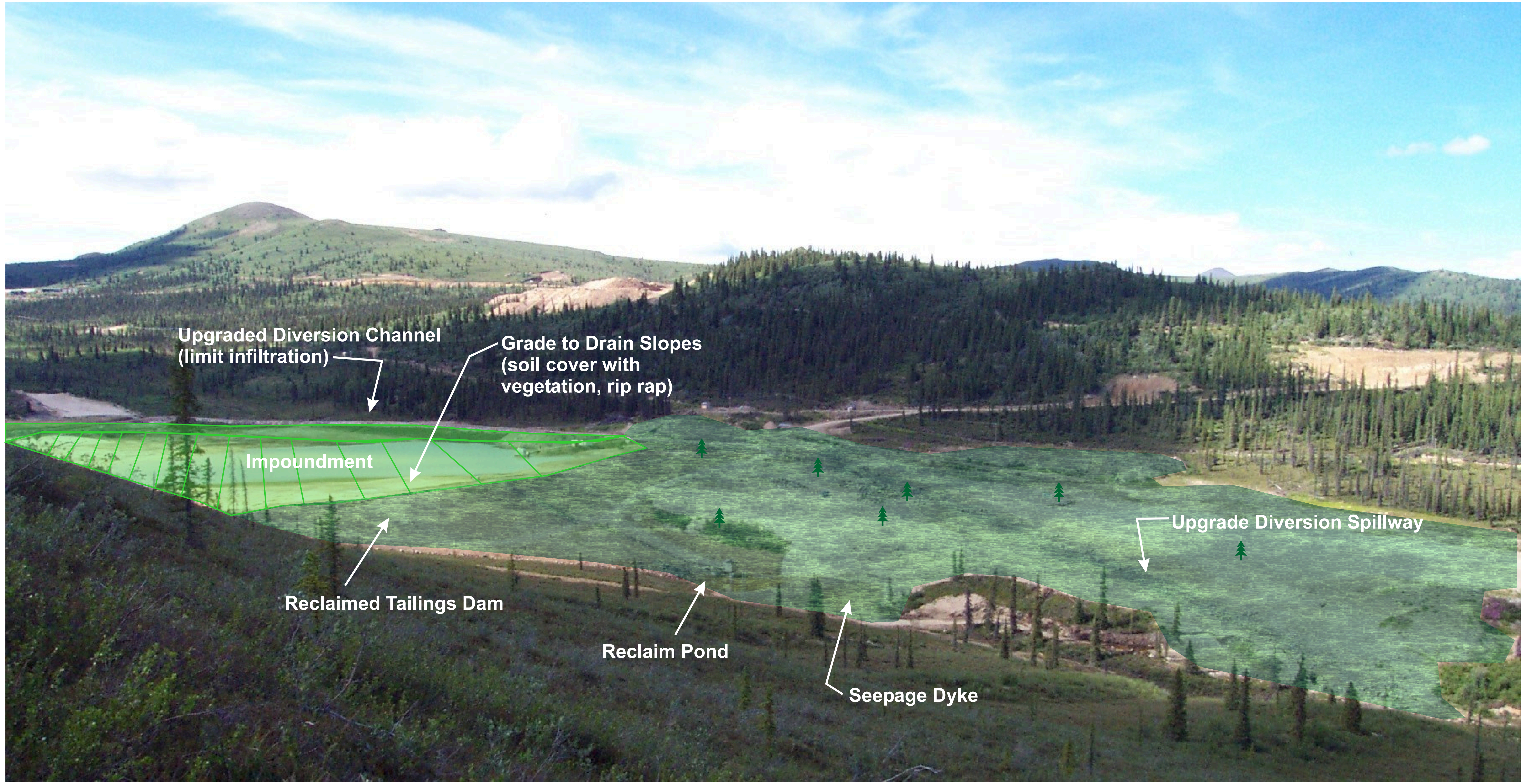
EBA Engineering Consultants Ltd.

PROJECT
MT. NANSEN
TAILING IMPOUND ASSESSMENT

CLIENT
GOVERNMENT OF YUKON
ENERGY, MINES & RESOURCES

TITLE
RESULTS OF SLOPE STABILITY ANALYSIS
(CURRENT FACILITY) WITH PROPOSED CAPPING

DATE 2004/04/04 DWN. JAB CHKD. EF FILE NO. 0201-1200081 FIGURE 3



EBA Engineering Consultants Ltd.				PROJECT: MOUNT NANSEN			
CLIENT: GOVERNMENT OF YUKON ENERGY, MINES & RESOURCES				TITLE: PREFERRED TAILINGS IMPOUNDMENT CLOSURE (RECLAMATION OF CURRENT FACILITY)			
DATE: May, 2004	DWN: KMW	CHKD: NEF		FILE NO.: 1200081	DWNG: FIGURE 4	REVISION:	

APPENDIX A

COST ESTIMATIONS

Removal of Tailings – In Pit Disposal

ACTIVITY	UNITS	QUANTITY	UNIT COST	COST
Excavate Old Tailings and Transport	m3	300,000	6	**1,800,000**
RECLAIM OLD TAILINGS SITE				
Soil (9 ha)	m3	27,000	15	405,000
Seeding	Ha	9	2,000	18,000
Fertilizer	Ha	9	500	4,500
Rip Rap for Slopes - wind and vegetation control	m3	2,000	10	20,000
Remove Tailings Discharge/pipelines, shacks	lump sum	1	20,000	20,000
Breach and stabilize old dam	m3	40,500	10	405,000
Subtotal				872,500
Contingency at 20%	lump sum	0.2	872,500	174,500
SUBTOTAL CLOSURE OF OLD TAILINGS FAC.				**1,047,000**
COVER IN PIT TAILINGS				
Grade and Contour filled slopes	Ha	9	5,000	45,000
Rip Rap for Slopes - wind and vegetation control	m3	2,000	10	20,000
SOIL AND VEGETATION COVER				
Soil (9 ha)	m3	27,000	15	405,000
Seeding	Ha	9	2,000	18,000
Fertilizer	Ha	9	500	4,500
Mob and Demob Contractors for New Tailings Reclaim	lump sum	1	20,000	20,000
Pit Boundary Groundwater Monitoring System	Well	8	15,000	120,000
Environmental Monitoring/Reclamation Mitigation				
Technician	5 years	1	250,000	250,000
Analytical	5 years	1	100,000	100,000
Mitigation	5 years	1	150,000	150,000
Subtotal				1,132,500
Management and Engineering at 15%	lump sum	0.15	1,132,500	169,875
Contingency at 20%	lump sum	0.2	1,132,500	226,500
SUBTOTAL TAILINGS CLOSURE - IN PIT				**1,528,875**
TOTAL TAILINGS CLOSURE - OLD & IN PIT				**4,375,875**

Removal of Tailings – New Impoundment

ACTIVITY	UNITS	QUANTITY	UNIT COST	COST
Excavate Old Tailings and Transport	m3	300,000	6	**1,800,000**
RECLAIM OLD TAILINGS SITE				
Soil (9 ha)	m3	27,000	15	405,000
Seeding	ha	9	2,000	18,000
Fertilizer	ha	9	500	4,500
Rip Rap for Slopes - wind and vegetation control	m3	2,000	10	20,000
Remove Tailings Discharge/pipelines, shacks	lump sum	1	20,000	20,000
Breach and stabilize old dam	m3	40,500	10	405,000
Subtotal				872,500
Contingency at 20%	lump sum	0.2	872,500	174,500
SUBTOTAL CLOSURE OF OLD TAILINGS FACILITY				**1,047,000**
CONSTRUCT NEW TAILINGS FACILITY				
Site Investigation		1	150,000	150,000
Design		1	20,000	20,000
Site Prep		1	200,000	200,000
Build Dam	m3	200,000	6	1,200,000
New Diversion Channel		1	100,000	100,000
Mob and Demob Contractors For Construction	lump sum	1	20,000	20,000
Subtotal				1,690,000
Management and Engineering for Construction at 15%	lump sum	0.15	1,690,000	253,500
Contingency at 20%	lump sum	0.2	1,690,000	338,000
SUBTOTAL NEW TAILINGS FACILITY				**2,281,500**
COVER NEW TAILINGS – CLOSURE				
Grade and Contour filled slopes	ha	9	5,000	45,000
Rip Rap for Slopes - wind and vegetation control	m3	2,000	10	20,000
SOIL AND VEGETATION COVER				
Soil (9 ha)	m3	27,000	15	405,000
Seeding	ha	9	2,000	18,000
Fertilizer	ha	9	500	4,500
Develop Wetland For New Tailings	ha	1	50,000	50,000
Mob and Demob Contractors for New Tailings Reclaim	lump sum	1	20,000	20,000

ACTIVITY	UNITS	QUANTITY	UNIT COST	COST
Environmental Monitoring/Reclamation Mitigation				
Technician	2 years	1	100,000	100,000
Analytical	2 years	1	40,000	40,000
Mitigation	2 years	1	60,000	60,000
Subtotal				762,500
Management and Engineering at 15%	lump sum	0.15	762,500	114,375
Contingency at 20%	lump sum	0.2	762,500	152,500
SUBTOTAL CLOSURE – NEW FACILITY				**1,029,375**
TOTAL CLOSURE - OLD & NEW FACILITY				**6,157,875**

Current Facility (Preferred Option)

ACTIVITY	UNITS	QUANTITY	UNIT COST	COST
COVER TAILINGS – CLOSURE				
Capping Fill	m3	125,000	10	1,250,000
Prep for borrow pit and haulage	lump sum	1	50,000	50,000
Grade and Contour filled slopes	ha	9	5,000	45,000
Rip Rap for Slopes - wind and vegetation control	m3	2,000	10	20,000
Pump and drain pond water	lump sum	1	100,000	100,000
Regrade tailings to develop est. level surface	ha	60	3,500	210,000
Sand drain fill	m3	20,000	15	300,000
Drainage trench/French Drain	m3	300	30	90,000
SOIL AND VEGETATION COVER				
Soil (9 ha)	m3	27,000	15	405,000
Seeding	ha	9	2,000	18,000
Fertilizer	ha	9	500	4,500
Remove Tailings Discharge/pipelines, shacks	lump sum	1	20,000	20,000
Diversion Channel/Spillway Upgrade	m	500	30	15,000
Develop Wetland	ha	1	50,000	50,000
Mob and Demob Contractors	lump sum	1	20,000	20,000
Environmental Monitoring/Reclamation Mitigation				
Technician	2 years	1	100,000	100,000
Analytical	2 years	1	40,000	40,000
Mitigation	2 years	1	60,000	60,000
Subtotal				2,797,500
Management and Engineering at 15%	lump sum	0.15	2,797,500	419,625
Contingency at 20%	Lump sum	0.2	2,797,500	559,500
TOTAL CLOSURE – CURRENT FACILITY				**3,776,620**