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From: H. F. McAlpine
Admin. Water Rights

Date: January 14, 2000
Subject: QZ99-043 Part A Section 10: Dam Safety Assessment of the Mt. Nansen Tailings Dam

Attached is a report submitted by Klohn-Crippen Consultants Ltd (Klohn), that is the interim phase of the Dam Safety Assessment being undertaken by the Department of Indian Affairs and Northern Development (DIAND) for the Mt Nansen Tailings Dam. The report was written subsequent to a compilation and review of data by EBA Engineering Consultants Ltd (EBA)

The Klohn report reviews the performance of some aspects of the dam and outlines further data requirements necessary for prediction of seismic performance of the structure. It is currently anticipated that this data may be obtained by a drilling program in the spring or early summer this year. Although the report predicts an adequate static factor of safety for the dam, seismic and long term performance of the dam remain outstanding issues. The report did not evaluate the consequences of excess pore pressures induced by thawing of the dam foundation.

Since submission of the October 1999 letter report, the Department (DIAND) has implemented several recommendations and is awaiting further analysis on others. The dam has been resurveyed and settlement pins installed. Seepage quality and quantity do not meet design expectations and as a result of the quality, the seepage must be pumped back to the main tailings pond. In November a flow meter was installed on the seepage return line in order to get more accurate estimates of the rate of seepage and the volume returned to the pond. The pond level has been lowered by approximately 400 mm through the treat and release of tailings supernatant which was carried out until December 15th 1999. As a result the width of the beach has been increased, but is estimated not to have reached the desired 50 m. width along the entire dam crest length.

This report is sent only for your information, however if you should have any questions please do not hesitate to call myself at 667 3225 or Mr David Sherstone at 667 3145.

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WATER RESOURCES DIVISION

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January 12, 2000

Indian and Northern Affairs
Water Resources Division
310-300 Main Street
Whitehorse, Yukon Territory
Y1A 2B5

Mr. H.F. (Bud) McAlpine, P.Eng.

Dear Mr. McAlpine:

BYG Tailings Dam, Mount Nansen, YT – Project Data Review Report

We are pleased to submit under the cover of this letter 12 copies of our project data review report. The purpose of this report is to provide an update of our project data review for your submission to the Yukon Territory Water Board. This review forms part of our ongoing dam safety assessment of the existing tailings dam at BYG's Mount Nansen Mine. A list of available project data is included in the reference section of this report.

Our preliminary review to date indicates that the BYG tailings dam appears to have adequate static safety factors against slope instability under its current general condition. However, potential seasonal and local conditions could influence the actual static safety factors. Ongoing instrumentation reading and dam inspection are required to monitor the dam stability.

In our report, tasks required for the evaluation of the seismic stability of the tailings dam are outlined. Other long-term and immediate dam safety related issues are also briefly discussed for your consideration of the long-term care and maintenance of the mine site facilities.

Yours truly,

KLOHN-CRIPPEN CONSULTANTS LTD.

Robert C. Lo

Robert C. Lo, P.Eng.
Project Manager

cc: Mr. Cord Hamilton, EBA Engineering Consultants Ltd.

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1. BACKGROUND

This review of project data was carried out as part of an assignment by Water Resources Division of the Department of Indian Affairs and Northern Development (DIAND) - Yukon Region to EBA and Klohn-Crippen to complete a dam safety assessment of the existing tailings dam at BYG's Mount Nansen Mine. The following outlines relevant references related to the history of the BYG tailings impoundment.

1.1 Dam Design

The final design of the tailings impoundment was documented in a report by Klohn-Crippen (1995). The report covers the following aspects: the characterization of site conditions, the design of the Main Tailings Dam, Seepage Control Dam and water management system, construction and instrumentation monitoring. Six appendices contain: test hole and test pit logs, laboratory data, thermistor readings, thermal, stability and seepage analyses and water balance calculations.

1.2 Dam Construction

The Main Tailings Dam (Dam 1) and Seepage Control Dam (Dam 2) were constructed mainly of natural sandfill borrowed from various borrow pits upstream and downstream of the Main Tailings Dam. The construction of the Main Tailings Dam, Seepage Control Dam, North Diversion Ditch and Emergency Spillway were completed in the fall of 1996, and documented in a report by Klohn-Crippen (1996). The report describes the borrow materials, the construction of the Main Tailings Dam, Seepage Control Dam, Emergency Spillway, permanent and temporary Diversion Ditches, the installation of additional thermistors and pneumatic piezometers, the ongoing monitoring and maintenance as well as construction related issues such as waste areas, haul roads, upstream cofferdam, construction equipment and dewatering. Eight appendices summarize field and laboratory construction control test data, geotextile manufacturer's specifications, thermistor readings, Dome Creek weir flows, construction contract, field daily, weekly reports, memoranda, and meeting minutes.

1.3 Tailings Impoundment Operation

The impoundment was used for tailings storage from approximately the late fall of 1996 to the spring of 1999 with a brief shutdown of about 3.5 months in the winter of 1997-1998. The mining operation ceased in the spring of 1999 due to the bankruptcy of the B.Y.G. Natural Resources (BYG), and the mine site facilities were initially in the care of the mine receiver, and now Ketza Construction on behalf of DIAND. The 1997 and 1998 annual review reports were prepared by BYG (1998 and 1999) during its operation.

In the spring of 1997, the North Diversion Ditch was extended along the west perimeter of the tailings impoundment (Klohn-Crippen 1997). Later in the summer, a toe buttress berm was added to improve the downstream slope stability as well as to control seepage that was exiting on the downstream slope of the Main Tailings Dam with accompanied internal "piping" erosion of damfill materials (Geo-Engineering 1997 and EBA 1999b). Some of the existing dam instrumentation was destroyed during the berm construction. Damage to the North Diversion Ditch and Emergency Spillway Channel during snowmelt was reviewed by Vista (1997); repair and ongoing maintenance of the Emergency Spillway have been implemented.

In the spring of 1998 new piezometers and thermistors were installed to replace the non-functional and damaged original instrumentation (EBA 1998). The North Diversion Ditch was also repaired. All records obtained from the 1998 instrumentation program for the period from April 1998 to December 1999 were reviewed by EBA (1999a). The results of their data review form the basis of our dam evaluation presented in Section 3.2.

The tailings pond level record indicates that the pond level rose steadily from March 13, 1997 at El. 1145.7 m to August 13, 1997 at El. 1150.03 m, except for minor brief drops. The pond level dropped to El. 1149.73 m on August 27, 1997 and stayed in a narrow range between El. 1149.55 m to El. 1149.88 m until January 20, 1999. There was an exceptionally low pond level reading of El. 1149.16 m on February 8, 1999. The pond level rose from El. 1149.77 m on April 21, 1999 to El. 1150.1 m on July 4, 1999 and essentially stayed around El. 1150 m until October 16, 1999. Since then, the pond level dropped gradually to El. 1149.6 m on December 3, 1999, the date of the last reading in the record reviewed by us.

The original invert elevation of the emergency spillway inlet was set at El. 1149.7 m at its upstream end. However, the recent survey by Yukon Engineering Services (YES 1999) conducted on October 28-31, 1999 indicated that the present invert elevation is at El. 1150.6 m. Figure 1 presents the Main Tailings Dam in plan based on this recent survey. To date the highest recorded pond level was at El. 1150.13 m on September 18, 1999, and no surface water has been spilled over the emergency spillway. Thus, the higher invert elevation obtained by the October 1999 survey is consistent with the recorded pond levels.

2. SITE VISIT

On September 16, 1999 our Robert Lo visited the site together with Mr. Bud McAlpine of DIAND, Mr. Cord Hamilton of EBA and Mr. Milos Stepanek of Geo-engineering. A site visit report was issued on October 19, 1999 (Klohn-Crippen 1999), presenting our general impression of the current condition of the BYG Tailings Impoundment as well as identifying some issues related to the safety and integrity of the dam that require immediate attention. The report was prepared in consultation with Mr. Cord Hamilton of EBA. Four recommendations outlined in the report are:

1. Lower the tailings pond level to maintain a tailings beach with a minimum width of about 50 m at all times.
2. Install a flow meter at the pump located at the Seepage Recovery Pond to improve the ongoing seepage monitoring.
3. Investigate the existing condition of the Emergency Spillway Channel to check what improvements to the slope protection of the channel may be required.
4. Carry out a survey on the Main Dam including the downstream buttress berm, emergency spillway, the North and West Diversion Ditches and accessible tailings beach above water as well as the Seepage Control Dam.

Items #2 and #4 have essentially been implemented, and the installed flow meter and new survey have provided valuable project data to assist in our review. Works related to Items #1 and #3 are ongoing, and additional surveys will be carried out, as required, to supplement the October 1999 survey.

3. PRESENT CONDITION

3.1 Tailings Impoundment

We understand that no surface water has been spilled from the Emergency Spillway Channel to date. During our site visit on September 16, 1999, the pond level was near its historical high (about El. 1150.1 m). Since then, the pond level dropped gradually for about 0.5 m to El. 1149.6 m on December 3, 1999. The design crest elevation of the Main Tailings Dam is at El. 1151.5 m. The recent survey indicates the dam crest elevation in a range of El. 1151.23 m to El. 1151.61 m, and the present invert elevation of the Emergency Spillway inlet channel at El. 1150.6 m (about 0.5 m higher than the highest pond level, 0.9 m below the design crest elevation of the dam, and 0.6 m below the present lowest point along the dam crest). The tailings beach surface at the south end of the dam assumes an average slope of about 1.4 % as measured in the survey. The beach slope in other areas was not surveyed due to difficult ground conditions.

Currently the operation of the water treatment plant as well as the site maintenance and monitoring are carried out by Ketza Construction, which acts as the mine caretaker for DIAND.

3.2 Main Tailings Dam

3.2.1 Site Observations

The Main Tailings Dam, in general, appeared to be in good condition during our site visit. Outlined in the following are some observations in specific areas:

- The downstream slope of the buttress berm near the right (south) abutment has local depressions and extensive cracks. Two survey pins were installed in the area to serve as reference points for facilitating future comparisons. In reviewing the circumstances of the 1997 berm construction, EBA considers that the surficial signs of fill adjustment may be attributed to the ongoing internal erosion and migration of sand fill into the coarser materials used to fill in an erosion channel present at the time along the original dam toe in the area.

- Ongoing erosion was observed at a downstream diversion trench located at the south abutment, starting from the south end of the Main Tailings Dam and continuing beyond the south end of the Seepage Control Dam.
- Seepage was observed daylighting along the downstream toe of the Main Tailings Dam buttress berm. The seepage was concentrated on the south abutment side and in the middle of the berm toe. However, at both points it was flowing clear through the coarse rock fill that forms the toe of the buttress berm. We understand that suspended solids in the seepage recovery pond have been higher than current.

3.2.2 Permafrost Degradation and Dam Settlement

EBA reviewed records of those thermistors installed in 1998 at 10 boreholes (see Figure 1 for their locations), and reported in their data review (Table 2 in EBA 1999a) that the foundation thaw depth within the dam proper (Boreholes BH #1 to #3, #5, #6 and #8) ranges from about 0.75 m at Borehole BH #1 to a maximum depth of 3.6 m to 4.9 m at Borehole BH #3. The concerns of permafrost degradation of the dam foundation are elaborated in Section 5.1.

The present maximum dam crest settlement as determined by the comparison of the 1999 survey data and the original design crest elevation of El. 1151.5 m is about 0.27 m, assuming that no new fill has been added to compensate for the ongoing dam settlement since the completion of the dam construction. If additional fill has been added in the past, the total crest settlement will be larger than that deduced here. The review of settlement pin data by EBA (1999d) also collaborates with the above observation.

3.2.3 Piezometric Level and Dam Slope Stability

Piezometric levels for five boreholes (Boreholes BH #1 to #3, #5 and #7) were plotted together with the pond level by EBA (1999a). These data are presented in Figures 2 to 6, using the same scale for both the piezometric and pond levels.

Limit-equilibrium stability analyses were carried out for the downstream slope of the maximum dam section based on the geometry of the dam and its downstream berm as shown on Figure 1. Salient features of the stability analyses including the soil properties (also summarized in Table 1), piezometric levels, failure surfaces and static safety factors are summarized in Figure 7. As shown in Table 1, two sets of strength parameters were used: (1) design strength set used in the design report (Klohn-Crippen 1995); and (2) reduced strength set, used to investigate the possible effect of reduced strength.

During foundation preparation for dam construction, the surficial organic layer was not removed due to its frozen condition and the limitation of construction equipment (Klohn-Crippen 1996). EBA (1998) instrumentation installation record confirms the presence of the organic layer, with a thickness in the range of 0.5 m to 2.8 m, beneath the dam base at the borehole locations. The review by EBA (1999a) of the thermistor data indicates that the organic layer at Boreholes BH #2 and #5 has already thawed out, while that at Boreholes BH #1, #6 and #8 still has a frozen zone with a thickness in the range of 0.5 m to 2 m. Thus, during the period of potentially ongoing thawing of the frozen organic subsoil, relative higher foundation pore pressure may exist locally prior to its dissipation due to consolidation. This could influence the local stability in the area, where the pore pressure is temporarily elevated. In our analyses, the highest recorded pore pressures at the existing piezometers were used. No additional allowance was made for even higher pore pressures due to thawing than those recorded to date.

Another seasonal effect as observed in the past is the freezing of the surficial foundation layer, which could, in turn, impede the drainage of the foundation seepage and raise the foundation pore pressure. The ongoing instrumentation monitoring program will provide valuable data to assess the significance of this seasonal effect.

Table 1 Summary of Soil Properties [(1)] Used in Stability Analyses

MATERIAL	UNIT WEIGHT (kN/M^3)	FICTION ANGLE (Degrees)	
		Reduced Strength	Design Strength
Upstream Tailings Deposits	17	25	30
Dam Fill	19	30	34
Downstream Berm Fill	19	30	34
Thawed Foundation	19	25	30

(1) Soil properties shown in Table 1 are the same as those presented in the design report (Klohn-Crippen 1995).

Table 2 summarizes the static safety factors against downstream slope instability. As shown in the table, the static safety factors of the downstream slope are in a range of 1.5 to 3.0 (with design strength), with a minimum value of about 1.5 near the surface of the downstream berm slope. With the reduced strength, the corresponding static safety factors are in a range of 1.3 to 2.5, with a minimum value of about 1.3 near the surface of the downstream berm slope. These preliminary results indicate that the general downstream slope appears to be stable. However, potential seasonal and local conditions could influence the actual static safety factors, and should be further examined closely in order to ensure the dam stability in the long-term condition.

The downstream slope stability under the seismic condition was not analyzed at this time. Two important factors need to be evaluated first before the seismic stability could be confidently assessed. These factors are: the seismic resistance of the dam foundation and dam fill and seismic hazard as outlined in Sections 4.1 and 4.2.

The upstream dam slope is very stable in both static and seismic conditions, as its slope stability is augmented by the weight of the tailings deposits overlying the dam slope.

Table 2 Summary of Static Safety Factors against Downstream Slope Instability

FAILURE[1] SURFACE	FACTOR OF SAFETY (Bishop Method)	
	Reduced Strength	Design Strength
1	1.5	1.8
2	1.7	2.0
3	2.5	3.0
4	1.5	1.9
5	1.6	1.9
6	1.9	2.3
7	1.9	2.2

(1) Infinite slope parallel to Downstream Berm Surface: Factor of Safety = 1.5 (Design Strength) and 1.3 (Reduced Strength).

3.2.4 Dam Seepage

A flow meter was installed in November 1999 to measure the seepage returning from the Seepage Recovery Pond to the tailings pond near the discharge end of the pump-back line (EBA 1999c). The flow rates calculated from both the daily and cumulative records from November 3 1999 to December 4, 1999 are plotted on Figure 8. The former represents the measured daily pumping rate, while the latter reflects the average pumping rate up to a specific date. EBA (1999c) also reviewed BYG's seepage records from March 29, 1999 to November 2, 1999 and concluded that a seepage pump-back rate in the range of 2.6 l/s to 2.9 l/s probably reflects the seepage condition not significantly affected by snowmelt or precipitation. This monitored seepage rate is about one order of magnitude higher than the value of 0.2 l/s estimated in the design report (Klohn-Crippen 1995). The potential reason for this difference is the fact that throughout the life of the tailings impoundment high pond levels have been maintained. Thus, the tailings beach is of insufficient width to act as the main seepage barrier as envisaged in the original design.

3.3 Seepage Control Dam

The general appearance of the Seepage Control Dam was similar to that of the Main Tailings Dam during our site visit. Some water was impounded in the Seepage Recovery Pond, and reddish stains were visible. A vertical culvert pipe was also observed leaning. Downstream of the Seepage Control Dam, seepage was observed to exit from its downstream toe at three locations. We understand that downstream of the Seepage Control Dam heaving of the creek bed was observed in the winter of 1998-1999, possibly due to freezing of seepage under the surficial frozen zone.

3.4 North and West Diversion Ditches and Emergency Spillway Channel

The North Diversion Ditch diverts Dome Creek from the northwest corner of the tailings impoundment along its north perimeter and returns the flow back into Dome Creek downstream of the Seepage Recovery Pond. Its downstream segment shares the channel with the Emergency Spillway outlet channel. The extended West Diversion Ditch picks up additional surface runoff along the west perimeter of the tailings impoundment. In June 1997, Vista (1997) reviewed the condition of the Emergency Spillway Channel and the North Diversion Ditch, and made recommendations for their maintenance. The tailings impoundment drainage aspect was reviewed by Vista in February 1998 (Vista 1998), and an impervious lining was recommended for the existing Diversion Ditches to reduce the entrance of ongoing seepage from the Diversion Ditches into the tailings pond.

Sand and silt sediments generally covered the ditch bottom along the West Diversion Ditch and the upstream segment of the North Diversion Ditch. As the gradient increases along the downstream segment of the North Diversion Ditch, the riprap protection reduces the downcutting of the ditch invert. Ongoing erosion and side slope adjustment as well as signs of slope-protection maintenance were visible.

4. LONG-TERM CONDITION

The mining operation at Mt. Nansen mine ceased in the spring of 1999. Normally in such a case the mine would be decommissioned in an orderly manner. Klohn-Crippen (1995) recommended ongoing monitoring of the foundation thawing, and at the time of mine closure to review the dam design earthquake, insitu density and liquefaction potential of the thawed foundation materials. In this section, we outline those issues that need to be addressed so that the long-term condition of the tailings dam could be evaluated (CDA 1999), and long-term strategies for the dam developed.

4.1 Dam Foundation and Dam Fill

Since the original dam foundation involved primarily fine sands in permafrost condition, the insitu density of the thawed foundation materials is critical information that needs to be obtained in the next phase. In addition, the characteristics of the thawed insitu organic layer should also be investigated to confirm its potential influence on the overall static and seismic dam stability.

The dam construction records (Klohn-Crippen 1996) also suggest that the dam fill density may not have uniformly achieved the specified minimum value of 95% of the Optimum Standard Proctor Density. Low-density areas in the downstream section may include the layer immediately above the dam/foundation contact, lower portions of the north abutment and a zone between El. 1136 m and 1148 m. In addition, the construction of the 1997 downstream toe berm was carried out as an emergency repair operation, and the work was not monitored in its entirety by an independent engineering firm (EBA 1999b). Thus, the proposed field investigation should include the evaluation of the insitu density of both the thawed foundation soil and the fill materials in the Main Dam and its downstream buttress berm, where construction records show potential density deficiency.

4.2 Seismic Hazard

CDA (1999) stated that dams shall be designed and evaluated to withstand ground motions associated with a maximum design earthquake (MDE), without release of the reservoir. Selection of the MDE for a dam shall be based on the consequences of dam failure. This task should be undertaken in the next phase of dam safety assessment.

4.3 Seismic Stability of Main Tailings Dam

The information to be acquired in Sections 4.1 and 4.2 will be used to analyze the stability of the Main Tailings Dam under the design earthquake condition compatible with the site seismicity and dam failure consequences.

4.4 Quality of Surface and Groundwater

We understand that the quality of mine site surface and groundwater is an ongoing environmental issue. Thus, the ongoing surface and groundwater management issues will be intertwined with the dam safety issues, as the two are closely related. Although the environmental issue is outside the present scope of dam safety assessment, it should be pursued concurrently so that an optimal strategy could be developed for the closure of the mine site facilities.

4.5 Permanent Spillway

The existing spillway is only an emergency spillway. The issue of permanent spillway needs to be addressed after the future direction of mine site water management is clearly defined.

5. IMMEDIATE DAM SAFETY ISSUES

This section presents immediate dam safety issues related to its ongoing care and maintenance during the interim period before the long-term strategy on the dam is developed.

5.1 Seepage-Induced Internal Erosion

The tailings impoundment has experienced high pond levels during most of its operation life since 1997. Since the shutdown of mining operation in the spring of 1999, the pond level rose and stayed at the maximum level of around El. 1150 m until October 1999. The latest pond level record indicates a pond level at El. 1149.6 m on December 3, 1999.

This practice of maintaining high pond levels has contravened the original design premise of maintaining a significant width of tailings beach as the main defense against seepage through the dam and its foundation and abutments. As a result, the dam itself has to rely more on the performance of a Geosynthetic Clay Liner placed along the upstream face of the dam, which was originally intended as a temporary seepage barrier, acting as a second line of defense against seepage. The lack of significant width of tailings beach also exacerbates the seepage through the dam foundation and abutments due to much shorter seepage paths than originally intended.

For these reasons, seepage flow has exceeded the original design estimates. The ongoing seepage not only increases the potential for internal erosion; it also accelerates the ongoing degradation of the foundation permafrost. The degradation process transforms the upper portion of the stable, relatively impervious permafrost foundation into thawed, less stable and more pervious and erodible silt-sand materials. As the permafrost thaws, the seepage zone will be enlarged with an ensuing increase in foundation and abutment seepage, which will further degrade the permafrost foundation. The existing project database does not permit the evaluation of whether the ongoing process of permafrost degradation and seepage flow has developed fully to a steady state. As more reliable data is collected, it is important to check the future trend of foundation thawing and seepage.

Moreover, the number of site staff has been drastically reduced to a few since the shutdown of the mining operation. The limited and poor condition of the equipment left on site and the existing infrastructure are inadequate to cope with any significant dam-related emergency situations. It is, therefore, critically important to increase the safety margin against a seepage-induced dam incident or even failure by increasing substantially the width of the prevailing tailings beach.

5.2 Dam Overtopping

The present defense against dam overtopping is the emergency spillway. Its proper functioning during flood events will be critical for preventing dam overtopping and ensuing breach of the tailings pond.

5.3 Safety Enhancement Measures

To reduce the above two threats against the tailings dam, particularly during the spring freshet next year, we recommend that the following actions be taken as early as practical:

1. Lower the tailings pond level to maintain a tailings beach with a minimum width of about 50 m at all times;
2. Investigate the cause of the local depressions and extensive cracks along the downstream slope of the buttress berm near the right (south) abutment area, and review potential measures to improve the situation; and
3. Investigate the existing condition of the emergency spillway channel to check what improvements to the slope protection of the channel may be required. This investigation should be carried out to a downstream point, where the Main Dam will no longer be threatened if the flow jumps out of

the spillway channel. The thorough review of the site record and discussion with personnel familiar with the past mine operation by EBA should be continued.

We trust that this report meets your requirements at this time, and we will work closely with DIAND and EBA in the next phase of the present assignment.

Yours truly,

KLOHN-CRIPPEN CONSULTANTS LTD.

Robert C. Lo, P.Eng.
Project Manager

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