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August 14, 1992

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Mr. Bill Dunn, P.Eng.
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Dear Mr. Dunn:

Re: Stability Assessment of Grum Waste Dumps

Following site inspections by Mr. A.F. Stewart on June 16 and July 30, 1992, and in accordance with various discussions and our proposal of June 22, 1992, Piteau Associates has completed a stability review of the waste dumps associated with the Grum Pit, including the Southeast Overburden Dump, the Main Waste Dump and the Southwest Waste Dump. The review was prompted primarily by recent incidents of instability at the Southeast Overburden Dump.

DESCRIPTION OF THE STABILITY ASSESSMENT

The stability assessment was initiated as an office evaluation of the proposed dump configurations. Subsequently, the study evolved to include preliminary recommendations regarding lift thicknesses, overall slope angles, setbacks, etc. No field investigations, other than brief site inspections in conjunction with other work at the mine, were carried out. To carry out the office assessment, all available data, plans, reports, etc. that were relevant to the proposed dumps were reviewed, including:

i) Topographic plans.

ii) "Preliminary Report on the Subsurface Conditions at the Proposed Mill Site", prepared by Monenco, and dated October 1977.

iii) "Feasibility Study of the Subsurface Conditions, Construction and Concrete Aggregates and Mine Waste Management Aspects at the Grum Deposit, Faro, Yukon", prepared by Monenco, and dated August 1979.

iv) "Grum Deposit Phase Two Geotechnical Studies (draft report)", prepared by Monenco and dated December 1979.

v) Letter report concerning Grum Overburden Dump prepared by Steffen Roberston & Kirsten (Canada) Inc. (SRK) dated May 21, 1992.

vi) Report concerning the results of laboratory soils testing and stability analyses for the Grum Overburden Dump, prepared by SRK and dated June 26, 1992.

vii) Portions of a report dated July 1989 containing the results of stability analyses of the Grum waste dumps (apparently prepared as part of the water licence application for the Grum deposit).

Following the review of available data, additional stability analyses were carried out. Based on these preliminary analyses, the suitability of the originally proposed dump designs were assessed and recommendations provided for alternate dump configurations.

ENGINEERING GEOLOGY

Other than a recent test pitting, sampling and laboratory testing program carried out by SRK for a portion of the Southeast Overburden Dump (see items v) and vi)), and a brief reconnaissance by the writer of shallow trenches through the Southeast Overburden Dump site, no detailed subsurface investigations have been carried out for any of the three waste dumps under consideration. As noted in previous reports by Monenco (see above), some test pitting was conducted to the south of the proposed Main Dump in 1977.

As discussed in SRK's report of May 21, 1992, soil conditions encountered in the recently excavated test pits in the area of the Southeast Waste Dump -

> ".....were generally uniform and consisted of organic topsoil over a weathered, soft to medium stiff, brown, clayey silt till which varied in thickness from 2 to 3 metres. It appears that the upper 1 to 2 metres was subjected to frost penetration, which may have reduced the shear strength of this surficial layer. Pockets of soft peat and organic silts were encountered in the upper 1 metre in test pit Nos. 3 and 4. In test pit 3, a 3 foot thick layer of sandy gravelly silt was encountered above the weathered till. Below the weathered till in all test pits is a stiff, blue grey, clayey silt till, which extends to the bottom of the test pit."

Based on a brief reconnaissance by the writer, it would appear that the above site conditions likely persist across the site. Exposures in shallow drainage trenches indicate that the sandy, gravelly layer may be reasonably continuous. In addition, soils above the stiff till may be saturated. The topography of the dump site slopes gently to moderately southward, with the upper portion of the site (i.e. above about the 1250m elevation) at an angle of about 4° to 5°.

Between the 1250 and 1244m elevations, the natural slope is <2° and the ground surface is swampy. Below about the 1244m elevation, the natural topography steepens to at least 11°.

No test pitting or any other form of subsurface investigations have been conducted for the Southwest Waste Dump. However, it is likely that foundation conditions are similar to those encountered in the vicinity of the Southeast Overburden Dump. Topographically, the dump foundation area is uneven but subdued, with natural slopes typically being less than about 4°.

As discussed above, the only subsurface investigations that have been conducted in the vicinity of the Main Waste Dump are a test pitting and laboratory testing program carried out in 1977 by Monenco. All test pits were excavated over a limited area to the south of the proposed dump site, within about 300m of Vangorda Creek. The results of the work indicate that, in general, subsurface materials are similar to those encountered in the SRK 1992 test pitting program for the Southeast Overburden Dump. However, it would also appear that a reddish brown to brown sand and gravel zone, up to at least 3m thick, is present over much of the area that was investigated. The natural topography under the proposed waste dump slopes southeastward toward Vangorda Creek at an angle of 7° to 10°, with locally steeper and flatter areas.

STRENGTH PARAMETERS

Strength parameters for the foundation materials that are assumed to underlie the waste dumps were evaluated by reviewing the test pit logs and the results of previous laboratory testing programs, particularly that conducted by SRK and discussed in their report of June 26, 1992. Both long and short term strength conditions were considered.

Relatively thin layers of organic topsoil typically consolidate very rapidly under applied load, and tend to behave as frictional materials. The underlying till material is likely to exhibit either frictional or undrained behaviour, depending on its density and water content. The deeper stiff or dense tills would likely dilate upon shearing. Consequently, these soils are considered to behave primarily as frictional materials when subjected to dump loading. On the basis of experience, a friction angle of $\phi = 35°$ was assumed for stability analyses, both in the long and short term. The upper till, which was reported on the test pit logs as being a soft to medium clayey silt till, will tend to shear in an undrained state. This material was characterized by laboratory testing as being primarily a low plasticity silty clay. Results of back analyses conducted by SRK following a dump failure at the Southeast Overburden Dump indicate that the upper till was loaded relatively rapidly and had an undrained strength of c = 14 to 43 kPa at the time of failure. Back analyses conducted by Piteau Associates tend to confirm an undrained strength in the order of c = 50 kPa.

Remoulded strengths for the upper till are anticipated to be in the order of 25% of the undisturbed or peak strength. Remoulding of the upper till foundation soil could occur due to strain incompatibility between the loose dumped overburden waste and the upper foundation soil (i.e. the consolidating soil waste could apply excessive strain to the upper till foundation soil). Unconsolidated undrained triaxial tests conducted on remoulded composite samples of this till are only appropriate for analyses where it is assumed that the foundation has already yielded. This would not be the case for analyzing the stability of a dump placed over a previously unfailed foundation.

In areas where the upper till is covered by, or characterized as, a granular soil and/or one that will not generate excess pore pressures when loaded by dumping (i.e. possibly under the proposed Main Dump), a frictional strength of ø = 35° is appropriate, both in the short and long term.

The waste material to be dumped comprises two general types. Loose overburden will be disposed of in the Southeast Overburden Dump and in a portion of the Southwest Dump. This overburden will be essentially the same material as the till foundation soils; however, the waste will be in a loose, remoulded state. As observed during a site inspection, some of this waste can be wet and/or soft. Assessments carried out by SRK indicate that such materials would have an undrained strength of c = 50 to 120 kPa. Our assessment of this material generally concurs and suggests an average strength of c = 85 kPa for loose dumped overburden, although development of this strength could lead to excessive straining of the foundation soils. Nonetheless, with time and compaction/consolidation, the waste material is expected to gain strength. In the long term, after pore pressures have dissipated, this material is likely to behave as a frictional material with an estimated strength of ø = 30°. Phyllite waste rock will be disposed of in the Main Dump and in the Southwest Waste Dump. This waste should behave as a frictional material with a minimum strength of about ø = 35°.

STABILITY ASSESSMENT OF SOUTHEAST OVERBURDEN DUMP

The proposed design for this dump, as illustrated in the 1989 water licence application, indicates that the dump would be built from the bottom up in a series of 15m high lifts to an elevation of 1290m (i.e. a maximum dump thickness in the order of 45m) at an overall slope angle of 17°. Stability analyses for the 1989 assessment were conducted using an effective stress approach. However, due to the nature of the materials and the likely rate of loading on the foundation, this approach is not felt to be valid for short term stability.

Short term stability was assessed using undrained strengths for the overburden waste and foundation materials. Results of these analyses indicate that slope failures can be expected to continue for the 15m lift heights that were originally proposed and the 15 to 20m lift that was being dumped during the site inspections. Instability can occur either through the loose dumped waste itself or through the softened upper till foundation material. Both of these types of failures are believed to have already occurred at one time or another at this dump. Failure through the waste appears to result from a combination of rapid dumping and oversteepening of the dump slopes, while failure through the foundation soil is likely related to strain incompatibility between the loose waste and the foundation soils.

Analysis results indicate that stability will improve as the lift heights are reduced (i.e. the waste will be placed in a more compacted state and there will be less strain incompatibility between the waste and the foundation soils). As discussed during a recent site visit, while lifts in the order of 2 to 3m thick would be most desirable from a stability standpoint, lifts of 6m thickness should result in acceptable stability. However, this should be confirmed by field trials and appropriate deformation monitoring. Dumping of overburden should be from the bottom up and should not extend onto the steeper portion of the dump site, below about the 1244m elevation. Notwithstanding this recommendation, the proposed dumping of a lift of phyllite waste rock around the toe of the overburden dump would provide improved stability to the overburden dump, particularly in the early stages of dump development, when stability is critical.

With regard to the overall configuration of the Southeast Overburden Dump, it is recommended that it be built in a series of 6m lifts to an overall slope angle of 2.5 horizontal to 1 vertical (i.e. 22°). Stability analyses indicate that such a configuration should have a factor of safety above 1.2, providing that excess pore pressures have dissipated and the foundation soils have consolidated. In the very long term case, it is anticipated that both the waste overburden and the foundation soils will behave as frictional materials.

It is recommended that as much of the dump crest as possible be utilized during dumping, to minimize the risk of dump failure. A slow rate of crest advance will allow the waste material to consolidate and the pore pressures in the foundation soils to dissipate (i.e. thus resulting in higher material strengths). If possible, dump advance rates should be limited to no more than

0.5m/day. To minimize infiltration of surface water into the dump, ponding of water should be prevented by maintaining a positive grade on the top of the dump. To minimize erosion and/or saturation of the dump face, water should also be prevented from draining over the dump crest. It would also be beneficial to regrade the ultimate dump face and cover it with a thin layer of phyllite waste rock to minimize erosion and channelling on the face.

A simple dump monitoring scheme is recommended for the waste dump. A straight line row of stakes along the crest of the dump would be useful to detect deformation. Regular visual inspections of the dump by mine personnel are also recommended. End dumping over the face of the dump should not be allowed. The present practise of dumping short of the crest and using dozers to push the waste over the crest should be continued.

With regard to any further investigations, the available test pitting and laboratory index testing are considered adequate for defining the type and behaviour of foundation soils under the dump. Because of the nature of the foundation soils, sophisticated triaxial testing is of limited value and is not recommended. The use of field trials, including intensive deformation monitoring and performance observations, is considered to provide the best confirmation of the proposed dump design.

STABILITY ASSESSMENT OF SOUTHWEST WASTE DUMP

It was proposed in 1989 that the Southwest Waste Dump would only be an average of 30m thick and would consist of a mixture of till overburden and phyllite waste rock. The dump would be constructed in 15m lifts, with the lower lift being till overburden and the upper lift a mixture of rock and soil.

Considering the lack of specific subsurface data concerning this waste dump, and since much of the dump will be constructed of till overburden that is assumed to be similar to that which is presently being placed in the Southeast Overburden Dump, it is recommended that the same initial dump design parameters outlined above be utilized for the Southwest Dump. These recommendations should be confirmed from a foundation investigation comprising test pitting, sampling, laboratory index testing, and field and laboratory measurements of undrained shear strengths.

STABILITY ASSESSMENT OF MAIN WASTE DUMP

It is proposed that the Main Waste Dump be constructed entirely of waste rock. While most of the waste would be phyllite, a cell of sulphide waste would also be incorporated into the dump. As illustrated in the 1989 water licence application, the dump would be constructed to the 1300m elevation in 30m lifts, from the bottom up, with the overall dump face angle being 25°.

A 30m high waste dump presently exists at the northern edge of the proposed waste dump. This dump, which apparently was constructed about two years ago, appears to be stable. The only signs of instability are some settlement cracks just behind the dump crest. However, the settlement and cracking do not appear to be active and likely date to the time of construction. It is noteworthy that some degree of settlement and cracking in the vicinity of the crest are normal occurrences in virtually all waste dumps.

From the limited amount of surficial soils data that are available, it is assumed that the existing and proposed dump is underlain essentially by frictional materials. For this case, the Factor of Safety of the existing dump could be in the order of 1.3. However, the lack of detailed subsurface data does not allow foundation strengths to be thoroughly evaluated. Hence, it is premature to perform a definitive stability assessment or derive firm conclusions regarding optimum dump lift heights, overall dump angle, etc. However, based on the work completed to date, the use of 30m high lifts appears to be reasonable. Should a dump foundation failure occur, this will likely indicate that the foundation materials have been overstressed and are behaving in an undrained manner. This could be due to the presence of cohesive soils or groundwater pressures that are dissipating more slowly than anticipated. In the unlikely event that foundation failures do occur, construction should be modified by adopting thinner lifts (<6m).

As it is understood that primary access to the Grum Pit will likely be through the Champ Zone, at a lower elevation than was originally planned, it should be possible to develop the Main Waste Dump in a series of 30m lifts from the bottom up. In addition to being relatively flexible, this approach should allow time for some pore pressure dissipation (assuming such pressures are generated) and strength gain to be achieved, and should also facilitate construction of the sulphide cell within the waste dump. With regard to the overall slope angle of the waste dump, if it is again assumed that the proposed dump is underlain essentially by frictional materials, it should be possible to develop the dump face at an overall slope angle of at least 1.75 horizontal to 1 vertical (i.e. 30°). However, as discussed for other dumps, a test pitting, sampling and laboratory index testing program should be performed to confirm the nature of foundation materials under the dump, and thus allow a more rigorous assessment of this dump to be made. Field trials would also be valuable for the assessment. As for the other dumps, advance rates for a given lift should be restricted to about 0.5m/day. The dump should also be graded to shed water.

With regard to the distance that the toe of the dump should be setback from Vangorda Creek, it is understood that a wildlife corridor is planned along the creek. There is also a requirement for a seepage collection ditch downslope of the toe of the dump. Considering these factors and that it is of utmost importance to protect the creek from being impacted by the dump, it is recommended that the toe of the dump should not extend below the 1100m elevation. This should provide a buffer zone or corridor at least 200m wide between the creek and the dump.

I hope the above letter regarding the Grum waste dumps is sufficient for your needs at this time. If you have any questions concerning the above, please do not hesitate to contact me.

Yours very truly,

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