

**Red Dog Mine  
Closure and Reclamation Plan**

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**Supporting Document C  
Geotechnical**

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**SD C1: Main Waste Stockpile Stability Assessments**

## Memorandum

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<b>To:</b>	File 1CT006.03	<b>Date:</b>	March 18 <sup>th</sup> , 2005
<b>cc:</b>		<b>From:</b>	Peter Mikes, Cam Scott
<b>Subject:</b>	Waste Stockpile Stability	<b>Project #:</b>	1CT006.03

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This memorandum summarizes previous geotechnical assessments of the Main Waste stockpile at the Red Dog mine site.

### 1 Initial Geotechnical Assessment and Design

The waste rock stockpile design was completed by Dames & Moore in 1987. Borehole investigations of the stockpile foundation materials were carried out in 1984 and 1987.

The north half of the dump foundation consisted of a tundra mat and vegetation while the south half consisted of poorly vegetated colluvial soils. The ground slopes in the area were typically between 10 to 12 percent with a maximum slope of 20 percent. The typical soil conditions consisted of 3 feet of frozen silt over 2 to 10 feet of gravely, silty sand (with an ice content between 0 and 30 percent by volume) over a shale bedrock. However, depths to bedrock of up to 18 feet were encountered. The drilling beneath the north portion of the dump indicated discontinuous permafrost. Groundwater depths within the boreholes varied between 9 and 40 feet.

Unconsolidated, undrained triaxial tests without pore water pressure measurements were taken of the borehole samples. From the testing, it was recommended the stockpile be built with no greater than 40-foot lifts at a slope no steeper than 1.2H:1V. In addition, a drainage key was required to be built at the base of the stockpile. Because of the angular shape and large size of the rock, it was assumed the surface water would drain freely through the stockpile. New stockpile construction over virgin ground would utilize a toe berm to provide stable configuration against toe failure.

### 2 1995 Geotechnical Assessments

In 1995, Dames & Moore re-analyzed the stability of the Main Waste Storage Area and presented a revised design recommendation. The re-assessment was based on a site visit, additional data from post construction performance of the first two stages of the stockpile, as well as additional test pits and laboratory analyses.

Surface reconnaissance during the D&M site visit found no evidence of slope instability of either the Stage I or Stage II fills. No longitudinal cracks along the crests or bulging at the base of the slopes were observed.

The results from the post construction analysis of the Stage II fill found that the in-situ strength of the overburden material was underestimated. In addition, the consolidated, undrained triaxial test showed the slope design should be sufficient against a block-type failure. The block-type failure tests do not take into account any strength gained from frozen conditions or consolidation of rocks.

The report also recommended that the full slope section without a shear key should be at least marginally stable and a shear key or toe berm would not be necessary for the construction of the Stage III fill or full section slope.

The D&M report found that the permeability of the waste rock was better than expected and additional drainage keys were not needed. The report did recommend constructing the fill with either a positive or passive approach, with the positive approach involving the installation of downslope gravel drains and the passive approach involving no drains and monitoring the slopes for any build-up of porewater pressures.

Three thermistors were installed in 1995 to monitor the amount of freeze-back of the stockpile fill. The thermistors were sunk 35 feet in depth. The thermistors did not reach the original topography. Thermistor data has shown the stockpile core temperature has been decreasing over time. In addition, five Acid Rock Drainage monitoring thermistors were installed in 1998.

### 3 2002 Assessments

The stability review of the waste dump by Golder in 2002 evaluated the stockpile construction, assessed the final stockpile design and recommended changes to the construction and operated procedures to improve the stability of the dump. Additional samples of waste rock and foundation soils were taken to determine the strength parameters of the proposed stockpile development.

The site visit by Golder Associates in 2002 found no signs of stockpile instability. Tension cracks were found near the dump crests but did not indicate large scale overall instability. Seepage was observed from various locations at the base of the dump, confirming the assumption of no phreatic surface developing within the stockpile.

The stability of the existing lifts of the waste dump was analyzed using the double-wedge instability mechanism. The testing determined that the factor of safety ranged between 1.5 and 1.9. The testing also found the pore pressure coefficient that would reduce the factor of safety to 1.0 to be high, at an order of 0.4. A pore pressure coefficient of 0.5 would indicate full saturation of the dump.

The ultimate waste rock stockpile, which at that time was planned to reach maximum elevations of 1315 feet at the north end and 1575 feet at the south end, was assessed under the following scenarios:

- Angle of repose slopes with drained foundation condition.
- Angle of repose slopes with drained foundation condition with a 0.05g seismic event.
- 2H:1V slope, long-term fully drained.
- 2H:1V slope, long-term fully drained with a maximum credible earthquake event of 0.1g.

The analysis of the dumps at angle of repose determined the factor of safety to range between 1.4 and 1.9 under static conditions and between 1.3 and 1.7 under pseudo-static conditions. Both situations were considered adequate for operating conditions. The analysis of the dumps resloped to 2H:1V found the factors of safety to be adequate for long-term closure. The lowest factor of safety encountered was 1.15 for the case where the design operating earthquake of 0.05g occurs during a period of high pore pressure in the resloped toe region. The resloped and drained dump is stable even under the MCE of 0.1g.

## 4 References

Dames & Moore, 1987a. *Geotechnical Design Report for Cominco Red Dog Mine Waste Dump Storage Areas*, July 1987.

Dames & Moore, 1996. *Final Report Re-evaluation of Design Recommendations, Main Waste Storage Area, Red Dog Mine*, March 1996.

Golder Associates, 2003. *Red Dog Waste Stability Review*, June 2003.

Teck Cominco, 2003. *Red Dog Mine Geotechnical Assessment, Waste Management Permitting Program Tasks B-03, C-01*, December 2003.