TECHNICAL MEMORANDUM

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TO:	Craig Goodings	**DATE:**	April 21, 2006
FROM:	Cam Clayton, P.Geo.	**JOB NO:**	05-1413-036A
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RE:	**ACCIDENTS AND MALFUNCTIONS**		

The following document describes general activities and mitigative actions that would be undertaken in response to accidents and malfunctions that could potentially occur during the course of mining activities at the Meadowbank Gold Project. Such accidents and malfunctions, such as fuel spills on site, un-planned tailings release to the environment, incidents involving aircraft and others, have been described in:

- Cumberland Resources Ltd, October 2005. Meadowbank Gold Project, Spill Contingency Plan; and
- Cumberland Resources Ltd, October 2005. Meadowbank Gold Project, Emergency Response Plan.

The impact assessment of such accidents and malfunctions on the physical environment, specifically water quality, quantity, and permafrost, has been described within each individual discipline or VEC and the impact matrices presented in:

- Cumberland Resources Ltd, October 2005. Meadowbank Gold Project, Physical Environment Impact Assessment Report.

These are summarized in Section 1 of this document.

In addition to these, Department of Fisheries and Oceans (DFO) and Indian and Northern Affairs Canada (INAC) have requested that a summary of potential 'worst-case' accidents and malfunctions, or 'rare events', for the Meadowbank Project be prepared. Specifically, DFO and INAC have requested consideration of the following systems:

50 BEST EMPLOYERS IN CANADA 2005 REPORT ON BUSINESS

CANADA'S 50 BEST MANAGED COMPANIES

1. The Portage Dewatering Dike System during mine operations.

2. The Portage Dewatering Dike System at closure.

3. The Tailings Dike during operations.

4. The Tailings Dike at post-closure.

Although the likelihood of failure of any of these systems is expected to be low, negligible, or non-existent, nonetheless an analysis of the potential activity or scenario, potential environmental effect, monitoring and mitigation and residual impacts worst-case scenario events are described in Section 2 for the dewatering dikes, and Section 3 for the tailings dike.

1.0 ACCIDENTS AND MALFUNCTIONS DURING GENERAL ACTIVITIES

A summary of potential accidents and malfunctions that could occur during operation within the mine footprint and along the all-weather road is provided in Table 1, followed by a description of the potential effects of these occurrences on fish and fish habitat. References are made to detailed emergency response plans, which will be developed during the regulatory phase of the project.

Table 1: Summary of Consequences and Proposed Monitoring/Action for Potential Accidents and Malfunctions

Accident	Scenario	Consequence	Action and Monitoring
Cargo Transportation Crash	Transport truck and contents overturn and spill into stream or lake (Whitehills Lake or Third Portage Lake)	Cargo of mill reagents (lime, sodium cyanide, acid, sulphur, flocculants, copper sulphate) or ammonium nitrate: Local smothering of stream or lake bottom sediments by spilled solids (e.g. lime, copper sulphate); local decrease of water quality.	Mobilize site crane, boom truck, excavator and vacuum truck to scene; remove intact material from water; construct isolating berm around spilled material; treat or neutralize affected area and dispose of salvaged products according to the detailed spill response plan for the particular constituent; monitor for residual contaminants and effects.
		Fuel tanker truck: Localized, short-term	mobilize site crane, boom truck, excavator and vacuum

Accident	Scenario	Consequence	Action and Monitoring
		decrease of water quality.	truck to scene; pump remaining product from tanker; absorb spilled product with spill kit materials; monitor for residual contaminants and effects.
		Sewage vacuum truck: Localized, short-term decrease of water quality.	mobilize site crane, boom truck, excavator and vacuum truck to scene; confirm vacuum tank has no leaks (pressure vessel); pump out contents into other tanker truck; monitor for residual contaminants and effects.
	Transport truck and contents overturn and spill onto land	All cargo (mill reagents, fuel, sewage): Localized, short-term smothering of vegetation by spilled material.	mobilize site crane, boom truck, excavator and vacuum truck to scene; remove spilled solids, neutralize residual material according to the detailed spill response plan for the particular constituent; monitor for residual contaminants and effects.
Commuter aircraft crash	Debris dispersed on the land	Potential for loss of life, spill from aircraft fuel reservoirs: Localized impact on vegetation.	Remove residual fuel, batteries, lubricants and transport in barrels by helicopter for disposal on site; removal of debris in winter to reduce impact on terrain.
Pipeline breakage	Tailing solids line breakage and spill of tailings on land	Spill of tailings on land, within mine footprint: Localized, short-term smothering of vegetation.	Shut tailing feed line; physically contain spill; remove spilled tailings and place back into impoundment; monitor for residual contaminants on the land.
	Tailing water	Flow of tailing reclaim	Shut tailing reclaim water

Accident	Scenario	Consequence	Action and Monitoring
	reclaim line breakage and flow of reclaim water on land	water on land within mine footprint.	line; capture water in sumps, drainage ditches or pit; pump water to tailing reclaim pond.
	Sewage line breakage and spill of sewage on land	Spill of sewage on land, within mine footprint.	Shut feed line; physically contain spill; construct sump to collect runoff; pump to tailing impoundment or let infiltrate depending on volume spilled; remove solids and place into tailing impoundment.
Fire	Fire damage to mining equipment or site buildings, spill of contents of truck reservoirs	Release of particulates and gases in air, spill of hazardous materials (e.g. fuel, oils, battery acid, etc.): Short-term degradation of air quality and potential for localized effect on vegetation (burn scar and spill)	Extinguish fire with appropriate chemical or water (as defined in detailed emergency response plan); monitor for airborne emissions; recover and incinerate all putrescibles (food items); remove debris and contaminated soil; segregate debris by material type (e.g. metals and plastics); dispose of residue into appropriate facility.
	Fire damage to containers of chemicals	Release of particulates and gases in air, spill of chemicals on land (e.g. lime, fuel, acids, etc.): Short-term degradation of air quality and potential for localized effect on vegetation (burn scar and spill)	Extinguish fire with appropriate chemical or water (as defined in detailed emergency response plan); monitor for airborne emissions; remove debris and contaminated soil; dispose of residue in appropriate facility.

1.1 Potential Impacts of Accidents and Malfunctions on Fish and Fish Habitat

Spills that would occur within the mine footprint would be contained with water retention structures such as sumps, drainage ditches and open pits, and residues would be disposed of according to a pre-determined protocol. Spills occurring within the mine footprint would have no effect on fish and fish habitat in the receiving environment outside the mine footprint.

The magnitude of impacts to fish and fish habitat along the all-weather road depends on the timing of a spill, the amount and type of material spilled and the particular stream or lake into which the spill occurs. An overall summary of habitat importance and utilization within streams crossed by the all-weather road is provided in Table 4-1 of the Habitat and Fisheries Assessment of the Proposed All-Weather Road (2005) submitted as part of the Environmental Impact Assessment provides an overall summary of habitat importance and utilization within streams crossed by the road. Notable details of the stream crossings are as follows:

- Only 6 of the 25 stream crossings (Bridges 1 to 5 and C-05) provide migratory and possibly spawning habitat for Arctic grayling and small numbers of other species including lake trout, round whitefish and Arctic char. Fish are only present in these streams during freshet (early-June) to mid-summer (late July) due to declining water levels. Fish are not present during the remainder of the year because of lack of water or frozen conditions (mid-September to late May).

- Sixteen of 29 potential crossing locations surveyed do not contain fish and have no or limited habitat value as the streams provide limited if any connectivity to productive, fish-bearing habitats downstream.

- Seven streams contained only ninespine stickleback and at one stream small numbers of grayling. In most cases these streams provided limited if any connectivity to downstream habitat.

- None of the streams crossed by the all-weather road sustain fish populations that are used by Baker Lake residents; none of the locations are actively fished for Arctic grayling.

For a worst-case spill event to occur, hazardous materials would have to be released in sufficient quantities in the six stream crossings (Bridges 1 to 5 and C-05) during the open water season (approximately 8 weeks, the most sensitive period being early June to early August) to have potentially harmful effects. Furthermore, none of the streams supports large numbers of fish, and none are not important for domestic fishing and none of the streams crossed represent major aquatic pathways that could carry contaminants very far or to areas that are frequented by local hunters or fishermen. Thus, provided that appropriate management measures are followed (e.g., appropriate speed limits for vehicles, proper packaging and containment, emergency response measures) the likelihood of such an event occurring is very low. Nevertheless, should a spill occur, impacts to fish and fish habitat would be very localized and restricted to a small area. None of the streams crossed represent major aquatic pathways that could carry contaminants very far or to areas that are frequented by local hunters or fishermen.

2.0 RARE EVENTS AND WORST CASE ACCIDENTS – PORTAGE DEWATERING DIKE SYSTEM

Stability analyses for the perimeter dewatering dike system, including slope stability and seepage, have been described in:

- Cumberland Resources Ltd., Project Alternatives Report. October, 2005; and
- Golder Associates Ltd., Report on Design of Dikes with Soil-Bentonite Cutoff Wall, Meadowbank Gold Project, October 23, 2003.

2.1 Description of the Portage Dewatering Dike System

The Portage Dike System refers to the Portage East Dike and the Goose Dike (see Figure 1). The construction methodology will involve the advancement of two rockfill berms across open water, followed by infilling with till, and subsequent excavation of a soil-bentonite cut-off wall (see Figure 2). The dike section will consist of a wide trapezoidal downstream rockfill shell that is 20 m in width at its crest, an inverted trapezoidal low permeability till section that is a minimum 5 m wide at its base, and a second wide trapezoidal upstream rockfill shell, also 20 m wide at its crest. The total crest width will be on the order of 70 m to 85 m or more, depending on water depth. The soil-bentonite cut-off wall extends through the till core, the foundation till, to the bedrock surface. The seepage cut-off element therefore consists of a very wide low permeability till section with a central soil-bentonite cut-off wall.

The dikes are considered high consequence structures, based on Canadian Dam Association criteria. Slope stability analyses show that the dikes will be stable under static and earthquake load conditions. The minimum calculated factor of safety for static conditions is 1.9, and the minimum calculated factor of safety for pseudo-static conditions is 1.5, both of which occur along a section through the southeast segment of the Goose Island Dike, through the deepest water, thus representing the ‘worst case’ dike section (see Figure 3, Section B-B’). These values exceed the minimum values indicated by the Dam Safety Guidelines (Canadian Dam Association, January 1999). Consequently, the risk of dike failure is considered to be low provided that the dikes are constructed according to design. Mitigation for this scenario is a comprehensive quality control and quality assurance program during construction.

2.1.1 East Dike

The East Dike will be constructed through shallow water and a series of islands to separate the eastern portion of Second Portage Lake from the future Portage Pit and the Tailings Impoundment Area behind the Tailings Dike. The East Dike will be a permanent structure that will separate Third Portage Lake from Second Portage Lake and maintain the existing water elevation difference of 1 meter.

The East Dike is expected to be 1 km in length with an average depth of only about 1.5 m, and maximum water depth of about 5 m (see Figure 4). Where water depths are less than about 2 m, it can be expected that the lakes in the area will freeze to bottom. Consequently, substantial portions of the foundation underlying the proposed East Dike are expected to be frozen.

2.1.2 Goose Dike

The Goose Dike will be approximately 2 km in length and is projected to have an average depth of 5 m. The Goose Dike will extend south from the Third Portage Peninsula, following the shallowest water where possible, to surround the Goose Island Deposit. The Goose Dike will encounter the deepest water of all the dewatering dikes for the project. This will occur along the southeast portion of the dike wall. Maximum water depth along the Goose Dike is about 16 m at the dike centerline, with a surface area of 2.7 ha below the water surface. The Goose Island dike will isolate approximately 90 ha of Third Portage Lake, which is 2.5% of the total surface area of Third Portage. From this 2.2 Mm^3 of water will be pumped to Third Portage Lake to allow development of the Goose Pit. Approximately 14.9 ha of the Goose Island dike lies between 0 m and 5 m depth while the remaining surface area (12.2 ha) is deeper than 5 m. At end of mine life the Goose Island Pit will have a volume of 14.6 Mm^3.

2.2 Failure Scenario During Operations

The ‘worst-case’ scenario for the dewatering dikes during operations would involve a movement of the dewatering dike that cracks the slurry wall sufficiently so as to compromise the integrity of the cut-off wall. However, the rockfill, which will have very high flow-through capacity, will not move. The water will flow through the upstream rockfill first, then through the till, and finally through the downstream rockfill berm. The upstream rockfill will choke the flow to some degree, and once the downstream toe of the dike begins to be inundated, flow will decrease.

Although this describes a ‘worst-case’ scenario, because of the design of the dike, the width of the dike section, and the inclusion of a low permeability till core in addition to the soil-bentonite cut-off wall, a catastrophic failure of pit dewatering dike system is not considered a credible failure mode. However, for the purposes of this document, the effects of such a failure are described below.

2.2.1 Potential Effect

In the case of the East Dike, the worst-case scenario would be associated with a short portion of the dike through the deepest water along the alignment at the south end of the dike (see Figure 4, Section F-F’). In this area water depth is approximately 2 m deep at the centreline of the dike, and up to about 6 m deep at the upstream (lakeside) toe. This inflow could potentially result in loss of life, and would result in cessation of mining, either temporarily or permanently. However, the pit crest is approximately 400 m from the toe of the dike in this area. Furthermore, the rockfill causeway constructed to the west of the main dike will provide additional impedance to water flow towards the pit area.

Upon completion of the East dike and dewatering of the northwest arm of Second Portage Lake, there will be approximately 10 million m^3 (Mm^3) of water remaining in Second Portage Lake. If the segment of dike at the deepest portion were suddenly removed, flow from Second Portage Lake into the pit would continue until the elevation of the lake drops by several metres, at which time the current lake bottom would be exposed and would act as a barrier to flow towards the pit. The volume of water associated with this drawdown would be on the order of about 6 million m^3. Some erosion of the till form the pit edge back towards the dike would be expected, so the depth of water loss from the lake may be greater than this, however this would take some time to fully develop.

Inflow to the pit could expose large amounts of shoreline and shoal habitat around the lake. Water flowing into the pit could entrain suspended solids and dissolved constituents from the dike material and pit walls. If necessary, the water could be retained within the pit and diked area and would be amenable to treatment (e.g. particle settling, in-situ amendment) before discharge, should it be required.

The ecological effects of this on fish and fish habitat would be to temporarily eliminate spawning by fish and result in reduced water quality from exposure of sediment to wave and wind induced erosion. The effect of this would be approximately one year. Inflow from Third Portage Lake to Second Portage Lake averages 11 Mm^3 annually. Presuming that the dike breach is repaired, water levels in Second Portage Lake would rise over the spring and summer to return to pre-breach elevations and would re-fill the lake in the event of a ‘worst-case’ scenario.

In the case of the Goose Dike, the worst-case scenario dike breach that could allow the greatest amount of water inflow would be associated with the southeast segment of the dike through deepest water along the alignment (see Figure 3, Section B-B’). In this area, water depth is approximately 16 m deep at the centreline of the dike, and up to 20 m deep at the upstream (lakeside) toe. The toe of the dike in this area is about 110 m from the crest of the pit. Furthermore, Goose Island separates the pit from the lake water in this area. Finally, it is planned to construct a series of finger dikes on the downstream (lake side) of the Goose Dike along its eastern edge. These finger dikes will extend up to about 400 m further eastward from the dike, and into the deepest water adjacent to the dike. The effect of these finger dikes will be to further reduce any potential for overall dike instability by creating a dike section up to 400 m in total width (crest to crest) in the area of the most critical section. Therefore, a catastrophic failure of the overall dike section is not considered to be a credible failure mode.

In the unlikely even that such a failure were to occur, the rate and volume of water entering the pit would depend on the magnitude of the breach and the length of time to repair the breach. Assuming a breach of catastrophic proportions and complete filling of the pit this would result in a drawdown of water level in Third Portage Lake.

Assuming that Third Portage Lake has a surface area of 36 km^2 and an approximate average depth of 18 m, the estimated volume of the lake is 650 Mm^3. The volume of Goose Pit (14.9 Mm^3) is approximately 2.3% of the volume of the lake. Drawdown of this worst-case scenario actually falls within the permissible annual withdrawal rate of water from under ice (DFO, 2005). If this volume of water is discharged to the pit the predicted decline in water level in Third Portage Lake would be ~0.4 m. This is slightly greater than the mean average annual difference between high and low water (0.3 m).

There would be a small impact to fish and fish habitat in Third Portage Lake in the event of a 0.4 m drop in water level. Areas used for spawning may be slightly nearer to the ice cover and a small amount of habitat might be vulnerable to freezing. Water quality within the pit would be temporarily impaired from an increase in suspended and dissolved solids, although water quality would return to near background during the first winter as sediment would settle under the ice cover.

2.2.2 Mitigation, Management, and Monitoring

Such a scenario as described, while possible, has a low probability of occurrence. If movement of the dike were sufficient to compromise the slurry cut-off, the wide till core would act as a secondary low permeability element. Water would first need to flow through the rockfill shell, then through the till element, the damaged cut-off, through more of the till element, through the filter element, and then through the downstream rockfill. Provided that the filter elements at the downstream interface of the till core and the rockfill shell are properly designed, then migration of the till into the rockfill will not occur. Some additional seepage may occur due to failure of the slurry cut-off; however this would be noted during regular monitoring and could be mitigated by placement of reverse filter and toe berm along the downstream toe. Consolidation of the till between the rockfills would also contribute to the integrity of the core material. This will occur naturally due to self-loading, however could be assisted by loading the till core area with rockfill during construction. Therefore, a catastrophic failure of the dike by this mechanism is not a credible failure mode.

If such a complex scenario did occur, it would have the most likely possibility of occurrence early in the project, when the area behind the dikes is first pumped down. Once sinking of the pit begins, the phreatic surface will be drawn down, and seepage from the lake will be lower than the level of the till. As the pit is deepened, seepage will move down and towards the pit. This will be similar to conditions currently observed at other mines in the north. Subsequent to dewatering, but prior to any equipment or personnel working in the dewatered area, there would be a dike commissioning period during which time monitoring data would be reviewed, and observations made to assess the performance of the dikes. Personnel and equipment would not be allowed into the dewatered area until after this commissioning period.

The use of appropriately sized filters in the design of dikes and dams is standard engineering practice, and is the key to preventing the internal erosion resulting from seepage. The current dike design includes the use of such a filter material on the upstream face of the inside rockfill. A filter can also be placed on the downstream face of the rockfill berm, and on the till exposed downstream of this berm, before a toe berm is placed. This would be done under dry conditions, and so would be a controlled procedure. This would prevent piping of the foundation materials, but not the till core. During the construction of the dikes a comprehensive quality control and quality assurance program would be undertaken.

During the operation of the dike, a series of monitoring instrumentation will be installed, including:

1. Thermistors to monitor the thermal regime in the dike and foundations;
2. Slope inclinometers or prisms to monitor deformations within the dikes; and
3. Piezometers to measure pressure and infer flow through the dikes.

Piezometers downstream of the cutoff would be monitored to see if pressures increase as the pit is deepened. Increasing pressure would indicate that less head loss is occurring across the seepage cutoff, which might indicate that a crack has formed, or that permeability is increasing, or that the pit is experiencing inflows from some other potential flow pathway. The instrumentation will be continuously monitored to identify any potentially problematic areas relating to dike instability. Mitigation measures for seepage and piping could include: pressure grouting of foundation materials, construction of toe berms and additional filter zones, de-pressurization wells, construction of a slurry cutoff wall just upstream of the suspected seepage area, jet grouting of the till in the suspected seepage or crack area, construction of a cutter soil mixing (CSM) wall in the suspected crack area, freezing using liquid nitrogen, sheet piling, toe drains and interceptor ditches within the down-stream overburden materials. Monitoring and mitigation strategies will be developed as part of an Operations Plan for the de-watering dikes.

2.3 Failure Scenario during Closure

At end of mine life, once the water quality of the pit lake has been determined to be suitable for release, a portion of the south end of the Goose Dike will be removed resulting in a hydraulic connection between the pit lake and Third Portage Lake. The East Dike will remain in place. The elevation of the pit lake will be equal to Third Portage Lake. The elevation difference between the pit lake and Second Portage Lake will be approximately 1 m. Consequently, there will be a low hydraulic gradient towards Second Portage Lake. During the closure and post-closure period, the channel that connects Third Portage to Second Portage Lake will carry the entire flow between the two lakes.

2.3.1 Potential Effect

A dike breach would create an additional outlet and cause water to leave the Portage/Goose pit area and spill into Second Portage Lake at a greater rate, partly at the expense of flow from the natural channel, causing a rise in water level in Second Portage Lake and a reduction in level in Third Portage Lake. Water would flow through the channel connecting Second Portage Lake to Tehek Lake until the water elevations in Second and Third Portage lakes equilibrated.

In the event of such a scenario, water would flow from Third Portage Lake, northward through the pit lake area, and then east through a potential dike breach and into Second Portage Lake. There is naturally large outlet capacity via the connecting channel from Second Portage to Tehek Lake. Water residence time in Second Portage Lake during and after mine development is less than one year. Thus, in the event of a dike breach any additional water added to Second Portage Lake would leave the system relatively quickly. Given the flow-through nature of the lake there would be little net change in Second Portage Lake volume or lake elevation as water would easily be absorbed into the much larger Tehek Lake.

Drawdown of Third Portage Lake would be limited, given the large size of the lake and the constriction points within the system that would slow drawdown.

The magnitude of drawdown in the event of a breach would depend on the magnitude and depth of the breach, time of year (winter ice cover would prevent loss of water), response time, and flow rate (i.e., the loss of water depends on the location of the breach and friction through the system). For example, total annual average discharge from Third Portage to Second Portage Lake is approximately 10 Mm^3 with a mean annual difference in water level between spring and fall of 0.3 m. Given the large size of Third Portage Lake (36 km^2), a breach resulting in the loss of 10 Mm^3 of water, which is equivalent to an entire open water season of runoff through all discharge channels would result in a drawdown of only about 0.3 m.

It would be unlikely that this volume of water would be lost before remedial actions could be taken, so reductions in water level in Third Portage Lake would be small and have only minor impacts to fish habitat in Third Portage Lake. Adverse impacts to water quality would not be expected given that water quality within Goose/Portage pits is expected to be very high.

2.3.2 Mitigation, Management and Monitoring

Internal erosion of the top 1 to 2 metres of till core could result in a progressively increasing void, and water flowing through the dike faster. However, this is extremely unlikely due to the low hydraulic gradient across the dike. Furthermore, the dike will be designed with appropriate filters to mitigate against such a scenario. Finally, such a scenario is more likely to occur during the operational phase of the dike when the hydraulic gradient across the dike section is much higher. However, if such a scenario were to occur it would not be considered a catastrophic failure mode due to the stability of the rockfill shoulders comprising the outside structural elements of the dike.

The use of appropriately sized filters in the design of dikes and dams is standard engineering practice, and is the key to preventing the internal erosion resulting from seepage. In the event that a breach occurred in the East Dike during closure, because the hydraulic gradient between the pit lake and Second Portage Lake is low, flow through such a breach could potentially be managed by the placement of rockfill material to reduce the flow of water and reduce potential internal erosion of the till core. Once equilibration of water levels is reached, the dike could then be repaired and hydrologic conditions restored.

During the operation of the dike, a series of monitoring instruments will be installed in the dike. Instrumentation will likely consist of thermistors to monitor the thermal regime in the dike and foundations, slope inclinometers or prisms to monitor deformations within the dikes, and vibrating wire piezometers to measure pressure and infer flow through the dikes.

The instrumentation will be continuously monitored during operations to identify any potentially problematic areas relating to dike instability. Information collected during this period of time would be used to further assess the long-term stability of the dikes, and to re-evaluate the closure scenario.

Additional information relating to potential failure modes, consequences, and monitoring programs are discussed in the following table.

Table 2: Meadowbank Dewatering Dikes Summary of Consequences and Proposed Monitoring/Action for Rare Event Based on Water Retaining Embankment Failure Modes Identified in ICOLD Study

Failure Mode	Scenario	Consequence	Monitoring/Action
Overtopping	(1) Lake level rises because of restricted outflow (excessive inflow is a far less likely scenario).	Water spill over the crest but, as this crest is both wide and comprises rockfill, no damage to the dike is credible. Mining operations might need to be abandoned, temporarily, but there will be considerable warning time given the design freeboard and the storage volume.	Freeboard should be part of daily safety information provided to mine management. Outflow channels should be inspected weekly during thaw and open water season
	(2) Dam crest settles	Water spills over crest and if	The situation envisaged in

Failure Mode	Scenario	Consequence	Monitoring/Action
	more than 2m over a distance of (say) 50m or so. This scenario requires rapid and extensive loss of support in the foundation since the rockfill of the dikes is essentially not settlement prone of itself. For foundation settlement of this magnitude to occur, a piping event must develop and which in itself might be a failure mode.	settlement was rapid might erode the crest.	this scenario should develop slowly with crest settlement evident at least several weeks before a run-away event developed. Easily observed cracks should be evident during summer period, but could be hidden during the winter. Systematic crest settlement monitoring is appropriate.
Internal Erosion	(1) Dike Section: Cut-off wall is defective and this defect arises in the same place as where the till core is also defective (and may be caused by it). Filters placed underwater and may segregate, leading to ongoing erosion of till core.	The till core will develop a progressively increasing void, and water will flow through the dike faster. But, this is not a catastrophic failure mode, because of the rockfill shoulders of the dike, and at its worst would lead to temporary suspension of mining.	Not necessary to monitor directly. Will become evident as localized intensive seepage at dike toe and can be repaired.
	(2) Dike Section: Although correctly constructed, cut-off wall looses bentonite because of filter incompatibility with downstream till and which then leads to ongoing erosion.	Same consequences as erosion because of defect, as above.	As above.
	(3) Foundation: Till	Limited seepage at the toe	No particular instrumentation

Failure Mode	Scenario	Consequence	Monitoring/Action
	is possibly non uniform with more transmissive zones and not self-filtering. It is possible that one of these zones may align with defective construction of the cut-off wall. Seepage would lead to internal erosion, and accelerate into a piping event because of the lack of filtering.	would accelerate into a major inflow, and could lead to the undermining of the dike if no action was taken. This is a credible catastrophic failure mode.	is needed as this failure mode will show itself as localized and increasing seepage. It should be detected by walk-over inspection by any experienced engineer or technician. Remedial action could comprise a reverse filter and rockfill buttress, easily done with normal equipment available at the mine.
Seepage within Embankment	Seepage on its own is not a credible failure scenario. The downstream rockfill zone is both large and very pervious, so that no seepage will daylight or lead to instability because of weak strengths. Any seepage related failures must include internal erosion, see above.	No credible consequences.	No scenario specific monitoring required.
Seepage within Foundation	If the till had a zone of more pervious soil (more sand like) within the till body and this more pervious zone was preferentially exposed to retained water pressure, then normal seepage would	This failure mechanism has caused embankment failures because of straightforward pore pressure induced instability. However, it is unclear that it could cause failure of the dikes because of their large width compared to the retained water head. The most likely consequence is	If this mechanism arises it should show itself during initial pit dewatering or very shortly thereafter. It is a reason for heightened inspection frequency during the time the pit is dewatered and extending for one year afterwards.

Failure Mode	Scenario	Consequence	Monitoring/Action
	transmit an unexpectedly high fraction of the reservoir head into the downstream part of the dike foundation.	downstream toe slumping requiring a localized stabilizing berm before the crest roadway could be reinstated.	
Internal Conduit Rupture	There are no water offtake works or other structures extending through the dikes.	Not applicable.	Not applicable.
Slope Instability	(1) Normal Operation: The rockfill shoulders to the dike have benign stress-strain behaviour and the design slopes are conservative. Slope failure requires failure in the foundation and which would then extend into the overlying dike.	A foundation failure would cause a rotational slip in the dike until the slope attained a stable angle. Such a failure would not jeopardize the overall dike integrity because of the relatively very large width of the rockfill shoulder to the dike height. This mechanism would limit access along the dike until repaired.	Because the foundation is till, this mechanism should develop slowly and be evident as developing by formation of observable tension cracks in the dike crest. It is most likely within a year of dewatering . Walk-over inspection of the dikes by trained inspector is an appropriate monitoring strategy.
	(2) Earthquake Induced: Occurrence of an extreme earthquake, a very rare event.	The extreme earthquake loading for this site is a low level event which would not trouble any engineered structure. In the case of rockfill dikes, even a large interpolate earthquake would not be expected to cause more than 300 mm of settlement. This would not be a failure situation. The crest is also erosion resistant for any earthquake induced wave action in the impounded water.	No monitoring is necessary.

Failure Mode	Scenario	Consequence	Monitoring/Action
Unexpected Settlements	The foundation is dense till overlying rock. There is no credible mechanism for 2m of settlement, which is what is needed for a water release event. Unexpected settlement of the till core is credible because of the uncompacted dumped-through-water construction.	2m of core settlement could lead to water flowing through the rockfill and over the settled core, but this would not cause failure of the rockfill shells. It would also be readily repaired by placing more end dumped till into the settled zone.	No enhanced monitoring required, as excessive settlement would be apparent from the seepage.

3.0 RARE EVENTS AND WORST CASE ACCIDENTS – TAILINGS DIKE SYSTEM AND TAILINGS IMPOUNDMENT AREA

Stability analyses for the tailings dike, including slope stability, thermal stability, and seepage, have been described in:

- Cumberland Resources Ltd., Project Alternatives Report. October, 2005; and
- Golder Associates Ltd., Report on Tailings Dike Basic Engineering Design, February 13, 2004.

3.1 Description of the Tailings Dike System

The Tailings Dike system is comprised of a Tailings Dike, a series of small perimeter dikes, and the natural basin of the northwest arm of Second Portage Lake. The dike is shown in plan on Figure 6, and in section on Figure 7. The proposed full and partial cutoff Tailings Dike cross-sections consist of:

- A rockfill element, constructed from run-of-mine waste rock, with the upstream and downstream faces designed at a 2H:1V slope;
- Upstream and downstream filter zones;
- A low-permeability compacted till cutoff element, either as a core to the dike, or as an element on the upstream face; and
- A minimum crest width of 30 m.

Additionally, for a Full Cutoff design, the cross-section includes:

- A low-permeability compacted till cutoff through the foundation soil.

- A pressure-grouted grout curtain through the fractured bedrock zone (at this time it has been assumed that the fractured bedrock is up to 20 m deep, based on available geotechnical drilling information along the dike alignment.)

The Tailings Dike is a high consequence structure, based on Canadian Dam Association (CDA) Dam Safety Guidelines. Slope stability analyses show that the dikes will be stable under static and earthquake load conditions. During operations, the minimum calculated factors of safety for static conditions is 2.0, and the minimum calculated factor of safety for pseudo-static conditions is 1.8, both of which occur during the early stages of mine life when free waster is ponded against the dike, with the water surface at approximately 120 m A.S.L. At the time when this scenario occurs, mining will be in the Portage Pit, south of the Tailings Dike, and not directly down-stream of the dike.

During closure the minimum factors of safety for static conditions is 4.9, and for pseudostatic conditions is 4.3. These values exceed the minimum values recommended by the Dam Safety Guidelines (Canadian Dam Association, January 1999). Consequently, the risk of credible failure of the Tailings Dike is considered to be low.

3.2 Failure Scenario during Operations

In the case of failure of the Tailings Dike during operations, the ‘worst-case’ scenario would involve catastrophic failure of the dike in the later stages of mining when personnel and machinery are working in the open pit directly down-stream of the Tailings Impoundment Area (TIA), and in association with a tailings mass that is unfrozen.

3.2.1 Potential Effect

The failure of the Tailings Dike could result in the sudden and unexpected release of tailings from the TIA into that portion of the Portage Pit immediately adjacent to the dike. This could potentially result in loss of life. This would result in cessation of mining activities, either temporarily or permanently.

There would be no effect on the receiving environment water quality, fish or fish habitat because mining activity would still be underway and the area would not yet be flooded.

3.2.2 Mitigation, Management and Monitoring

The scenario described is similar to the 'End of Deposition' failure mode modeled in the stability analyses, the geometry of which is shown on Figure 8. The calculated Factors-of-Safety for this failure mode, under static and pseudo-static conditions, are 2.3 and 2.2, respectively. Consequently, the likelihood of such a failure mode developing is low. At the time of such a potential occurrence, it is expected that the tailings pond will be approximately 200 m to 300 m northwest of the face of the tailings dike. Furthermore, thermal modeling indicates the tailings and tailings dike will be in a frozen or semi-frozen state, and that the facility will tend to the frozen state in the long term. Therefore this is not a credible catastrophic failure mode.

Mitigation against such a failure mode occurring will be to design the Tailings Dike to be physically stable under static and pseudo-static loading conditions. During the construction of the dikes a comprehensive quality control and quality assurance program would be undertaken to confirm foundation conditions, material type and quality, and to adjust designs as necessary to reflect actual or unexpected conditions found during construction. Prior to operations, a management plan such as suggested by the Mining Association of Canada's "Guide to the Management of Tailings Facilities" (1998) will be developed for the operation of the tailings facility, and will include the operational controls and monitoring activities. During operations, instrumentation will be installed to monitor not only the physical performance of the Tailings Dike itself, but also the performance of the TIA, including:

During the operation of the dike, a series of monitoring instrumentation will be installed, including:

1. Thermistors to monitor the thermal regime in the dike and foundations;
2. Slope inclinometers or prisms to monitor deformations within the dikes; and
3. Piezometers to measure pressure and infer flow through the dikes.

Thermistors will be installed in selected areas such as: between the toe of the Tailings Dike and the crest of the open pit; in the Tailings Dike embankment and foundation; and in the tailings mass itself, to monitor the thermal regime and compare with predicted scenarios. Vibrating wire piezometers will be installed in the foundation of the Tailings Dike, as well as adjacent to the downstream toe of the dike, the purpose of which will be to monitor pore pressure changes in the foundation materials. The stability of the foundation materials and of the dike can be enhanced through the use of a stabilizing toe berm or through freezing.

3.3 Failure Scenario during Closure

In the case of failure of the Tailings Dike during closure, the 'worst-case' scenario would involve catastrophic failure of the dike during the closure period after water has been allowed to flood the Portage Pit side of the Tailings Dike, and assumes the Tailings Dike and TIA are not frozen.

3.3.1 Potential Effect

Failure of the Tailings Dike during the closure period is not expected to result in loss of life, as mining operations will be finished.

Under this scenario, a catastrophic failure of the Tailings Dike could result in the sudden and unexpected release of dike material and tailings into the Portage Pit lake area. This could potentially produce a wave that could over-top the East Dike, resulting in internal erosion of the core and leading to increased flow of water from the Portage Pit area to the Second Portage Lake area, as described under Section 1.5 above.

Such a scenario would destroy fish habitat along the dike face and smother benthic habitat outwards from the failure area. Suspended solids and dissolved metals would increase in the water column and would cause displacement of fish and possible toxicity of some bottom sediments, depending on how much tailings material was lost. The new face would be subject to chronic erosion of fine tailings material until such time as a new, stable dike face could be established. Failure of the dike would not cause a change in water level. Impacts would be very localized because the Tailings Dike is situated in the upper part of a blind arm of the lake with an extremely limited drainage area and low turnover. Consequently, transport of suspended sediment away from the area would be restricted and the area of impact would be relatively small.

3.3.2 Mitigation, Management, and Monitoring

The scenario described is similar to the ‘Closure’ failure mode modeled in the stability analyses. The calculated Factors-of-Safety for this failure mode, under static and pseudo-static conditions, are 4.9 and 4.3, respectively. Consequently, the likelihood of such a failure mode developing is low. Furthermore, thermal modeling indicates the tailings and tailings dike will be in a frozen or semi-frozen state, and that the facility will tend to the frozen state in the long term. Therefore this is not a credible catastrophic failure mode.

Mitigation against such a failure mode occurring will be to design the Tailings Dike to be physically stable under static and pseudo-static loading conditions, and to monitor instrumentation during the mine life to assess the overall performance of the dike and the overall Tailings Impoundment Area. During operations, instrumentation will be installed to monitor not only the physical performance of the Tailings Dike itself, but also the performance of the TIA. Thermistors will be installed in selected areas such as: between the toe of the Tailings Dike and the crest of the open pit; in the Tailings Dike embankment and foundation; and in the tailings mass itself, to monitor the thermal regime and compare with predicted scenarios. Vibrating wire piezometers will be installed in the foundation of the Tailings Dike, as well as adjacent to the downstream toe of the dike, the purpose of which will be to monitor pore pressure changes in the foundation materials. The stability of the foundation materials and of the dike can be enhanced through the use of a stabilizing toe berm or through freezing. Data gathered during the operational period of the TIA can be used to re-evaluate the performance of the Tailings Dike structure in the context of longer term stability.

3.4 Attenuation Pond Saddle Dams 4 and 3

Five saddle dams will be constructed in specific areas around the limits of the tailings basin. The locations are shown on Figure 9.

The dams will be constructed using rockfill and will have a trapezoidal cross section, with a 10 m crest width (see Figure 10). The dams will have a compacted till core. A filter zone will be placed on the downstream side of the till core to transition between the till and the coarse rockfill. The height of the dams will vary, but will have a final crest elevation of 143.5 m. The base width of the dams will depend on the final height, but are expected to be on the order of 20 m. Of the five saddle dams, only Dam 4 and Dam 3 are in a position to potentially release either attenuation water, reclaim water, or tailings to Third Portage Lake in the event of a catastrophic failure.

Saddle Dam 4 is located at the northwest end of the Second Portage Lake Tailings Impoundment Area between the TIA and Third Portage Lake. The purpose of the Saddle Dam will be to allow additional storage capacity to be gained within the attenuation pond area during Years 1 to 4 of operations, and for management of reclaim water beginning in Year 5 until the end of the mine life.

Saddle Dam 3 is located along the west margin of the tailings facility, approximately two thirds of the distance between the Tailings Dike and the Attenuation/Reclaim Pond. The purpose of the dam is to allow additional capacity of the Tailings Impoundment Area to be gained over the life of the mine.

3.4.1 Failure Scenario During Operation

In the case of Saddle Dam 4 a breach or complete failure could result in the uncontrolled release of water to Third Portage Lake. In Year 1 to 4, the possibility of this event occurring is not credible for the expected site conditions because the water level will be below the base of the Saddle Dam. However, there is the possibility that additional attenuation water storage is required resulting in an attenuation pond surface elevation higher than currently predicted. In this situation, water would be ponded against Saddle Dam 4. Under these extraordinary conditions, the water would consist of mine runoff that is currently predicted to meet discharge requirements. Some particle entrainment may occur from water flowing over or through the breached dike; however the effects caused by this are considered to be minor.

In the case of Saddle Dam 3 failure could potentially result in flow of tailings toward Third Portage Lake. This scenario is only credible if the tailings are not frozen.

Potential Effect

Should the breach occur after Year 5 during operation, water flowing into Third Portage Lake would consist of tailing reclaim water which is predicted to exceed MMER guidelines for a number of constituents. As a worst case, a maximum volume of 2 Mm^3 of tailing water could be released to Third Portage Lake. Impacts to water quality and fish would be very localized and short lived.

In the case of Saddle Dam 3, a worst case scenario would involve the flow of non-frozen tailings into Third Portage Lake. Such a scenario would destroy fish habitat and smother benthic habitat outwards from the failure area. Suspended solids and dissolved metals would increase in the water column and would cause displacement of fish and possible toxicity of some bottom sediments, depending on how much tailings material was lost.

Mitigation, Management, and Monitoring

The Saddle Dams will have minimum crest width of 10 m. The base width for the dams will be on the order of 20 m, although this will vary with height, and will therefore be inherently stable. The height of the dams is expected to be on the order of 6 m to 8 m. The dams will be designed according to Canadian Dam Association guidelines. The dams will be constructed under controlled conditions. During the construction of the dams a comprehensive quality control and quality assurance program would be undertaken to confirm foundation conditions, material type and quality, and to adjust designs as necessary to reflect actual or unexpected conditions found during construction. The dams will eventually freeze, which will enhance stability. Therefore, failure of the Saddle Dams by full breaching or foundation and slope failure is not considered to be credible.

In the case of Saddle Dam 4, the maximum volume of water that could be released into Third Portage Lake by a complete failure would be approximately 2 Mm^3 assuming that the pond is completely full. Hydrological modelling of average conditions indicates, however, that the pond capacity does not exceed the capacity of the natural basin in Years 1 to 5 (i.e., no water would be released by a breach). As stated failure of the dam is not considered to be credible.

In the case of Saddle Dam 3 there is a negligible risk that the tailings would reach Third Portage Lake because the tailings will be deposited in thin layers which will freeze annually and will not flow. Tailings will be deposited from east to west, and from south to north (i.e. from the southwest edge of the TIA) so that reclaim water will be managed away from the Saddle Dam. Consequently, only dry tailings will be against the face of Saddle Dam 3. The distance from Saddle Dam 3 to Third Portage Lake is about 150 m at its closest point. If the tailings are not frozen, assuming an angle of runout of 6 degrees, tailings would flow approximately 95 m and hence would never reach Third Portage Lake. Furthermore, the access road to the mine site crosses between Third Portage Lake and the tailings facility. This could potentially act as a secondary barrier to flow if necessary, as it will likely be a minimum of 2 m above existing ground surface through this area.

3.4.2 Failure Scenario Post-Closure

In the case of Saddle Dam 4, at closure reclaim pond water will be pumped to the treatment plant, the basin behind the Saddle Dam will be drained and filled with run-of-mine, acid-buffering ultramafic waste rock which would freeze over time. Failure of Saddle Dam 4 is not considered to be credible.

Potential Effect

The waste rock behind the Saddle Dam will be essentially dry and will eventually freeze. No effects to water quality, fish or fish habitat is expected.

Mitigation, Management, and Monitoring

As described previously, the dams will be designed according to Canadian Dam Association guidelines. The dams will be constructed under controlled conditions. During the construction of the dams a comprehensive quality control and quality assurance program would be undertaken to confirm foundation conditions, material type and quality, and to adjust designs as necessary to reflect actual or unexpected conditions found during construction. The dams will eventually freeze, which will enhance stability. Therefore, failure of the Saddle Dams by full breaching or foundation and slope failure is not considered to be credible.

3.5 Stormwater Dike

The Stormwater Dike is located at the northwest end of the Second Portage Lake, through the deepest area of the Northwest Basin. The location of the Stormwater Dike was selected to optimize the storage capacity of the main tailings basin, and of the attenuation storage pond. The dike will separate the tailings basin from the attenuation storage pond during Years 1 through 4 of operations. After Year 4, the basin will be used to manage reclaim water. At the end of mine life, the remaining reclaim water will be treated and released once discharge criteria are met. The emptied basin will be filled with non-acid generating ultramafic rock, and will eventually freeze.

The Stormwater Dike will be constructed using rockfill and will have a trapezoidal cross section, with a 10 m crest width (see Figure 10). The dike will have a compacted till core. A filter zone will be placed on both the upstream and downstream sides of the till core to transition between the till and the coarse rockfill. The maximum cross section height of the dike will be about 23.5 m with a final crest elevation of 143.5 m. At the maximum cross section, the width of the base of the dike will be approximately 95 m.

3.5.1 Failure Scenario During Operation

If slope failure of the Stormwater Dike were to occur when tailings are at their maximum elevation, and if the tailings are not frozen, this could potentially result in the sudden release of tailings into the reclaim pond area causing the development of a wave that could potentially overtop Saddle Dam 4 causing it to fail and releasing tailings and reclaim water to Third Portage Lake.

Potential Effect

A breach or failure of the Stormwater Dike may cause a wave-induced overtopping of the Saddle Dam 4, although this is not expected to release a considerable volume of water to Third Portage Lake. The volume of water released would be limited to that present above 134 meters in elevation (height of the Saddle Dam). Tailings are not expected to “flow” out of the impoundment because they will be deposited in thin lifts in the TIA to enhance the annual rate of freezing. The potential impacts on Third Portage Lake water quality, fish and fish habitat would likely be minor, very localized and short-lived.

Mitigation, Management, and Monitoring

The dike will be designed according to Canadian Dam Association guidelines. The dike will be constructed under controlled conditions. During the construction of the dike a comprehensive quality control and quality assurance program would be undertaken to confirm foundation conditions, material type and quality, and to adjust designs as necessary to reflect actual or unexpected conditions found during construction. The dike will eventually freeze, which will enhance stability. Failure of the dike is not considered to be credible.

3.5.2 Failure Scenario Post-Closure

Upon completion of mining, the remaining reclaim water in the reclaim pond will be treated and released once discharge criteria are met. The emptied basin will be backfilled with non-acid generating ultramafic rock, and will eventually freeze.

Potential Effect

There will be no environmental effect on the receiving environment.

Mitigation, Management, and Monitoring

The dike will be designed according to Canadian Dam Association guidelines. The dike will be constructed under controlled conditions. During the construction of the dike a comprehensive quality control and quality assurance program would be undertaken to confirm foundation conditions, material type and quality, and to adjust designs as necessary to reflect actual or unexpected conditions found during construction. The

Stormwater Dike will have frozen rock on its north side, and frozen tailings on its south side after the completion of mining. Consequently, structural failure of the dike is not considered to be credible.

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