SUPPORTING DOCUMENT 18

GIANT MINE
RISK ASSESSMENTS FOR PHASE 2 ALTERNATIVES

SUPPORTING DOCUMENT 18

GIANT MINE
RISK ASSESSMENTS FOR PHASE 2 ALTERNATIVES

Prepared for:

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
PreCambrian Building
Suite 500, 4920 52nd Street
Yellowknife, NT
X1A 3T1

Prepared by:

STEFFEN ROBERTSON AND KIRSTEN (CANADA) INC.
Suite 800, 580 Hornby Street
Vancouver, B.C. V6C 3B6
Tel: (604) 681-4196 • Fax: (604) 687-5532
E-mail: vancouver@srk.com Web site: www.srk.com

DECEMBER 2002

SUPPORTING DOCUMENT 18

GIANT MINE
RISK ASSESSMENTS FOR PHASE 2 ALTERNATIVES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

SUPPORTING DOCUMENT 18

GIANT MINE
RISK ASSESSMENTS FOR PHASE 2 ALTERNATIVES

1. RISK CATEGORIES

A risk analysis was completed to evaluate the probability of significant arsenic discharges under each alternative. For each of the Phase 2 alternatives, three categories of risk were considered:

- Short-term risk – The risk that a quantity of arsenic sufficient to affect ecological or human health could be released to the receiving environment during the preparation or implementation phase of each alternative;

- Long-term risk – The risk that a quantity of arsenic sufficient to affect ecological or human health could be released to the receiving environment from the site after complete implementation of each alternative, within a period of 500 years after implementation.

- Worker health and safety risks – The conventional safety risks and the arsenic-related health risks that would be faced by workers active in the preparation, implementation, and post-implementation activities.

For the first two categories, probabilities of arsenic release were estimated and then converted to qualitative expressions of risk using the guidelines shown in Table 1. For the third category, the qualitative terms were used throughout.

TABLE 1
Terminology used for Short-Term and Long-Term Risks

Qualitative Term	Typical Risk of Significant Arsenic Release
High	≥ 1 in 100
Moderate	≥1 in 1000
Low	> 1 in 10,000
Very Low	≤ 1 in 10,000

2. RISKS OF ARSENIC RELEASE IN SHORT TERM

To assess the short-term risks associated with each alternative, it was assumed that a single release of 1000 kg or more of arsenic would be significant in terms of environmental or human health effects. Attachment 1 provides a human health and ecological risk assessment to support this assumption.

The preparation and implementation activities required under each alternative were then listed, and the probability of a significant arsenic release from each activity was estimated. To derive the probability estimates, it was assumed that each of the individual activities in each alternative would be designed and carried out in keeping with the state of the art. The resulting estimates are shown in Table 2.

Table 2 also shows the total probability of a significant arsenic release in the short-term. Working backwards through the tables, the major sources of risk can be identified:

- The low and low to moderate risks of short-term arsenic release under Alternatives A and B arise primarily from the potential for a spill from the water treatment sludge line or sludge pond. The risks are slightly higher under Alternatives A1 through A3 because the water being treated will contain much higher concentrations of arsenic than the water being treated in Alternatives B2 or B3.
- The low to moderate risks associated with Alternatives C, F and G1 arise from the potential for spills or releases during the dust extraction process. Since most of the extraction and dust transport will be underground in Alternative C, risks are slightly lower that those for Alternatives F and G1.
- The highest short-term risks are under Alternative D, and arise from the off-site transportation of dust to a secure disposal area. Shipment of the arsenic dust off-site to Edmonton would require approximately 12,000 trucks driving approximately 1500 kilometres, or approximately 20 million vehicle-kilometres. Traffic statistics show that fatal accidents occur once every 200 million to 400 million vehicle-kilometres. Using those statistics, the risk of a fatal accident involving one of the arsenic-bearing trucks would be roughly 0.5% to 1%. The additional safety and training requirements associated with the shipment of hazardous materials would lead to a reduction in those values. On the other hand, non-fatal accidents (for which no statistics were found) could cause significant release of arsenic. The rough estimates were therefore adopted.

TABLE 2
Risks of Arsenic Release in Short Term

Alternative	Estimated Probability of Arsenic Release >1000 kg				Total Probability of Arsenic Release >1000 kg	Risk	
	Dust Extraction	Dust Transportation	Dust Processing & Water Treatment	Residue Disposal			
A1	n/a	n/a	0.0001	0.0001	0.0002	1 in 5000	Low - Moderate
A2	n/a	n/a	0.0001	0.0001	0.0002	1 in 5000	Low - Moderate
A3	n/a	n/a	0.0001	0.0001	0.0002	1 in 5000	Low - Moderate
B2	n/a	n/a	0.00005	0.00005	0.0001	1 in 10000	Very Low
B3	n/a	n/a	0.00005	0.00005	0.0001	1 in 10000	Very Low
C	0.0001	0.0001	0.0001	0.00001	0.00031	1 in 3000	Low - Moderate
D	0.0001	0.01	0.0001	0.00001	0.01021	1 in 100	High
F	0.0001	0.001	0.0001	0.00001	0.00121	1 in 1000	Moderate
G1	0.0001	0.001	0.0001	0.00001	0.00121	1 in 1000	Moderate

Prepared by: DEH
Checked by: DBM

3. RISKS OF ARSENIC RELEASE IN LONG TERM

The results of the ecological and human health risk assessments presented in Chapter 4 and Supporting Document 6, suggest that there would be no human health impacts and minimal ecological impacts even at arsenic release rates higher than 4000 kg per year. To err on the side of caution in the alternatives assessment, a long-term release of 4000 kg per year was assumed to be significant.

The rates of long-term arsenic release under each alternative were predicted through a series of calculations that are presented in detail in Supporting Document 17. All of the alternatives are expected to keep arsenic releases to about half of the current rates, *i.e.* to less than 500 kg per year, when they function as intended.

However, a lack of maintenance or site supervision would eventually result in significantly higher arsenic release rates under most of the alternatives. To assess those risks, three cases were considered for each alternative:

- A one-year failure of the water collection and treatment system, for example due to significant mechanical failures;
- A ten-year failure of the water treatment system and other site maintenance activities, for example due to a major war interrupting federal funding.
- A 100-year failure of all of the site maintenance and operation functions, including water collection, treatment and site security, for example due to a complete collapse of civil order and government.

Each type of failure was then assigned a probability. The probability of a one-year failure was estimated at 0.04, based on an assumption that significant breakdowns of such systems could arise once every 25 years. The probability that there would be ten consecutive years without maintenance of the site was estimated to be 0.005 or one in 200. The reasoning in that case was that North America has not seen a major war since the 1860's, roughly 200 years ago. The probability of a complete collapse of governance was assumed to be 0.005, or one in 2,000, based on the record of near continuous civil governance of western societies for the last two millenia.

The rates of arsenic release for each alternative under each of the above cases was then estimated. The overall probability of a significant long-term arsenic release under each alternative was obtained by summing all of the cases where the arsenic release rate is predicted to exceed 4000 kg/yr.

The estimates are summarized in Table 3. The last column of the table shows the overall long-term risks associated each alternative. The major sources of risk can be identified as follows:

- The long-term risks associated with Alternative A are high because of the reliance on perpetual pumping to collect highly contaminated water. Alternative A1 has a particularly high long-term risk, because the minimal drawdown means that contaminated water could escape the site if there is even a one-year failure of the water collection and treatment system. Alternatives A2 and A3 pose lower risks because, in the event of a collections system failure, the groundwater table would take several years to recover before any contaminated water would leave site.

- Alternative B2 and B3 pose lower long term risks because the ground around the arsenic trioxide dust would remain frozen for many years, even without intervention. In the case of Alternative B3, the large volume of the frozen block would keep the dust isolated for many decades. (That effect is described in Supporting Document 9).

- Alternative C poses very low long term risks because dust in the deep disposal vaults would effectively be isolated from all contact with the ecosphere.

- The low and very low long-term risks from Alternatives D, F and G1 are associated with the requirement for collection and treatment of leachate from residue disposal areas, and the differences among the three arise from differences in the stability of the residues. Alternative G1 produces a less stable residue than Alternative F, and therefore poses a slightly higher long-term risk.

TABLE 3
Risks of Arsenic Release in Long Term

Alternative	Estimated Arsenic Release Rates (kg/yr)				Total Probability of Arsenic Release > 2000 kg/yr	Risk	
	As Designed	If 1-Year Failure (P=0.04)	If 10-Year Failure (P=0.005)	If 100-Year Failure (P=0.0005)			
A1	493	16000	16000	16000	0.0455	1 in 20	High
A2	542	450	16000	16000	0.0055	1 in 200	Moderate
A3	541	450	16000	16000	0.0055	1 in 200	Moderate
B2	493	1500	1500	5000	0.0005	1 in 2000	Low
B3	493	1500	1500	5000	0.0005	1 in 2000	Low
C	494	1500	1500	2000	<<0.0005	<<1 in 2000	Very Low
D	494	1500	1500	1500	<<0.0005	<<1 in 2000	Very Low
F	497	1500	1500	2000	<<0.0005	<<1 in 2000	Very Low
G1	538	1500	2500	5000	0.0005	1 in 2000	Low

Prepared by: DEH
Checked by: DBM

4. WORKER HEALTH AND SAFETY RISKS

A qualitative worker health and safety risk assessment was completed to consider the conventional risks (*i.e.* industrial accident risks) and arsenic exposure risks to workers involved in each of the alternatives. Risks were characterized by interviewing engineers familiar with major steps in each alternative and subjectively rating risks as "high", "moderate", or "low", with the categories assumed to refer to conditions typical of the mining industry.

To facilitate the risk analysis process, the activities required under the various Phase 2 alternatives were grouped as follows:

- Drilling and installation of wells and/or freezing systems
- Dust extraction and transport
- Dust processing
- Water treatment
- Residue disposal.

A simple system of "low", "moderate" and "high" risk qualifiers was selected to be used. The results of the analysis are summarized in Table 4. The following conclusions can be drawn:

- Alternatives A and B present the lowest risk to the worker health and safety due to the limited exposure of the workers to both conventional and arsenic risks.

- Alternatives C, D, F and G1 require handling of the arsenic trioxide dust in confined underground conditions, which is the main contributor to the higher worker health and safety risks.

TABLE 4
Results of the Workers Health and Safety Risk Analysis

Alternative	Conventional Risk of Each Activity					Arsenic Exposure Risks of Each Activity					Overall Worker Risk
	Drilling & Installations	Dust Extraction & Transport	Dust Processing	Water Treatment	Residue Disposal	Drilling & Installations	Dust Extraction & Transport	Dust Processing	Water Treatment	Residue Disposal	
A1	Low	n/a	n/a	Low	Low	Low	n/a	n/a	Low	Low	Low
A2	Low	n/a	n/a	Low	Low	Low	n/a	n/a	Low	Low	Low
A3	Low	n/a	n/a	Low	Low	Low	n/a	n/a	Low	Low	Low
B2	Low	n/a	n/a	Low	Low	Low	n/a	n/a	Low	Low	Low
B3	Low	n/a	n/a	Low	Low	Low	n/a	n/a	Low	Low	Low
C	Low	Moderate	n/a	Low	Low	Low	Moderate	n/a	Low	Low	Moderate
D	Low	Moderate	Low	Low	Low	Low	Moderate	Moderate	Low	Low	Moderate
F	Low	Moderate	Low	Low	Low	Low	Moderate	Moderate	Low	Low	Moderate
G1	Low	Moderate	Low	Low	Low	Low	Moderate	Moderate	Low	Low	Moderate

5. SUMMARY

Table 5 presents a summary of the risks associated with each of the Phase 2 alternatives.

TABLE 5
Summary of Risk Assessment for Phase 2 Alternatives

Alternative	**Probability of Significant Arsenic Release**		**Worker Health & Safety Risk**
	Short Term	Long Term	
A1. Water Treatment with Minimum Control	Low	High	Low
A2. Water Treatment with Drawdown	Low	Moderate	Low
A3. Water Treatment with Seepage Control	Low	Moderate	Low
B2. Passive Ground Freezing	Very Low	Low	Low
B3. Active Ground Freezing	Very Low	Low	Low
C. Deep Disposal	Low	Very Low	Moderate
D. Removal & Surface Disposal	High	Very Low	Moderate
F. Removal, Au Recovery & As Stabilization	Moderate	Very Low	Moderate
G1. Removal & Cement Stabilization	Moderate	Low	Moderate

This report, **Risk Assessment of Phase 2 Alternatives,** was prepared by:

STEFFEN ROBERTSON AND KIRSTEN (CANADA) INC.

Daryl Hockley, P.Eng.
Principal

APPENDIX A

Assessment of Spill Risks

SENES Consultants Limited

MEMORANDUM

TO:	Daryl Hockley	33100
FROM:	Bruce Halbert	19 September 2002
SUBJ:	Giant Mine Risk Assessment Consequences of a Spill of Arsenic Trioxide to Back Bay	

In August of this year we submitted our draft report entitled "Tier 2 Risk Assessment for Management of Arsenic Trioxide Dust, Giant Mine". That assessment addressed issues related to ecological and human health risks posed by long-term releases of arsenic to the environment from the Giant Mine site, as well as, the risks posed by historic levels in the aquatic and terrestrial environments in the Yellowknife study area. In addition to the above, we were asked to assess the potential consequences of an accidental spill of arsenic dust to Baker Creek. This memorandum documents the results of that assessment.

The simulation of a one-time dissolved arsenic spill in Baker Creek was carried out to evaluate the impact on Back Bay and North Yellowknife Bay water quality. A spill size of 2000 kg arsenic reaching the bay in one day was assumed. For the purpose of the spill simulation, the Back Bay area was partitioned as shown previously in Figure 1. Segment 1A comprises a relatively small area adjacent to Baker Creek outlet. This segment is affected most severely by the spill. Segment 1B is the southern part of Back Bay near the City of Yellowknife. Segment 1C is the central and northern part of Back Bay. This is the largest segment located between the source of the spill and North Yellowknife Bay (Segment 2).

Dispersive mass transport was evaluated as outlined in the LAKEVIEW model detailed in Appendix B of our August 2002 draft report. The parameter values used in the spill assessment are summarized Table 1. A baseline load of approximately 3 kg/d arsenic was used as the steady state load to the Bay via Baker Creek. The total volume and the total surface area of the Back Bay segments and North Yellowknife Bay were identical with those used in calibrating the model and subsequent simulations detailed in the August 2002 report. Based on the model calibration work discussed in Appendix B, a freshwater inflow to Segment 1C from North Yellowknife Bay (Segment 2) equal to 30% of the Yellowknife River flow into Segment 2 was applied. This flow intrusion was extrapolated to Segment 1A and Segment 1B on the basis of the ratio of the segment areas. The remaining parameters including the calibrated physical and chemical characteristics of the sediment were identical to those used in other simulations.

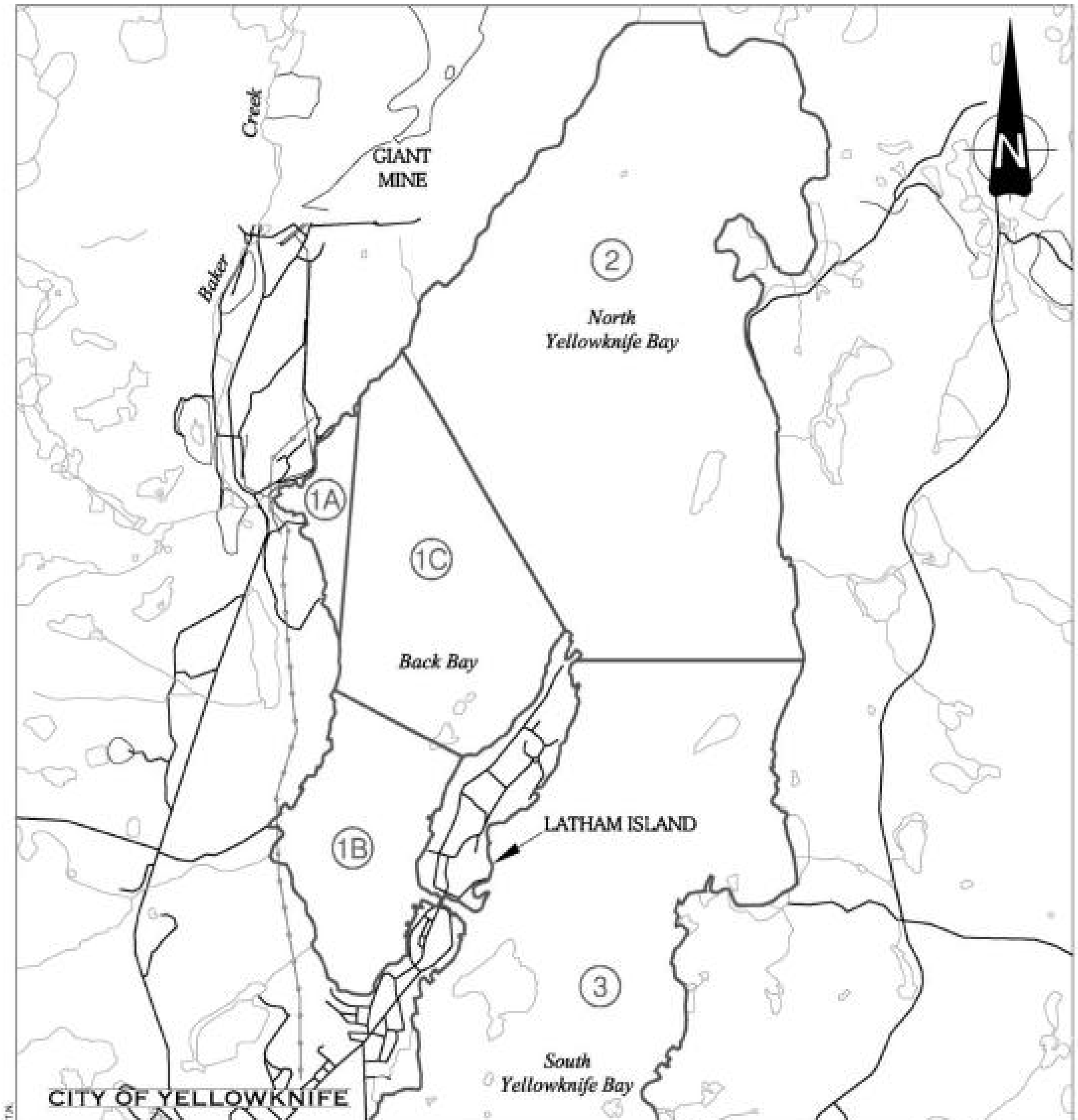

FIGURE 1

BACK BAY SEGMENTS FOR
SPILL ASSESSMENT

TABLE 1
PARAMETER VALUES FOR BACK BAY SPILL ASSESSMENT

Parameter Symbol	Description	Units	Nominal Value
W_i	Arsenic Loading via Baker Creek - Base Line load - Arsenic Spill Size	 kg/d kg	 3.0 2000.0
V_i	Volume of Lake Segment: - Segment 1A: Back Bay - Segment 1B: Back Bay - Segment 1C: Back Bay - Segment 2: Yellowknife Bay	 m^3 m^3 m^3 m^3	 $7.24 x10^5$ $5.24 x10^6$ 1.14×10^7 $4.40 x10^7$
z_i	Mean Depth of Segment: - Segment 1A: Back Bay - Segment 1B: Back Bay - Segment 1C: Back Bay - Segment 2: Yellowknife Bay	 m m m m	 3.3 5.9 11.7 8.3
A_i	Surface Area of Segment: - Segment 1A: Back Bay - Segment 1B: Back Bay - Segment 1C: Back Bay - Segment 2: Yellowknife Bay	 km^2 km^2 km^2 km^2	 0.219 0.887 0.972 5.301
λ	Distance Between Segment Midpoints: - Segment 1A and 1C - Segment 1B and 1C - Segment 1C and 2	 km km km	 0.857 0.540 1.365
A_j	Cross-sectional Area Between Segments: - Segment 1A and 1C - Segment 1B and 1C - Segment 1C and 2	 m^2 m^2 m^2	 4.785×10^3 4.522×10^3 1.814×10^4
Q_j	Freshwater Inflow to Segment: - Baker Creek - Segment 1A Back Bay * - Segment 1B Back Bay ** - Segment 1C Back Bay ***	 m^3/d m^3/d m^3/d m^3/d	 1.59×10^4 1.15×10^5 4.02×10^5 9.41×10^5
k_D	Solid-to-Liquid Partition Coefficient - Sediment - Suspended Biosolids - Iron hydroxide	 m^3/kg m^3/kg m^3/kg	 0.5 2.5 5.0
ε	Porosity of Lake Sediment	-	0.85
v_i	solids settling velocity in water column	m/yr	25
?	Sediment Dry Density	kg/m^3	1,500
z_j	Thickness of Sediment Exchange Zone	m	0.03

* Flow = 15,900 m^3/d from Baker Creek and 99,170 m^3/d from Segment 1C.
** Flow = 402,000 m^3/d from Segment 1C.
*** Flow = 941,000 m^3/d from North Yellowknife Bay and Baker Creek.

Model calibration for the spill assessment involved the estimation of "baseline" concentrations in each of the segments corresponding to a steady 3 kg/d load. These concentrations served as initial concentrations before the spill occurred as well as final concentrations approached after the spill effects subsided. Calculations were carried out for 90 days following the spill using a nominal time step size of 0.1 day.

Arsenic concentrations in surface water near the mouth of Baker Creek would be in excess of 125 mg/L (125,000 µg/L) immediately after the spill. However, this concentration peak is expected to dissipate rapidly. The time course of the impact at the midpoint of each segment is shown in Figure 2. In addition, the baseline and the peak concentrations at the midpoints of each segment are summarized in Table 2. A maximum value of nearly 1,800 µg/L is predicted at the midpoint in Segment 1A two days after the spill. The main direction of contaminant flow is toward Yellowknife Bay. In central Back Bay (Segment 1C), a peak concentration of 71.5 µg/L is predicted approximately one week after the spill. By the time the spill reaches North Yellowknife Bay, the arsenic concentration is greatly attenuated. Maximum contaminant levels of 12.7 µg/L are expected around day 18 at this location. The southern part of Back Bay (Segment 1B) is off the main direction of contaminant flow. The primary means of contaminant transport into this region is via dispersion from Segment 1C. For this reason, the peak concentration is expected to be slightly less (10.9 µg/L) in spite of being physically closer to Baker Creek than North Yellowknife Bay.

In contrast to the predicted effects on surface water quality, the expected impact on the sediment porewater is marginal and probably not measurable. This is because of the short duration of the spill and the rapid dispersion of the contaminant over the entire study region. Similarly, the solid phase arsenic concentrations are not expected to change significantly. As shown in Figure 2, the spill is expected to influence the study area for less than 3 months. By the end of 3 months, the concentrations in the entire study area are predicted to return to their baseline level.

TABLE 2
BASELINE AND PEAK ARSENIC CONCENTRATIONS IN BACK BAY AND NORTH YELLOWKNIFE BAY

Bay Segment	Surface Water		Sediment Porewater	
	Baseline (mg/L)	**Peak (mg/L)**	**Baseline (mg/L)**	**Peak (mg/L)**
1A	29.0	1,770	175	178
1B	2.1	10.9	15.7	15.7
1C	7.0	71.5	47.0	49.3
2	2.0	12.7	15.7	15.7

FIGURE 2
TIME COURSE OF SPILL IMPACT IN BACK BAY AND YELLOWKNIFE BAY