SUPPORTING DOCUMENT 17

GIANT MINE
ESTIMATES OF ARSENIC RELEASE

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ARSENIC RELEASE ESTIMATES

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ARSENIC RELEASE ESTIMATES

1. INTRODUCTION

This report presents estimates of arsenic release to surface or groundwater for the existing surface sources (current and post-closure), and for each of the management alternatives presented in Section 4 of the accompanying report. For each alternative, long-term arsenic release is estimated for the underground sources (arsenic chambers, tailings backfill, waste rock backfill, and bedrock and mine workings), seepage from existing surface sources that is captured by the underground workings (tailings ponds, polishing pond, open pits, contaminated soils), and any surface sources that would result from water treatment and/or stabilization of the arsenic trioxide dust (treatment plant sludges, autoclave stabilized dust, bitumen stabilized dust, or cement stabilized dust).

The arsenic releases from most of the sources would be sent to a water treatment plant prior to discharge. In those cases, the arsenic released to the receiving environment has been estimated based on the treatment efficiencies presented in Senes (2001), (Supporting Document 8). In a few of the alternatives (e.g. the freezing alternative), water treatment would stop once residual arsenic loading in the mine reaches acceptable levels. Therefore, the long-term arsenic releases are assumed to be discharged directly to the receiving environment.

With the exception of estimates made for current conditions, all of the arsenic release estimates reflect long-term post-closure conditions, after the management alternatives have been implemented. "Long-term" conditions are assumed to be reached when the "medium-term" flushing and extraction of residual arsenic from around the chambers and stopes is complete, and arsenic concentrations in those areas are similar to those in the remainder of the flooded mine.

The report is organized as follows:

- Chapter 2 presents a water and load balance for the surface arsenic releases, under current and post-closure conditions.
- Chapter 3 presents the estimates of arsenic release associated with each of the management alternatives.
- Chapter 4 presents arsenic release from the treatment plant.
- Chapter 5 presents an overall summary of the loading estimates.

2. SURFACE SOURCES

An estimate of the current arsenic releases to Baker Creek from surface components of the mine can be made by calculating the total amount of arsenic observed at the mouth of Baker Creek, and subtracting the amount observed in the treatment plant effluent and in Baker Creek upstream of the point of discharge. These calculations are presented in Table 2.1. As shown in the table, the total amount measured at the mouth of Baker Creek was approximately 1096 kg/yr. Approximately 288 kg/yr of this was from surface runoff from upstream of the mine, and approximately 432 kg/yr occurred as effluent from the treatment plant. Therefore, the current arsenic release from all surface sources at the mine is estimated to be on the order of 376 kg/yr.

TABLE 2.1
Overall Arsenic Mass Balance

Sources	**Flow (m3)**	**Concentration. (mg/L)**	**Current Arsenic releases in and to Baker Creek (kg/yr)**
Mouth of Baker Creek	5,770,000	0.19	1096
Treatment Plant Effluent (2001 data)	1,100,000	0.4	432
Surface Runoff from Watershed (upstream of mine)	5,770,000		288
Calculated Arsenic release from Surface Sources	na		376

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Surface remediation measures presented in the Abandonment and Restoration Plan (Golder 2001) will reduce the amount of arsenic loading from the surface sources. To evaluate the potential magnitude of the reduction, it is necessary to apportion this amount between the different sources, and then evaluate the effect of the remediation options. These calculations were completed as part of the Abandonment and Restoration Plan (Golder 2001). However, they were based on somewhat different assumptions of background loading, tailings seepage, and source concentrations, and included loading from the underground mine and treatment plant. A simplified version of the calculations was therefore developed for use in evaluating the effectiveness of the surface remedial options on the surface arsenic releases. The calculations were modified for consistency with the assumptions used in the underground calculations, and calibrated to reflect current arsenic releases observed in the treatment plant and Baker Creek. Results are presented for current surface conditions and for future post-closure conditions, assuming the remediation measured described in the Abandonment and Restoration plan (Golder 2001) will be implemented. The resulting estimates of arsenic release must be added to the amounts originating from each mine alternative.

Arsenic releases were estimated by multiplying the footprint areas for each source by a runoff coefficient and the total precipitation to give the flow for each minesite component, and then multiplying the resulting flows by source concentrations. Flows from the Northwest Tailings Pond were considered to be a special case because of the pond, and were estimated based on a preliminary water balance on the pond. The water balance indicated that total flows from the impoundment are approximately 700 m^3/day. Flows from the older tailings areas were handled by assuming an infiltration coefficient and multiplying this by the total precipitation. In all of the tailings areas, the total releases were calculated, and then divided this into the amounts that would infiltrate to the underground workings, the amounts that would seep laterally through the dams and the amount of lateral seepage that would reach the polishing pond. However, because arsenic releases to the underground are handled in the underground calculations (Section 3.2), they are set to zero in these calculations. Any surface runoff reporting to the polishing pond was assumed to be treated at an 84.1% rate of efficiency. Although the Golder calculations assumed all of the loading was to Yellowknife Bay, our current calculations conservatively assume that all of the loading will enter Baker Creek before entering Yellowknife Bay.

General assumptions used in the calculations are presented in Table 2.2. As indicated in the table, the only change in the basic assumptions between the current conditions and the post-closure conditions is to the tailings infiltration coefficient. This value is reduced to 3% based on the assumption that a low permeability cover would be constructed over the tailings (Golder 2001).

TABLE 2.2
General Calculation Assumptions

Parameter	**Units**	**Current Conditions**	**Post-Closure**
Mean annual precipitation	mm/yr	276	276
Runoff coefficient		40%	40%
Runoff rate	mm/yr	110	110
	L m-2 yr-1	110	110
Tailings infiltration coefficient*		15%	3%
Tailings infiltration rate	mm/yr	41	8.3
	L m-2 yr-1	41	8.3
Sludge & settling pond removal		84%	84%

* As explained in the text, a water balance was used to derive flows from the Northwest Pond

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Component specific assumptions are presented in Table 2.3. The footprint areas were taken directly from Golder (2001). Flows were calculated using these areas and the assumptions discussed above. The source concentrations for the Northwest tailings area and the contaminated soils (>350 ppm) were adjusted until the estimated releases for the current conditions model were approximately equal to the releases currently observed in Baker Creek (Table 5.1). Both the current and post-closure assumptions are presented in Table 2.3. Where there was a change resulting from one of the remedial measures presented in Golder (2001), the change is highlighted in bold text. The adjustments reflect the following remedial actions:

- The Northwest pond would be drained, and covered with a low permeability cover.
- Heavily contaminated soil would be consolidated in the Northwest Tailings Impoundment. This will reduce the footprint area and therefore flow.
- The Tailings spills, the older tailings areas, and the beached Back Bay tailings would be covered, reducing the infiltration to 3%.

The effectiveness of these remedial actions will depend on a number of design conditions. The Golder numbers were used without detailed review.

TABLE 2.3
Component Specific Assumptions

Component	Footprint Area (ha)	Flow (m3/yr)	Source Conc. (mg/L)	Release to UG Mine (%)	Direct Release (%)	Release to Polishing Pond (%)
Current Conditions						
Northwest Tailings	45.7	255,500	2	57	30.1	12.9
Contaminated Soil (>350 ppm)	26	28,704	3	0	100	0
Contaminated Soil (<350 ppm)	420	463,680	0.1	0	100	0
Tailings Spills	30	12,420	1	0	100	0
Older Tailings Areas	49.9	20,658	4.4	9	48	43
Beached Back Bay Tailings	5	2,070	0.05	0	100	0
Post-Closure						
Northwest Tailings	45.7	**3,784**	2	57	30.1	12.9
Contaminated Soil (>350 ppm)	**3**	**3,312**	3	0	100	0
Contaminated Soil (<350 ppm)	420	463,680	0.1	0	100	0
Tailings Spills	30	**2,484**	1	0	100	0
Older Tailings Areas	49.9	**4,132**	4.4	9	48	43
Beached Backbay Tailings	5	**414**	0.05	0	100	0

Notes: **Bold** values indicate there is a change in the post-closure assumptions resulting from a remedial action

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The estimates of arsenic release from surface sources are summarized in Table 2.4, with details provided in Appendix A. As indicated above, the mass balance was calibrated by adjusting the source concentrations. Therefore, the total arsenic mass from the surface sources is intended to match closely with the observed mass. The single largest sources are the Northwest Tailing Pond and the more heavily contaminated soils. There is considerable uncertainty in the arsenic releases from each of these areas. However, for the purposes of this assessment, this uncertainty is not important because both of those sources will be cleaned up substantially following reclamation.

In the risk assessment, the post-closure arsenic releases in Table 2.4 will need to be added to the arsenic released for each of the arsenic trioxide management alternatives to give the total release from the mine. The background release rate of 288 kg/yr (Table 2.1) must be added to this to give the total release to the receiving environment following implementation of the surface closure measures.

TABLE 2.4

Arsenic Releases from Surface Sources under Current and Post-Closure Conditions

Sources	**Arsenic Release to Receiving Environment**	
	Current (kg/yr)	**Post-Closure (kg/yr)**
Surface Sources		
'Northwest Tailings Pond	164	2
'Minesite Soil > 350 mg/kg Arsenic	86	10
'Minesite Soil < 350 mg/kg Arsenic	46	46
'Tailings spills	12	2.5
'Old Tailings Area	50	10
'Beached Back Bay Tailings	0.10	0.02
Total	**359**	**71***
Observed Release from Surface Sources (from Table 2.1)	**376**	na

* This must be added to the background load of 288 kg/year to give the total post closure load from the surface sources (i.e. 359 kg/year).

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3. ARSENIC RELEASE RESULTING FROM ARSENIC TRIOXIDE MANAGEMENT ALTERNATIVES

3.1 Overview of Arsenic Sources

The management alternatives are described in the Main Report. Table 3.1 lists the long-term arsenic sources associated with each management alternative. The sources can be divided into three groups:

- seepage from existing surface sources captured by the underground workings;
- underground sources; and,
- residues from the ex-situ Management Alternatives.

Estimates of arsenic release for the seepage captured by the workings, and for sources within the underground workings are presented in Section 3.2. Estimates of arsenic release from the arsenic residues are presented in Section 3.3.

3.2 Estimates of Arsenic Release from Underground Arsenic Sources

3.2.1 Calculation Method

Estimates of arsenic release for surface sources that are intercepted by the underground workings and for each of the underground sources were made by multiplying the vertical and lateral groundwater flows associated with each source (Supporting Document 2), by their corresponding arsenic concentrations (Supporting Documents 3, 4 and 5). The arsenic releases were then added together to give the total arsenic released to the underground workings.

Arsenic releases from any new arsenic chambers that would be constructed as part of the deep disposal alternative were handled in a separate set of calculations. Groundwater flow through the deep arsenic chambers is expected to be minimal due to the relatively low permeability of the deep bedrock, and the low hydraulic gradient, and the construction of bulkheads to limit flow through the chambers. A simple calculation to show the potential magnitude of arsenic loading from the deep chambers was completed as follows.

TABLE 3.1

Potential Long-Term Sources of Arsenic for Each Management Alternative

Alternatives		Arsenic Sources		
		Existing Surface Sources	Underground Sources	Surface Residues
A1	Collect and Treat (Minimum Control)	background tailings ponds open pits contaminated soils	arsenic chambers and stopes backfilled tailings and waste rock bedrock and mine walls water level 10 m below GSL	treatment plant sludges
A2	Collect and Treat (Maintain Drawdown)	as above	as above except water level at 425 Level	as above
A3	Collect and Treat (Control Seepage)	as above	as above	as above
B	Ground Freezing	as above	as above except arsenic chambers and stopes would be frozen and the mine would be reflooded to 10m below GSL	as above.
C	Removal and Deep Disposal	as above	as above except new arsenic chambers would be constructed at the 2000 level	as above
D	Removal and Disposal Off-Site	as above	backfilled tailings and waste rock bedrock and mine walls Mine would be reflooded to 10m below GSL	as above
E	Removal and Purification	as above	as above	as above
F	Removal and Pressure Oxidation	as above	as above	treatment plant sludges autoclave residues
G1	Removal and Cement Stabilization	as above	as above	treatment plant sludges cement stabilized residues
G2	Removal and Bitumen Stabilization	as above	as above	treatment plant sludges bitumen stabilized residues

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Checked by: DDS

- The total ditch flows to the 2000 Level workings were approximately 30 L/min. The chloride concentration of this water was roughly 10 x less than observed in the deep groundwater seepage, suggesting that only 10% of this water actually originated in the 2000 Level.

- The current hydraulic gradient between Great Slave Lake and the mine is 600/L, where L is the distance from the lake to the mine workings. The hydraulic gradient that would develop under fully reflooded conditions is only 6/L. Therefore, the gradient would be only 1% of the current gradient, and the groundwater inflows would be 1% of the current inflows.

- At a flow rate of 0.03 L/min, and an arsenic concentration of 5.6 to 9.6 g/L, this would result in a release of 90 to 150 kg/year from the deep chambers.

In using these estimates, it would be conservative to assume that all of this release would daylight in Baker Creek. However, due to the strong salinity of the deep groundwater, it is more likely that it would remain at depth, and that only a small portion would reach the receiving environment.

3.2.2 Flow Estimates

Details on the estimation of groundwater flows for each of the management scenarios are provided in Supporting Document 2. Table 3.2 provides a summary of the groundwater flows associated with each of the in-situ management alternatives. The flows associated with the ground freezing alternative are also used for estimating residual releases from the ex-situ alternatives where arsenic had been removed from the chambers and stopes, and the mine is fully reflooded.

Most of the flows in Table 3.2 were calculated based on the footprint or cross sectional area of the source (for vertical and lateral flows, respectively). However, there are few exceptions:

TABLE 3.2
Flows Associated with Each Management Alternative

Arsenic Sources	Current $(m^3/year)$	A1 Minimum Control $(m^3/year)$		A2 Maintain Drawdown $(m^3/year)$	A3 Control Seepage $(m^3/year)$	B Ground Freezing* $(m^3/year)$
		No bypass	Bypass			
Vertical Flow						
arsenic chambers and stopes	3,105	61	61	3,105	418	0
roaster tailing backfill	12,024	45	45	420	420	0
flotation tailings backfill	12,024	45	45	420	420	0
waste rock backfill	48,213	989	989	14,794	14,794	0
regional bedrock/mine walls	9,086	68,819	68,819	57,357	57,357	69,711
contaminated soil	14,342	14,342	14,342	14,342	14,342	14,342
South, Central and North Tailings Ponds	441	441	441	441	441	441
Northwest Pond	146,100	1,440	1,440	1,440	1,440	1,440
Settling Pond/Polishing Pond	5,281	5,281	5,281	5,281	5,281	5,281
Open Pits	40,782	40,782	40,782	40,782	40,782	40,782
Subtotal (Vertical)	**291,398**	**132,245**	**132,245**	**138,383**	**135,696**	**131,998**
Lateral Flow						
arsenic chambers and stopes	0	1,331	133	0	0	0
roaster tailing backfill	0	21,712	21,712	36,535	36,535	21,926
flotation tailings backfill	0	21,712	21,712	36,535	36,535	21,926
waste rock backfill	0	45,849	45,849	77,149	77,149	46,300
bedrock, mine workings	486,687	45,849	47,047	77,149	77,149	46,300
Subtotal (Lateral)	**486,687**	**136,453**	**136,453**	**227,368**	**227,368**	**136,453**
Total from Underground	**778,084**	**268,698**	**268,698**	**365,752**	**363,065**	**268,451**

Note: The estimates for ground freezing can be used for all of the ex-situ alternatives.

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1. Vertical flow through the arsenic chambers and stopes was increased to account for the relatively high arsenic releases observed in the underground water and load balance (Supporting Document 3). This increase only applies to the alternatives where the chambers and stopes are above the water table and where no additional seepage control measures are in place (i.e. current conditions and dewatering to the 425 Level). Proportional flows are used for the minimum control option where 3 of the chambers (11, 12 and 14) are above the final water level because these areas are relatively dry compared to the arsenic stopes. Under the seepage control alternative, the area overlying the stopes and chambers would be backfilled and covered to minimize the funnelling effect of the pits. Therefore proportional flows are also used for this alternative.

2. Flows through the arsenic chambers and stopes were set to zero in the ground freezing option to reflect isolation of the chambers from groundwater flow.

3. Vertical flow from the Northwest Tailings Pond was calculated based on a water balance of the tailings pond (Supporting Document 2), which indicated that approximately 700 m^3/day was lost to seepage. Based on the underground mass balance, it was estimated that approximately 400 m^3/day of this water infiltrates to the underground workings. Therefore, under current flow conditions, 400 m^3/day, or 146,000 m^3/year seeps from the Northwest Tailings Pond to the underground workings. Following reclamation of the surface facilities, the Northwest Tailings Pond will be drained, and covers will be installed. This will reduce the seepage to levels that are comparable to the other tailings areas. The infiltration rate through the Northwest pond is therefore reduced to 5% precipitation for all of the management alternatives.[1]

3.2.3 Source Concentrations

Source concentrations used in the predictions are based on data from the mine water sampling programs (Supporting Document 3), and solids testing programs (Supporting Documents 4 and 5), as well as information provided in the Abandonment and Restoration Plan (Golder 2001).

Source concentrations for the arsenic trioxide are summarized in Table 3.3. Source concentrations for unsaturated (current) conditions are based on the maximum concentrations observed at the face of the bulkheads (Supporting Document 3). Source concentrations for flooded conditions are based on the solubility tests completed by Canmet (Supporting Document 5). It should be noted that the source concentrations are sensitive to temperature. Therefore, a higher solubility has been assigned to saturated arsenic trioxide dust for the deep disposal option, where temperatures are likely to be closer to 10°C.

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[1] Note that the flows from the Northwest Pond have been reduced for the post-closure estimates of arsenic release only. Northwest Pond Flows presented in Supporting Document 2 are also used to support cost estimates for pumping during the medium-term treatment period, and were left at 400 m^3/day assuming the Northwest Pond would be used to store water from the mine.

TABLE 3.3
Source Concentrations for Arsenic Trioxide Dust

Source	Arsenic Concentration (g/L)	
	Unsaturated Conditions	Flooded Conditions
Arsenic Chambers (5°C)	4	4.7 to 9.0
Deep Disposal (10°C)	na	5.6 to 9.6

Source: Supporting Documents 3 and 5.

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Source concentrations for the other underground sources are summarized in Table 3.4. Source concentrations for unsaturated (current) conditions are based on seepage concentrations from known sources in the mine (Supporting Document 3). Source concentrations for flooded conditions are based on the leach extraction tests described under the solids testing programs (Supporting Document 4). These concentrations are appropriate for the first several pore volumes of water through the system. However, with the exception of the roaster tailings, concentrations in these other sources are expected to slowly decrease over time as stored oxidation products are flushed from the solids. As discussed in Supporting Document 4, the roaster tailings contain significant amounts of arsenic associated with secondary iron oxide minerals. Reductive dissolution of the iron oxides will provide a long term source of dissolved arsenic in the roaster tailings.

TABLE 3.4
Source Concentrations for Other Sources in the Underground Mine

Source	Arsenic Concentration (mg/L)	
	Unsaturated Conditions	Flooded Conditions
Backfilled Flotation Tailings	5	5
Backfilled Roaster Tailings	5	10
Backfilled Waste Rock	1.5	1.5
Bedrock and Mine Walls	0.05	1.5

Source: Supporting Documents 3 and 4.

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Source concentrations for the existing surface components are presented in Table 2.3. The concentrations are based on seepage data from the mine water sampling programs discussed in Supporting Document 3. The South, Central and North Tailings ponds are assumed to be similar to the Northwest tailings pond. Open pits were assigned a value similar to that observed in the bedrock and mine walls. Due to the limited amount of data for the contaminated soils, this number has been adjusted based on results in the Interim Abandonment and Restoration Plan (Golder 2001).

TABLE 3.5
Source Concentrations for Existing Surface Components
(Golder 2001)

Component	As (mg/L)
Northwest Tailings Pond	7
South, Central and North Tailings Ponds	7
Polishing/Settling Ponds	1
Open Pits	0.5
Contaminated Soils	2*

* Assumes surface closure measures are in place.
10 mg/L is used for the current conditions model

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Checked by: DBM

3.2.4 Estimates of Arsenic Release to the Underground Mine Prior to Water Treatment

Estimates of Arsenic Release for the underground workings are summarized in Table 3.6, with complete calculation sheets provided in Appendix B. Under all of these alternatives except ground freezing, this water would be directed to the water treatment plant prior to discharge. Discharges from the treatment plant are discussed in Chapter 4.

The results are briefly explained as follows:

- The minimum control alternative is very sensitive to assumptions of lateral groundwater flow through the chambers. Therefore, a range of estimates is provided. The upper estimate assumes that flow would be proportional to the cross sectional area of the chambers, while the lower estimate assumes that 90% of the flow would bypass the chambers. The estimated arsenic release is less than the current releases to the treatment plant due to the reduction of vertical infiltration, which is proportionally higher through the arsenic chambers, and due to the reduction in groundwater inflows resulting from the lower hydraulic gradient.

- Arsenic releases for the maintain drawdown alternative would be slightly lower than the current release. The main differences are that there would be a slightly higher release from the tailings backfill under flooded conditions, and a slightly lower release from the Northwest tailings pond resulting from the surface closure measures.

- The seepage control alternative would involve reducing infiltration to the arsenic chambers by backfilling the pits, installing covers, grouting, and possibly re-routing Baker Creek. The reduction in vertical flow through the chambers results in a significant reduction in loading.

- The ground freezing alternative would result in complete isolation of the arsenic chambers and stopes, resulting in a significant reduction in loading. Lower hydraulic gradients would also reduce the flux through the other underground sources. The estimated arsenic release for this alternative reflects residual releases from surface facilities, backfill and mine workings. These are also applicable to all of the ex-situ alternatives. In all of the ex-situ alternatives, the arsenic chambers will be flushed to remove any residual arsenic trioxide. These calculations therefore apply only to the long-term post closure conditions when arsenic has been completely removed from the chambers.

TABLE 3.6
Estimates of Arsenic Release in the Underground Workings

Arsenic Sources	Current (kg/year)	A1 Minimum Control		A2 Maintain Drawdown (kg/year)	A3 Control Seepage (kg/year)	B Ground Freezing* (kg/year)
		no bypass	bypass			
Vertical Flow						
arsenic chambers and stopes	12,419	244	244	12,419	1,671	0
roaster tailing backfill	60	0.2	0.2	2.1	2	0
flotation tailings backfill	60	0.2	0.2	2.1	2	0
waste rock backfill	72	1.5	1.5	22	22	0
regional bedrock/mine walls	0.45	3.4	3.4	2.9	2.9	3.5
contaminated soil	143	29	29	29	29	29
South, Central and North Tailings Ponds	3.1	3.1	3.1	3.1	3.1	3.1
Northwest Pond	1,023	10	10	10	10	10
settling pond/polishing pond	5.3	5.3	5.3	5.3	5.3	5.3
open pits	20	20	20	20	20	20
Subtotal (Vertical)	**13,806**	**317**	**317**	**12,515**	**1,768**	**71**
Lateral Flow						
arsenic chambers and stopes	0	9,120	912	0	0	0
roaster tailing backfill	0	217	217	365	365	219
flotation tailings backfill	0	109	109	183	183	110
waste rock backfill	0	69	69	116	116	69
bedrock, mine workings	730	69	71	116	116	69
Subtotal (Lateral)	**730**	**9,583**	**1,377**	**779**	**779**	**468**
Total from Underground	**14,536**	**9,900**	**1,694**	**13,295**	**2,548**	**539**

* the estimates for ground freezing can be used for all of the ex-situ alternatives.

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Checked by: DBM

3.3 Estimation of Arsenic Release from Surface Residues

3.3.1 Calculation Method

Surface residues include the two types of treatment sludges (lime and iron precipitates), process residues, cement stabilized dust and bitument stabilized dust. In alternatives E and F the iron treatment sludges would be combined with the purification or pressure oxidation residues, while in alternatives G1 and G2, any lime treatment sludges would be combined with the cement or bitumen stabilized wastes. Therefore there will be only two landfills for these alternatives. As discussed in the Main Document and in Supporting Document 16, these will be placed in lined and covered landfills, with a leachate recovery system. Leachate will be directed to the treatment plant prior to discharge.

Estimates of arsenic release from the landfills were made by calculating the total volume of infiltration that could enter the landfill, and multiplying this by the concentration associated with each of the residues. The volume of infiltration was determined from the net infiltration rate and the inside footprint area of each landfill. The footprint area is dependent on the volume of residue and the height that it would be placed. Volume estimates for each of the alternatives are provided in the Main Document. Footprint areas for the landfills are presented in Supporting Document 16. For the purposes of these calculations, alternatives with similar volumes of waste have been grouped, and the largest footprint is used in the calculations. Table 3.7 summarizes the footprints used in the calculations.

3.3.2 Infiltration Estimates

Infiltration into the landfills was assumed to be equivalent to 1×10^{-7} cm/s, which is a typical rate through a degraded cover. This is equivalent to 32 mm, or roughly 12% of the precipitation. Leakage from the liners is assumed to be equivalent to 0.22 mm based on HELP modelling completed for a project with a similar liner design.

3.3.3 Source Concentrations

Source concentrations for surface components that would result from long-term water treatment, and/or the ex-situ alternatives are summarized in Table 3.7. These concentrations were taken from the following sources:

- Pilot testing for the cement stabilized lime precipitation sludges has not been completed to date. Therefore, there is no data on the solubility of this material. The arsenic concentration in the leachate would likely be controlled by the solubility of calcium arsenite and/or calcium arsenate. The laboratory program on cement stabilized dust indicates the pH would likely be around 10 (Supporting Document 14). For calculations in this report, it has been assumed the arsenic concentration would be at the solubility limit of calcium arsenite, the more soluble species. This value is approximately 350 mg As/L at pH 10 (Nishimura et al, 1988).

- The concentrations used for the iron precipitation sludges are based on typical porewater concentrations in treatment plant sludges at other mines. Iron arsenate is a relatively stable material at slightly acidic to neutral pH with arsenic solubility ranging from 0.01 to <0.2 mg As/L at pH 4 to 5.2 and 0.13 mg As/L at pH 7 when the iron to arsenic molar ratio is greater than 3

(CANMET 2000). Best available technology water treatment plants using iron precipitation produce discharge water containing average arsenic concentrations of 0.025 to 0.18 mg/L (Supporting Document 8). Since the arsenic concentration in leachate from the landfilled sludge would be similar to water treatment discharge, leachate from the iron arsenate sludge would be collected and discharged directly to the environment. The arsenic concentration in the leachate is conservatively assumed to be 0.2 mg As/L.

- The concentrations for the autoclave residues were taken from Supporting Document 13. However, pilot testing has not been completed on this material. Therefore, there is a significant amount of uncertainty associated with these values. If the residues are fully converted to scorodite and iron arsenate, the concentrations would be relatively low, i.e. less than 1 mg/L. However, concentrations could be much higher (as high as 100 mg/L) if some of the arsenic trioxide is not converted. For the purposes of these calculations, it is conservatively assumed that full conversion would not occur, and that the source concentration would be 100 mg/L.

- Concentrations for the bitumen and cement stabilized wastes are from Supporting Document 14.

3.3.4 Estimates of Arsenic Release from Treatment Sludges and Arsenic Residues Prior to Water Treatment

Estimates of arsenic release from the treatment sludges and arsenic residues are provided in Table 3.7. As indicated in the table, the arsenic release to the treatment plant are very high for several of these alternatives. Arsenic releases following water treatment are discussed in Chapter 4.

TABLE 3.7

Arsenic Release from Treatment Sludges and Surface Residues

Residue	Treatment Sludges Only		Process Residues and Iron Sludges		Stabilized Dust and Lime Sludges	
	Lime Precipitation (with cement stabilization)	Oxidation/Iron Precipitation	Purification Residues	Pressure Oxidation Residues	Cement	Bitumen
Alternatives	B, C, D and F	All except E and F	E	F	G1	G2
Volume (m3)	37,500	22,000	189,000	1,332,000	377,500	437,500
Footprint (m2)	7,803	6,454	28,675	87,223	35,095	39,337
Infiltration Rate (mm/yr)	32	32	32	32	32	32
Leakage Rate (mm/yr)	0.22	na*	0.22	0.22	0.22	0.22
Volume (m3/yr)						
Total	250	207	918	2791	1123	1259
To Treatment Plant	248	na*	911	2772	1115	1250
Leakage through Liner	1.7	na*	6.3	19	7.7	9
Concentration of Leachate (mg/L)	350	0.2	100	100	5600	340
Concentration from Treatment Plant (mg/L)	0.5	na*	0.5	0.5	0.5	0.5
Arsenic Release (kg/yr)						
To Treatment Plant	87	na*	91	277	6246	425
Through Liner	0.60	na*	0.63	1.9	43	2.9

Notes: * Not applicable because any leachate collected on the liner would discharge directly to the environment.
The total release from this source would be very small (0.041 kg/year).

Prepared by: KSS
Checked by: DBM & DDS

4. ARSENIC RELEASE FROM THE WATER TREATMENT PLANT

4.1 Treatment Plant Effectiveness

Water pumped from the underground mine and water collected from any of the surface landfills will be treated prior to discharge, as necessary, to ensure that arsenic releases are within acceptable limits.

A review of water treatment alternatives is presented in Supporting Document 8. All of the treatment alternatives considered in the report were considered to be capable of achieving the Federal Metal Mines Effluent Regulation limit of <0.5 mg/L.

4.2 Arsenic Release from the Treatment Plant

A summary of the flows and arsenic releases to and from the treatment plant for each of the alternatives is presented in Table 4.1. Arsenic releases from the treatment plant are calculated by multiplying the flow by a concentration of 0.5 mg/L.

TABLE 4.1
Arsenic Release from the Treatment Plant

Alternative	To Treatment Plant					Arsenic Release From Treatment Plant
	From Underground		From Surface Residues		Total Flows	
	Flows	Arsenic Release (kg/year)	Flows	Arsenic Release (kg/year)		
Current	778,084	14,536			778,084	389
A1a Minimum Control (no bypass)	268,698	9,900			268,698	134
A1b Minimum Control (bypass)	268,698	1,694			268,698	134
A2 Maintain Drawdown	365,752	13,295			365,752	183
A3 Seepage Control	363,065	2,548			363,065	182
B Ground Freezing	268,451	539	248	87	268,699	134
C Removal and Deep Disposal	268,451	689	248	87	268699	134
D Removal and Off-Site Disposal	268,451	539	248	87	268699	134
E Removal and Purification	268,451	539	1159	178	269610	135
F Removal and Pressure Oxidation	268,451	539	3020	364	271471	136
G1 Cement Stabilization	268,451	539	1363	6333	269814	135
G2 Bitumen Stabilization	268,451	539	1498	512	269949	135

Prepared by: KSS
Checked by: DBM

5. SUMMARY AND CONCLUSIONS

Arsenic releases from existing surface sources were estimated based on current observed releases to Baker Creek. Long-term, post-closure estimates were made following the assumptions used in the Abandonment and Restoration Plan (Golder 2001). Under post-closure conditions, the current surface loads can be reduced from current arsenic releases of approximately 664 kg/year (excluding treatment plant effluent) to approximately 359 kg/year, including approximately 288 kg/year of background loads from upstream of the mine and approximately 71 kg/year from the mine site. These releases are presented in the second column of Table 5.1.

Estimates of arsenic releases from the underground workings range from 13,295 kg/year in the maintain drawdown alternative (A2) to 539 in the ground freezing (B) and ex-situ alternatives (D through G2). Estimates of arsenic releases from the surface landfills range from zero in the in-situ alternatives to 6871 kg/year in the cement stabilization alternative. These releases are summarized in the third and fourth columns of Table 5.1. A small amount of arsenic from the surface landfills would be released as leakage through the liners. These estimates are summarized in the fifth column of Table 5.1.

All of the alternatives except possibly ground freezing would require long-term water treatment. Loads to and from the water treatment plant (Chapter 4) are summarized in the sixth and seventh columns of Table 5.1.

The arsenic releases from the existing sources, direct discharges and from the treatment plant were added to give the total amount of arsenic released to the receiving environment (Baker Creek), assuming the treatment plant would be operated in perpetuity. These values are presented in the eighth column of Table 5.1. In the unlikely event that the water treatment plant would stop operating at some time in the future, the total arsenic release without treatment is also presented (column nine). It should be noted that, in the absence of any treatment, any arsenic releases from the underground workings would flow laterally towards Great Slave Lake, but would likely be dispersed over a very large area before daylighting in the receiving environment. In using these estimates, it would be conservative to assume that all of the arsenic would be discharged directly into Baker Creek.

TABLE 5.1

Summary of Arsenic Release to the Receiving Environment for Different Management Alternatives

Alternative	**From Existing Surface Sources (kg/yr)**	**From UG Sources (kg/yr)**	**From Landfills (kg/yr)**	**Direct Releases (kg/yr)**	**To Treatment Plant (kg/yr)**	**From Treatment Plant (kg/yr)**	**Total With Treatment (kg/yr)**	**Total Without Treatment (kg/yr)**
Current (for comparison)	664	14,536	na	0	14,536	389	1053	15,200
A1a Minimum Control (no bypass)	359	9,900	na	0	9,900	134	493	10,259
A1b Minimum Control (bypass)	359	1,694	na	0	1,694	134	493	2,053
A2 Maintain Drawdown	359	13,295	na	0	13,295	183	542	13,654
A3 Seepage Control	359	2,548	na	0	2,548	182	541	2,902
B Ground Freezing	359	539	na	0	626	134	493	985
C Removal and Deep Disposal	359	689	87	0.60	776	134	494	1,135
D Removal and Off-Site Disposal	359	539	87	0.60	626	134	494	985
E Removal and Purification	359	539	178	1.2	717	135	495	1,077
F Removal and Pressure Oxidation	359	539	364	2.5	903	136	497	1,264
G1 Cement Stabilization	359	539	6,333	44	6,871	135	538	7,274
G2 Bitumen Stabilization	359	539	512	3.5	1,051	135	498	1,413

Prepared by: KSS
Checked by: DBM

6. RECOMMENDATIONS

The long-term estimates of arsenic release developed herein provide a basis for comparing the different management alternatives. In further design and permitting of any selected alternative, there could be a need to further refine the estimates of long term arsenic release. Recommendations for reducing the uncertainties in the arsenic release estimates are specific to each alternative. For example, further characterization of deep groundwater flows in the underground workings would be required for the deep disposal alternative.

One set of uncertainties common to all of the alternatives are the post-closure estimates of arsenic release from surface sources. The estimates used herein are taken largely from Golder (2001). SRK believes those estimates are sufficiently accurate for use n the examination of arsenic trioxide management alternatives. However, the estimates will need to be reviewed as part of further development of the surface abandonment and reclamation plan. SRK recommends that regular seep surveys of the surface mine components be initiated to support those efforts.

The estimates of arsenic concentrations from underground sources after reflooding could be improved through further laboratory testing and, possibly, test flooding of a portion of the underground workings, as recommended in Supporting Document 4.

This report, **Giant Mine, Arsenic Release Estimates**, has been prepared by:

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7. REFERENCES

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APPENDIX A

Arsenic Release Estimates for Surface Sources

Table A1 - Surface Loading Model - Current Conditions

Assumptions and Inputs			
Mean annual precipitation	276	mm/yr	Fracflow 1999, YK airport data 1968-1996
Runoff coefficient	40%		
Runoff rate	110.4	mm/yr	
	110.4	L m-2 yr-1	
Tailings infiltration coefficient	15%		"pre-closure" Only use these values for the unponded areas
Tailings infiltration rate	41.4	mm/yr	
	41.4	L m-2 yr-1	
Treatment plant removal	84.1%		
Sludge & settling pond removal	84.1%		
Water treatment efficiency	97.5%		
Northwest Tailings Pond			
Surface area	45.7	ha	
	457000	m2	
Infiltration and Seepage Loss	255500000	L yr-1	Based on 700 m3/day from pond - see MDR Tailings Water Balance
As Concentration	2	mg/L	Based on Golder seep samples - higher amount used for direct infiltration to UG
Total Load	511	kg yr-1	
Proportion			
to U/G	57%		Included in the groundwater model
to Trapper Creek	13%		
to Trapper Lake	17%		
to Polishing & Settling Ponds	13%		
As Loads to surface			
to Trapper Creek	66	kg yr-1	
to Trapper Lake	88	kg yr-1	
to Polishing & Settling Ponds	66	kg yr-1	
Load to YK Bay	164	kg yr-1	
Minesite Soil > 350 mg/kg Arsenic			
Surface area	26	ha	Golder field investigation
	260000	m2	
Runoff	28704000	L yr-1	
As Concentration	3	mg/L	Used higher value than Golder based on extraction test data, and to get a better closure
Surface Load	86	kg yr-1	
Load to YK Bay	86	kg yr-1	
Minesite Soil < 350 mg/kg Arsenic			
Surface area	420	ha	area of drawdown cone
	4200000	m2	
Runoff	463680000	L yr-1	NEW
	0.1	mg/L	Replaced infiltrations with a runoff component
	46	kg yr-1	
Load to YK Bay	46	kg yr-1	
Tailings Spills			
Surface area	30	ha	
	300000	m2	
Runoff	12420000	L yr-1	Replaced infiltration with runoff component
Concentration	1	mg/L	
	12	kg yr-1	
Load to YK Bay	12	kg yr-1	

Old Tailings Areas (Infiltration only)

South Tailings pond

Surface area	28	ha	
	280000	m2	
Infiltration	11592000	L yr-1	
As Concentration	4.4	mg/L	
South Pond load	51	kg yr-1	
Proportion			
to U/G	5%		Included in the groundwater model
to Central Pond	60%		
to Baker Creek	20%		
direct to YK Bay	15%		
As Loads			
to Central Pond	31	kg yr-1	
to Baker Creek	10	kg yr-1	
direct to YK Bay	8	kg yr-1	

Central Tailings pond

Surface area	12.6	ha	
	126000	m2	
Infiltration	5216400	L yr-1	
As Concentration	4.4	mg/L	
Central Pond Load	23	kg yr-1	
from South Pond	31	kg yr-1	
Total Central Pond	54	kg yr-1	
Proportion			
to U/G	5%		Included in the groundwater model
to North Pond	60%		
to Baker Creek	20%		
direct to YK Bay	15%		
As Loads			
to North Pond	32	kg yr-1	
to Baker Creek	11	kg yr-1	
direct to YK Bay	8	kg yr-1	

North Tailings pond

Surface area	9.3	ha	
	93000	m2	
Infiltration	3850200	L yr-1	
As Concentration	4.4	mg/L	
North Pond Load	17	kg yr-1	
from Central Pond	32	kg yr-1	
Total North Pond	49	kg yr-1	
Proportion			
to U/G	5%		Included in the groundwater model
to Polishing & Settling Ponds	80%		
to Baker Creek	0%		
direct to YK Bay	15%		
As Loads			
to Polishing & Settling Ponds	39	kg yr-1	
to Baker Creek	0	kg yr-1	
direct to YK Bay	7	kg yr-1	

Old Tailings area totals

Old Tailings area totals	91
Load to Baker creek	21
Direct load to YK Bay	23
Load to Polishing & Settling Ponds	39
Load to YK Bay	50

Beached Back Bay Tailings

Surface area	5	ha	
	50000	m2	
Infiltration	2070000	L yr-1	
As Concentration	0.05	mg/L	EBA Report 0701-99-14263.008
Load to YK Bay	0.1	kg yr-1	

Surface Runoff from Watershed (upstream of treatment plant discharge)

Surface area	5225	ha	This is the total catchment area, and is therefore gives an upper bound on the background flows
	52250000	m2	
Runoff	5.768E+09	L yr-1	
As Concentration	0.05	mg/L	2001 Data - Golder and Senes had 0.08, which was the total load at the mouth of Baker Ck
Load to YK Bay	288	kg yr-1	

Surface Runoff from Watershed (Mouth of Baker Creek)

Surface area	5225	ha	This is the total catchment area, and is therefore gives an upper bound on the background flows
	52250000	m2	
Runoff	5.768E+09	L yr-1	
As Concentration	0.19	mg/L	2001 Data - includes treatment plant discharges
Load to YK Bay	1096	kg yr-1	

Overall Balance

Total Surface Sources	359.5	kg.yr-2	Does not include the background load
Treated Volume	1,079,566	m3	From SNP (2001 data), Senes used 0.3 mg/L and flows of 1,700,000m3, and came up with 500 kg/yr
Effluent Conc.	0.4	mg/L	
Effluent Load	432	kg/yr	
Total Est. Minesite Load to YK Ba	791.3		
Measured Minesite Load	808	kg.yr-1	Actual Total load at mouth of Baker Creek - Background Load - from SNP

Table A2 - Surface Loading Model - Post-Closure Conditions

Assumptions and Inputs			
Mean annual precipitation	276	mm/yr	Fracflow 1999, YK airport data 1968-1996
Runoff coefficient	40%		
Runoff rate	110.4	mm/yr	
	110.4	L m-2 yr-1	
Tailings infiltration coefficient	3%		"engineered cover"
Tailings infiltration rate	8.28	mm/yr	
	8.28	L m-2 yr-1	
Treatment plant removal	84.1%		
Sludge & settling pond removal	84.1%		
Water treatment efficiency	97.5%		
Northwest Tailings Pond			
Surface area	45.7	ha	
	457000	m2	
Infiltration and Seepage Loss	3783960	L yr-1	Use tailings infiltration rate once pond is gone
As Concentration	2	mg/L	Based on Golder seep samples - higher amount used for direct infiltration to UG
Total Load	8	kg yr-1	
Proportion			
to U/G	57%		Included in the groundwater model
to Trapper Creek	13%		
to Trapper Lake	17%		
to Polishing & Settling Ponds	13%		
As Loads to surface			
to Trapper Creek	1	kg yr-1	
to Trapper Lake	1	kg yr-1	
to Polishing & Settling Ponds	1	kg yr-1	
Load to YK Bay	2	kg yr-1	
Minesite Soil > 350 mg/kg Arsenic			
Surface area	3	ha	soil removed to NW Tailings Pond
	30000	m2	
Runoff	3312000	L yr-1	
As Concentration	3	mg/L	
Surface Load	10	kg yr-1	
Load to YK Bay	10	kg yr-1	
Minesite Soil < 350 mg/kg Arsenic			
Surface area	420	ha	area of drawdown cone
	4200000	m2	
Runoff	463680000	L yr-1	NEW
	0.1	mg/L	Replaced infiltrations with a runoff component
	46	kg yr-1	
Load to YK Bay	46	kg yr-1	
Tailings Spills			
Surface area	30	ha	
	300000	m2	
Runoff	2484000	L yr-1	NEW
	1	mg/L	Replaced infiltration with runoff component
	2.5	kg yr-1	
Load to YK Bay	2.5	kg yr-1	

Old Tailings Areas (Infiltration only)

South Tailings pond

Surface area	28	ha	
	280000	m2	
Infiltration	2318400	L yr-1	
As Concentration	4.4	mg/L	
South Pond load	10	kg yr-1	
Proportion			
to U/G	5%		Included in the groundwater model
to Central Pond	60%		
to Baker Creek	20%		
direct to YK Bay	15%		
As Loads			
to Central Pond	6	kg yr-1	
to Baker Creek	2	kg yr-1	
direct to YK Bay	2	kg yr-1	

Central Tailings pond

Surface area	12.6	ha	
	126000	m2	
Infiltration	1043280	L yr-1	
As Concentration	4.4	mg/L	
Central Pond Load	5	kg yr-1	
from South Pond	6	kg yr-1	
Total Central Pond	11	kg yr-1	
Proportion			
to U/G	5%		Included in the groundwater model
to North Pond	60%		
to Baker Creek	20%		
direct to YK Bay	15%		
As Loads			
to North Pond	6	kg yr-1	
to Baker Creek	2	kg yr-1	
direct to YK Bay	2	kg yr-1	

North Tailings pond

Surface area	9.3	ha	
	93000	m2	
Infiltration	770040	L yr-1	
As Concentration	4.4	mg/L	
North Pond Load	3	kg yr-1	
from Central Pond	6	kg yr-1	
Total North Pond	10	kg yr-1	
Proportion			
to U/G	5%		Included in the groundwater model
to Polishing & Settling Ponds	80%		
to Baker Creek	0%		
direct to YK Bay	15%		
As Loads			
to Polishing & Settling Ponds	8	kg yr-1	
to Baker Creek	0	kg yr-1	
direct to YK Bay	1	kg yr-1	

Old Tailings area totals

Old Tailings area totals	18
Load to Baker creek	4
Direct load to YK Bay	5
Load to Polishing & Settling Ponds	8
Load to YK Bay	10

Beached Back Bay Tailings

Surface area	5	ha	
	50000	m2	
Infiltration	414000	L yr-1	
As Concentration	0.05	mg/L	EBA Report 0701-99-14263.008
Load to YK Bay	0.02	kg yr-1	

Surface Runoff from Watershed (upstream of treatment plant discharge)

Surface area	5225	ha	This is the total catchment area, and is therefore gives an upper bound on the background flows
	52250000	m2	
Runoff	5768400000	L yr-1	
As Concentration	0.05	mg/L	2001 Data - Golder and Senes had 0.08, which was the total load at the mouth of Baker Ck
Load to YK Bay	288	kg yr-1	

Surface Runoff from Watershed (Mouth of Baker Creek)

Surface area	5225	ha	This is the total catchment area, and is therefore gives an upper bound on the background flows
	52250000	m2	
Runoff	5768400000	L yr-1	
As Concentration	0.19	mg/L	2001 Data - includes treatment plant discharges
Load to YK Bay	1096	kg yr-1	

Overall Balance

Total Surface Sources	71.3	kg.yr-2	Does not include the background load
Treated Volume	1,079,566	m3	From SNP (2001 data), Senes used 0.3 mg/L and flows of 1,700,000m3, and came up with 500 kg/yr
Effluent Conc.	0.4	mg/L	
Effluent Load	432	kg/yr	
Total Est. Minesite Load to YK Ba	503.1		
Measured Minesite Load	808	kg.yr-1	Actual Total load at mouth of Baker Creek - Background Load - from SNP

APPENDIX B

Arsenic Release Estimates for Underground Sources

Table B1
Current Conditions

DUPUIT FLOW - lateral GW flow (includes recharge)

K = '[q-(R(L/2))] * 2L / [h1^2-h2^2]

K:	1.0E-08	m/s	deep bedrock - not rounded to neare
	0.00086	m/day	deep bedrock
h1=	125	m	- height of seepage fac
h2=	610	m	- depth of dewatered sect
distance (L)=	900	m	
"q" (flow/unit area)	0.222	m2/d	
TOTAL LATERAL GROUNDWATER INFLOW:	**1332**	**m3/d**	

Option Dependent Variables

Drawdown "Depth to Water", (m):	**610**
Constant Head boundary height, h2 (m):	610
Height of seepage wall, h1 (m):	**125**

INFILTRATION

Source Type	Footprint Area (m2)	Infiltration Rate	Infil vol. (m3/day)	Vert. Infiltr. Source Concentration (kg/m3)	Daily Load (kg/day)	Annual Load (kg/year)
arsenic dust - funnelled flow from pits	5,050	N/A	4.25	4	17.000	6209
arsenic dust - infiltration from Baker Creek	5,050	N/A	4.25	4	17.000	6209
roaster tailing backfill	290,625	15%	32.9	0.005	0.165	60
flotation tailings backfill	290,625	15%	32.9	0.005	0.165	60
waste rock backfill	874,022	20%	132	0.0015	0.198	72
regional bedrock/mine walls	219,628	15%	25	0.00005	0.001	0.5
contam soil	260,000	20%	39	0.01	0.393	143
South Pond	0	5%	0.0	0.007	0.000	0.0
Central Pond	14,356	5%	0.5	0.007	0.004	1.4
North Pond	17,605	5%	0.7	0.007	0.005	1.7
NW Pond	104,436	N/A	**400**	0.007	2.800	1023
Settling Pond	35,300	20%	5.3	0.001	0.005	1.9
Polishing Pond	60,440	20%	9.1	0.001	0.009	3.3
Open Pits	147,863	100%	112	0.0005	0.056	20
Baker Creek (in mine area)	**74,707**				0.000	0.0
total:	**2,325,000**	**total:**	**798**	**total:**	**37.8**	**13,806**

GROUNDWATER FLOW

Source Type	Cross-sectional Area (m2)	% of saturated area	GW Flow. (m3/day)	Source Concentration (kg/m3)	Daily Load (kg/day)	
dust	0	0.0%	0	6.85	0.0	0.0
roaster tailing backfill	0	0.0%	0	0.01	0.0	0.0
flotation tailings backfill	0	0.0%	0	0.005	0.0	0.0
waste rock backfill	0	0.0%	0	0.0015	0.0	0.0
bedrock/tunnels	375,000	100.0%	1,332	0.0015	2.0	730
total:	**375,000**	100.0%	**1,332**		**2.0**	**730**

Total Flow (m3/day) = 2,130 **40** **14536**

Prepared by: KSS
Checked by: DBM

Table B2
Minimum Drawdown (10 m below lake)

DUPUIT FLOW - lateral GW flow (includes recharge)
K = '[q-(R(L/2))] * 2L / [h1^2-h2^2]

K:	1.0E-08	m/s	deep bedrock - not rounded to neare
	0.00086	m/day	deep bedrock
h1=	590	m	- height of seepage face
h2=	610	m	- depth of dewatered sect
distance (L)=	900	m	
"q" (flow/unit area)	0.062	m2/d	
TOTAL LATERAL GROUNDWATER INFLOW:	**374**	**m3/d**	

Option Dependent Variables

Drawdown "Depth to Water", (m):	**20**
Constant Head boundary height, h2 (m):	610
Height of seepage wall, h1 (m):	**590**

INFILTRATION

Source Type	Footprint Area (m2)	Infiltration Rate	Infil vol. (m3/day)	Vert. Infiltr. Source Concentration (kg/m3)	Daily Load (kg/day)	Annual Load (kg/year)
arsenic dust - funnelled flow from pits	737	15%	0.1	4	0.334	122
arsenic dust - infiltration from Baker Creek	737	15%	0.1	4	0.334	122
roaster tailing backfill	1,085	15%	0.1	0.005	0.001	0.22
flotation tailings backfill	1,085	15%	0.1	0.005	0.001	0.22
waste rock backfill	17,924	20%	3	0.0015	0.004	1.5
regional bedrock/mine walls	1,663,434	15%	188	0.00005	0.009	3.4
contam soil	260,000	20%	39	0.002	0.079	29
South Pond	0	5%	0.0	0.007	0.000	0.0
Central Pond	14,356	5%	0.5	0.007	0.004	1.4
North Pond	17,605	5%	0.7	0.007	0.028	10
NW Pond	104,436	5%	3.9	0.007	0.037	14
Settling Pond	35,300	20%	5.3	0.001	0.005	1.9
Polishing Pond	60,440	20%	9.1	0.001	0.009	3.3
Open Pits	147,863	100%	112	0.0005	0.056	20
Baker Creek (in mine area)	**74,707**				0.000	0.0
total:	**2,325,000**	**total:**	**362**	**total:**	**0.9**	**329**

GROUNDWATER FLOW

Source Type	Cross-sectional Area (m2)	% of satuarted area	GW Flow. (m3/day)	Source Concentration (kg/m3)	Daily Load (kg/day)	
dust	15,856	1.0%	4	6.85	25.0	9120
roaster tailing backfill	258,597	15.9%	59	0.01	0.6	217
flotation tailings backfill	258,597	15.9%	59	0.005	0.3	109
waste rock backfill	546,069	33.6%	126	0.0015	0.2	69
bedrock/tunnels	546,069	33.6%	126	0.0015	0.2	69
total:	**1,625,187**	100.0%	**374**		**26.2**	**9,583**
		Total Flow (m3/day) =	**736**		**27**	**9912**

Prepared by: KSS
Checked by: DBM

Table B3
Minimum Drawdown (10 m below lake) (With bypass)

DUPUIT FLOW - lateral GW flow (includes recharge)
K = '[q-(R(L/2))] * 2L / [h1^2-h2^2]

K:	1.0E-08	m/s	deep bedrock - not rounded to neare
	0.00086	m/day	deep bedrock
h1=	590	m	- height of seepage face
h2=	610	m	- depth of dewatered sect
distance (L)=	900	m	
"q" (flow/unit area)	0.062	m2/d	
TOTAL LATERAL GROUNDWATER INFLOW:	**374**	**m3/d**	

Option Dependent Variables

Drawdown "Depth to Water", (m):	**20**
Constant Head boundary height, h2 (m):	610
Height of seepage wall, h1 (m):	**590**

INFILTRATION

Source Type		Footprint Area (m2)	Infiltration Rate	Infil vol. (m3/day)	Vert. Infiltr. Source Concentration (kg/m3)	Daily Load (kg/day)	Annual Load (kg/year)
arsenic dust - funnelled flow from pits		737	15%	0.1	4	0.334	122
arsenic dust - infiltration from Baker Creek		737	15%	0.1	4	0.334	122
roaster tailing backfill		1,085	15%	0.1	0.005	0.001	0
flotation tailings backfill		1,085	15%	0.1	0.005	0.001	0
waste rock backfill		17,924	20%	3	0.0015	0.004	1.5
regional bedrock/mine walls		1,663,434	15%	188	0.00005	0.009	3
contam soil		260,000	20%	39	0.002	0.079	29
South Pond		0	5%	0.0	0.007	0.000	0.0
Central Pond		14,356	5%	0.5	0.007	0.004	1.4
North Pond		17,605	5%	0.7	0.007	0.005	1.7
NW Pond		104,436	5%	3.9	0.007	0.028	10
Settling Pond		35,300	20%	5.3	0.001	0.005	1.9
Polishing Pond		60,440	20%	9.1	0.001	0.009	3.3
Open Pits		147,863	100%	112	0.0005	0.056	20
Baker Creek (in mine area)		**74,707**				0.000	0.0
	total:	**2,325,000**	**total:**	**362**	**total:**	**0.9**	**317**

GROUNDWATER FLOW

Source Type		Cross-sectional Area (m2)	% of satuarted area	GW Flow. (m3/day)	Source Concentration (kg/m3)	Daily Load (kg/day)	
dust		15,856	1.0%	0.36	6.85	2.5	912
roaster tailing backfill		258,597	15.9%	59	0.01	0.6	217
flotation tailings backfill		258,597	15.9%	59	0.005	0.3	109
waste rock backfill		546,069	33.6%	126	0.0015	0.2	69
bedrock/tunnels		546,069	33.6%	129	0.0015	0.2	71
	total:	**1,625,187**	100.0%	**374**		**3.8**	**1,377**
		Total Flow (m3/day) =		**736**		**4.6**	**1693.8**

Prepared by: KSS
Checked by: DBM

Table B4
Dewater to 425 Level

DUPUIT FLOW - lateral GW flow (includes recharge)
K = '[q-(R(L/2))] * 2L / [h1^2-h2^2]

K:	1.0E-08	m/s	deep bedrock - not rounded to neare
	0.00086	m/day	deep bedrock
h1=	512	m	- height of seepage fac
h2=	610	m	- depth of dewatered sect
distance (L)=	900	m	
"q" (flow/unit area)	0.104	m2/d	
TOTAL LATERAL GROUNDWATER INFLOW:	**623**	**m3/d**	

Option Dependent Variables

Drawdown "Depth to Water", (m):	**100**
Constant Head boundary height, h2 (m):	610
Height of seepage wall, h1 (m):	**512**

INFILTRATION

Source Type	Footprint Area (m2)	Infiltration Rate	Infil vol. (m3/day)	Vert. Infiltr. Source Concentration (kg/m3)	Daily Load (kg/day)	Annual Load (kg/year)
arsenic dust - funnelled flow from pits	5,050	N/A	4.25	4	17.000	6209
arsenic dust - infiltration from Baker Creek	5,050	N/A	4.25	4	17.000	6209
roaster tailing backfill	10,157	15%	1.2	0.005	0.006	2.1
flotation tailings backfill	10,157	15%	1.2	0.005	0.006	2.1
waste rock backfill	268,194	20%	41	0.0015	0.061	22
regional bedrock/mine walls	1,386,393	15%	157	0.00005	0.008	2.9
contam soil	260,000	20%	39	0.002	0.079	29
South Pond	0	5%	0.0	0.007	0.000	0.0
Central Pond	14,356	5%	0.5	0.007	0.004	1.4
North Pond	17,605	5%	0.7	0.007	0.005	1.7
NW Pond	104,436	5%	3.9	0.007	0.028	10
Settling Pond	35,300	20%	5.3	0.001	0.005	1.9
Polishing Pond	60,440	20%	9.1	0.001	0.009	3.3
Open Pits	147,863	100%	112	0.0005	0.056	20
Baker Creek (in mine area)	**74,707**				0.000	0.0
total:	**2,325,000**	**total:**	**379**	**total:**	**34.3**	**12,515**

GROUNDWATER FLOW

Source Type	Cross-sectional Area (m2)	% of satuarted area	GW Flow. (m3/day)	Source Concentration (kg/m3)	Daily Load (kg/day)	
dust	0	0.0%	0	6.85	0.0	0.0
roaster tailing backfill	258,597	16.1%	100	0.01	1.0	365
flotation tailings backfill	258,597	16.1%	100	0.005	0.5	183
waste rock backfill	546,069	33.9%	211	0.0015	0.3	116
bedrock/tunnels	546,069	33.9%	211	0.0015	0.3	116
total:	**1,609,331**	100.0%	**623**		**2.1**	**779**
	Total Flow (m3/day) =		**1,001**		**36**	**13295**

Prepared by: KSS
Checked by: DBM

Table B5
Dewater to 425 Level with Seepage Control

DUPUIT FLOW - lateral GW flow (includes recharge)
K = '[q-(R(L/2))] * 2L / [h1^2-h2^2]

K:	1.0E-08	m/s	deep bedrock - not rounded to neare
	0.00086	m/day	deep bedrock
h1=	512	m	- height of seepage fac
h2=	610	m	- depth of dewatered sect
distance (L)=	900	m	
"q" (flow/unit area)	0.104	m2/d	
TOTAL LATERAL GROUNDWATER INFLOW:	**623**	**m3/d**	

Option Dependent Variables
Drawdown "Depth to Water", (m): **100**
Constant Head boundary height, h2 (m): 610
Height of seepage wall, h1 (m): **512**

INFILTRATION

Source Type	Footprint Area (m2)	Infiltration Rate	Infil vol. (m3/day)	Vert. Infiltr. Source Concentration (kg/m3)	Daily Load (kg/day)	Annual Load (kg/year)
arsenic dust - funnelled flow from pits	5,050	15%	0.6	4	2.288	836
arsenic dust - infiltration from Baker Creek	5,050	15%	0.6	4	2.288	836
roaster tailing backfill	10,157	15%	1.2	0.005	0.006	2.1
flotation tailings backfill	10,157	15%	1.2	0.005	0.006	2.1
waste rock backfill	268,194	20%	41	0.0015	0.061	22
regional bedrock/mine walls	1,386,393	15%	157	0.00005	0.008	3
contam soil	260,000	20%	39	0.002	0.079	29
South Pond	0	5%	0.0	0.007	0.000	0.0
Central Pond	14,356	5%	0.5	0.007	0.004	1.4
North Pond	17,605	5%	0.7	0.007	0.005	1.7
NW Pond	104,436	5%	3.9	0.007	0.028	10
Settling Pond	35,300	20%	5.3	0.001	0.005	1.9
Polishing Pond	60,440	20%	9.1	0.001	0.009	3.3
Open Pits	147,863	100%	112	0.0005	0.056	20
Baker Creek (in mine area)	**74,707**				0.000	0.0
total:	**2,325,000**	**total:**	**372**	**total:**	**4.8**	**1,768**

GROUNDWATER FLOW

Source Type	Cross-sectional Area (m2)	% of satuarted area	GW Flow. (m3/day)	Source Concentration (kg/m3)	Daily Load (kg/day)	
dust	0	0.0%	0	6.85	0.0	0.0
roaster tailing backfill	258,597	16.1%	100	0.01	1.0	365
flotation tailings backfill	258,597	16.1%	100	0.005	0.5	183
waste rock backfill	546,069	33.9%	211	0.0015	0.3	116
bedrock/tunnels	546,069	33.9%	211	0.0015	0.3	116
total:	**1,609,331**	100.0%	**623**		**2.1**	**779**
	Total Flow (m3/day) =		**994**		**7**	**2548**

Prepared by: KSS
Checked by: DBM

Table B6
Total Reflood (Ground Freezing Option)

DUPUIT FLOW - lateral GW flow (includes recharge)
K = '[q-(R(L/2))] * 2L / [h1^2-h2^2]

K:	1.0E-08	m/s	deep bedrock - not rounded to neare
	0.00086	m/day	deep bedrock
h1=	590	m	- height of seepage fac
h2=	610	m	- depth of dewatered sect
distance (L)=	900	m	
"q" (flow/unit area)	0.062	m2/d	
TOTAL LATERAL GROUNDWATER INFLOW:	**374**	**m3/d**	

Option Dependent Variables

Drawdown "Depth to Water", (m):	**20**
Constant Head boundary height, h2 (m):	610
Height of seepage wall, h1 (m):	**590**

INFILTRATION

Source Type	Footprint Area (m2)	Infiltration Rate	Infil vol. (m3/day)	Vert. Infiltr. Source Concentration (kg/m3)	Daily Load (kg/day)	Annual Load (kg/year)
arsenic dust - funnelled flow from pits	0	0%	0.0	4	0.000	0
arsenic dust - infiltration from Baker Creek	0	0%	0.0	4	0.000	0
roaster tailing backfill	0	15%	0.0	0.005	0.000	0
flotation tailings backfill	0	15%	0.0	0.005	0.000	0
waste rock backfill	0	20%	0	0.0015	0.000	0
regional bedrock/mine walls	1,685,001	15%	191	0.00005	0.010	3.5
contam soil	260,000	20%	39	0.002	0.079	29
South Pond	0	5%	0.0	0.007	0.000	0.0
Central Pond	14,356	5%	0.5	0.007	0.004	1.4
North Pond	17,605	5%	0.7	0.007	0.005	1.7
NW Pond	104,436	5%	3.9	0.007	0.028	10
Settling Pond	35,300	20%	5.3	0.001	0.005	1.9
Polishing Pond	60,440	20%	9.1	0.001	0.009	3.3
Open Pits	147,863	100%	112	0.0005	0.056	20
Baker Creek (in mine area)	**74,707**				0.000	0.0
total:	**2,325,000**	**total:**	**361**	**total:**	**0.2**	**71**

GROUNDWATER FLOW

Source Type	Cross-sectional Area (m2)	% of satuarted area	GW Flow. (m3/day)	Source Concentration (kg/m3)	Daily Load (kg/day)	
dust	**0**	0.0%	0	6.85	0.0	0.0
roaster tailing backfill	258,597	16.1%	60	0.01	0.6	219
flotation tailings backfill	258,597	16.1%	60	0.005	0.3	110
waste rock backfill	546,069	33.9%	127	0.0015	0.2	69
bedrock/tunnels	546,069	33.9%	127	0.0015	0.2	69
total:	**1,609,331**	100.0%	**374**		**1.3**	**468**

Total Flow (m3/day) =	**735**	**1.5**	**539**

Prepared by: KSS
Checked by: DBM