KGHM

Geochemical Source Terms for Ajax Mine Components

Project No. J933-4

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1. Introduction

1.1 Introduction and Background

Lorax Environmental Services Ltd. (Lorax) was retained by KGHM Ajax (KAM) to predict and evaluate the drainage quality of the mine rock storage facilities (MRSF), ore stockpile, tailings storage facility (TSF), and pit walls for the Ajax Project. Mine rock is hereby defined as any blasted uneconomic rock material that is not expected to be processed and will be stored on site long-term. Predicted average annual source term concentrations and loads in drainage from Ajax mine components are reported in this memorandum. For most mine components, unsaturated drainage concentrations and loadings were developed by:

(i) using laboratory-based kinetic test loading rates;

(ii) scaling laboratory leaching rates to those expected in full scale mine rock storage facilities;

(iii) geochemical modeling of secondary mineralogical controls; as well as

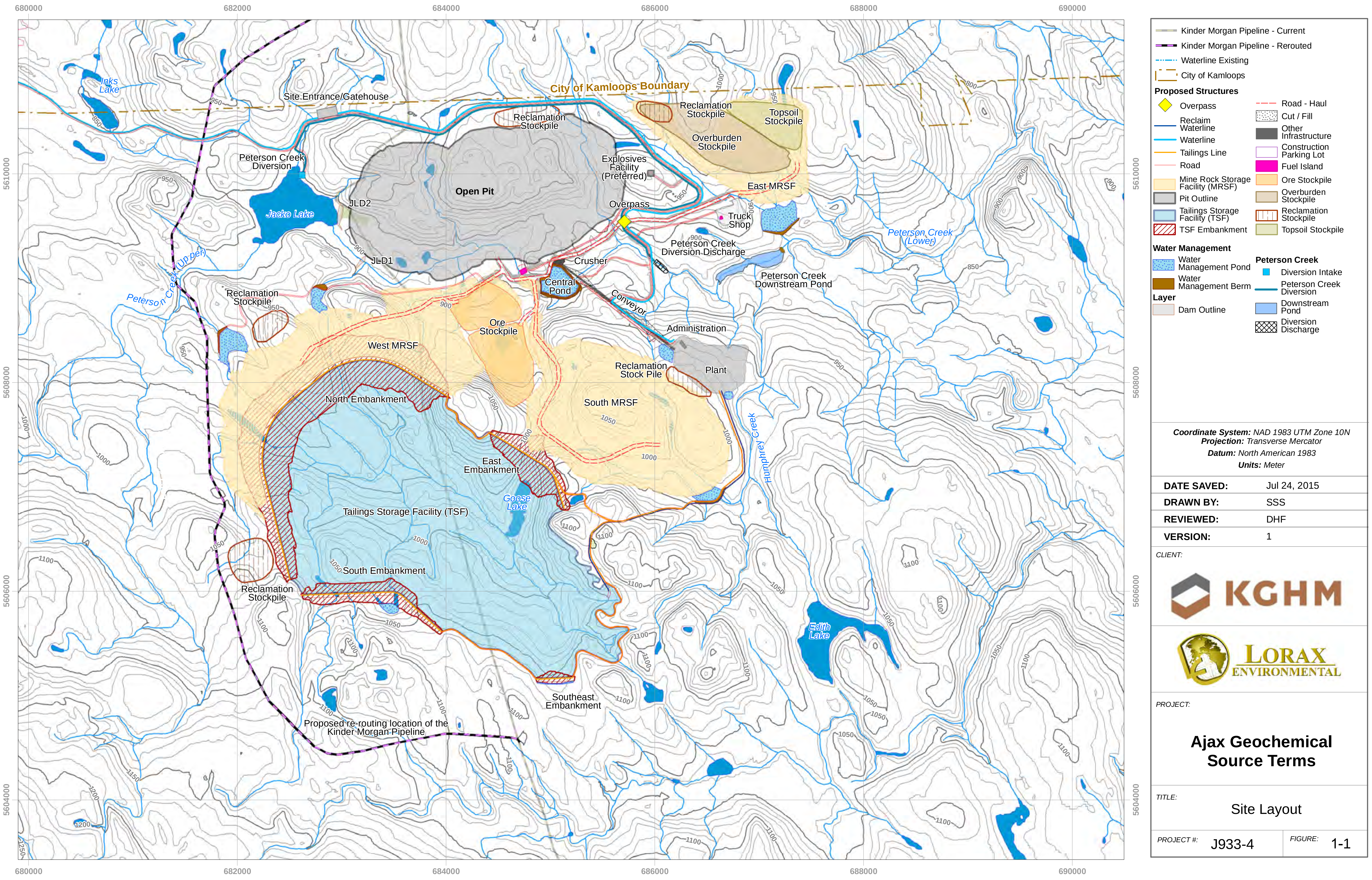
(iv) model validation/calibration by comparison to field bin results and available site drainage chemistry data.

The derivation of tailings process water and saturated tailings seepage source terms were derived either (1) directly from concentrations observed in kinetic test leachates or supernatant from metallurgical tests (if water:solid ratios were similar to operational conditions) or (2) from geochemical equilibria.

Nitrogen source terms in Ajax mine site drainage were developed using a separate approach. In contrast to most geochemical species that are leached through the dissolution of minerals contained in Ajax mine rock, the release of nitrogen species is largely related to the mobilization of blasting residues and depends on explosives used, blasting techniques, and water/rock ratios.

Operational and closure geochemical source terms are provided for the mine facilities illustrated in Figure 1-1 and listed below:

- East MRSF;
- West MRSF & North Embankment;
- South MRSF & East Embankment;
- Pit Backfill;
- South Embankment;
- Southeast Embankment;
- Pit Walls;
- Temporary Ore Stockpile; and
- TSF.



Coordinate System: *NAD 1983 UTM Zone 10N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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Ajax Geochemical Source Terms

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Site Layout

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FIGURE: 1-1

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The predicted geochemical source terms presented in this memorandum are in support of the Environmental Assessment Application/Environmental Impact Statement (EIS) report that evaluates the potential impact of mine drainage. Specifically, the predicted geochemical source terms from the MRSFs, the ore stockpile, the TSF and pit walls are used as input into the project-scale water quality model prepared by Knight Piésold Ltd. (KP) that predicts water chemistry at various locations at the mine site and in the downstream receiving environment. Long-term pit wall runoff quality predictions also feed into a numerical pit lake model to evaluate the evolution of pit lake water after mine closure (Lorax, 2015).

Drainage chemistry from the MRSFs and ore stockpile is influenced by a number of factors that are related to the geochemical and physical characteristics of the materials. Factors driving drainage quality in such mine environments are summarized below and were accounted for in the derivation of the Ajax geochemical source terms.

Geology/Geochemistry

The aqueous geochemical signatures produced by water in contact with the various lithologies is predominately controlled by the carbonate and sulphide mineral assemblages present in each rock type. Dissolved sulphate signatures in mine drainage are typically associated with the dissolution of sulphate and sulphide minerals where the trace element aqueous geochemical signature is largely influenced by the type and quantity of sulphur-bearing minerals present in the solid phase. Nitrogen loadings are directly related to the volume of blasted rock, porosity and surface water infiltration.

Physical Characteristics

The physical characteristics of the exposed rock also affect drainage chemistry. For example, the particle size distribution of the mine rock influences the degree of water-rock interactions by controlling the exposed surface area. The surface area of a given particle increases exponentially relative to mass as the particle size decreases. Therefore, weathering of the finest particles exerts the dominant control on drainage chemistry. These fine particles may comprise a relatively small mass of the MRSF but contribute a relatively large proportion of the dissolved load.

Unsaturated Hydrology

The nature of unsaturated fluid flow pathways in MRSFs has important implications for the geochemical behaviour of mine rock systems. It was shown that the rate at which minerals weather chemically in laboratory tests is typically many times faster than rates inferred from field observations (Malmström *et al.*, 2000). This discrepancy is in part due to the formation of distinct flow channels within the mine rock pile that results in the incomplete flushing of weathering products (Nichol *et al.*, 2005) and nitrogen compounds.

Temperature

Temperatures affect sulphide oxidation rates, with decreased oxidation rates observed with decreasing temperature following an Arrhenius relationship (Nicholson *et al.*, 1988). A temperature factor was applied for the pit wall and inactive tailings beaches to account for the average monthly temperatures that are below freezing for three months of the year at the Ajax site.

The following section describes the approach taken to model drainage quality for the various Ajax mine components, while results are presented in Section 3. Model description and results for the nitrogen source term predictions are given in Section 4.

2. Drainage Chemistry Predictions

2. Drainage Chemistry Predictions

The methodology and parameters used to calculate the pore water chemistry associated with mine rock and tailings storage facilities using the combined results of laboratory kinetic test work as well as geochemical modeling of mineralogical controls is discussed in the following. A detailed discussion of the kinetic test methods and results is provided in Lorax (2015).

2.1 Mine Rock Storage Facilities and Ore Stockpile

The various work steps leading the development of MRSF geochemical source terms at the Ajax mine are outlined in the flow chart illustrated in Figure 2-1. In the following, TSF embankments containing mine rock are referred to as MRSFs, as the model steps leading to the development of drainage chemistry predictions are equivalent. The basis for the development of the source terms is partitioning the geochemical loading rates measured by kinetic testing relative to the distinct geochemical characteristics associated with the geologic units. Five major geological units are identified at the Ajax site including:

- Sugarloaf Diorite (SLD);
- Iron Mask Hybrid (IMH);
- Mafic Volcanic (MAFV);
- Picrite (PICR);
- Sugarloaf Volcanic Hybrid (SVHYB).

Subdivision of these five units into pit location and degree of albitization for the SLD unit led to the development of 13 block model units that are being used for mine planning purposes. Additionally, three different ore grades (low, medium, and high) are discriminated, where low- and medium-grade ore will occasionally be stored in a temporary ore stockpile during operations when excess ore is produced.

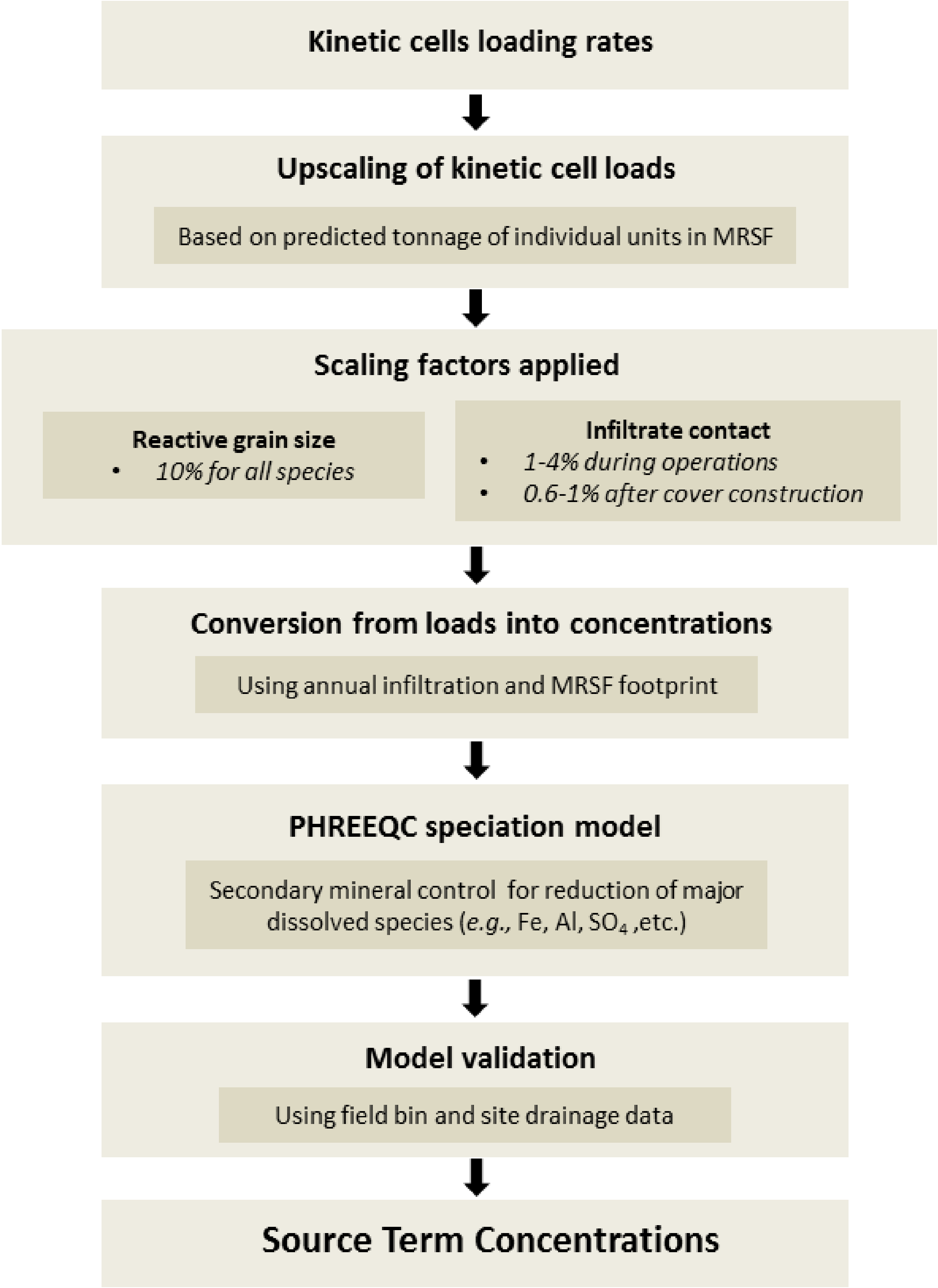

Figure 2-1: Flow chart outlining methods used to generate Ajax MRSF drainage chemistry predictions.

2.1.1 Kinetic Test Loading Rates

Concentrations measured in humidity cell leachates are converted into loading rates (in mg/kg/wk) using the following equation:

$$L_i = C_i \text{ x } V / M / T \qquad (1)$$

where L and C are respectively the geochemical load and concentration of species i, V is the leachate volume, M is the rock sample mass used for the experiment, and T is the time interval between leachate sampling events.

Kinetic test samples were selected from each of the geologically-defined “geomet” units that are tracked in the Ajax block model. In cases where several kinetic tests were available to represent a single geomet unit, the loading rates from each kinetic test were combined in proportion to the percentage of samples with a similar non-sulphate S content in the static test population for that unit. The proportions of measured kinetic test loading rates applied for each block model unit and ore grade are listed in Table 2-1.

Data from kinetic test cells that were initiated in 2014 are only incorporated in the operational drainage chemistry prediction model due to the lack of long-term data from these cells. The portion of the total mine rock that is designated to unit No. 99 in the Ajax block model is assigned loading rates equivalent to the SLD kinetic test samples (Table 2-1) in agreement with the sulphur content expected in this mine rock. This approach is conservative even though the geochemical composition of this material will have a negligible effect on the overall drainage chemistry as it makes up less than 0.3% of the MRSF tonnages.

The model input solutions applied to develop MRSF and ore stockpile operational source terms were based on early, but relatively stable loading rates (*i.e.*, median of cycles 16-20). For closure scenarios, fully stable kinetic test loading rates (*i.e.*, median of last 5 analytical cycles) were utilized (MRSF and TSF embankments). The composite geochemical loading rates derived from the kinetic tests used to model contact-water from each of the Ajax mine components are given in Appendix A.

Table 2-1:
Proportioning of Ajax kinetic tests used to generate model input loading rates for MRSFs and the ore stockpile

Geounit	Description	Col-1	Col-2	Col-3	Col-4	Col-5	Col-6	Col-7	Col-8	Col-9	Col-10	Col-11	Col-12	Col-13	Col-14
		SLD Ore	SLD	High-S SLD	IMH	IMH	MAFV/PICR	IMH	IMH	SVHYB	PICR	PICR	MAFV	Low-grade Ore	Ore
MRSF/ Embankments															
1	**West SLD (weak)**	-	82%	18%	-	-	-	-	-	-	-	-	-	-	-
2	**West SLD (mod.)**	-	86%	14%	-	-	-	-	-	-	-	-	-	-	-
3	**West SLD (strong)**	-	100%	0%	-	-	-	-	-	-	-	-	-	-	-
4	**IMH**	-	-	-	50%/25%	50%/25%	-	25%	25%	-	-	-	-	-	-
5	**West SVHYB**	-	100%	0%	-	-	-	-	-	-	-	-	-	-	-
6	**West SVHYB**	-	100%	0%	-	-	-	-	-	-	-	-	-	-	-
7	**PICR**	-	-	-	-	-	100%	-	-	-	81%	19%	-	-	-
8	**West MAFV**	-	-	-	-	-	100%	-	-	-	-	-	100%	-	-
9	**East SLD (weak)**	-	76%	24%	-	-	-	-	-	-	-	-	-	-	-
10	**East SLD (mod.)**	-	83%	17%	-	-	-	-	-	-	-	-	-	-	-
11	**East SLD (strong)**	-	87%	13%	-	-	-	-	-	-	-	-	-	-	-
12	**East MAFV**	-	-	-	-	-	100%	-	-	-	-	-	100%	-	-
13	**East SVHYB**	-	100%	0%	-	-	-	-	-	-	-	-	-	-	-
99	***'Catch-all'***	-	72%	28%	-	-	-	-	-	-	-	-	-	-	-
Ore Stockpile															
-	**Low-grade**	-	-	-	-	-	-	-	-	-	-	-	-	100%	-
-	**Medium-grade**	-	-	-	-	-	-	-	-	50%	-	-	-	50%	-
-	**High-grade**	50%	-	-	-	-	-	-	-	-	-	-	-	-	50%

Notes: Proportions indicated in red and blue identify cells used for short- and long-term leaching rates, respectively. Proportions indicated in black were applied to both scenarios.

2.1.2 Derivation of Annual Geochemical Loads for Individual MRSF

Geochemical source terms were derived for a total of six MRSFs and one ore stockpile. Figure 1-1 illustrates the layout of the Ajax Facilities at closure and Table 2-2. Lists the maximum dimensions for these facilities as used in the drainage quality prediction model. Note that in two cases, the footprints of MRSFs overlap with those of TSF embankments (West MRSF/North Embankment and South MRSF/East embankment). For these mine components, a combined source term accounting for the overall tonnage and combined footprint was provided. Due to the placement of an HDPE-liner at the bottom of some TSF areas, the water balance assumes that only around half of the material stored in the Main, South and Southwest embankments will be contacted by infiltration. This was accounted for in the upscaling exercise of these MRSFs. Refer to Appendix B for a detailed breakdown of the block model units and ore tonnages used for each modelling time step.

The maximum potential annual mass loading rates for each geomet unit (Appendix A) were combined in proportion to the quantity of each mine rock type that will be stored in each MRSF (Appendix B). The combined loads in units of mg/kg/wk are converted to annual loads (mg/yr) by multiplying by 52.14 weeks.

Table 2-2:
Maximum footprint area and tonnage of the MRSFs

West MRSF & North Embankment	
Footprint (m^2)	1,810,000
Tonnage (Mt)	288
South MRSF & East Embankment	
Footprint (m^2)	2,100,000
Tonnage (Mt)	349
East MRSF	
Footprint (m^2)	1,160,000
Tonnage (Mt)	68
Ore Stockpile	
Footprint (m^2)	660,000
Tonnage (Mt)	55
Backfill	
Footprint (m^2)	592,872
Tonnage (Mt)	183
South Embankment	
Footprint (m^2)	131,033
Tonnage (Mt)	4.5
Southeast Embankment	
Footprint (m^2)	22,220
Tonnage (Mt)	0.20

2.1.3 Scaling Factors

The maximum potential annual load is adjusted to account for the different scale between the laboratory test and the MRSF. The scale factors for the Ajax MRSFs include particle size and water content, which are listed for the MRSFs and ore stockpile in Table 2-3.

Table 2-3:
Scaling factors used for MRSFs and the ore stockpile

	Grain size	Contact water	Bulk Correction
MRSF			
West MRSF & North Embankment			
operations 5	10%	3%	0.30%
operations 10	10%	2%	0.16%
EOM	10%	1%	0.10%
PC	10%	1%	0.06%
South MRSF & East Embankment			
operations 5	10%	4%	0.40%
operations 10	10%	1%	0.14%
EOM	10%	1%	0.13%
PC	10%	1%	0.08%
East MRSF			
operations 5	10%	4%	0.40%
operations 10	10%	4%	0.39%
EOM	10%	4%	0.39%
PC	10%	1%	0.11%
Backfill			
EOM	10%	1%	0.09%
South Embankment			
EOM/PC	10%	5%	0.50%
Southeast Embankment			
EOM/PC	10%	10%	1.00%
Ore Stockpile			
Max. extent	10%	3%	0.30%
Year 17	10%	3%	0.30%

Notes: EOM = End of mine; PC = Post-closure

Particle size

The particle size distribution (PSD) of the mine material influences the degree of water-rock interactions by controlling the exposed surface area. Strömberg and Banwart (1999) observed a large difference in weathering rates between fine particles and larger mine rock at the Aitik mine in northern Sweden. In their study, particles with diameters smaller than 25 mm were shown to account for more than 80% of sulphide and silicate weathering. The finer particle sizes within MRSF are typically only a small fraction of the total mass of the storage facility, however the precise PSD is variable between different mine-sites and strongly dependent on geological properties and blasting technique.

For Ajax mine rock, it is estimated that 10% of the mass of material contained in the MRSF are reactive. This value accounts for how the PSD of the kinetic tests (100% < 1/4”) differs from that expected in the mine rock facilities (10% < 1/4”) and is consistent with observations in studies by Fines *et al.* (2003), Frostad *et al.* (2005), and Neuner *et al.* (2009).

Water contact

Laboratory kinetic experiments are conducted using relatively high water/rock ratios that result in the flushing of a high proportion of the rock material placed into the cells. The infiltration and flow through unsaturated mine rock piles has been subject to research and most studies suggest that only a portion of the rock mass contained in a MRSF is contacted by infiltrating water. In one study, for example, a small-scale trial rock facility was disassembled one year after its construction and the distribution of moisture contents within the facility indicated that the development of preferential flow paths is an important process (Marcoline *et al.*, 2006). Under low-flow conditions, water is retained in and will travel through the fine fractions within the MRSF, whereas heavy rainfalls may flush relatively higher proportions of the coarser grain sizes (Andrina *et al.*, 2009, Neuner *et al.*, 2009). The larger the mine storage facility for a given infiltration rate, the more rock material will be physically shielded from water contact as preferential flow paths develop. Especially in dry climates where low infiltration rates occur, extremely low water/rock ratios within the MRSF will induce the development of geochemical equilibrium conditions (Morin, 2013). Therefore, after a certain mass of rock material has been flushed, further physical contact may not necessarily lead to additional release of geochemical loads as saturation limits are reached (Kirchner & Mattson, 2015).

In addition to the already low infiltration rates inferred for the project area, a cover system will be implemented on all Ajax MRSFs at closure, further reducing the water and oxygen ingress. The Ajax water balance assumes an additional reduction in infiltration rates. As a result of this decreased infiltration, corresponding decreases in geochemical loads can be expected (*e.g.*, Nichol *et al.*, 2005, Marcoline *et al.*, 2006). As a first approximation, the reduction in geochemical loading rates is assumed be similar to the reduction in infiltration achieved by the cover and was set to 50-70%, according to the water/rock ratio in the individual MRSF.

Based on the discussion from above and knowledge gained from field studies, contact water factors for the operational scenario (no cover) were calculated based on the tonnage/infiltration ratio and range from 1%-4%. After cover construction, this value drops to 0.6%-1% for the reclaimed MRSFs. Multiplied with the particle size scaling factor of

10%, the overall applied bulk scaling factor falls between 0.1% and 0.4% and 0.06% and 0.1% (Table 2-3) for operational and closure scenarios, respectively. This range is in agreement with bulk scaling factors reported for MRSF in semi-arid environments (Kirchner & Mattson, 2015).

Temperature

A temperature adjustment factor was not applied to the mine rock or ore source terms due to the large scale of the MRSFs and ore stockpiles relative to the quantity of rock that would be affected by the expected frost penetration depth at the Ajax site.

2.1.4 Conversion of Loading to Concentration

Average annual pore water concentrations were calculated by dividing the scaled geochemical loads (in mg/year) by the volume of water predicted to infiltrate into the MRSF. These volumes are calculated by multiplying the annual infiltration rate by the footprint of the MRSF. Annual infiltration rates into the MRSFs were provided by BGC and are 27 mm/yr for exposed mine rock surfaces and 8 mm/yr for covered mine rock surfaces.

Initial selenium (Se) concentrations predicted for the MRSFs that were derived from scaling factors ranged from 0.003 mg/L to 0.038 mg/L which is lower than values observed in site monitoring data (Table 2-4). This suggests that Se behaves more conservatively than other dissolved trace elements, which is consistent with studies evaluating the influence of scale on metal loading rates, where Se concentrations were found to be underestimated if scaled the same way as other trace metals such as Cu or Pb (*e.g.,* Kirchner & Mattson, 2015). Thus, a more conservative approach was undertaken to estimate Se source terms, as described below.

Table 2-4:
Comparison of upscaled Se concentrations and 95th percentile values of site drainage databases

Initial MRSF Prediction	
Min	0.003
Median	0.012
Max	0.038
Mine Rock Piezometers	
Median	0.041
95th Percentile	0.042
Field Bins	
Median	0.002 – 0.022
95th Percentile	0.004 – 0.034

Selenium is commonly incorporated into the gypsum mineral structure (Fernández-González, 2006) and released proportionately to sulphate (SO_4) during the congruent dissolution of gypsum. The two species showed a strong positive correlation in drainage from the Ajax field bins. The slope of the linear regression between SO_4 and Se from FB7 was used to estimate the Se concentrations from the Ajax MRSFs. Predicted Se concentrations are based on the modelled SO_4 concentrations according to:

$$\text{Se (predicted)} = \text{RS} * \text{SO}_4 \text{ (scaled)} \qquad (2)$$

where RS = regression slope = 0.0001. Note that if the upcsaled SO_4 concentration was lower than the value after equilibration with gypsum in PHREEQC, the former was used to calculate Se concentrations for the different MRSFs.

2.1.5 Secondary Mineral Controls

For some, if not most dissolved species, upscaling of loads from laboratory kinetic tests to simulate drainage chemistry will lead to supersaturation of these elements with respect to a number of secondary minerals. PHREEQC contains an extensive thermodynamic database allowing for the evaluation of minerals that are likely to precipitate within the MRSF after equilibration with the atmosphere. For the various Ajax source term locations, all output solutions were integrated into PHREEQC speciation model (database: Minteq v.4) and saturation indices were evaluated individually. If appropriate, precipitation of certain secondary minerals commonly identified in mining environments was imposed to reduce concentrations of insoluble species such as ferric iron and aluminum. Refer to Table 2-5 for an overview of mineral phases that were allowed to precipitate after equilibration with the atmosphere.

Table 2-5:
Overview of secondary phase allowed to precipitate in the PHREEQC speciation model

Mineral	Chemical Formula
Barite	$BaSO_4$
Calcite	$CaCO_3$
Celestite	$SrSO_4$
Dolomite	$(Ca,Mg)(CO_3)_2$
Ferrihydrite	$Fe(OH)_3$
Gibbsite	$Al(OH)_3$
Gypsum	$CaSO_4*2H_2O$
Malachite	$CuCO_3$
Quartz	SiO_2
Rhodochrosite	$MnCO_3$

2.1.6 Model Validation

As a final step, the PHREEQC model output was compared to water quality results from analogue data sources. These data sources are highly valuable in re-assessing solubility limits under site conditions and provide an excellent opportunity to validate the predicted geochemical source terms that are often not available at many proposed mining projects. To maintain conservatism, the modelled output solutions were only capped if individual species exceeded the highest 95th percentile value reported in either (i) field bin leachates, (ii) mine rock piezometers installed in the historic Ajax backfill, or (iii) a neutral drainage database from BC porphyry copper minesites (SRK, 2004). Cap values used for this model step are provided in Appendix C-1.

2.1.7 Example Calculation

An example calculation outlining the derivation of the sulphate source term concentration for the East MRSF is provided below.

<u>Copper Source Term Concentration in the East MRSF (year 10):</u>

1) Scale median weekly kinetic leachate load (proportional to geounits) to MRSF tonnage and year

   *(Average weekly load) * (time) * (rock unit tonnage) = Maximum annual MRSF load*

   6.61×10^{-5} mg/kg/wk * 52.14 weeks * 68 Mt = 2.34×10^{8} mg/yr

2) Apply scaling factors to account for hydrogeological pathways and grain size:

   *(Maximum annual MRSF load) * (grain size factor) * (contact factor) * (cover factor) = Scaled MRSF load*

   2.34×10^{8} mg/yr * 0.1 * 0.039 *1.0 = 9.12×10^{5} mg/yr

3) Convert into concentrations

   (Scaled MRSF load) / (infiltrate volume) = scaled concentrations

   9.12×10^{5} mg/yr / 31,221,585 L/yr = 0.029 mg/L

4) Apply secondary mineral controls

   Application of the speciation model PHREEQC (Minteq v.4 database) predicts that malachite precipitation (1.4×10^{-7} moles) will lead to a reduction in dissolved copper concentration to 0.011 mg/L

5) Model validation by comparison to site data

   Considering the overall composition of the East MRSF, a value of 0.011 mg/L copper is conservative, however does not exceed the highest 95th PCTL value observed in the reference database used (0.11 mg/L). Therefore no cap was applied.

2.2 Tailings Storage Facility

Tailings slurry will be deposited in the TSF that will have a footprint of 390 ha at closure (Figure 1-1). The tailings slurry will be discharged from spigots positioned along the length of the North and East embankments forming a southeast-sloping beach towards the tailings pond. Depending on which spigots are operating at a given time, the tailings beaches may be active or inactive leading to variable saturation of the tailings surface. A possible closure option is to cover the exposed tailings with a 2 m thick layer of mine rock, till and topsoil. The cover material will be compacted and graded to minimize infiltration into the TSF.

Due to the fine particle size (P_{80} = 60-210 µm), the hydrogeological and geochemical regime in the TSF is markedly different from that in the MRSFs. For example, during operations the majority of the tailings mass will be saturated inhibiting oxygen ingress (and therefore sulphide oxidation) into most of the TSF. After closure, pore water is expected to slowly drain leaving a growing unsaturated zone. However, the combined effects of moisture content, slow oxygen diffusion rates as a result of the fine grain size, and oxygen consumption by sulphide minerals will limit the thickness of active oxidation even under unsaturated conditions. In consideration of the distinct flow properties inherent to the TSF, geochemical loads and concentrations are predicted for the following water sources:

- Tailings beach runoff – active and inactive;
- TSF seepage – operations;
- TSF seepage – post-closure;
- Process water.

2.2.1 Tailings Beach (active and inactive)

Geochemical source term predictions for exposed tailings beaches were derived by applying kinetic test loading rates in a similar fashion as described for the MRSF. Loading rates from the three most representative tailings kinetic tests (Table 2-6) were combined to derive a composite loading rate. Active and inactive beach source terms were modelled by applying median kinetic test loading rates from cycles 0-20 and 5-20, respectively. The composite geochemical loading rates derived from the kinetic tests used to model contact-water from each of the Ajax mine components are given in Appendix A.

Table 2-6:
Proportioning of Ajax kinetic test used to generate composite loading rates for active and inactive tailings beaches

Description	T1	T3	T5
Tailings Beach	33%	33%	33%

Geochemical loading rates were upscaled for the mass of tailings in 1 m^2 unit surface area of tailings beach accounting for the modeled thickness of the active sulphide oxidation zone. This was done to create flexibility in the water quality model as tailings beach exposures vary over time in response to tailings addition and pond size fluctuations.

Due to the high water content of the tailings slurry, an active oxidation zone thickness of 1 cm is applied to the active tailings beach. Due to the high proportion of rinsing of the shallow material on an active tailings beach and a representative PSD in the kinetic test sample, loading rates were not scaled to account for grain size or contact water and the tailings humidity cell loading rates were upscaled directly for the mass associated with a 1 m^2 x 1 cm volume.

Once the tailings deposition ceases and the beach is inactive, the water level is expected to recede to approximately 3 m below the surface and the oxidation depth becomes strongly dependent on particle size, moisture content, and sulphide content within the tailings profile. The thickness of the zone where tailings are actively oxidizing was calculated using the reactive transport model MIN3P (Mayer *et al*., 1999). In order to determine a representative thickness, the model parameters were varied to evaluate the possible range of oxidation zone depth and thickness. Assumptions used to model two end-member scenarios bracketing the oxidation depth are given in Table 2-7. Results indicate that sulphide oxidation will occur over a tailings thickness of about 1-3 m depending on the input parameters. For the geochemical source term predictions, an oxidation zone thickness of 2 m was modelled, which is consistent with field observations of visible oxidation from test pits at the Afton TSF (Figure 2-2).

Table 2-7:
Input parameters used to calculate thickness of the active oxidation zone in unsaturated tailings using MIN3P

Source term	**Case**	**Hydr. conductivity**	**Sand**	**Silt**	**Clay**	**Bulk density**	**Total S**	**Water table below surface**	**Infiltration**	**Oxidation zone thickness**
		m/s	%	%	%	g/cm3	%	m	mm	m
Operation	lower	2.E-07	60	38	2	1.55	0.0016	4	37	1.3
	upper	2.E-08	1	71	28	1.55	0.0031	2	37	3
Post-closure	lower	2.E-07	60	38	2	1.55	0.0016	50	37	1.5
	upper	2.E-08	1	71	28	1.55	0.0031	50	37	2

Figure 2-2: Photograph of a test pit constructed in the historic Ajax tailings

In accordance with the water balance model provided by others, annual infiltration rates were set at 37 mm/yr for exposed tailings surface. Given that the low expected infiltration rates will lead to the development of preferential flow paths, an adjustment factor of 3% (4% contact water; 75% temperature) was applied (Table 2-8).

Table 2-8:
Scaling factors applied for the inactive tailings beach source term

	Grain size	Contact water	Temp	Bulk Correction
Inactive beach	100%	4%	75%	3%

Following this scaling exercise, model steps to convert to concentrations and evaluate secondary mineral controls with PHREEQC were conducted to contact water quality predictions for active and inactive tailings beaches. The modelled output solutions were subsequently capped if individual species exceeded the maximum 95th percentile value reported in either (i) laboratory columns (T2, T4), (ii) tailings field bin, or (iii) water analyses taken from monitoring wells within the TSF containing the historic Ajax tailings (Appendix C-2). The tailings beach source terms are reported as loads per unit area to facilitate input into the water quality model.

2.2.2 TSF Saturated Seepage – Operations

A large portion of the tailings will be saturated during operations, largely inhibiting oxygen transport into the tailings mass and limiting the rate of sulphide oxidation within these saturated tailings. Concentrations measured in the saturated tailings column test and supernatant analysis were used to represent suboxic TSF pore water seepage. Seepage water chemistry from saturated zones in the TSF are predicted as the higher 95th percentile value of the following two data sources:

- Saturated tailings column testing that was initiated at the Lorax laboratory in 2014 to evaluate metal leaching under saturated conditions (Lorax, 2015); and
- analyses that were conducted on tailings supernatant collected during bench-scale and pilot scale metallurgical testing.

2.2.3 TSF Seepage – Post-Closure

Once mining operations have ceased and tailings slurry discharge is suspended, the water balance indicates that the TSF is expected to fully drain within 300 years (BGC, 2015), leaving tailings material unsaturated in the long-term. The thickness of active sulphide oxidation under these conditions was determined using MIN3P. A range of scenarios was modelled for a fully drained tailings profile indicating that the active sulphide zone maintains a thickness between 1.5 and 2.5 m (Table 2-7) as the oxidation front moves deeper into the tailings profile. Therefore, even if tailings are entirely drained, geochemical loads are predicted to be driven by an active oxidation zone with a thickness of 2 m. This is in accordance with observations from the Afton TSF (Figure 2-2). Concentrations were calculated applying an 8 mm/yr infiltration rate for the covered surface during the post-closure period.

In addition, the geochemical load contribution by a NPAG cover system to tailings pore water was investigated as some species may be more readily leached from mine rock *versus* tailings. As such, cover drainage chemistry was modelled on a unit area basis (1 m^2) as described in Section 2.1.1 assuming a cover thickness of 2 m. For any given species, where this model yielded concentrations exceeding those calculated for the TSF pore water, the higher of the two values was adopted for the final source term.

2.2.4 Process Water

Process water represents a large portion of the water balance in the Ajax TSF and will be partly recycled to the mill for further processing of ore. Lorax has conducted analyses on supernatants decanted from tailings slurries that were generated during both bench- and pilot-scale metallurgical tests. These should be comparable in composition to the process water on site. To maintain conservatism, the 95th percentile of all supernatants analyzed (n=8) was used as the process water source term concentration.

Certain dissolved species form oxyanions under oxic conditions and are therefore relatively mobile under alkaline conditions expected in the process water. These include As, Mo, Sb, Se, Tl, U, and V. As the process water is recycled in the mill, it was conservatively assumed that these species will accumulate in response to addition of new ore material to the process water. These loads (Table 2-9) were calculated for each recycling step based on maximum values released from water extractions including tailings supernatant tests, shake flask extraction tests and first rinses from columns and humidity cells and represent the mass load that will accumulate for every recycling iteration.

Table 2-9:
Geochemical loads for anionic species that are expected to accumulate during recycling of process water

	Load (mg/t_{tails}/cycle)
Sb	12
As	18
Mo	554
Se	5
Tl	0.1
U	23
V	11

2.2.5 TSF Pond Concentration Caps

The various TSF source terms described above are, in conjunction with the water balance model, integrated to predict the overall TSF pond chemistry that will form during operations. Due to the strong evaporative nature of the TSF pond system and the conservative assumptions made with respect to geochemical evapo-concentration, it was considered appropriate to apply concentration caps to the TSF pond to account for attenuation mechanisms and solubility limits. These were developed using (i) the maximum concentrations measured in tailings contact water that underwent a small-scale evaporation experiment at the Lorax laboratory and (ii) selected 90th percentile values from water analysis in nearby evaporative lakes. In the experiment, around 30L of tailings supernatant in contact with solid tailings material were placed under a heat lamp until almost all water (96%) was lost to evaporation. Chemical analyses of the contact water were conducted at various time steps to understand the behaviour of different species as a function of evaporative water loss. These values were subsequently compared to the 90th percentile values measured in lake data. For major ions as well as As and Zn, the higher value of the two datasets was used. As a result of near-conservative concentration increases observed in the evaporation experiment for B, Li, Se, and Mo over time, no cap value was assigned for these species. The final concentration caps are reported in Appendix C-3.

2.3 Pit Walls

Contaminant release rates from the pit walls are controlled by the exposed lithology, the overall surface area of the pit walls, and the nature of water-rock interaction (*i.e.*, precipitation rinsing versus lake inundation pathways). Geochemical loading rates were derived for four major mine rock types that will be exposed in the pit walls namely SLD, IMH, MAFV, PICR. An additional source term is provided for ore exposures (SLD ore). Due to the potential geochemical loading pathways from the pit walls, separate geochemical loading terms were developed for loading from precipitation rinsing the pit walls (*i.e*., pit wall runoff) and pit lake water inundating and dissolving loads that have accumulated in the outer layer of the pit wall. Figure 2-3 provides an overview of the various work stages leading to chemistry predictions of pit wall contact water. Assumptions inherent to the pit wall source term derivations are discussed below.

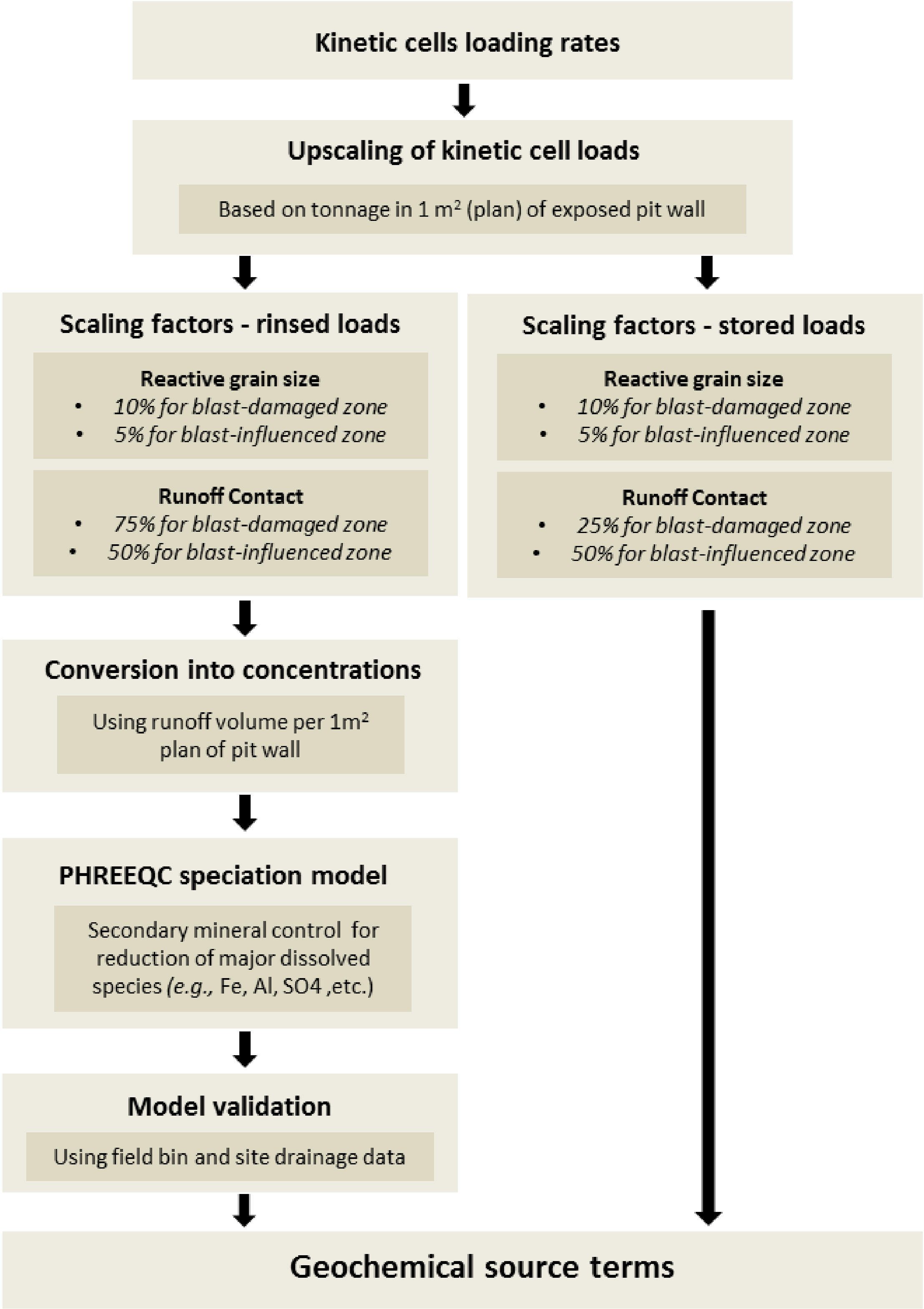

Figure 2-3: Flow chart outlining methods used to generate pit wall geochemical loading predictions

2.3.1 Rinsed Loading from Exposed Pit Wall

2.3.1.1 Wall Exposure Calculation

A lab-to-field adjustment for grain size was applied to the wall rock in order to account for the difference in specific area between the kinetic cell samples and the fractured pit wall rock. The final pit walls are expected to be fractured as a result of blasting operations. Fracturing of the pit walls exposes the wall rock to weathering and hence wall rock drainage will have the geochemical signature of the respective rock type. In this assessment, it was assumed that controlled blasting would be used at the limits of the proposed open pit mine. However, controlled blasting of rock does not completely eliminate fracture of underlying rock, but results in a transition zone extending into the pit walls. The blast-fractured transition zone comprises a crushed zone, damaged zone and an influenced zone. The crushed zone would be removed for processing or disposal, and the damaged and influenced zones would remain in place upon closure of the mine and be subjected to ongoing weathering. The penetration depth of this transition zone into the wall rock is dependent on a variety of parameters. Hustrulid (1999) estimated ranges of 0.85 to 1.05 m and 2.65 to 3.15 m for the blast-damaged and the blast-influenced zones, respectively. These estimates are based on controlled blasting and an intermediate rock strength. For the Ajax pit walls, penetration depths of 0.9 and 2.9 m were chosen for the blast-damaged and the blast-influenced zones, respectively.

To provide source terms readily adjustable to account for changing exposures of the pit wall, loads were calculated per square meter (plan) of exposed unit. Knowing the average angle of the pit wall from the bottom to the top of the pit, the appropriate length of the according angled surface can be calculated. For the Ajax pit, an average pit wall angle of 45º would yield a tilted exposure factor of 1.41 per m^2 (plan). Multiplying this factor with the thickness of the blast-damaged and blast-influenced zones as well as the bulk density of the material then provides the total mass of rock exposed per m^2 (plan).

2.3.1.2 Assigning Loading Rates from Kinetic Tests

Dissolved mass loading rates from exposed pit walls were calculated in a manner similar to that conducted for mine rock using statistically representative humidity cell leachates as input solutions for the different lithologies. Pit wall runoff chemistry for the major geological units were approximated by scaling loading rates from kinetic testing (Table 2-10). Data from kinetic test cells that were initiated in 2014 are only incorporated in the operational drainage chemistry prediction model due to the lack of long-term data from these cells.

Table 2-10:
Proportioning of Ajax kinetic test used to generate composite loading rates for pit walls

Unit	**Col-2** SLD	**Col-3** High-S SLD	**Col-4** IMH	**Col-5** IMH	**Col-6** MAFV/ PICR	**Col-7** IMH	**Col-8** IMH	**Col-10** PICR	**Col-11** PICR	**Col-12** MAFV
IMH	-	-	50%/25%	50%/25%	-	25%	25%	-	-	-
SLD	*86%*	*14%*	-	-	-	-	-	-	-	-
PICR	-	-	-	-	100%	-	-	81%	19%	-
MAFV	-	-	-	-	100%	-	-	-	-	100%

Notes: Proportions indicated in red and blue identify cells used for short- and long-term leaching rates, respectively.
Proportions indicated in black were applied to both scenarios.

Acidic loading rates were developed to represent the portions of the pit wall that may turn acidic after long-term exposure. Potentially acid generating (PAG) samples were not identified in IMH mine rock such that this unit is excluded from this modelling step. The acidic loading rates were derived from NP-depleted SLD humidity cell sample HC4 that has a leachate pH between 5 and 6 (Lorax, 2015). This sample is characterized by its relatively high total sulphur content relative to the range of S measured in the mine rock samples, thus representing a conservative proxy for pit wall exposures. More recently, carbonate-leached experiments have also been initiated for other lithologies containing PAG samples (*i.e.*, MAFV and PICR), however at the time of reporting, stabilized leaching rates were not yet available for these tests. Therefore, metal release rates and pH from these lithologies under carbonate-depleted conditions were extrapolated from the relationship of neutral *versus* carbonate-depleted leaching characteristics from the SLD unit. Specifically, this was achieved by applying an “acid factor” to each species that is expected to be impacted by the acidification of drainage, which is calculated as:

$$\text{Acid factor} = L_{i\text{-HC4}} / L_{i\text{-HC2}} \qquad (3)$$

where L_i is the loading rate for species i in the acidic (HC4) and neutral (HC2) SLD humidity cell leachates.

2.3.1.3 Scaling Factors

The hydrogeological regime associated with pit walls differs markedly from blast-rock storage facilities and can be described as primarily fracture-controlled. Over time, however, portions of the blast-damaged zone are expected to crumble and form small-scale mine rock piles on underlying benches. For the Ajax pit walls it was assumed that 75% of this accumulated mass will be contacted by meteoric water and release a geochemical load to the surrounding environment. As for MRSFs, a grain size scaling factor of 10% was applied for material exposed in this outer pit wall layer while a 75% temperature correction accounts for surficial freezing of rock material for three months out of the year.

The blast-influenced zone is expected to remain in place with focussed fluid flow fracture-networks being the primary water-rock contact mechanism. The contact water factor for this component will be lower than for the blast-damaged zone and was estimated to be 50%. Furthermore, while difficult to directly compare with humidity cell samples, a grain size scaling factor of 5% was applied for this zone, assuming that the exposed surface area is limited by fractures (Table 2-11).

Table 2-11:
Scaling factors used for pit walls

	Grain size	Contact water	Temperature	Bulk Correction
Blast-damaged	10%	75%	75%	5.60%
Blast-fractured	5%	50%	100%	2.50%

Scaled loads calculated for each of the five exposure types were multiplied by 52.14 weeks to obtain an annual loading value for the various species and converted into concentrations simply by dividing the loads by the amount of annual wall runoff (92 and 102 L/m^2/yr for operational and closure, respectively). Secondary mineral controls then were modeled in the same manner as described for the MRSFs in Section 2.1. The reference database used to cap neutral pit wall runoff concentrations as a final step (model validation) was the same as that used for MRSF (Appendix C-1). For the acidic pit wall source terms, the 95th percentile values of a database compiling slightly acidic ($4<pH<6$) drainage analyses from various porphyry-copper mines (SRK, 2004) were used as concentration limits.

2.3.2 Stored Load from Inundated Pit Wall

For sulphidic pit walls, a key model assumption is that only a portion of the geochemical load produced by sulphide oxidation will be flushed from the walls during rainfall events. The remaining unrinsed oxidized load is stored on the pit wall. Sulphide minerals continue to oxidize and thereby accumulating the stored loads on the wall (*e.g.*, in the form of less soluble sulphate salts and metal oxides) that will be available for dissolution upon inundation of the pit wall during flooding. Therefore, an annual stored loading value was calculated as the difference between the total load predicted to be released from sulphide oxidation and the load removed during exposed pit wall flushing by precipitation. This load will accumulate until the pit lake rises and floods the respective exposures at which point the entire mass of stored material is expected to be released to the pit lake.

3. Geochemical Source Term Results

3. Geochemical Source Term Results

Selected geochemical source term predictions for the Ajax MRSFs, TSF and pit walls presented below in Table 3-1, Table 3-2 and Table 3-3, respectively. The concentrations represent reasonably conservative concentrations that would be expected to persist in drainage for a time frame on the order of 200 years following the construction of the facility. The layers of conservatism implemented into the model are summarized below:

- Bulk scaling factors are somewhat higher than those back-calculated at an arid mine-site with acidic drainage and smaller MRSF (Kirchner & Mattson, 2015).
- Adsorption and co-precipitation were not considered as attenuation mechanisms in PHREEQC.
- Caps were applied only if the highest 95th PCTL concentration of the following database was exceeded. Reference data sources included:
  - Field bin leachates;
  - mine rock piezometers installed in the historic Ajax backfill;
  - neutral drainage database from BC porphyry copper minesites;
  - historic Ajax tailings pore-water.
- Selenium concentration through upscaling were considered non-conservative and were increased to a value that correlates with sulphate concentrations derived from kinetic test results.

Refer to Appendix D for a complete overview of all geochemical source term results.

Table 3-1:
Predicted seepage chemistry for the Ajax MRSFs at different mine phases

	pH	Alk.	SO_4	Al	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo	Ni	Pb	Sb	Se	U	V	Zn
West MRSF & North Embankment																				
Year 5	8.0	132	1673	0.0032	0.081	504	0.00019	0.0036	0.011	0.00028	54	0.060	0.47	0.085	0.0014	0.052	0.080	0.0069	0.11	0.029
Year 10	8.0	130	1660	0.0031	0.081	497	0.00023	0.0055	0.011	0.00028	56	0.088	0.71	0.10	0.0012	0.049	0.080	0.0097	0.11	0.033
Year 20	8.0	128	1649	0.0031	0.081	491	0.00025	0.0063	0.011	0.00028	57	0.10	0.83	0.11	0.0011	0.048	0.080	0.011	0.11	0.035
Post-Closure	7.9	112	1447	0.0027	0.081	478	0.00018	0.0018	0.012	0.00033	79	0.049	1.3	0.057	0.00039	0.015	0.045	0.0058	0.11	0.027
South MRSF & East Embankment																				
Year 5	8.0	124	1616	0.0030	0.081	469	0.00020	0.0050	0.011	0.00030	64	0.088	0.64	0.083	0.00090	0.076	0.080	0.0099	0.11	0.043
Year 10	8.0	123	1611	0.0030	0.081	465	0.00023	0.0059	0.011	0.00030	65	0.10	0.76	0.094	0.00084	0.074	0.080	0.011	0.11	0.044
Year 20	8.0	123	1610	0.0030	0.081	465	0.00022	0.0059	0.011	0.00030	65	0.10	0.75	0.093	0.00084	0.074	0.080	0.011	0.11	0.044
Post-Closure	7.9	105	1430	0.0026	0.081	432	0.00017	0.0021	0.012	0.00037	99	0.067	1.1	0.052	0.00060	0.020	0.043	0.0067	0.11	0.038
East MRSF																				
Year 5	7.9	122	1598	0.0029	0.081	458	0.000080	0.0019	0.011	0.00031	67	0.045	0.22	0.029	0.00091	0.080	0.064	0.0050	0.11	0.039
Year 10	7.9	122	1598	0.0029	0.081	458	0.000080	0.0019	0.011	0.00031	67	0.045	0.21	0.029	0.00091	0.080	0.063	0.0050	0.11	0.039
Year 20	7.9	122	1598	0.0029	0.081	458	0.000080	0.0019	0.011	0.00031	67	0.045	0.21	0.029	0.00091	0.080	0.063	0.0050	0.11	0.039
Post-Closure	7.9	116	1457	0.0028	0.081	504	0.000050	0.0010	0.011	0.00031	69	0.036	0.36	0.025	0.00035	0.011	0.013	0.0024	0.11	0.021
Backfill																				
Year 20	7.9	120	1598	0.0029	0.081	450	0.00045	0.0063	0.012	0.00032	72	0.19	1.5	0.19	0.00064	0.080	0.080	0.015	0.11	0.064
South Embankment																				
Year 20	8.0	126	1634	0.0031	0.081	482	0.00029	0.0063	0.011	0.00029	59	0.13	1.0	0.12	0.00090	0.048	0.080	0.014	0.11	0.041
Post-Closure	8.0	121	1485	0.0030	0.062	534	0.000090	0.00082	0.011	0.00029	60	0.025	0.54	0.015	0.00021	0.0070	0.023	0.0036	0.11	0.014
Southeast Embankment																				
Year 20	8.0	133	1618	0.0032	0.081	539	0.00016	0.0042	0.011	0.00027	50	0.068	0.55	0.064	0.00047	0.025	0.080	0.0075	0.11	0.021
Post-Closure	8.0	130	1529	0.0032	0.033	572	0.000050	0.00044	0.011	0.00027	50	0.013	0.29	0.0081	0.00011	0.0037	0.012	0.0019	0.11	0.0073
Ore Stockpile																				
Max. extent	8.2	199	1638	0.0046	0.048	537	0.0011	0.0063	0.11	0.00021	29	0.46	0.83	0.043	0.0017	0.023	0.080	0.015	0.11	0.023
Year 17	8.2	199	1632	0.0046	0.050	540	0.00075	0.0063	0.11	0.00021	29	0.46	0.75	0.037	0.0014	0.022	0.080	0.015	0.11	0.015

Notes: All concentrations are given in mg/L; Alkalinity is reported in terms of $CaCO_3$

Table 3-2:
Predicted contact-water chemistry for the Ajax TSF at different mine phases

	Unit	pH	Alk.	SO_4	Al	Sb	As	Cd	Ca	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	U	V	Zn
Beach runoff (active)	mg/m^2/yr	8.0	4865	51590	0.12	0.100	0.12	0.0022	18849	0.044	0.41	0.0099	0.0063	1817	1.5	7.5	0.19	0.40	0.081	0.56	0.28
Beach runoff (inactive)	mg/m^2/yr	7.9	3896	48234	0.096	0.100	0.12	0.016	12325	0.25	0.44	0.013	0.024	3622	10	37	0.62	1.5	0.34	0.59	0.74
Operations seepage	mg/L	7.8	246	1498	0.0023	0.0047	0.0073	0.000092	627	0.00072	0.0066	0.00040	0.00062	45	0.087	0.35	0.0059	0.0021	0.0091	0.0046	0.015
Closure seepage w/o NAG cover	mg/L	7.9	105	1304	0.0026	0.0027	0.0033	0.00044	333	0.0068	0.012	0.00036	0.00065	98	0.27	1.0	0.017	0.041	0.0091	0.016	0.020
Closure seepage with NAG cover	mg/L	7.9	105	1304	0.0026	0.012	0.073	0.00044	333	0.0068	0.046	0.00036	0.00065	98	0.27	1.3	0.017	0.041	0.010	0.11	0.024
Process-water - Initial	mg/L	7.7	50	1616	0.047	0.0047	0.0073	0.000092	612	0.00072	0.0066	0.030	0.00062	61	0.087	0.22	0.0059	0.0021	0.0091	0.0045	0.015

Notes: Alkalinity is reported in terms of $CaCO_3$.

Table 3-3:
Predicted Ajax pit wall runoff chemistry at different mine phases

	pH	Alk.	SO_4	Al	Sb	As	Cd	Ca	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	U	V	Zn
Operational (mg/L)																				
IMH	8.0	126	1623	0.0031	0.056	0.081	0.000020	480	0.00076	0.011	0.00029	0.00066	58	0.022	0.075	0.0041	0.016	0.0026	0.11	0.025
SLD	8.0	131	1616	0.0032	0.011	0.018	0.00046	547	0.0063	0.011	0.00027	0.00044	52	0.20	1.8	0.18	0.080	0.015	0.11	0.045
MAFV	8.0	138	1703	0.0033	0.030	0.081	0.00033	522	0.00097	0.011	0.00026	0.0036	48	0.0046	0.27	0.13	0.068	0.0057	0.11	0.039
PICR	8.0	141	1707	0.0033	0.055	0.081	0.000090	539	0.00073	0.0094	0.00026	0.00071	49	0.014	0.050	0.075	0.054	0.00023	0.024	0.011
SLD ore	8.1	167	1660	0.0040	0.011	0.019	0.00077	590	0.0063	0.011	0.00022	0.0010	34	0.52	0.42	0.024	0.080	0.0098	0.11	0.017
Post-Closure (mg/L) - rinsed																				
IMH	8.0	122	1488	0.0030	0.0065	0.039	0.000020	540	0.00051	0.011	0.00029	0.00023	58	0.021	0.038	0.0029	0.0042	0.0014	0.11	0.013
SLD - neutral	8.0	126	1514	0.0031	0.0030	0.015	0.00012	558	0.00067	0.011	0.00028	0.000080	54	0.017	0.66	0.0060	0.030	0.0052	0.11	0.0080
SLD - acidic	6.2	2.0	1935	0.0074	0.0028	0.00060	0.0013	490	0.49	2.9	0.0088	0.00044	177	0.15	0.015	1.0	0.079	0.00044	0.0082	0.060
MAFV/PICR - neutral	8.0	130	1569	0.0032	0.012	0.081	0.00010	583	0.0016	0.011	0.00028	0.00014	53	0.027	1.5	0.12	0.032	0.00097	0.062	0.013
MAFV/PICR - acidic	5.7	0.46	2139	0.30	0.011	0.00060	0.0010	536	1.1	5.4	0.0079	0.00075	180	0.24	0.030	1.0	0.080	0.000080	0.0024	0.097
SLD ore - neutral	8.0	129	1517	0.0032	0.0027	0.016	0.00034	574	0.00065	0.011	0.00027	0.000090	46	0.024	2.1	0.0018	0.080	0.0024	0.087	0.0049
SLD ore - acidic	6.1	1.3	2115	0.022	0.0025	0.00060	0.0037	637	0.48	7.5	0.0063	0.00049	118	0.21	0.030	0.32	0.080	0.00020	0.0035	0.036
Post-Closure (mg/m^2/yr) - stored																				
IMH	-	96966	3101	11	0.49	2.9	0.0013	17004	0.038	1.2	0.99	0.017	7551	1.6	2.8	0.22	0.43	0.10	24	0.96
SLD - neutral	-		21962	2.8	0.22	1.1	0.0090	22100	0.050	1.7	1.0	0.0060	5092	1.3	49	0.45	0.85	0.38	15	0.60
SLD - acidic	-	-	58676	7.3	0.21	0.21	0.097	12677	37	521	0.65	0.033	13111	11	1.1	80	2.2	0.032	0.61	4.4
MAFV/PICR - neutral	-		23770	10	0.86	24	0.0072	14247	0.12	1.3	0.90	0.010	8276	2.0	112	8.7	1.1	0.072	4.6	0.97
MAFV/PICR - acidic	-	-	63508	27	0.80	4.5	0.077	8173	85	397	0.58	0.056	21309	18	2.5	1558	2.7	0.0061	0.18	7.2
SLD ore - neutral	-		79511	2.2	0.20	1.2	0.025	43732	0.048	1.8	0.72	0.0066	3387	1.8	156	0.13	1.9	0.18	6.5	0.36
SLD ore - acidic	-	-	212431	5.6	0.18	0.23	0.27	25086	35	555	0.47	0.036	8722	16	3.5	24	4.9	0.015	0.26	2.7

Notes: Alkalinity is reported in terms of $CaCO_3$.

4. Nitrogen Source Terms

4. Nitrogen Source Terms

4.1 Methodology

4.1.1 Background

The release of nitrogen from explosives loaded in boreholes and from explosive residue on blasted rock surfaces occurs by dissolution of nitrogen compounds into water and subsequent aqueous transport to the downstream receiving environment. Elevated concentrations of nitrogen can be toxic to aquatic organisms. The British Columbia Ministry of Environment (MOE) continues to refine water quality guidelines for nitrogen compounds which implement safe conditions or levels intended to protect the most sensitive species and sensitive life stage, indefinitely (Meays, 2009).

The nitrogen compounds ammonia (NH_3) and nitrate (NO_3) are constituents of the explosives, while nitrite (NO_2) is typically an intermediate oxidation product of ammonia. Nitrogen compounds in explosive mixtures are readily water soluble, with solubility rates varying from minutes for ANFO (ammonium nitrate fuel oil) to weeks for water resistant emulsion mixtures as described by Revy (1996). For open pit mining operations the export of nitrogen to the receiving environment has been observed to be predominantly in the form of nitrate, and to a lesser extent, nitrite and ammonia (Ferguson and Leask, 1988). Concentrations of nitrogen species in mine-site effluents depend on the type and quantity of explosives used for blasting and the blasting efficiency. Nitrogen export from the project area will be influenced by explosives handling and blasting practices as well as site specific conditions. The export of nitrogen is controlled by implementing best blasting practices to maximize explosive consumption during blasting by avoiding explosive losses within the pit prior to detonation and minimizing non-detonated explosive residue stored on mine rock.

Explosive residue on blasted rock is stored in MRSF and the release of nitrogen compounds is directly related to the volume of blasted rock, porosity and surface water infiltration. Water is stored and moves slowly in rock piles leading to a time lag between rock deposition and observed release of nitrogen at significant concentrations (Baily *et al*, 2013). Preferential flow paths develop within a rock pile leading to partial and gradual wetting from the outer to the inner portions of the pile. The nitrogen available for leaching is limited to the wetted areas of the pile and over time newly wetted areas will release stored nitrogen; therefore, nitrogen release from a large rock pile can persist after rock placement.

4.2 General Assumptions

Nitrogen loads for the Ajax mine were derived using scheduled annual blasted rock, stockpiled mine rock, ROM ore and explosive tonnages data provided by KAM (June 2014 Mine Plan). Nitrogen species (NO_3, NH_3 and NO_2) are provided as annual loads (kg) to allow for on-going adjustments to the water balance (and infiltration volumes). Additional key model assumptions are summarized below:

- Explosive use, and mine rock and ore production and placement will proceed as per the mine plan;
- Explosive types to be used are ANFO (34% N) and Emulsion (27.5% N). Explosive use throughout the life of the mine is expected to be 90% Emulsion and 10% ANFO. Based on these proportions, the average nitrogen content of the total planned explosives is 28.15% by weight N. This value is used to calculate nitrogen loadings from blasted rock.
- The model assumes that best explosive use and blasting practices will be implemented to maximize explosive consumption during blasting and to minimize explosive residue on mine rock surfaces.
- The Ferguson and Leask (1988) model for mine sites using greater than 20% Emulsion was applied to estimate nitrogen loads from blasted mine rock and ore. Consistent with the Ferguson and Leask model, a high nitrogen loading rate (5.1%) is assigned to ‘wet (flowing) conditions’ (*i.e.*, challenging blast conditions) and a low rate (0.94%) is assigned to ‘favourable blast conditions’.
- An average of 28.1% wet holes (with flowing water) is assumed for each year of blasting. The number of wet holes was derived based on the life-of-mine material release schedule with the lowest bench assumed to have 90% wet holes and the benches above the water table assumed to have 20% wet holes.
- The observations at the Diavik Diamond Mines and British Columbia surface coal mine rock studies are a reasonable proxy for mining and site conditions that will be encountered at the Ajax mine.

4.3 Derivation of Mine Rock Drainage Nitrogen Loadings

4.3.1 Nitrogen Loading Estimates (Ferguson and Leask (1988) Model)

The Ferguson and Leask (1988) method was used to estimate annual nitrogen loads to stockpiled Ajax mine rock and ore. Ferguson and Leask (1988) studied coal mines discharges in southeastern British Columbia and described an empirical method for estimating annual nitrogen loads to MRSF based on the amount and type of explosive used annually. The Ferguson and Leask model uses Emulsion as a proxy for challenging blasting conditions typically encountered in wet holes (with flowing water) where ANFO cannot be used. Emulsion used in favorable blasting conditions can be expected to detonate as efficiently as ANFO, therefore, the Ferguson and Leask equation was modified to assign the high loading rate to explosives detonated in wet holes (with flowing water) and the low loading rate to explosives detonated in the remaining holes.

The planned explosive use and mine rock production volumes were used to estimate annual nitrogen loads to each stockpile (Table 4-1) based on the Ferguson and Leask (1988) equation for mines that use more than 20% emulsion:

$$N_{Load\ (k)} = 0.94\% \times E_{An(k)} + 5.1\% \times E_{Em(k)}$$

Where,

$N_{Load\ (k)}$ = annual nitrogen load (kg N) in year k of mine operation;

$E_{An(k)}$ = annual explosive use (kg N) under favourable conditions in year k of mine operation;

$E_{Em(k)}$ = annual explosive use (kg N) under challenging (wet) conditions in year k mine operation;

(Note: average nitrogen content of the total planned explosives is 28.15% by weight N.)

Table 4-1:
Planned Explosive Use, Mine Rock Placement and Estimated Annual Nitrogen Loading to Mine Rock at the Ajax Mine

Mine Year	**Y0**	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**	**Y7**	**Y8**	**Y9**	**Y10**	**Y11**	**Y12**	**Y13**	**Y14**	**Y15**	**Y16**	**Y17**	**Y18**	**Y19**
Planned Blasting Metrics																				
pF (t/t) [1]	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032	0.00032
% wet (flowing) conditions	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%	28.1%
East MRSF																				
Blasted rock (t)	0	0	18,250,418	29,590,148	18,362,025	0	0	1,797,409	0	0	0	0	0	0	0	0	0	0	0	0
Favourable blast conditions (t)	0	0	4,211	6,828	4,237	0	0	415	0	0	0	0	0	0	0	0	0	0	0	0
Wet (flowing) conditions (t)	0	0	1,646	2,669	1,656	0	0	162	0	0	0	0	0	0	0	0	0	0	0	0
Estimated N Load (kg as N)	0	0	34,773	56,379	34,985	0	0	3,425	0	0	0	0	0	0	0	0	0	0	0	0
West MRSF & Main Embankment [2]																				
Blasted rock (t)	766,201	1,597,999	5,566,000	24,000,000	29,717,800	20,000,000	18,905,200	17,682,400	0	12,888,600	25,347,300	17,483,400	21,372,574	61,261,118	31,857,208	1,100,000	0	0	0	0
Favourable blast conditions (t)	177	369	1,284	5,538	6,857	4,615	4,362	4,080	0	2,974	5,849	4,034	4,932	14,136	7,351	254	0	0	0	0
Wet (flowing) conditions (t)	69	144	502	2,164	2,680	1,804	1,705	1,595	0	1,162	2,286	1,577	1,927	5,525	2,873	99	0	0	0	0
Estimated N Load (kg as N)	1,460	3,045	10,605	45,728	56,622	38,106	36,020	33,691	0	24,557	48,295	33,311	40,721	116,722	60,698	2,096	0	0	0	0
South MRSF & East Embankment [2]																				
Blasted rock (t)	1,096,137	17,949,464	14,730,564	17,557,539	14,678,101	36,196,962	27,772,760	51,745,099	72,478,101	44,537,083	9,129,146	41,803,848	1,269,400	203,500	13,287,419	0	0	0	0	0
Favourable blast conditions (t)	253	4,142	3,399	4,051	3,387	8,353	6,409	11,940	16,725	10,277	2,107	9,646	293	47	3,066	0	0	0	0	0
Wet (flowing) conditions (t)	99	1,619	1,328	1,583	1,324	3,264	2,505	4,667	6,536	4,017	823	3,770	114	18	1,198	0	0	0	0	0
Estimated N Load (kg as N)	2,088	34,199	28,066	33,453	27,966	68,967	52,916	98,591	138,094	84,857	17,394	79,649	2,419	388	25,317	0	0	0	0	0
TSF South Embankment [2, 3]																				
Blasted rock (t)	0	0	0	0	0	0	12,600	615,300	1,519,350	2,377,200	0	0	0	0	0	0	0	0	0	0
Favourable blast conditions (t)	0	0	0	0	0	0	3	142	351	549	0	0	0	0	0	0	0	0	0	0
Wet (flowing) conditions (t)	0	0	0	0	0	0	1	55	137	214	0	0	0	0	0	0	0	0	0	0
Estimated N Load (kg as N)	0	0	0	0	0	0	24	1,172	2,895	4,529	0	0	0	0	0	0	0	0	0	0
TSF Southeast Embankment [2, 3]																				
Blasted rock (t)	0	0	0	0	0	0	0	0	24,150	178,500	0	0	0	0	0	0	0	0	0	0
Favourable blast conditions (t)	0	0	0	0	0	0	0	0	6	41	0	0	0	0	0	0	0	0	0	0
Wet (flowing) conditions (t)	0	0	0	0	0	0	0	0	2	16	0	0	0	0	0	0	0	0	0	0
Estimated N Load (kg as N)	0	0	0	0	0	0	0	0	46	340	0	0	0	0	0	0	0	0	0	0
Temporary Ore Stockpile																				
Blasted rock (t)	0	0	4,332,962	4,370,238	5,239,706	1,027,568	0	1,914,406	2,684,831	7,782,030	16,490,629	11,021,654	8,600,065	1,660,476	1,617,129	3,556,331	2,967,274	2,782,328	4,806,685	1,678,635
Favourable blast conditions (t)	0	0	1,000	1,008	1,209	237	0	442	620	1,796	3,805	2,543	1,984	383	373	821	685	642	1,109	387
Wet (flowing) conditions (t)	0	0	391	394	473	93	0	173	242	702	1,487	994	776	150	146	321	268	251	433	151
Estimated N Load (kg as N)	0	0	8,256	8,327	9,983	1,958	0	3,648	5,115	14,827	31,420	21,000	16,386	3,164	3,081	6,776	5,654	5,301	9,158	3,198
Back Fill MRSF																				
Blasted rock (t)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	54,514,825	52,357,758	50,371,841	22,759,772	3,325,724
Favourable blast conditions (t)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12,580	12,082	11,623	5,252	767
Wet (flowing) conditions (t)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,916	4,722	4,543	2,053	300
Estimated N Load (kg as N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	103,868	99,758	95,974	43,365	6,337

Notes:

1. pF = powder factor, which is the quantity of explosives required to fragment 1 tonne of rock, calculated based on the average of total planned annual explosive use and total planned annual blasted rock (*i.e.*, pit total which includes all scheduled stockpiled mine rock and run-of-mine (ROM) ore);

2. A 50% scale factor was applied to rock tonnages used in the TSF embankments to account for the liner applied on the inside of the TSF and the resulting semi-permeable nature of the dam.
A 50% scaling factor is consistent with other source term derivations for the Ajax mine and is based on the assumption that the liner will prevent water from contacting 50% of the rock in the embankment.

3. The smaller embankments for the TSF (*i.e.*, south and southeast dams) were constructed using mine rock stored in the West MRSF; therefore, the annual tonnage used to construct the smaller embankments was subtracted from the West MRSF tonnage.

4.3.2 Nitrogen Release Rate and Lag Time

A nitrogen release rate for Ajax mine rock piles was derived and used to estimate annual releases of nitrogen from stockpiled rock during open inflow conditions. Observations at Diavik mine reported by Baily *et al* (2013) indicate the release of significant levels of nitrogen in mine rock test piles commenced with the third freshet (*i.e.*, the third year) after rock deposition. As noted in Table 4-2, approximately 8.2% of the total nitrogen load was released in the first three years after mine rock placement.

Table 4-2:
Diavik Mine Nitrogen Release Rates from Basal Drain Test Piles (from Baily, 2013)

	N stored expressed as % N used for blasting	N released from 2007-2010 expressed as % N used for blasting	N release rate from 2007 to 2010 expressed as % of N stored *
Blasted Rock Leach Test	5.4	5.4	100%
Type III test pile	5.4	0.45	8.3%
Type I test pile	5.4	0.43	8.0%
Test pile average	-	-	8.2%

Notes: * Derived using data presented in Section 3.1 and Table 5 of Baily (2013).

Increases in precipitation are expected to lead to increased infiltration and increased nitrogen release to water infiltrating through a MRSF. The mean annual precipitation (MAP) observed at Diavik is 280 mm (Fretz *et al*, 2011), with approximately 40% occurring as rainfall (Environment Canada, 2008). The climate in Kamloops is considered to be continental and semi-arid bordering on desert, therefore, the area receives very little precipitation. The MAP for the Ajax mine (275 mm) is very similar to the precipitation levels observed at Diavik mine (280 mm); therefore, the nitrogen release rate and flush delay observed during field tests at Diavik (Baily, 2013) are applied to the derivations of nitrogen loadings from the Ajax mine. This assumes that 8.2% of the estimated residue in the Ajax mine rock piles are released each year, commencing the third freshet (year 3) after rock deposition.

4.3.3 Cover Attenuation Factor

During closure (after Y22 in the model), the MRSFs (and TSF embankments) will be decommissioned by resloping and covering to reduce water infiltration. Under restricted infiltration conditions (*i.e.*, after the installation of a cover to divert infiltration water) infiltration and flushing rates of the pile will be reduced. The reduction of mine rock infiltration flows is expected to reduce the nitrogen release from MRSF, therefore a cover attenuation factor was derived proportional to the change in flow between open condition and the covered condition. The cover attenuation factor was used to model reduction in nitrogen release due to cover installation. The cover attenuation factor was calculated as follows:

$$a_{(k)} = \frac{F_{Closed\ (k)}}{F_{Open\ (max)}}$$

Where,

$a_{(k)}$ = nitrogen release cover attenuation factor for the covered condition in year k;

$F_{Closed\ (k)}$ = mine rock pile inflow for the covered condition in year k; and

$F_{Open\ (max)}$ = mine rock pile inflow for the open condition at maximum pile build out.

Cover placement on the MRSFs and TSF embankments reduces infiltration contact with particles in the piles to 30% of the uncovered condition, which is a condition consistent with water balance model. The amount of nitrogen released for the three years following covering of the piles is, therefore, reduced to 30% of the uncovered condition due to the reduced amount of infiltration contact water in the covered condition. Following cover placement, the proportion of wetted surfaces would decrease. To account for the effect of cover placement, after year 3 of the cover condition, nitrogen loadings are reduced at a rate of 8.2% per year through the post-closure period.

4.3.4 Annual Nitrogen Release Estimates

Nitrogen release from each annual mine rock layer is expected to commence three years after rock placement and the appearance of significant nitrogen species concentrations in drainage water as described above. For each layer the nitrogen release was calculated using the release rate, the cover attenuation factor and the estimated amount of stored nitrogen within the layer as shown below. Significant nitrogen release in year zero (the year of rock layer placement) and years one and two (the years after rock layer placement) is not expected and is therefore assumed to be zero (0) for each of those three years.

$$N_{Layer\ Release\ (a)} = r_{EG} \times a_{(k)} \times N_{Layer\ Store\ (a-1)}$$

Where,

$N_{Layer\ Release\ (a)}$ = nitrogen released (kg N) from mine rock layer in year a after layer placement;

r_{EG} = nitrogen release rate estimated for the Ajax mine location;

$a_{(k)}$ = nitrogen release rate attenuation factor in year *k* of mine operation; and

$N_{Layer\ Store\ (i-1)}$ = nitrogen stored (kg N) in mine rock in year *a-1* after layer placement.

Nitrogen storage in each annual mine rock layer is the difference between the amount of nitrogen loaded to the layer in year zero of layer placement, and the cumulative amount of nitrogen released from the layer since the load was placed. The entire nitrogen load was assumed to be stored in each annual layer for year zero as well as years one and two after placement; from year three onwards the stored nitrogen was reduced by the nitrogen released each year as represented by the following equation:

$$N_{Layer\ Store\ (i)} = N_{Layer\ Load\ (i=0)} - \sum_{a=2}^{i, i\geq 2} N_{Layer\ Release\ (a)}$$

Where,

$N_{Layer\ Store\ (i)}$ = nitrogen stored (kg N) in mine rock layer in year *i* after placement;

$N_{Layer\ Load\ (i=0)}$ = initial nitrogen load (kg N) to the rock layer year zero of placement; and

$N_{Layer\ Release\ (a)}$ = nitrogen released (kg N) from annual mine rock layer year *a* after placement.

The total annual nitrogen store in the MRSF was calculated by summing the nitrogen stored in each annual mine rock layer:

$$N_{Total\ Store\ (k)} = \sum_{i=0}^{n} N_{Layer\ Store\ (i,k)}$$

Where,

$N_{Total\ Store\ (k)}$ = total nitrogen stored (kg N) in the mine rock pile at the end of year *k*; and

$N_{Layer\ Store\ (i,k)}$ = nitrogen stored (kg N) in rock layer *i* in at the end of year *k*, where *n* equals the number of annual mine rock layers placed to the end of year *k*.

The total annual nitrogen release from the MRSF was calculated by summing the nitrogen release from each annual mine rock layer:

$$N_{Total\ Release\ (k)} = \sum_{i=0}^{n} N_{Layer\ Release\ (i,k)}$$

Where,

$N_{Total\ Release\ (k)}$ = total nitrogen released (kg N) from the MRSF in year *k*; and

$N_{Layer\ Release\ (i,k)}$ = nitrogen released (kg N) from annual mine rock layer *i* in year *k*, where *n* equals the number of annual mine rock layers placed to the end of year *k*.

The results of nitrogen storage and release calculations for mine rock stockpiles are presented in Figure 4-1 and Figure 4-2.

In order to address the temporary storing of ore, and therefore the limited time for nitrogen release from the stockpile, the model assumes that any unit of ore is stored no longer than five years on surface before being sent to the mill for processing. The five year storage time is based on median values calculated from the planned ore stockpile balance from Y2 to Y19. This method predicts conservative estimates of nitrogen loadings from the temporary stockpiled ore, with maximum loadings ensuing the first year of rock placement. Based on projected ore stock balances for the Ajax mine, 1) ore extracted and stored in Y1 is sent to mill within that same year therefore no loadings are anticipated from this material, and 2) all ore extracted after Y19 is stored less than 3 years before being sent to mill and therefore no significant loadings are anticipated from this material. Nitrogen Species Loadings.

4.3.5 Nitrogen Species Loadings

The annual nitrogen species loadings for stockpiled mine rock and ore seepage were estimated using the total annual nitrogen release and the nitrogen species distribution of nitrate (87%), ammonia (11%) and nitrite (2%) according to observations by Ferguson and Leask (1988). The concentration of each species was estimated using the following equation, with the results of calculations graphed in

Figure 4-3 and Figure 4-5 and summarized in summarized in Table 4-3 through Table 4-5.

$$N_{Source\ Term\ Species\ (k)} = \frac{N_{Total\ Release\ (k)} \times p_{N\ Species} \times 1000}{F_{(k)}}$$

Where,

$N_{Source\ Term\ Species\ (k)}$ = nitrogen species source term (mg/L) in year *k* seepage;

$N_{Total\ Release\ (k)}$ = total nitrogen released (kg N) from the MRSF in year *k*;

$p_{N\ Species}$ = proportion of nitrogen as a specific species (*i.e.*, nitrate, nitrite, ammonia); and

$F_{(k)}$ = MRSF inflow (m^3) for year *k*.

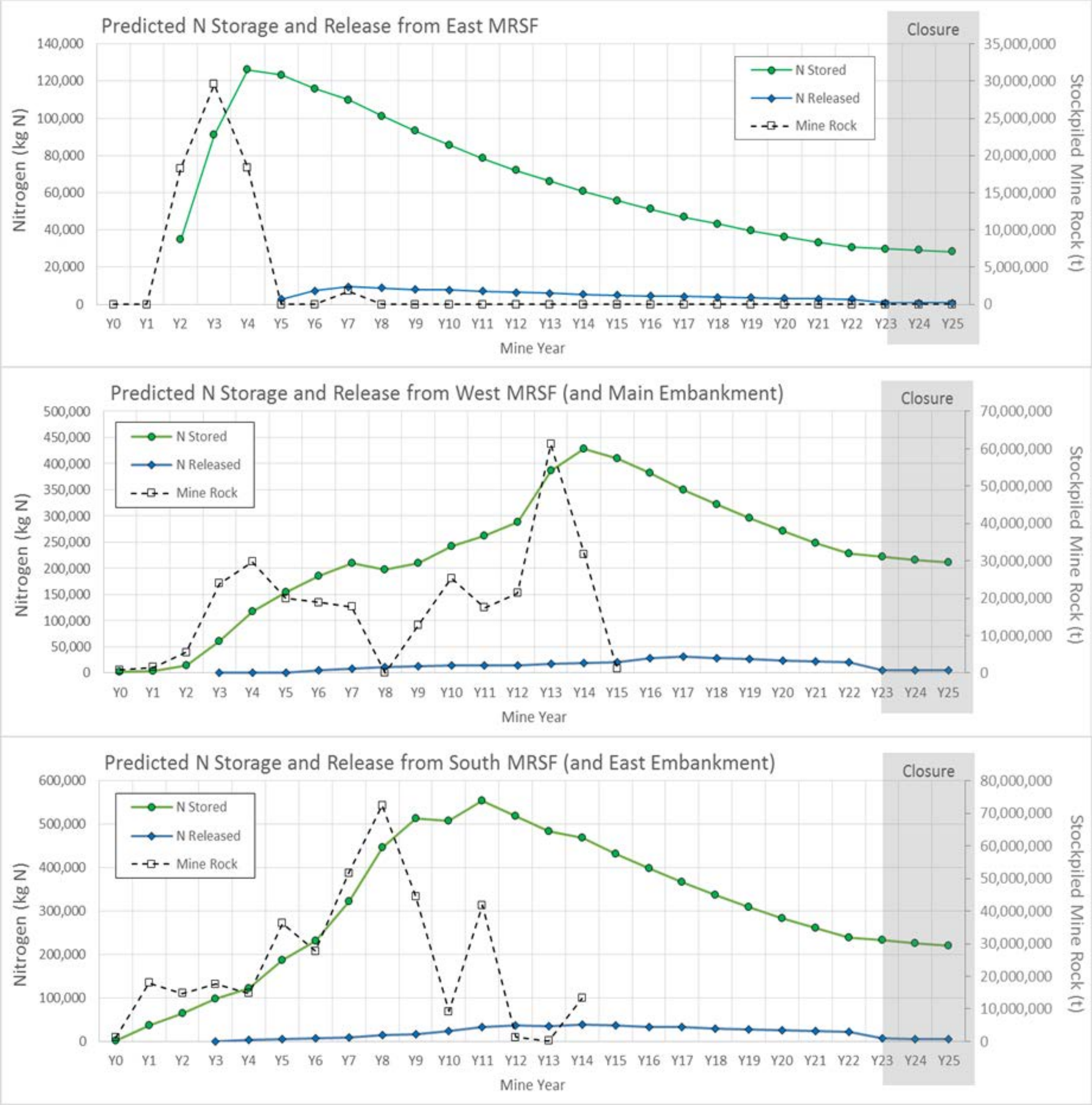

Figure 4-1: **Predicted annual nitrogen storage and release from stockpiled mine rock in the East, West and South MRSF.**

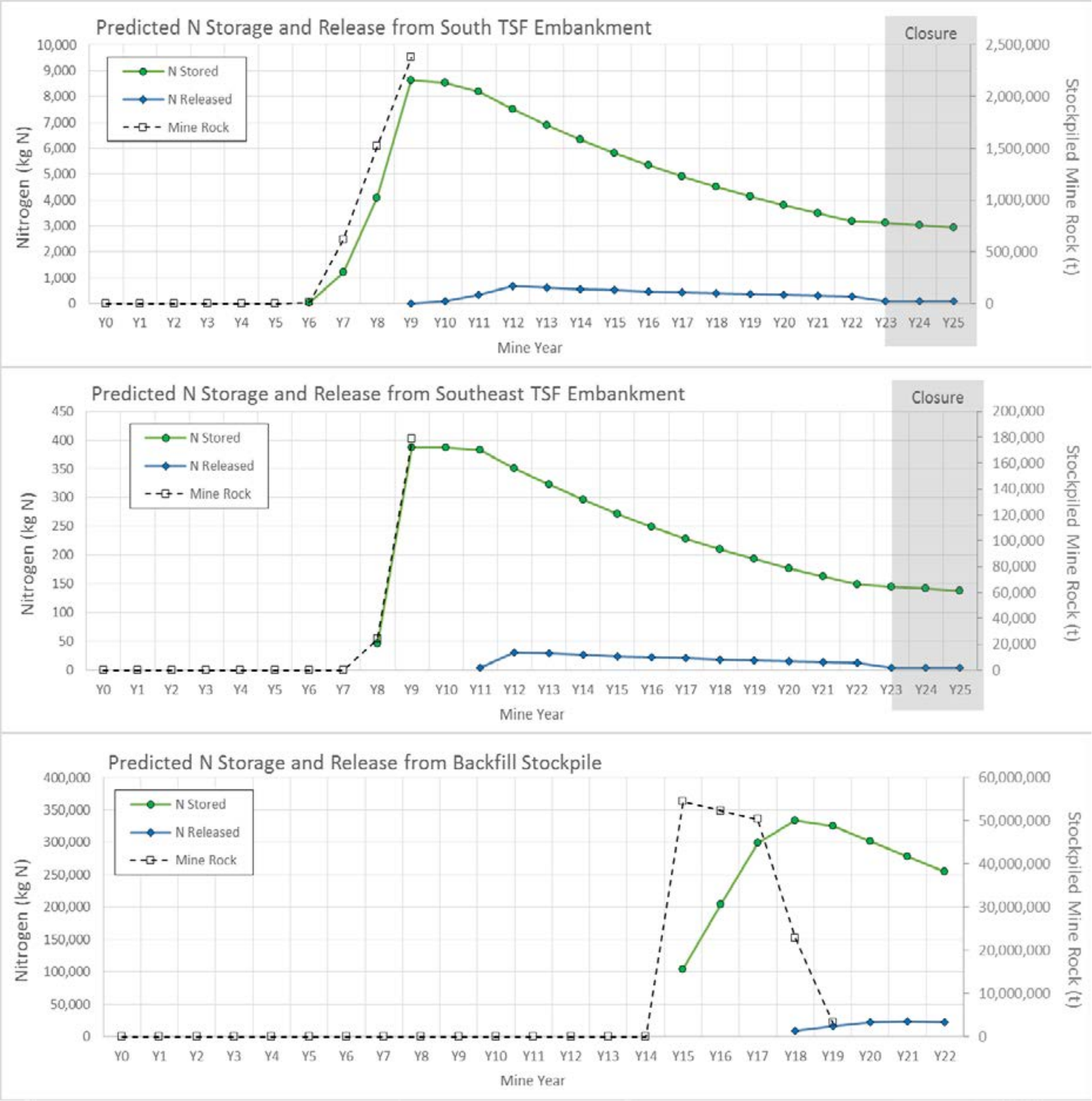

Figure 4-2: **Predicted annual nitrogen storage and release from the small TSF Embankments (South and Southeast) and the Pit Backfill Stockpile.**

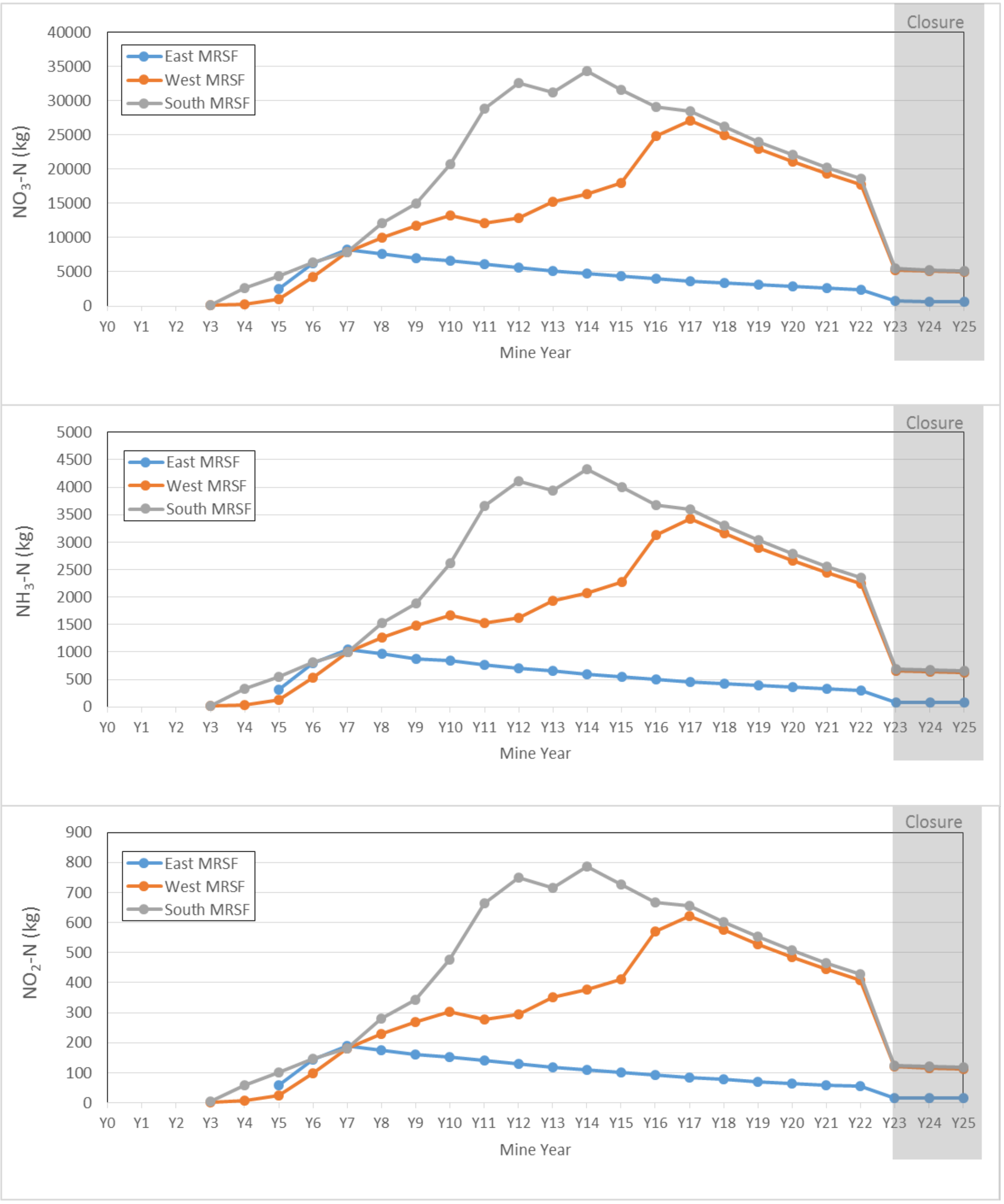

Figure 4-3: **Annual nitrate, ammonia and nitrite loadings (kg) for the East, West and South MRSF.**

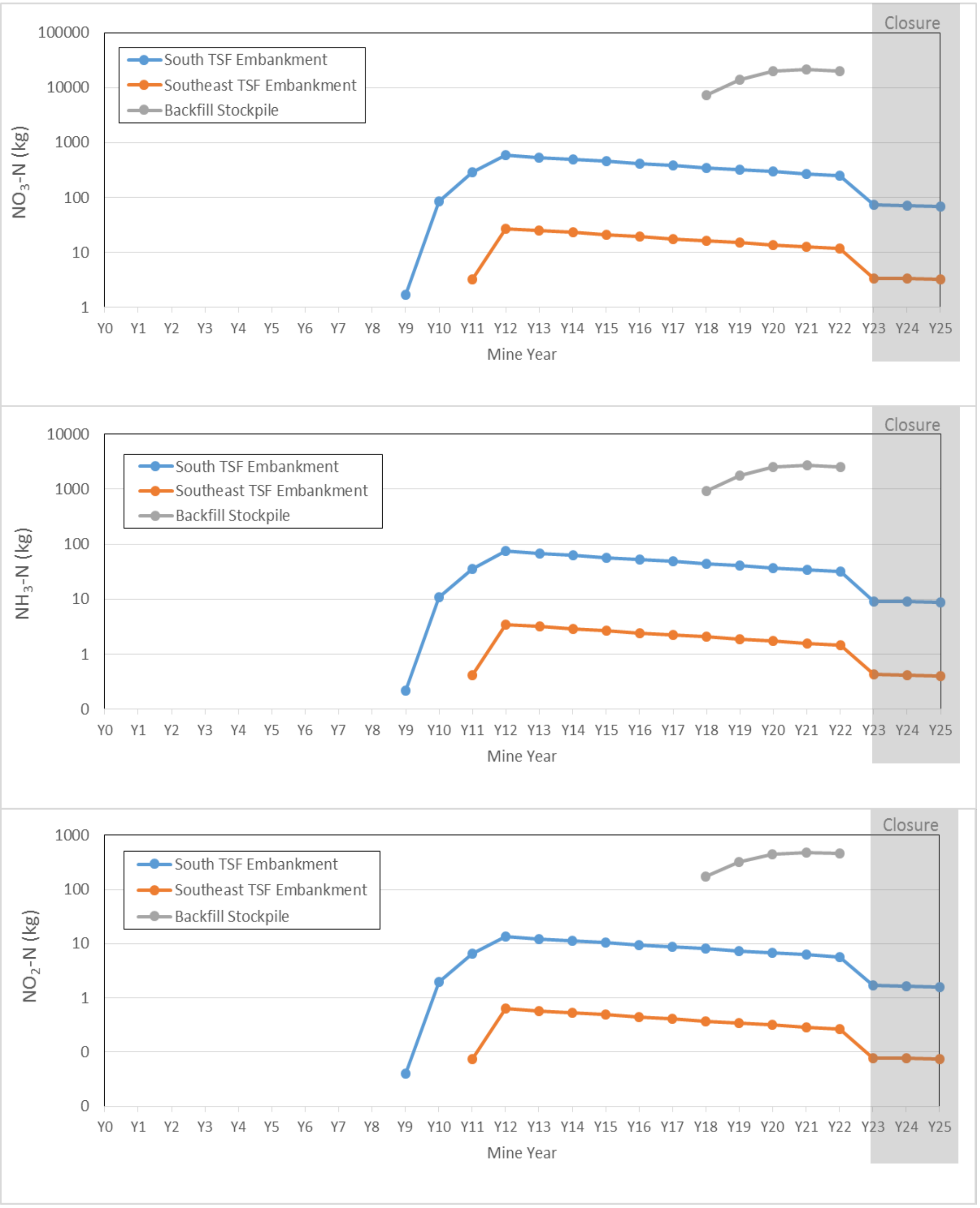

Figure 4-4: Annual nitrate, ammonia and nitrite loadings (kg) for the small TSF Embankments (South and Southeast) and the Pit Backfill Stockpile.

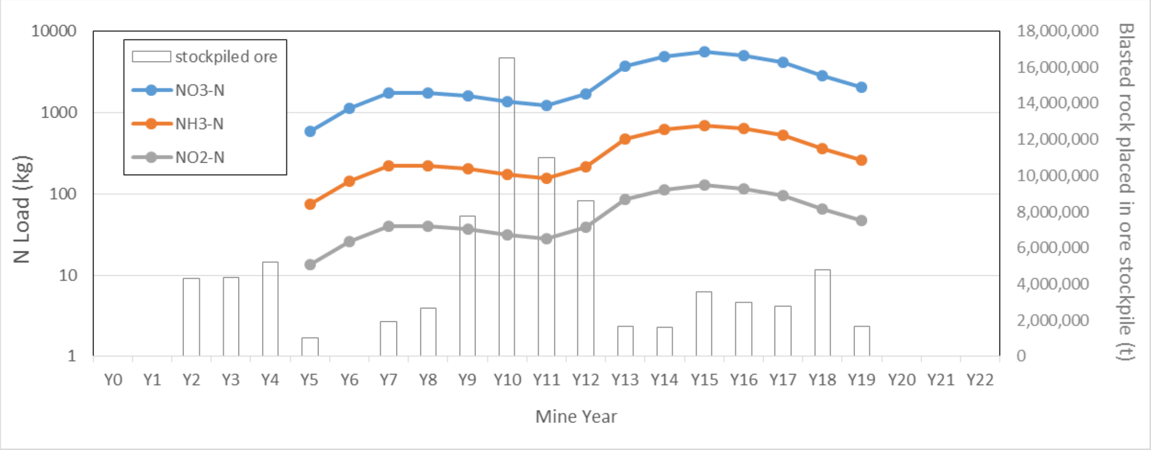

Figure 4-5: Annual nitrate, ammonia and nitrite loadings (kg) for the temporary ore stockpile. Note that there is a three year delay in nitrogen release from the stockpiled ore.

Table 4-3:
Source Terms for Nitrate, Ammonia and Nitrite for the East, West and South MSRF

Mine Year	East MSRF				West MSRF				South MSRF			
	Annual N Release (kg)	**Annual N source Term NO3-N (kg)**	**Annual N source Term NH3-N (kg)**	**Annual N source Term NO2-N (kg)**	**Annual N Release (kg)**	**Annual N source Term NO3-N (kg)**	**Annual N source Term NH3-N (kg)**	**Annual N source Term NO2-N (kg)**	**Annual N Release (kg)**	**Annual N source Term NO3-N (kg)**	**Annual N source Term NH3-N (kg)**	**Annual N source Term NO2-N (kg)**
Y0	0	0	0	0	0	0	0	0	0	0	0	0
Y1	0	0	0	0	0	0	0	0	0	0	0	0
Y2	0	0	0	0	0	0	0	0	0	0	0	0
Y3	0	0	0	0	120	104.1	13.2	2.4	171	149.0	18.8	3.4
Y4	0	0	0	0	360	313	39.6	7.2	2,962	2,577	326	59.2
Y5	2,851	2,481	314	57.0	1,200	1,044	132	24.0	5,020	4,368	552	100.4
Y6	7,241	6,299	796	145	4,851	4,220	534	97.0	7,352	6,396	809	147
Y7	9,516	8,279	1047	190	9,096	7,914	1,001	182	9,042	7,867	995	181
Y8	8,735	7,600	961	175	11,475	9,983	1,262	230	13,956	12,142	1,535	279
Y9	8,019	6,977	882	160	13,488	11,734	1,484	270	17,151	14,921	1,887	343
Y10	7,642	6,649	841	153	15,144	13,176	1,666	303	23,829	20,731	2,621	477
Y11	7,016	6,104	772	140	13,903	12,095	1,529	278	33,198	28,883	3,652	664
Y12	6,440	5,603	708	129	14,776	12,855	1,625	296	37,434	32,568	4,118	749
Y13	5,912	5,144	650	118	17,525	15,246	1,928	350	35,791	31,138	3,937	716
Y14	5,427	4,722	597	108.5	18,819	16,373	2,070	376	39,387	34,267	4,333	788
Y15	4,982	4,335	548	99.6	20,615	17,935	2,268	412	36,356	31,630	3,999	727
Y16	4,574	3,979	503	91.5	28,496	24,791	3,135	570	33,407	29,064	3,675	668
Y17	4,199	3,653	462	84.0	31,136	27,089	3,425	623	32,743	28,487	3,602	655
Y18	3,854	3,353	424	77.1	28,755	25,017	3,163	575	30,058	26,151	3,306	601
Y19	3,538	3,078	389	70.8	26,397	22,966	2,904	528	27,594	24,006	3,035	552
Y20	3,248	2,826	357	65.0	24,233	21,082	2,666	485	25,331	22,038	2,786	507
Y21	2,982	2,594	328	59.6	22,246	19,354	2,447	445	23,254	20,231	2,558	465
Y22	2,737	2,382	301	54.7	20,421	17,767	2,246	408	21,347	18,572	2,348	427
Closure												
Y1	801	697	88.1	16.0	5,976	5,199	657	120	6,247	5,434	687	125
Y2	781	680	85.9	15.6	5,829	5,071	641	117	6,093	5,301	670	122
Y3	762	663	83.8	15.2	5,685	4,946	625	114	5,943	5,170	654	119
Y4	700	609	77.0	14.0	5,219	4,541	574	104	5,456	4,746	600	109
Y5	642	559	70.6	12.8	4,791.2	4,168	527	96	5,008	4,357	551	100
Y10	419	364	46.1	8.4	3,123.6	2,718	344	62	3,265	2,841	359	65
Y25	116	101	12.8	2.3	866	753	95	17	905	787	100	18
Y50	14	12	1.5	0.3	102	89	11	2.0	107	93	12	2.1
Y75	1.6	1.4	0.2	0.03	12	10	1.3	0.2	13	11	1.4	0.3

Table 4-4:
Source Terms for Nitrate, Ammonia and Nitrite for the Small TSF Emabnkments (South and Southeast) and Pit Backfill Stockpile

Mine Year	TSF South Embankment				TSF Southeast Embankment				Backfill			
	Annual N Release (kg)	**Annual N source Term NO3-N (kg)**	**Annual N source Term NH3-N (kg)**	**Annual N source Term NO2-N (kg)**	**Annual N Release (kg)**	**Annual N source Term NO3-N (kg)**	**Annual N source Term NH3-N (kg)**	**Annual N source Term NO2-N (kg)**	**Annual N Release (kg)**	**Annual N source Term NO3-N (kg)**	**Annual N source Term NH3-N (kg)**	**Annual N source Term NO2-N (kg)**
Y0	0	0	0	0	0	0	0	0	0	0	0	0
Y1	0	0	0	0	0	0	0	0	0	0	0	0
Y2	0	0	0	0	0	0	0	0	0	0	0	0
Y3	0	0	0	0	0	0	0	0	0	0	0	0
Y4	0	0	0	0	0	0	0	0	0	0	0	0
Y5	0	0	0	0	0	0	0	0	0	0	0	0
Y6	0	0	0	0	0	0	0	0	0	0	0	0
Y7	0	0	0	0	0	0	0	0	0	0	0	0
Y8	0	0	0	0	0	0	0	0	0	0	0	0
Y9	2.0	1.7	0.2	0.04	0	0	0	0	0	0	0	0
Y10	98	85.2	10.8	2.0	0	0	0	0	0	0	0	0
Y11	327	285	36.0	6.5	3.8	3.3	0.4	0.1	0	0	0	0
Y12	672	585	73.9	13.4	31.4	27.3	3.4	0.6	0	0	0	0
Y13	617	537	67.8	12.3	28.8	25.0	3.2	0.6	0	0	0	0
Y14	566	493	62.3	11.3	26.4	23.0	2.9	0.5	0	0	0	0
Y15	520	452	57.2	10.4	24.3	21.1	2.7	0.5	0	0	0	0
Y16	477	415	52.5	9.5	22.3	19.4	2.4	0.4	0	0	0	0
Y17	438	381	48.2	8.8	20.4	17.8	2.2	0.4	0	0	0	0
Y18	402	350	44.2	8.0	18.8	16.3	2.1	0.4	8,517	7,410	937	170
Y19	369	321	40.6	7.4	17.2	15.0	1.9	0.3	15,999	13,919	1,760	320
Y20	339	295	37.3	6.8	15.8	13.8	1.7	0.3	22,557	19,624	2,481	451
Y21	311	271	34.2	6.2	14.5	12.6	1.6	0.3	24,263	21,109	2,669	485
Y22	286	248	31.4	5.7	13.3	11.6	1.5	0.3	22,793	19,830	2,507	456
Closure												
Y1	83.6	72.7	9.2	1.7	3.9	3.4	0.4	0.1				
Y2	81.5	70.9	9.0	1.6	3.8	3.3	0.4	0.1				
Y3	79.5	69.2	8.7	1.6	3.7	3.2	0.4	0.1				
Y4	73.0	63.5	8.0	1.5	3.4	3.0	0.4	0.1				
Y5	67.0	58.3	7.4	1.3	3.1	2.7	0.3	0.1				
Y10	43.7	38.0	4.8	0.9	2.0	1.8	0.2	0.04				
Y25	12.1	10.5	1.3	0.2	0.6	0.5	0.1	0.01				
Y50	1.4	1.2	0.2	0.03	0.1	0.1	0.01	0.001				

Table 4-5:
Source Terms for Nitrate, Ammonia and Nitrite for the Temporary Ore Stockpile

Mine Year	Annual N Release (kg)	Annual N source Term NO_3-N (kg)	Annual N source Term NH_3-N (kg)	Annual N source Term NO_2-N (kg)
Y0	0	0	0	0
Y1	0	0	0	0
Y2	0	0	0	0
Y3	0	0	0	0
Y4	0	0	0	0
Y5	677	589	74.5	13.5
Y6	1,304	1,135	143	26.1
Y7	2,016	1,754	222	40.3
Y8	2,011	1,750	221	40.2
Y9	1,846	1,606	203	36.9
Y10	1,553	1,351	171	31.1
Y11	1,400	1,218	154	28.0
Y12	1,967	1,711	216	39.3
Y13	4,277	3,721	471	86
Y14	5,649	4,914	621	113
Y15	6,334	5,511	697	127
Y16	5,801	5,047	638	116
Y17	4,785	4,163	526	96
Y18	3,269	2,844	360	65.4
Y19	2,342	2,037	258	46.8
Y20	0	0	0	0
Y21	0	0	0	0
Y22	0	0	0	0

4.4 Derivation of Pit Water Nitrogen Loadings

Contaminant release rates from the pit walls are controlled by the overall surface area of the pit walls, and the nature of water-rock interaction (*e.g.*, precipitation rinsing and sloughing of rock). There is limited storage of nitrogen within the pit as blasted rock is removed for processing or storage after blasting. Significant export of nitrogen from mine pit contact water is generally expected during active mining only.

Nitrogen species source terms for mine pit discharge water were estimated based on observations of pit water at Diavik Diamond Mine surface mining operations and at surface coal mines in British Columbia. Concentrations of nitrogen species in Diavik pit water have been observed to vary significantly on a daily basis depending on pit water inflows, types of explosives used, specific blasting conditions for each blast pattern and the timing of blasting. From 2003 to 2005 daily ammonia concentrations in Diavik pit A154 water varied from approximately 1 mg/L to 37 mg/L, with monthly average ammonia concentrations ranging from approximately 3 mg/L to 14 mg/L (GRAPHIC B-3 in SNC, 2006). During this time period ammonia ranged from 3% to 61% (and averaged 35%) of the total nitrogen in the pit water (GRAPHIC B-4 in SNC, 2006), from this it was inferred that average monthly concentrations of total nitrogen in the Diavik pit water ranged from approximately 3 mg/L to 40 mg/L. The primary nitrogen species in Diavik pit water are considered to be ammonia and nitrate (Cameron, 2007); this is consistent with observations by Pommen (1983) and Ferguson and Leask (1988) at surface coal mines.

The average monthly nitrogen source term concentration in Ajax pit water is estimated to be 25 mg/L total nitrogen based on the operational observations at Diavik mine and at British Columbia surface coal mines. Daily levels are expected to fluctuate based on factors such as explosive type used, blast design and execution (*i.e.*, spills during loading or misfires due to dislodgment or desensitization), precipitation, surface water and groundwater flows.

The pumping of pit water to the process plant will allow time for oxidation of ammonia to nitrate, therefore, the nitrogen species distribution reporting to the receiving environment is expected to be similar to that observed at surface coal mines in British Columbia, and is modeled based on the average distributions reported by Ferguson and Leask (1988) with nitrate, ammonia and nitrite respectively comprising 87%, 11% and 2% of the total nitrogen concentration as shown in Table 4-6 below.

Table 4-6:
Ajax pit water best judgement nitrogen species source terms.

	Total Nitrogen (mg/L as N)	**Nitrate (mg/L as N)**	**Ammonia (mg/L as N)**	**Nitrite (mg/L as N)**
Pit water source term	25	22	2.8	0.50

4.5 Derivation of Tailings Effluent Nitrogen Loadings

Tailings slurry produced during ore processing will be pumped to the TSF located in the southern part of the Ajax property perimeter covering a final footprint of 349 ha that will be confined by several embankments constructed with mine rock. Blasted ROM ore is transferred to the mill for processing and the entire stored nitrogen load is assumed to be exported with the tailings. The nitrogen species are water soluble and are expected to be present entirely within the tailings slurry.

Annual nitrogen loads exported with the tailings were derived using total blasted tonnages of ore and the Ferguson and Leask (1988) model for mine sites using greater than 20% emulsion. Nitrogen release from the tailings was assumed to be immediate to the process water. The final annual nitrogen loads in the tailings liquid phase were determined by subtracting the estimated nitrogen releases from the temporarily stockpiled ore (calculated above) from the total available nitrogen calculated from the ROM ore (Table 4-7).

Nitrogen species in tailings pond effluent are distributed according to 75.1% nitrate, 13.5% ammonia and 11.4% nitrite. The proportions of nitrogen species are consistent with observations made for flotation tailings pond effluent at other mine sites in British Columbia. Annual nitrogen species loadings to tailings liquid phase is presented in Table 4-8.

Table 4-7:
Blasted Tonnages for ROM Ore and Estimated Annual Nitrogen Release to Tailings Effluent

Mine Plan	Blasting Metrics		Run-Of-Mine (ROM) Ore				Temp. Ore Pile	Total Annual N Release (kg) to Tailings Effluent
	pF (t/t)	**% wet (flowing) conditions**	**Blasted Tonnage**	**Favourable blast conditions (t)**	**Wet (flowing) conditions (t)**	**Estimated N Load (kg) for ROM Ore**	**Total Annual N Release (kg)**	
Y0	0.00032	28.1%	0	0	0	0	0	**0**
Y1	0.00032	28.1%	2,468,044	570	223	4,702	0	**4,702**
Y2	0.00032	28.1%	20,841,468	4,809	1,880	39,710	0	**39,033**
Y3	0.00032	28.1%	21,900,000	5,054	1,975	41,726	0	**40,422**
Y4	0.00032	28.1%	21,900,000	5,054	1,975	41,726	0	**39,710**
Y5	0.00032	28.1%	24,322,752	5,613	2,194	46,343	677	**44,331**
Y6	0.00032	28.1%	19,603,195	4,524	1,768	37,350	1,304	**35,504**
Y7	0.00032	28.1%	21,806,255	5,032	1,967	41,548	2,016	**39,995**
Y8	0.00032	28.1%	22,052,488	5,089	1,989	42,017	2,011	**40,617**
Y9	0.00032	28.1%	21,900,000	5,054	1,975	41,726	1,846	**39,759**
Y10	0.00032	28.1%	21,900,000	5,054	1,975	41,726	1,553	**37,449**
Y11	0.00032	28.1%	21,900,000	5,054	1,975	41,726	1,400	**36,078**
Y12	0.00032	28.1%	21,900,000	5,054	1,975	41,726	1,967	**35,392**
Y13	0.00032	28.1%	21,696,208	5,006	1,957	41,338	4,277	**35,537**
Y14	0.00032	28.1%	21,900,000	5,054	1,975	41,726	5,649	**36,941**
Y15	0.00032	28.1%	21,900,000	5,054	1,975	41,726	6,334	**38,458**
Y16	0.00032	28.1%	21,900,000	5,054	1,975	41,726	5,801	**39,385**
Y17	0.00032	28.1%	21,900,000	5,054	1,975	41,726	4,785	**41,726**
Y18	0.00032	28.1%	21,900,000	5,054	1,975	41,726	3,269	**41,726**
Y19	0.00032	28.1%	21,900,000	5,054	1,975	41,726	2,342	**41,726**
Y20	0.00032	28.1%	21,919,102	5,058	1,977	41,763	0	**41,763**
Y21	0.00032	28.1%	21,900,000	5,054	1,975	41,726	0	**41,726**
Y22	0.00032	28.1%	2,642,617	610	238	5,035	0	**5,035**

Table 4-8:
Source Terms for Nitrate, Ammonia and Nitrite in Tailings Effluent

Mine Year	Tailings (pond effluent)			
	Annual N Release (kg)	Annual N source Term NO3-N (kg)	Annual N source Term NH3-N (kg)	Annual N source Term NO2-N (kg)
Y0	0	0	0	0
Y1	4,702	3,532	635	536
Y2	39,033	29,313	5,269	4,450
Y3	40,422	30,357	5,457	4,608
Y4	39,710	29,823	5,361	4,527
Y5	44,331	33,293	5,985	5,054
Y6	35,504	26,664	4,793	4,047
Y7	39,995	30,036	5,399	4,559
Y8	40,617	30,504	5,483	4,630
Y9	39,759	29,859	5,368	4,533
Y10	37,449	28,124	5,056	4,269
Y11	36,078	27,094	4,870	4,113
Y12	35,392	26,580	4,778	4,035
Y13	35,537	26,689	4,798	4,051
Y14	36,941	27,743	4,987	4,211
Y15	38,458	28,882	5,192	4,384
Y16	39,385	29,578	5,317	4,490
Y17	41,726	31,337	5,633	4,757
Y18	41,726	31,337	5,633	4,757
Y19	41,726	31,337	5,633	4,757
Y20	41,763	31,364	5,638	4,761
Y21	41,726	31,337	5,633	4,757
Y22	5,035	3,781	680	574

5. Closure

5. Closure

This Lorax report was prepared and reviewed by the undersigned.

Yours sincerely,
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Appendices:

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Appendix A: Geochemical Loading Rates for Mine Rock Geounits, Ore and Tailings

Date	**SO_4**	**Cl**	**F**	**Br**	**Al**	**Sb**	**As**	**Ba**	**Be**	**B**	**Cd**	**Ca**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**
MRSF																	
Geounit 1																	
Operational	25	0.016	0.015	0.0089	0.00082	0.000048	0.000072	0.0017	0.00000059	0.0025	0.0000020	9.3	0.000015	0.000056	0.00019	0.00028	0.0000017
Post-closure	1.3	0.0046	0.00098	0.0049	0.00015	0.000013	0.000063	0.0049	0.00000029	0.00065	0.00000057	1.2	0.0000070	0.0000027	0.000089	0.000054	0.00000031
Geounit 2																	
Operational	21	0.013	0.015	0.0089	0.00085	0.000043	0.000067	0.0017	0.00000059	0.0024	0.0000017	8.0	0.000015	0.000048	0.00018	0.00029	0.0000017
Post-closure	1.1	0.0043	0.00098	0.0049	0.00015	0.000011	0.000059	0.0051	0.00000029	0.00064	0.00000045	1.1	0.0000072	0.0000026	0.000091	0.000053	0.00000031
Geounit 3																	
Operational	10	0.0059	0.016	0.0089	0.00095	0.000029	0.000051	0.0016	0.00000059	0.0021	0.00000080	3.8	0.000015	0.000019	0.00017	0.00030	0.0000017
Post-closure	0.45	0.0032	0.00096	0.0048	0.00016	0.0000064	0.000049	0.0057	0.00000032	0.00060	0.000000053	0.95	0.0000080	0.0000023	0.000096	0.000048	0.00000032
Geounit 4																	
Operational	0.57	0.050	0.0083	0.0080	0.0011	0.00021	0.0017	0.0025	0.00000038	0.0037	0.00000008	0.98	0.000010	0.0000028	0.000065	0.00025	0.000002
Post-closure	0.15	0.0031	0.0014	0.0045	0.00052	0.000024	0.00014	0.0052	0.00000030	0.00074	0.000000062	0.83	0.0000075	0.0000019	0.000057	0.000048	0.00000084
Geounit 5																	
Operational	10	0.0059	0.016	0.0089	0.00095	0.000029	0.000051	0.0016	0.00000059	0.0021	0.00000080	3.8	0.000015	0.000019	0.00017	0.00030	0.0000017
Post-closure	0.45	0.0032	0.00096	0.0048	0.00016	0.0000064	0.000049	0.0057	0.00000032	0.00060	0.000000053	0.95	0.0000080	0.0000023	0.000096	0.000048	0.00000032
Geounit 6																	
Operational	10	0.0059	0.016	0.0089	0.00095	0.000029	0.000051	0.0016	0.00000059	0.0021	0.00000080	3.8	0.000015	0.000019	0.00017	0.00030	0.0000017
Post-closure	0.45	0.0032	0.00096	0.0048	0.00016	0.0000064	0.000049	0.0057	0.00000032	0.00060	0.000000053	0.95	0.0000080	0.0000023	0.000096	0.000048	0.00000032
Geounit 7																	
Operational	2.1	0.012	0.0041	0.0071	0.00018	0.00021	0.020	0.0037	0.00000016	0.012	0.00000037	0.58	0.000012	0.0000028	0.000036	0.00016	0.0000028
Post-closure	1.2	0.0032	0.0027	0.0041	0.00055	0.000045	0.0013	0.0041	0.00000028	0.0016	0.00000038	0.75	0.000020	0.0000061	0.000069	0.000047	0.00000053
Geounit 8																	
Operational	2.7	0.018	0.0077	0.0077	0.00055	0.00012	0.0015	0.0033	0.00000018	0.0066	0.0000013	1.1	0.000014	0.0000038	0.000074	0.00018	0.000031
Post-closure	1.2	0.0032	0.0027	0.0041	0.00055	0.000045	0.0013	0.0041	0.00000028	0.0016	0.00000038	0.75	0.000020	0.0000061	0.000069	0.000047	0.00000053
Geounit 9																	
Operational	30	0.019	0.015	0.0089	0.00078	0.000055	0.000079	0.0017	0.00000059	0.0026	0.0000025	11	0.000015	0.000070	0.00019	0.00028	0.0000017
Post-closure	1.6	0.0051	0.00099	0.0050	0.00014	0.000015	0.000067	0.0046	0.00000027	0.00067	0.00000075	1.3	0.0000067	0.0000029	0.000086	0.000056	0.00000031
Geounit 10																	
Operational	24	0.015	0.015	0.0089	0.00083	0.000047	0.000071	0.0017	0.00000059	0.0025	0.0000020	9.1	0.000015	0.000055	0.00019	0.00028	0.0000017
Post-closure	1.3	0.0046	0.00098	0.0049	0.00015	0.000013	0.000062	0.0049	0.00000029	0.00065	0.00000056	1.2	0.0000070	0.0000027	0.000089	0.000054	0.00000031
Geounit 11																	
Operational	21	0.013	0.015	0.0089	0.00085	0.000043	0.000067	0.0017	0.00000059	0.0024	0.0000017	7.9	0.000015	0.000047	0.00018	0.00029	0.0000017
Post-closure	1.1	0.0042	0.00098	0.0049	0.00015	0.000011	0.000059	0.0051	0.00000029	0.00064	0.00000044	1.1	0.0000073	0.0000026	0.000091	0.000053	0.00000031
Geounit 12																	
Operational	2.7	0.018	0.0077	0.0077	0.00055	0.00012	0.0015	0.0033	0.00000018	0.0066	0.0000013	1.1	0.000014	0.0000038	0.000074	0.00018	0.000031
Post-closure	1.2	0.0032	0.0027	0.0041	0.00055	0.000045	0.0013	0.0041	0.00000028	0.0016	0.00000038	0.75	0.000020	0.0000061	0.000069	0.000047	0.00000053
Geounit 13																	
Operational	10	0.0059	0.016	0.0089	0.00095	0.000029	0.000051	0.0016	0.00000059	0.0021	0.00000080	3.8	0.000015	0.000019	0.00017	0.00030	0.0000017
Post-closure	0.45	0.0032	0.00096	0.0048	0.00016	0.0000064	0.000049	0.0057	0.00000032	0.00060	0.000000053	0.95	0.0000080	0.0000023	0.000096	0.000048	0.00000032
Geounit 99																	
Operational	33	0.021	0.014	0.0089	0.00075	0.000059	0.000084	0.0017	0.00000059	0.0027	0.0000027	12	0.000015	0.000078	0.00019	0.00028	0.0000017
Post-closure	1.8	0.0054	0.00100	0.0050	0.00014	0.000017	0.000071	0.0044	0.00000027	0.00068	0.00000087	1.4	0.0000064	0.0000030	0.000085	0.000058	0.00000031

Date	**Li**	**Mg**	**Mn**	**Hg**	**Mo**	**Ni**	**P**	**K**	**Se**	**Si**	**Ag**	**Na**	**Sr**	**Tl**	**Sn**	**U**	**V**	**Zn**
MRSF																		
Geounit 1																		
Operational	0.00023	1.2	0.00086	0.00000	0.0075	0.00084	0.00067	1.1	0.000074	0.40	0.00000030	0.31	0.086	0.0000015	0.000013	0.000094	0.00069	0.00017
Post-closure	0.000079	0.27	0.000067	0.00000	0.0030	0.000026	0.00014	0.34	0.000048	0.25	0.00000015	0.041	0.014	0.00000069	0.0000032	0.000020	0.00079	0.000031
Geounit 2																		
Operational	0.00022	1.1	0.00077	0.00000	0.0066	0.00066	0.00058	0.93	0.000067	0.40	0.00000030	0.31	0.076	0.0000013	0.000013	0.000091	0.00071	0.00017
Post-closure	0.000079	0.27	0.000067	0.00000	0.0025	0.000023	0.00014	0.32	0.000044	0.26	0.00000016	0.041	0.013	0.00000061	0.0000032	0.000020	0.00081	0.000031
Geounit 3																		
Operational	0.00018	0.71	0.00045	0.00000	0.0037	0.000059	0.00027	0.46	0.000041	0.39	0.00000030	0.30	0.044	0.00000059	0.000013	0.000080	0.00077	0.00017
Post-closure	0.000077	0.26	0.000068	0.00000	0.00095	0.000013	0.00014	0.23	0.000030	0.27	0.00000017	0.041	0.012	0.00000032	0.0000032	0.000022	0.00086	0.000032
Geounit 4																		
Operational	0.00013	0.32	0.000080	0.00000	0.00027	0.000015	0.00028	0.39	0.0000098	0.41	0.00000017	0.69	0.014	0.00000036	0.000058	0.0000094	0.0024	0.000091
Post-closure	0.00016	0.37	0.000078	0.00000	0.00014	0.000011	0.00013	0.49	0.000021	0.26	0.00000015	0.038	0.014	0.00000030	0.000015	0.0000050	0.0012	0.000047
Geounit 5																		
Operational	0.00018	0.71	0.00045	0.00000	0.0037	0.000059	0.00027	0.46	0.000041	0.39	0.00000030	0.30	0.044	0.00000059	0.000013	0.000080	0.00077	0.00017
Post-closure	0.000077	0.26	0.000068	0.00000	0.00095	0.000013	0.00014	0.23	0.000030	0.27	0.00000017	0.041	0.012	0.00000032	0.0000032	0.000022	0.00086	0.000032
Geounit 6																		
Operational	0.00018	0.71	0.00045	0.00000	0.0037	0.000059	0.00027	0.46	0.000041	0.39	0.00000030	0.30	0.044	0.00000059	0.000013	0.000080	0.00077	0.00017
Post-closure	0.000077	0.26	0.000068	0.00000	0.00095	0.000013	0.00014	0.23	0.000030	0.27	0.00000017	0.041	0.012	0.00000032	0.0000032	0.000022	0.00086	0.000032
Geounit 7																		
Operational	0.00013	0.45	0.000056	0.00000	0.00020	0.00029	0.000071	1.8	0.000058	0.41	0.000000047	0.55	0.012	0.0000012	0.0000075	0.00000089	0.000092	0.000043
Post-closure	0.00011	0.43	0.00011	0.00000	0.0059	0.00046	0.00012	2.0	0.000056	0.29	0.00000014	0.035	0.011	0.0000029	0.0000012	0.0000038	0.00024	0.000051
Geounit 8																		
Operational	0.00014	0.30	0.000018	0.00000	0.0010	0.00049	0.000077	1.0	0.000040	0.49	0.000000051	0.67	0.020	0.0000014	0.0000035	0.000022	0.0015	0.00015
Post-closure	0.00011	0.43	0.00011	0.00000	0.0059	0.00046	0.00012	2.0	0.000056	0.29	0.00000014	0.035	0.011	0.0000029	0.0000012	0.0000038	0.00024	0.000051
Geounit 9																		
Operational	0.00025	1.4	0.0010	0.00000	0.0088	0.0011	0.00081	1.3	0.000086	0.40	0.00000030	0.31	0.10	0.0000019	0.000013	0.000099	0.00066	0.00017
Post-closure	0.000080	0.27	0.000067	0.00000	0.0037	0.000030	0.00014	0.38	0.000054	0.25	0.00000015	0.041	0.014	0.00000082	0.0000032	0.000019	0.00077	0.000031
Geounit 10																		
Operational	0.00023	1.2	0.00085	0.00000	0.0074	0.00081	0.00066	1.1	0.000073	0.40	0.00000030	0.31	0.085	0.0000015	0.000013	0.000094	0.00069	0.00017
Post-closure	0.000079	0.27	0.000067	0.00000	0.0029	0.000026	0.00014	0.34	0.000047	0.25	0.00000016	0.041	0.014	0.00000068	0.0000032	0.000020	0.00079	0.000031
Geounit 11																		
Operational	0.00022	1.1	0.00076	0.00000	0.0066	0.00064	0.00057	0.92	0.000066	0.40	0.00000030	0.31	0.076	0.0000013	0.000013	0.000091	0.00071	0.00017
Post-closure	0.000079	0.27	0.000067	0.00000	0.0025	0.000023	0.00014	0.32	0.000044	0.26	0.00000016	0.041	0.013	0.00000060	0.0000032	0.000020	0.00081	0.000031
Geounit 12																		
Operational	0.00014	0.30	0.000018	0.00000	0.0010	0.00049	0.000077	1.0	0.000040	0.49	0.000000051	0.67	0.020	0.0000014	0.0000035	0.000022	0.0015	0.00015
Post-closure	0.00011	0.43	0.00011	0.00000	0.0059	0.00046	0.00012	2.0	0.000056	0.29	0.00000014	0.035	0.011	0.0000029	0.0000012	0.0000038	0.00024	0.000051
Geounit 13																		
Operational	0.00018	0.71	0.00045	0.00000	0.0037	0.000059	0.00027	0.46	0.000041	0.39	0.00000030	0.30	0.044	0.00000059	0.000013	0.000080	0.00077	0.00017
Post-closure	0.000077	0.26	0.000068	0.00000	0.00095	0.000013	0.00014	0.23	0.000030	0.27	0.00000017	0.041	0.012	0.00000032	0.0000032	0.000022	0.00086	0.000032
Geounit 99																		
Operational	0.00026	1.5	0.0011	0.00000	0.0097	0.0013	0.00090	1.4	0.000093	0.41	0.00000030	0.31	0.11	0.0000021	0.000013	0.00010	0.00064	0.00017
Post-closure	0.000081	0.27	0.000067	0.00000	0.0041	0.000033	0.00013	0.41	0.000058	0.24	0.00000014	0.041	0.015	0.00000091	0.0000032	0.000019	0.00075	0.000031

Date	**SO_4**	**Cl**	**F**	**Br**	**Al**	**Sb**	**As**	**Ba**	**Be**	**B**	**Cd**	**Ca**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**
MRSF																	
Pit Walls																	
SLD																	
Operational	22	0.014	0.015	0.0089	0.00085	0.000044	0.000068	0.0017	0.00000059	0.0024	0.0000018	8.2	0.000015	0.000049	0.00018	0.00029	0.0000017
Post-closure - neutral	1.2	0.0043	0.00098	0.0049	0.00015	0.000012	0.000060	0.0050	0.00000029	0.00064	0.00000047	1.2	0.0000072	0.0000026	0.000090	0.000053	0.00000031
Post-closure - acidic	11	0.046	0.014	0.068	0.028	0.000046	0.000046	0.012	0.000017	0.0015	0.000015	2.3	0.0000068	0.019	0.18	0.0016	0.000014
IMH																	
Operational	0.57	0.050	0.0083	0.0080	0.0011	0.00021	0.0017	0.0025	0.00000038	0.0037	0.00000008	0.98	0.000010	0.0000028	0.000065	0.00025	0.000002
Post-closure - neutral	0.15	0.0031	0.0014	0.0045	0.00052	0.000024	0.00014	0.0052	0.00000030	0.00074	0.000000062	0.83	0.0000075	0.0000019	0.000057	0.000048	0.00000084
MAFV																	
Operational	2.7	0.018	0.0077	0.0077	0.00055	0.00012	0.0015	0.0033	0.00000018	0.0066	0.0000013	1.1	0.000014	0.0000038	0.000074	0.00018	0.000031
Post-closure - neutral	1.2	0.0032	0.0027	0.0041	0.00055	0.000045	0.0013	0.0041	0.00000028	0.0016	0.00000038	0.75	0.000020	0.0000061	0.000069	0.000047	0.00000053
Post-closure - acidic	3.3	0.0030	0.0025	0.0039	0.0014	0.000042	0.00024	0.0060	0.0000028	0.0013	0.0000041	0.43	0.000019	0.0044	0.021	0.000031	0.0000029
PICR																	
Operational	2.1	0.012	0.0041	0.0071	0.00018	0.00021	0.020	0.0037	0.00000016	0.012	0.00000037	0.58	0.000012	0.0000028	0.000036	0.00016	0.0000028
Post-closure - neutral	1.2	0.0032	0.0027	0.0041	0.00055	0.000045	0.0013	0.0041	0.00000028	0.0016	0.00000038	0.75	0.000020	0.0000061	0.000069	0.000047	0.00000053
Post-closure - acidic	3.3	0.0030	0.0025	0.0039	0.0014	0.000042	0.00024	0.0060	0.0000028	0.0013	0.0000041	0.43	0.000019	0.0044	0.021	0.000031	0.0000029
SLD ore acidic																	
Operational	100	0.060	0.016	0.0090	0.00023	0.000036	0.00011	0.0017	0.00000060	0.0046	0.0000055	35	0.000015	0.00022	0.0012	0.00024	0.0000024
Post-closure - neutral	4.2	0.0038	0.0011	0.0053	0.00011	0.000010	0.000063	0.0011	0.00000012	0.00082	0.0000013	2.3	0.0000019	0.0000025	0.000096	0.000038	0.00000035
Post-closure - acidic	11	0.0036	0.00099	0.0049	0.00029	0.0000097	0.000012	0.0017	0.0000012	0.00068	0.000014	1.3	0.0000018	0.0019	0.029	0.000025	0.0000019
Ore Stockpile																	
Low-Grade Ore																	
Operational	78	0.046	0.006	0.0069	0.00016	0.000047	0.000111	0.0011	0.00000016	0.0068	0.0000013	26	0.000002	0.000020	0.00025	0.00016	0.0000028
Medium-Grade Ore																	
Operational	80	0.049	0.004	0.0073	0.00039	0.000041	0.000072	0.0011	0.00000017	0.0099	0.0000029	29	0.000001	0.000040	0.00036	0.00017	0.0000039
High-Grade Ore																	
Operational	62	0.042	0.020	0.0082	0.00030	0.000170	0.000199	0.0013	0.00000039	0.0041	0.0000072	20	0.000008	0.000123	0.00089	0.00021	0.0000017
Tailings Storage Facility																	
Active	20	0.23	0.034	0.068	0.010	0.00060	0.00086	0.022	0.0000045	0.0092	0.0000035	14	0.00011	0.000072	0.0011	0.00069	0.000010
Inactive	20	0.20	0.033	0.068	0.011	0.00064	0.00078	0.031	0.0000045	0.0066	0.0000045	13	0.00011	0.000071	0.0011	0.00069	0.000018

Notes: all loading rates are given in mg/kg/wk

Date	**Li**	**Mg**	**Mn**	**Hg**	**Mo**	**Ni**	**P**	**K**	**Se**	**Si**	**Ag**	**Na**	**Sr**	**Tl**	**Sn**	**U**	**V**	**Zn**
MRSF																		
Pit Walls																		
SLD																		
Operational	0.00022	1.1	0.00078	0.00000053	0.0068	0.00069	0.00059	0.95	0.000068	0.40	0.00000030	0.31	0.078	0.0000014	0.000013	0.000091	0.00070	0.00017
Post-closure - neutral	0.000079	0.27	0.000067	0.00000016	0.0026	0.000024	0.00014	0.32	0.000045	0.26	0.00000016	0.041	0.013	0.00000062	0.0000032	0.000020	0.00080	0.000031
Post-closure - acidic	0.00028	0.96	0.011	0.0000023	0.00012	0.034	0.00069	0.57	0.00028	1.1	0.0000018	0.072	0.015	0.0000064	0.000032	0.0000046	0.000028	0.0018
IMH																		
Operational	0.00013	0.32	0.000080	0.00000	0.00027	0.000015	0.00028	0.39	0.0000098	0.41	0.00000017	0.69	0.014	0.00000036	0.000058	0.0000094	0.0024	0.000091
Post-closure - neutral	0.00016	0.37	0.000078	0.00000	0.00014	0.000011	0.00013	0.49	0.000021	0.26	0.00000015	0.038	0.014	0.00000030	0.000015	0.0000050	0.0012	0.000047
MAFV																		
Operational	0.00014	0.30	0.000018	0.00000026	0.0010	0.00049	0.000077	1.0	0.000040	0.49	0.000000051	0.67	0.020	0.0000014	0.0000035	0.000022	0.0015	0.00015
Post-closure - neutral	0.00011	0.43	0.00011	0.00000014	0.0059	0.00046	0.00012	2.0	0.000056	0.29	0.00000014	0.035	0.011	0.0000029	0.0000012	0.0000038	0.00024	0.000051
Post-closure - acidic	0.00026	1.1	0.00095	0.00000013	0.00013	0.082	0.000039	1.2	0.00014	1.2	0.00000051	0.043	0.0053	0.0000035	0.0000006	0.00000032	0.0000095	0.00038
PICR																		
Operational	0.00013	0.45	0.000056	0.00000024	0.00020	0.00029	0.000071	1.8	0.000058	0.41	0.000000047	0.55	0.012	0.0000012	0.0000075	0.00000089	0.000092	0.000043
Post-closure - neutral	0.00011	0.43	0.00011	0.0000001	0.0059	0.00046	0.00012	2.0	0.000056	0.29	0.00000014	0.035	0.011	0.0000029	0.0000012	0.0000038	0.00024	0.000051
Post-closure - acidic	0.00026	1.1	0.00095	0.00000013	0.00013	0.082	0.000039	1.2	0.00014	1.2	0.00000051	0.043	0.0053	0.0000035	0.00000063	0.00000032	0.0000095	0.00038
SLD ore acidic																		
Operational	0.00036	5.6	0.0100	0.00000030	0.017	0.00056	0.0013	2.3	0.00015	0.50	0.00000030	0.50	0.40	0.00000060	0.0031	0.00016	0.00017	0.00018
Post-closure - neutral	0.000071	0.18	0.000093	0.00000018	0.0082	0.0000070	0.00016	0.30	0.000100	0.21	0.000000069	0.036	0.013	0.00000084	0.00082	0.0000093	0.00034	0.000019
Post-closure - acidic	0.00018	0.46	0.00083	0.00000016	0.00018	0.0013	0.000049	0.17	0.00025	0.85	0.00000026	0.044	0.0066	0.0000010	0.00043	0.00000079	0.000013	0.00014
Ore Stockpile																		
Low-Grade Ore																		
Operational	0.00021	3.0	0.0009	0.00000	0.0016	0.0001	0.00007	0.5	0.000019	0.67	0.00000005	0.32	0.15	0.0000003	0.000017	0.00006	0.00093	0.00003
Medium-Grade Ore																		
Operational	0.00019	1.7	0.0037	0.00000	0.0016	0.0001	0.00007	0.4	0.000025	0.48	0.00000005	0.31	0.16	0.0000004	0.000015	0.00004	0.00052	0.00006
High-Grade Ore																		
Operational	0.00062	4.1	0.0057	0.00015	0.0207	0.0003	0.00067	2.4	0.000374	0.41	0.00000017	0.50	0.24	0.0000014	0.0015639	0.00011	0.00015	0.00010
Tailings Storage Facility																		
Active	0.0014	3.8	0.0025	0.0000023	0.012	0.00031	0.0021	4.2	0.00066	2.0	0.0000023	1.4	0.14	0.0000056	0.00015	0.00013	0.00093	0.00047
Inactive	0.0013	3.8	0.0028	0.0000023	0.010	0.00029	0.0020	3.6	0.00067	1.9	0.0000023	1.0	0.13	0.0000056	0.00013	0.00013	0.00092	0.00045

Notes: all loading rates are given in mg/kg/wk

Appendix B:
Mine Rock and Ore Tonnage

	Uneconomic Mine Rock														Ore			
	Unit 1	**Unit 2**	**Unit 3**	**Unit 4**	**Unit 5**	**Unit 6**	**Unit 7**	**Unit 8**	**Unit 9**	**Unit 10**	**Unit 11**	**Unit 12**	**Unit 13**	**Unit 99**	**Low-grade**	**Medium-grade**	**High-grade**	**Total**
West MRSF & Main Embankment																		
Year 5	216,126	2,047,523	417,842	40,188,613	383,641	445,114	27,422,343	9,191,734	4,951,777	7,646,971	-	24,242	73,853	25,545	-	-	-	93,035,323
Year 10	2,593,390	2,513,270	431,528	81,589,149	1,203,253	1,100,797	33,246,842	9,858,892	19,238,438	18,944,402	-	3,007,608	991,401	25,545	-	-	-	174,744,516
EOM	4,546,838	3,511,405	431,528	148,904,883	1,509,384	1,357,078	36,133,938	9,860,700	38,600,701	38,576,772	-	3,007,608	1,005,728	741,324	-	-	-	288,187,886
South MRSF & East Embankment																		
Year 5	1,480,243	3,362,856	1,170,682	76,380,510	788,981	528,594	16,251,347	2,346,489	4,878,117	7,927,409	-	-	176,883	-	-	-	-	115,292,109
Year 10	5,534,920	4,850,093	1,230,560	227,478,970	2,512,752	1,177,048	31,861,564	2,869,871	26,108,351	25,211,252	-	2,270,339	1,460,018	8,935	-	-	-	332,574,673
EOM	6,352,530	4,892,463	1,230,560	241,293,642	2,512,752	1,177,048	32,297,224	2,869,871	27,434,224	25,586,270	-	2,288,617	1,460,018	8,935	-	-	-	349,404,156
East MRSF																		
Year 5	326,081	897,491	127,784	56,874,239	248,587	169,548	6,897,261	104,835	510,526	-	-	8,801	37,437	-	-	-	-	66,202,591
Year 10	326,081	897,491	127,784	58,671,648	248,587	169,548	6,897,261	104,835	510,526	-	-	8,801	37,437	-	-	-	-	68,000,000
EOM	326,081	897,491	127,784	58,671,648	248,587	169,548	6,897,261	104,835	510,526	-	-	8,801	37,437	-	-	-	-	68,000,000
Backfill																		
EOM	3,437,530	-	-	101,883,332	-	-	15,823,203	-	20,150,329	34,259,597	-	6,524,497	771,582	-	-	-	-	182,850,070
Ore Stockpile																		
Max (year 11)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28084779	27377652	9387	55471818
Year 17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43335959	7683425	0	51019384

Appendix C: Geochemical Caps

KGHM

APPENDIX C.1 MINE ROCK AND ORE GEOCHEMICAL CAP

	Sulphate	**Cl**	**F**	**Br**	**Al**	**Sb**	**As**	**Ba**	**Be**	**B**	**Cd**	**Ca**
Porphyry Copper Site Analogue												
Database	1531				0.2	0.08	0.03				0.01	727
Waste Rock piezometer												
MW12-01	1775	20	0.47	1.0	0.0039	0.0041	0.0056	0.047	0.00018	0.12	0.0014	255
MW12-02	1785	19	0.47	1.0	0.0020	0.015	0.021	0.033	0.00018	0.12	0.0014	241
Field Bins												
B1 (IMH)	89	4.6	0.23		0.061	0.0024	0.081	0.079	0.00060	0.41	0.000043	26
B2 (SLD)	681	5.2	0.20		0.016	0.0020	0.0061	0.076	0.0012	0.20	0.00027	193
B3 (IMH)	52	1.4	0.34		0.038	0.0024	0.0024	0.037	0.00050	0.12	0.000040	23
B4 (Picrite)	189	2.4	0.046		1.4	0.0028	0.039	0.19	0.0010	0.19	0.00011	38
B7 (SLD)	399	3.5	0.14		0.017	0.0021	0.040	0.085	0.0010	0.046	0.00023	125
Cap	**1785**	**20**	**0.47**	**1.0**	**1.4**	**0.080**	**0.081**	**0.19**	**0.0012**	**0.41**	**0.0070**	**727**

	Cr	**Co**	**Cu**	**Fe**	**Pb**	**Li**	**Mg**	**Mn**	**Hg**	**Mo**	**Ni**	**P**
Porphyry Copper Site Analogue												
Database			1	0.2	0.00		101	4	0.000	0.3	0.2	
Waste Rock piezometer												
MW12-01	0.00018	0.0017	0.0062	0.010	0.000088	0.033	315	0.088	0.000010	3.5	0.014	0.050
MW12-02	0.00018	0.0025	0.015	0.010	0.000088	0.034	317	0.12	0.000019	3.4	0.028	0.050
Field Bins												
B1 (IMH)	0.0037	0.00019	0.017	0.12	0.000093	0.0060	16	0.0035	0.000050	0.073	0.00097	0.30
B2 (SLD)	0.0017	0.00025	0.026	0.030	0.00012	0.012	68	0.0018	0.000050	1.1	0.0012	0.30
B3 (IMH)	0.0020	0.00010	0.0032	0.042	0.000050	0.0077	25	0.00083	0.000050	0.12	0.00050	0.30
B4 (Picrite)	0.023	0.0063	0.022	1.6	0.00024	0.010	39	0.060	0.000050	0.50	0.064	0.30
B7 (SLD)	0.0010	0.00028	0.11	0.033	0.00010	0.010	47	0.0064	0.000050	0.87	0.0017	0.30
Cap	**0.023**	**0.0063**	**0.11**	**1.6**	**0.0036**	**0.034**	**317**	**4.0**	**0.00043**	**3.5**	**0.21**	**0.30**

	K	**Se**	**Si**	**Ag**	**Na**	**Sr**	**Tl**	**Sn**	**U**	**V**	**Zn**
Porphyry Copper Site Analogue											
Database	39	0.30		0.00001	54						0.8
Waste Rock piezometer											
MW12-01	49	0.044	7.4	0.000018	151	3.6	0.000020	0.00018	0.015	0.0038	0.0035
MW12-02	54	0.041	7.9	0.000018	160	3.6	0.000041	0.00019	0.013	0.0037	0.0021
Field Bins											
B1 (IMH)	45	0.024	7.9	0.000012	15	0.22	0.00012	0.00012	0.0011	0.11	0.083
B2 (SLD)	8.9	0.014	8.0	0.000025	3.6	1.3	0.00025	0.00025	0.0019	0.039	0.043
B3 (IMH)	6.6	0.017	7.7	0.000010	8.7	0.30	0.00010	0.00010	0.0010	0.045	0.030
B4 (Picrite)	80	0.0036	10	0.000025	9.1	0.38	0.00020	0.00020	0.00071	0.041	0.032
B7 (SLD)	17	0.034	15	0.000020	4.2	0.68	0.00020	0.00020	0.00068	0.031	0.023
Cap	**80**	**0.30**	**15**	**0.000025**	**160**	**3.6**	**0.00025**	**0.00025**	**0.015**	**0.11**	**0.80**

Notes: all values are in mg/L and represent 95th PCTL values of the respective databases; The highest observed field bin leachate value for Cu (0.11 mg/L) was used as a cap since this value roughly represents the equilibrium value with malachite

APPENDIX C.2 SATURATED AND UNSATURATED TAILINGS GEOCHEMICAL CAP

	Sulphate	**Cl**	**F**	**Br**	**Al**	**Sb**	**As**	**Ba**	**Be**	**B**	**Cd**	**Ca**
Laboratory test data												
Supernatants	1616	112	0.40	0.25	0.047	0.0047	0.007	0.038	0.00020	0.093	0.00009	612
Field Bin	2501	18	0.40		0.030	0.0020	0.0011	0.081	0.00020	0.092	0.00010	537
Saturated column	275	20	0.42	0.40	0.018	0.0015	0.0070	0.042	0.000010	0.066	0.00018	46
T2	341	0.78			0.068	0.0017	0.0029	0.054	0.000010	0.061	0.00034	90
T4	1160				0.0093	0.0027	0.0023	0.035	0.000010	0.12	0.000089	217
Afton Tailings area												
CPT 14-46	1070	20	3.3	1.0	0.18	0.0018	0.20	0.030	0.00020	0.38	0.000077	35
CPT 14-32	538	48	1.4	1.0	0.24	0.00045	0.022	0.047	0.00020	0.22	0.000051	19
CPT 14-27	875	28	2.4	1.0	0.51	0.00052	0.022	0.038	0.00020	0.41	0.000034	14
M5 301	1004	14	0.57	1.0	3.4	0.00051	0.0033	0.10	0.00020	0.51	0.00026	84
M5 203	1625	37	0.52	1.0	0.22	0.00050	0.0016	0.028	0.0010	0.87	0.00017	55
M5 202	2011	39	0.49	1.0	0.99	0.00036	0.0018	0.030	0.00020	0.71	0.00045	131
Unaturated term cap	**2501**	**39**	**0.57**	**1.0**	**3.4**	**0.0027**	**0.0033**	**0.10**	**0.0010**	**0.87**	**0.00045**	**537**
Saturated term cap	**1616**	**112**	**3.3**	**1.0**	**0.51**	**0.0047**	**0.20**	**0.047**	**0.00020**	**0.41**	**0.00018**	**612**

	Cr	**Co**	**Cu**	**Fe**	**Pb**	**Li**	**Mg**	**Mn**	**Hg**	**Mo**	**Ni**	**P**
Laboratory test data												
Supernatants	0.00041	0.00072	0.0066	0.030	0.0006	0.0066	61	0.087	0.000056	0.22	0.0059	0.13
Field Bin	0.00026	0.0068	0.0032	0.010	0.00010	0.051	239	0.39	0.000019	0.21	0.017	0.077
Saturated column	0.00010	0.00044	0.0018	0.0014	0.000021	0.0017	6.8	0.0078	0.000010	0.35	0.0014	0.019
T2	0.0017	0.00051	0.0086	0.022	0.0022	0.015	54	0.021	0.000020	3.5	0.0022	0.043
T4	0.00068	0.0041	0.0091	0.043	0.00038	0.027	98	0.16	0.000010	0.76	0.0092	0.0045
Afton Tailings area												
CPT 14-46	0.00025	0.00020	0.013	0.11	0.00016	0.010	3.2	0.053	0.000010	0.30	0.00068	19
CPT 14-32	0.00045	0.00043	0.022	0.19	0.00010	0.010	7.5	0.19	0.000010	0.86	0.0023	2.2
CPT 14-27	0.00099	0.00041	0.056	0.35	0.00020	0.012	8.9	0.080	0.000010	0.25	0.0020	7.7
M5 301	0.0079	0.0041	0.028	3.6	0.069	0.0050	87	0.22	0.000046	0.032	0.0070	0.26
M5 203	0.0014	0.00050	0.0036	0.25	0.0032	0.025	76	0.014	0.000010	0.018	0.0012	0.89
M5 202	0.0025	0.0013	0.015	1.2	0.019	0.0050	299	0.13	0.000010	0.0094	0.0069	2.2
Unaturated term cap	**0.0079**	**0.0068**	**0.028**	**3.6**	**0.069**	**0.051**	**299**	**0.39**	**0.000046**	**3.5**	**0.017**	**2.2**
Saturated term cap	**0.00099**	**0.00072**	**0.056**	**0.35**	**0.00062**	**0.012**	**61**	**0.19**	**0.000056**	**0.86**	**0.0059**	**19**

	K	**Se**	**Si**	**Ag**	**Na**	**Sr**	**Tl**	**Sn**	**U**	**V**	**Zn**
Laboratory test data											
Supernatants	32	0.0021	7.4	0.00020	78	3.1	0.000023	0.00028	0.0091	0.0045	0.015
Field Bin	55	0.041	8.4	0.000020	115	6.1	0.00032	0.00020	0.0091	0.014	0.011
Saturated column	30	0.00046	5.7	0.0000050	75	0.49	0.0000045	0.000045	0.00016	0.0019	0.011
T2	20	0.023	7.5	0.000040	55	1.1	0.00010	N/A	0.0038	0.0027	0.0060
T4	52	0.022	5.3	0.000019	37	2.5	0.000029	0.00067	0.0038	0.0011	0.0079
Afton Tailings area											
CPT 14-46	10	0.00091	2.7	0.000020	452	1.9	0.00010	0.00026	0.000089	0.0086	0.0060
CPT 14-32	12	0.00020	6.6	0.000020	347	0.73	0.00010	0.00020	0.0022	0.0037	0.0060
CPT 14-27	17	0.00042	6.1	0.000020	532	0.83	0.00010	0.00020	0.0022	0.0056	0.0060
M5 301	7.9	0.010	9.0	0.000049	263	2.5	0.000050	0.00010	0.0015	0.016	0.020
M5 203	17	0.039	5.0	0.000050	796	1.9	0.00025	0.0011	0.0051	0.0034	0.015
M5 202	23	0.017	9.3	0.000010	576	5.3	0.000050	0.00084	0.0071	0.0062	0.015
Unaturated term cap	**55**	**0.041**	**9.3**	**0.000050**	**796**	**6.1**	**0.00032**	**0.0011**	**0.0091**	**0.016**	**0.020**
Saturated term cap	**32**	**0.0021**	**7.4**	**0.00020**	**532**	**3.1**	**0.00010**	**0.00028**	**0.0091**	**0.0086**	**0.015**

APPENDIX C.3 TSF POND GEOCHEMICAL CAP

	Br	**Cl**	**F**	**SO_4***	**NO_3**	**NO_2**	**P**	**Al**	**Sb**	**As***	**Ba**	**Be**	**B**	**Cd**	**Ca**	**Cr****	**Co**	**Cu**
TSF Pond Cap	2.0	2010	1.4	30170	21	2.8	0.0042	0.0053	0.021	0.022	0.054	0.000053	none	0.000035	653	0.10	0.014	0.042

	Fe*	**Pb**	**Li**	**Mg***	**Mn**	**Mo**	**Ni**	**K***	**Se**	**Si**	**Ag**	**Na***	**Sr**	**Tl**	**Sn**	**U**	**V**	**Zn***
TSF Pond Cap	0.089	0.000074	none	3675	0.77	none	0.026	393	none	23	0.000046	8496	22	0.00019	0.00084	0.13	0.0053	0.14

Notes: * The highest value from the pond experiment and 90th percentile database of evaporative lakes was used for these species.

** Cr was below detection limit (DL) in all analyses such that the highest DL was used as a cap

Appendix D:
Geochemical Source Term

KGHM

	Time Step/Scenario	pH	Alkalinity	Sulphate	Cl	F	Br	Al	Sb	As	Ba	Be	B
Concentrations (mg/L)													
West MRSF & Main Embankment	Year 5	8.0	132	1673	8.9	0.47	1.0	0.0032	0.052	0.081	0.029	0.00010	0.41
	Year 10	8.0	130	1660	9.7	0.47	1.0	0.0031	0.049	0.081	0.030	0.00012	0.41
	Year 20	8.0	128	1649	10	0.47	1.0	0.0031	0.048	0.081	0.031	0.00013	0.41
	Post-closure	7.9	112	1447	2.2	0.47	1.0	0.0027	0.015	0.081	0.046	0.00018	0.41
South MRSF & East Embankment	Year 5	8.0	124	1616	16	0.47	1.0	0.0030	0.076	0.081	0.036	0.00016	0.41
	Year 10	8.0	123	1611	17	0.47	1.0	0.0030	0.074	0.081	0.036	0.00017	0.41
	Year 20	8.0	123	1610	17	0.47	1.0	0.0030	0.074	0.081	0.036	0.00017	0.41
	Post-closure	7.9	105	1430	2.9	0.47	1.0	0.0026	0.020	0.081	0.060	0.00025	0.41
East MRSF	Year 5	7.9	122	1598	20	0.47	1.0	0.0029	0.080	0.081	0.038	0.00016	0.41
	Year 10	7.9	122	1598	20	0.47	1.0	0.0029	0.080	0.081	0.038	0.00016	0.41
	Year 20	7.9	122	1598	20	0.47	1.0	0.0029	0.080	0.081	0.038	0.00016	0.41
	Post-closure	7.9	116	1457	1.4	0.47	1.0	0.0028	0.011	0.081	0.040	0.00013	0.37
Backfill	Year 20	7.9	120	1598	20	0.47	1.0	0.0029	0.080	0.081	0.041	0.00023	0.41
South Embankment	Year 20	8.0	126	1634	12	0.47	1.0	0.0031	0.048	0.081	0.032	0.00015	0.41
	Post-closure	8.0	121	1485	1.2	0.45	1.0	0.0030	0.0070	0.062	0.033	0.00010	0.26
Southeast Embankment	Year 20	8.0	133	1618	6.1	0.47	1.0	0.0032	0.025	0.081	0.026	0.000080	0.41
	Post-closure	8.0	130	1529	0.65	0.24	0.82	0.0032	0.0037	0.033	0.027	0.000050	0.13
Ore Stockpile	Max extent	8.2	199	1638	20	0.47	1.0	0.0046	0.023	0.048	0.012	0.000086	0.41
	Year 17	8.2	199	1632	20	0.47	1.0	0.0046	0.022	0.050	0.012	0.000075	0.41
TSF seepage (saturated)	operations	7.8	246	1498	112	0.42	0.40	0.0023	0.0047	0.0073	0.023	0.00020	0.093
Process-water	operations	7.7	50	1616	112	0.40	0.25	0.047	0.0047	0.0073	0.038	0.00020	0.093
TSF seepage w/o NAG cover	Post-closure	7.9	105	1304	19	0.57	1.0	0.0026	0.0027	0.0033	0.059	0.00044	0.65
TSF seepage with NAG cover	Post-closure	7.9	105	1304	19	0.57	1.0	0.0026	0.012	0.073	0.059	0.00044	0.65
Pit wall - IMH	operational	8.0	126	1623	14	0.47	1.0	0.0031	0.056	0.081	0.032	0.00010	0.41
Pit wall - SLD	operational	8.0	131	1616	3.5	0.47	1.0	0.0032	0.011	0.018	0.028	0.00015	0.41
Pit wall - MAFV	operational	8.0	138	1703	4.5	0.47	1.0	0.0033	0.030	0.081	0.025	0.000050	0.41
Pit wall - PICR	operational	8.0	141	1707	3.1	0.47	1.0	0.0033	0.055	0.081	0.025	0.000040	0.41
Pit wall - SLD ore	operational	8.1	167	1660	13	0.47	1.0	0.0040	0.011	0.019	0.016	0.000041	0.41
Pit wall - IMH	Post-closure	8.0	122	1488	0.84	0.39	1.0	0.0030	0.0065	0.039	0.032	0.000080	0.20
Pit wall - SLD	Post-closure	8.0	126	1514	1.1	0.25	1.0	0.0031	0.0030	0.015	0.029	0.000070	0.16
Pit wall - SLD - acidic	Post-closure	6.2	2.0	1935	1.0	0.24	1.2	0.0074	0.0028	0.00060	0.021	0.00075	0.14
Pit wall - MAFV/PICR	Post-closure	8.0	130	1569	0.81	0.47	1.0	0.0032	0.012	0.081	0.029	0.000070	0.41
Pit wall - MAFV/PICR - acidic	Post-closure	5.7	0.46	2139	0.76	0.64	0.99	0.30	0.011	0.00060	0.021	0.00071	0.34
Pit wall - SLD ore	Post-closure	8.0	129	1517	0.98	0.27	1.0	0.0032	0.0027	0.016	0.027	0.000030	0.21
Pit wall - SLD ore - acidic	Post-closure	6.1	1.3	2115	0.92	0.25	1.3	0.022	0.0025	0.00060	0.011	0.00031	0.18
Loads (mg/m^2/yr)													
TSF beach runoff (active)	operations	-	4865	51590	139	21	37.00	0.12	0.100	0.12	0.95	0.00259	5.6
TSF beach runoff/infiltration (inactive)	operations	-	3896	48234	715	21.2	37.00	0.10	0.100	0.12	2.19	0.01636	24.1
Pit wall - IMH	Stored; post-closure	-		3101	62	29	91	11	0.49	2.9	105	0.0061	15
Pit wall - SLD	Stored; post-closure	-		21962	82	19	93	2.8	0.22	1.1	96	0.0056	12
Pit wall - SLD - acidic	Stored; post-closure	-	-	58676	77	17	87	7.3	0.21	0.21	142	0.056	10
Pit wall - MAFV/PICR	Stored; post-closure	-		23770	60	50	79	10	0.86	24	78	0.0052	31
Pit wall - MAFV/PICR - acidic	Stored; post-closure	-	-	63508	56	47	74	27	0.80	4.5	115	0.053	25
Pit wall - SLD ore	Stored; post-closure	-		79511	72	20	100	2.2	0.20	1.2	22	0.0023	16
Pit wall - SLD ore - acidic	Stored; post-closure	-	-	212431	68	19	94	5.6	0.18	0.23	32	0.023	13

Notes: Alkalinity is reported in terms of $CaCO_3$

	Time Step/Scenario	Cd	Ca	Cr	Co	Cu	Fe	Pb	Li	Mg	Mn	Hg	Mo	Ni
Concentrations (mg/L)														
West MRSF & Main Embankment	Year 5	0.00019	504	0.0035	0.0036	0.011	0.00028	0.0014	0.034	54	0.060	0.000090	0.47	0.085
	Year 10	0.00023	497	0.0037	0.0055	0.011	0.00028	0.0012	0.034	56	0.088	0.00010	0.71	0.10
	Year 20	0.00025	491	0.0037	0.0063	0.011	0.00028	0.0011	0.034	57	0.10	0.00011	0.83	0.11
	Post-closure	0.00018	478	0.0059	0.0018	0.012	0.00033	0.00039	0.034	79	0.049	0.000090	1.3	0.057
South MRSF & East Embankment	Year 5	0.00020	469	0.0048	0.0050	0.011	0.00030	0.00090	0.034	64	0.088	0.00013	0.64	0.083
	Year 10	0.00023	465	0.0048	0.0059	0.011	0.00030	0.00084	0.034	65	0.10	0.00014	0.76	0.094
	Year 20	0.00022	465	0.0048	0.0059	0.011	0.00030	0.00084	0.034	65	0.10	0.00014	0.75	0.093
	Post-closure	0.00017	432	0.0075	0.0021	0.012	0.00037	0.00060	0.034	99	0.067	0.00013	1.1	0.052
East MRSF	Year 5	0.000080	458	0.0046	0.0019	0.011	0.00031	0.00091	0.034	67	0.045	0.00012	0.22	0.029
	Year 10	0.000080	458	0.0046	0.0019	0.011	0.00031	0.00091	0.034	67	0.045	0.00012	0.21	0.029
	Year 20	0.000080	458	0.0046	0.0019	0.011	0.00031	0.00091	0.034	67	0.045	0.00012	0.21	0.029
	Post-closure	0.000050	504	0.0039	0.0010	0.011	0.00031	0.00035	0.034	69	0.036	0.000070	0.36	0.025
Backfill	Year 20	0.00045	450	0.0066	0.0063	0.012	0.00032	0.00064	0.034	72	0.19	0.00019	1.5	0.19
South Embankment	Year 20	0.00029	482	0.0041	0.0063	0.011	0.00029	0.00090	0.034	59	0.13	0.00012	1.0	0.12
	Post-closure	0.000090	534	0.0027	0.00082	0.011	0.00029	0.00021	0.034	60	0.025	0.000050	0.54	0.015
Southeast Embankment	Year 20	0.00016	539	0.0021	0.0042	0.011	0.00027	0.00047	0.030	50	0.068	0.000060	0.55	0.064
	Post-closure	0.000050	572	0.0014	0.00044	0.011	0.00027	0.00011	0.022	50	0.013	0.000030	0.29	0.0081
Ore Stockpile	Max extent	0.0011	537	0.00083	0.0063	0.11	0.00021	0.0017	0.034	29	0.46	0.00013	0.83	0.043
	Year 17	0.00075	540	0.00084	0.0063	0.11	0.00021	0.0014	0.034	29	0.46	0.00011	0.75	0.037
TSF seepage (saturated)	operations	0.00018	627	0.00041	0.00072	0.0066	0.00040	0.00062	0.0066	45	0.087	0.000056	0.35	0.0059
Process-water	operations	0.000092	612	0.00041	0.00072	0.0066	0.030	0.00062	0.0066	61	0.087	0.000056	0.22	0.0059
TSF seepage w/o NAG cover	Post-closure	0.00044	333	0.0079	0.0068	0.012	0.00036	0.00065	0.051	98	0.27	0.000046	1.0	0.017
TSF seepage with NAG cover	Post-closure	0.00044	333	0.0079	0.0068	0.046	0.00036	0.00065	0.051	98	0.27	0.000084	1.3	0.017
Pit wall - IMH	operational	0.000020	480	0.0028	0.00076	0.011	0.00029	0.00066	0.034	58	0.022	0.000070	0.075	0.0041
Pit wall - SLD	operational	0.00046	547	0.0038	0.0063	0.011	0.00027	0.00044	0.034	52	0.20	0.00014	1.8	0.18
Pit wall - MAFV	operational	0.00033	522	0.0035	0.00097	0.011	0.00026	0.0036	0.034	48	0.0046	0.000070	0.27	0.13
Pit wall - PICR	operational	0.000090	539	0.0031	0.00073	0.0094	0.00026	0.00071	0.033	49	0.014	0.000060	0.050	0.075
Pit wall - SLD ore	operational	0.00077	590	0.00034	0.0063	0.011	0.00022	0.0010	0.034	34	0.52	0.000062	0.42	0.024
Pit wall - IMH	Post-closure	0.000020	540	0.0021	0.00051	0.011	0.00029	0.00023	0.034	58	0.021	0.000040	0.038	0.0029
Pit wall - SLD	Post-closure	0.00012	558	0.0019	0.00067	0.011	0.00028	0.000080	0.020	54	0.017	0.000040	0.66	0.0060
Pit wall - SLD - acidic	Post-closure	0.0013	490	0.0017	0.49	2.9	0.0088	0.00044	0.050	177	0.15	0.000040	0.015	1.0
Pit wall - MAFV/PICR	Post-closure	0.00010	583	0.0052	0.0016	0.011	0.00028	0.00014	0.027	53	0.027	0.000040	1.5	0.12
Pit wall - MAFV/PICR - acidic	Post-closure	0.0010	536	0.0049	1.1	5.4	0.0079	0.00075	0.067	180	0.24	0.000030	0.030	1.0
Pit wall - SLD ore	Post-closure	0.00034	574	0.00049	0.00065	0.011	0.00027	0.000090	0.018	46	0.024	0.000040	2.1	0.0018
Pit wall - SLD ore - acidic	Post-closure	0.0037	637	0.00046	0.48	7.5	0.0063	0.00049	0.045	118	0.21	0.000040	0.030	0.32
Loads (mg/m^2/yr)														
TSF beach runoff (active)	operations	0.0022	18849	0.068	0.044	0.41	0.0099	0.006	0.83	1817	1.5	0.00148	7.5	0.19
TSF beach runoff/infiltration (inactive)	operations	0.0164	12325	0.2921	0.2499	0.44	0.0135	0.0242	1.89	3622	10.12	0.00169	37	0.622
Pit wall - IMH	Stored; post-closure	0.0013	17004	0.15	0.038	1.2	0.99	0.017	3.3	7551	1.6	0.0030	2.8	0.22
Pit wall - SLD	Stored; post-closure	0.0090	22100	0.14	0.050	1.7	1.0	0.0060	1.5	5092	1.3	0.0031	49	0.45
Pit wall - SLD - acidic	Stored; post-closure	0.097	12677	0.13	37	521	0.65	0.033	3.7	13111	11	0.0029	1.1	80
Pit wall - MAFV/PICR	Stored; post-closure	0.0072	14247	0.39	0.12	1.3	0.90	0.010	2.0	8276	2.0	0.0026	112	8.7
Pit wall - MAFV/PICR - acidic	Stored; post-closure	0.077	8173	0.36	85	397	0.58	0.056	5.0	21309	18	0.0025	2.5	1558
Pit wall - SLD ore	Stored; post-closure	0.025	43732	0.036	0.048	1.8	0.72	0.0066	1.4	3387	1.8	0.0033	156	0.13
Pit wall - SLD ore - acidic	Stored; post-closure	0.27	25086	0.034	35	555	0.47	0.036	3.3	8722	16	0.0031	3.5	24

Notes: Alkalinity is reported in terms of $CaCO_3$

	Time Step/Scenario	P	K	Se	Si	Ag	Na	Sr	Tl	Sn	U	V	Zn
Concentrations (mg/L)													
West MRSF & Main Embankment	Year 5	0.080	44	0.080	6.6	0.000025	160	3.6	0.00025	0.00025	0.0069	0.11	0.029
	Year 10	0.10	42	0.080	6.6	0.000025	160	3.6	0.00025	0.00025	0.0097	0.11	0.033
	Year 20	0.12	41	0.080	6.6	0.000025	160	3.6	0.00025	0.00025	0.011	0.11	0.035
	Post-closure	0.083	39	0.045	6.6	0.000025	24	3.6	0.00025	0.00025	0.0058	0.11	0.027
South MRSF & East Embankment	Year 5	0.13	38	0.080	6.6	0.000025	160	3.6	0.00025	0.00025	0.0099	0.11	0.043
	Year 10	0.15	37	0.080	6.6	0.000025	160	3.6	0.00025	0.00025	0.011	0.11	0.044
	Year 20	0.15	37	0.080	6.6	0.000025	160	3.6	0.00025	0.00025	0.011	0.11	0.044
	Post-closure	0.11	32	0.043	6.5	0.000025	33	3.6	0.00025	0.00025	0.0067	0.11	0.038
East MRSF	Year 5	0.12	36	0.064	6.6	0.000025	160	3.6	0.00021	0.00025	0.0050	0.11	0.039
	Year 10	0.12	36	0.063	6.6	0.000025	160	3.6	0.00021	0.00025	0.0050	0.11	0.039
	Year 20	0.12	36	0.063	6.6	0.000025	160	3.6	0.00021	0.00025	0.0050	0.11	0.039
	Post-closure	0.059	43	0.013	6.6	0.000025	17	3.6	0.00025	0.00025	0.0024	0.11	0.021
Backfill	Year 20	0.22	35	0.080	6.6	0.000025	160	3.6	0.00025	0.00025	0.015	0.11	0.064
South Embankment	Year 20	0.14	40	0.080	6.6	0.000025	160	3.6	0.00025	0.00025	0.014	0.11	0.041
	Post-closure	0.045	48	0.023	6.6	0.000025	13	3.6	0.00021	0.00025	0.0036	0.11	0.014
Southeast Embankment	Year 20	0.075	52	0.080	6.6	0.000025	95	3.6	0.00015	0.00025	0.0075	0.11	0.021
	Post-closure	0.024	57	0.012	6.6	0.000025	6.9	2.4	0.00011	0.00025	0.0019	0.11	0.0073
Ore Stockpile	Max extent	0.037	97	0.080	6.6	0.000021	160	3.6	0.00018	0.00025	0.015	0.11	0.023
	Year 17	0.033	98	0.080	6.6	0.000021	153	3.6	0.00014	0.00025	0.015	0.11	0.015
TSF seepage (saturated)	operations	0.13	35	0.0021	6.6	0.00020	78	3.1	0.000020	0.00028	0.0091	0.0046	0.015
Process-water	operations	0.13	32	0.0021	7.4	0.00020	78	3.1	0.000023	0.00028	0.0091	0.0045	0.015
TSF seepage w/o NAG cover	Post-closure	0.20	22	0.041	6.5	0.000050	103	6.1	0.00032	0.0011	0.0091	0.016	0.020
TSF seepage with NAG cover	Post-closure	0.20	22	0.041	6.5	0.000050	103	6.1	0.00032	0.0011	0.010	0.11	0.024
Pit wall - IMH	operational	0.077	40	0.016	6.6	0.000025	160	3.6	0.00010	0.00025	0.0026	0.11	0.025
Pit wall - SLD	operational	0.15	50	0.080	6.6	0.000025	80	3.6	0.00025	0.00025	0.015	0.11	0.045
Pit wall - MAFV	operational	0.019	54	0.068	6.6	0.000010	160	3.6	0.00025	0.00025	0.0057	0.11	0.039
Pit wall - PICR	operational	0.018	55	0.054	6.6	0.000010	141	3.0	0.00025	0.00025	0.00023	0.024	0.011
Pit wall - SLD ore	operational	0.019	94	0.080	6.6	0.000010	82	3.6	0.00011	0.00025	0.0098	0.11	0.017
Pit wall - IMH	Post-closure	0.037	49	0.0042	6.6	0.000025	10	3.6	0.000080	0.00025	0.0014	0.11	0.013
Pit wall - SLD	Post-closure	0.036	52	0.030	6.6	0.000025	11	3.4	0.00016	0.00025	0.0052	0.11	0.0080
Pit wall - SLD - acidic	Post-closure	0.011	32	0.079	6.5	0.00015	13	1.7	0.00019	0.00043	0.00044	0.0082	0.060
Pit wall - MAFV/PICR	Post-closure	0.032	56	0.032	6.6	0.000025	9.0	2.7	0.00025	0.00025	0.00097	0.062	0.013
Pit wall - MAFV/PICR - acidic	Post-closure	0.010	101	0.080	6.5	0.00013	11	1.4	0.00090	0.00016	0.000080	0.0024	0.097
Pit wall - SLD ore	Post-closure	0.040	53	0.080	6.6	0.000020	9.3	3.4	0.00021	0.00025	0.0024	0.087	0.0049
Pit wall - SLD ore - acidic	Post-closure	0.013	83	0.080	6.5	0.000070	11	1.7	0.00026	0.11	0.00020	0.0035	0.036
Loads (mg/m^2/yr)													
TSF beach runoff (active)	operations	1.2	1882	0.40	245	0.0015	861	84	0.0033	0.040	0.081	0.56	0.28
TSF beach runoff/infiltration (inactive)	operations	7.40	822	1.50	242	0.00187	3799	225	0.0117	0.040	0.338	0.59	0.74
Pit wall - IMH	Stored; post-closure	2.7	9890	0.43	5330	0.0031	778	285	0.0061	0.30	0.10	24	0.96
Pit wall - SLD	Stored; post-closure	2.6	6157	0.85	4876	0.0030	780	253	0.012	0.061	0.38	15	0.60
Pit wall - SLD - acidic	Stored; post-closure	0.84	3602	2.2	20151	0.011	955	127	0.014	0.032	0.032	0.61	4.4
Pit wall - MAFV/PICR	Stored; post-closure	2.4	38603	1.1	5447	0.0026	671	202	0.056	0.023	0.072	4.6	0.97
Pit wall - MAFV/PICR - acidic	Stored; post-closure	0.75	22580	2.7	22510	0.0097	822	101	0.067	0.012	0.0061	0.18	7.2
Pit wall - SLD ore	Stored; post-closure	3.0	5680	1.9	3933	0.0013	687	251	0.016	16	0.18	6.5	0.36
Pit wall - SLD ore - acidic	Stored; post-closure	0.93	3322	4.9	16253	0.0049	841	126	0.019	8.3	0.015	0.26	2.7

Notes: Alkalinity is reported in terms of $CaCO_3$