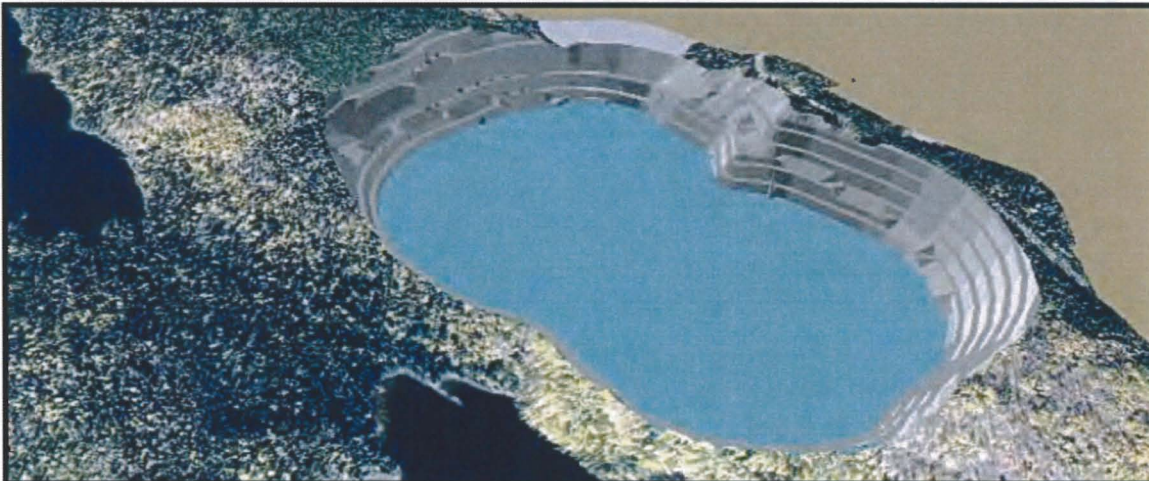




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Morrison Copper/Gold Project
British Columbia, Canada

Morrison Copper/Gold Project: Water Quality and Water Balance Model



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Morrison Copper/Gold Project: Water Quality and Water Balance Model

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Acronyms and Abbreviations

ABA	Acid Base Accounting
ANFO	ammonia nitrate fuel oil
BC	British Columbia
BC MOE	British Columbia Ministry of the Environment
CCME	Canadian Council of Ministers of the Environment
DGBM	Deposit Geochemical Block Model
EA	Environmental Assessment
EDCM	Empirical drainage chemistry model
Klohn	Klohn Crippen Berger Ltd.
masl	metres above sea level
ML/ARD	metal leaching and acid rock drainage
MMER	Metal Mining Effluent Regulation
not-PAG	not potentially acid-generating
NP	neutralization potential
PRISM	Parameter-elevation Regression on Independent Slopes Model
the Project	Morrison Copper/Gold Project
Rescan	Rescan Environmental Services Ltd.
SNPRs	sulphide-based net potential ratios
TSF	tailings storage facility
TSS	total suspended solids
Wardrop	Wardrop Engineering Inc.

1. Introduction

The Morrison Copper/Gold Project (the Project) is a proposed 21-year open pit mining project in north-central British Columbia (BC). During operations, mine tailings will be discharged to a tailings storage facility (TSF) to the northeast of Morrison Lake; the TSF will operate as a zero surface discharge facility. Excess mine water will be stored within the TSF, with a percentage of the water recycled to the process plant as reclaim water. In addition, waste rock will be stored directly to the northeast of the open pit. At the end of operations, the TSF pond will be allowed to fill up to the closure spillway elevation. This will ensure that a water cover is maintained over the tailings to minimize metal leaching and acid rock drainage (ML/ARD). Any excess water in the TSF will be directed to the open pit and contribute to pit filling. The pit will be allowed to fill to a level of approximately 728 meters above sea level (masl) following closure. Once the pit reaches this elevation, water levels will be managed to maintain a hydraulic gradient from Morrison Lake to the pit, ensuring containment of pit water. Any excess water that would cause the pit lake elevation to exceed 728 masl would be treated prior to release to Morrison Lake.

This report considers the site-wide water balance and water quality of the TSF and open pit. It predicts the effects of mass loadings from the different mine components (loading sources) to the TSF pond and pit lake water quality as well as downstream receptors such as streams and Morrison Lake. The modelling study uses a conservative mass-water balance modelling approach, in which all loadings entering the pit lake and TSF are assumed to contribute to the overall water quality of these water bodies. Source term water quality (2009d) was conservative, meaning water quality modeling results would produce worst case water quality prediction, given the available data at this time. The model incorporates, where possible, data produced from baseline field monitoring programs and laboratory ML/ARD test work undertaken on site-specific samples. Analogue Source term water quality is also incorporated into the modelling as Bell and Granisle Mine geology and geochemistry is considered similar enough to Morrison geology and geochemistry (for further descriptions of source term water quality inputs to modelling, see Rescan 2009d). The study uses best available data at the time of the reporting; however, model predictions will be sensitive to any changes in input data, if source term water quality data updates are developed or made available in the future.

The model focuses on the following:

- predicting TSF water balance during operations, closure, and post-closure periods;
- predicting TSF water quality during operations, closure, and post-closure periods;
- predicting pit lake water quality during closure and post-closure periods;
- predicting water balance within receiving environment during operations, closure, and post-closure periods;
- predicting water quality within receiving environment during operations, closure, and post-closure periods.

The report is written in support of the Environmental Assessment (EA) Application for the Project.

1.1 Outline of Modelling Approach

The TSF and open pit are modelled using a water and mass balance approach. The model was developed using the software GoldSim. The model accounts for all inputs, outputs, and water storage, geochemical parameters in the TSF and open pit, as well as tailings solids within the TSF. The model undertakes mixing calculations that consider the reservoirs (bodies of water) as fully mixed, and does not account for any concentration gradients within these reservoirs.

Model limitations include simultaneous geochemical reactions or simulation of complex hydrodynamic and mixing processes (e.g., stratification) within the ponds and pit lake. However, given the shallow depth of the TSF pond (~5 m at closure), a mixing model is appropriate. Further description and discussion of assumptions regarding pit lake complete mixing are explained in Chapter 9.

The modelling approach assumes that all parameters are non-reactive and do not decay or react over time and is therefore conservative with respect to water quality predictions. This approach is thought to be acceptable for waterbodies where pH is close to neutral and concentrations are relatively low. Reactions between parameters are assumed to be of lesser importance than the uncertainties associated with estimating inflows and outflows from the mine components. However, additional reactive modelling using the software PHREEQC (Parkhurst and Appelo 1999) was incorporated for water quality predictions at important time periods during post-closure, such as when the TSF pond and pit lake reach final “full” elevations and when these waterbodies are thought to reach steady state. This approach considers real geochemical processes such as solid-phase precipitation upon solution saturation and metal(loid) adsorption onto iron(hydroxides) to model more realistic environmental conditions.

1.2 Regulatory Criteria

During mine operations and into closure/post-closure, the discharge water quality to the receiving environment from the TSF and/or open pit must comply with applicable federal and provincial regulatory standards and limits. Before an effluent discharge permit is issued by the provincial government, the Project must demonstrate that they are able to comply with federal and provincial criteria and standards or they must provide evidence as to why the effluent discharge permit should contain less stringent, site-specific values. The Water Management Plan for the Project indicates that the TSF will be operated as a zero surface discharge facility during operations, closure, and into the early years of post-closure. However, an effluent discharge permit will be required during the post-closure period after the pit lake fills, when discharges are expected from the open pit to maintain a reverse groundwater gradient and the pit lake elevation at 728 masl.

The federal mine effluent criteria are defined by the Metal Mining Effluent Regulation (MMER) under the *Fisheries Act* (1985) and are administered by Environment Canada. The regulation applies to any new mine that discharges effluent in excess of 50 m³ per day. The criteria apply to

“end-of-pipe” concentrations, with samples taken at the outlet of the facility before dilution with natural receiving waters.

Table 1.2-1 shows the criteria for parameters considered under MMER. The criteria refer to total metals (i.e., the sum of metals dissolved in the water (dissolved metals) and metals associated with suspended solids in the water) and they are regulated on the maximum monthly mean concentration at the discharge point. The MMER criteria apply to all mine phases, including construction, operation, closure, and post-closure. The MMER criteria are onerous to change to site-specific criteria because a change would require a Schedule II amendment through a federal Order in Council. This type of amendment would be a significantly time-consuming and costly process.

In BC, effluent discharge objectives are based on the *Objectives for the Mining, Smelting and Related Industries* (BC MOE 1979). The objectives describe a range of concentrations for each discharge parameter with the site-specific level to be determined based on the sensitivity of the receiving environment. The range of values for parameters covered by the objectives is provided in Table 1.2-1. The objectives are generally measured against dissolved metal concentrations in the effluent. An operational mine will have to comply with water quality limits set out in a provincial effluent discharge permit, with site-specific discharge limits based on the objectives. Site-specific values for the provincial effluent discharge permit can be based on high concentrations of key parameters at the Project site; the presence of aquatic species assemblages that are less sensitive to elevated concentrations of certain parameters; and economic/technical considerations, such as evidence that the proponent is providing the best-available water treatment. Examples of provincial effluent discharge permits for other mines in BC are outlined in Table 1.2-1.

These permits apply to sulphate, fluoride, ammonia, total suspended solids (TSS), pH, and to dissolved metals concentrations. It should be noted that the permits outlined in Table 1.2-1 were issued before the development of the most recent MMER criteria, such that suspended sediment concentrations within the example permits are higher than current MMER guideline value. For the Project, the effluent will be required to comply with the MMER guideline value for suspended solids of 15 mg/L.

BC also has Approved and Working Water Quality Guidelines (BC MOE 2006b, 2006a) for the protection of freshwater aquatic life, which are based on total metal concentrations in the receiving environment and measured downstream of the effluent discharge point from the Project Site. These guidelines are similar to the Canadian Water Quality Guidelines (CWQGs), published by the Canadian Council of Ministers of the Environment (CCME 1999) and that are the federal guidelines for protecting aquatic life. Notably, although the receiving water guideline values are for total metals, effluent discharge permits developed by the province have been issued for dissolved metals.

Table 1.2-1
Morrison Copper/Gold Project: Relevant Regulatory Criteria

	End of Pipe Discharge (mg/L)						Receiving Water (mg/L)	
	MMER	Provincial Objectives BC MOE Permit Range	Eskay Creek Mill Effluent Discharge Criteria	Equity Mine Silt Check Dam Criteria	Equity Mine Diversion Pond Dam Criteria	Island Copper Mine	CCME Guidelines	BC Freshwater Aquatic Life
	Total Metals	Dissolved Metals	Dissolved Metals	Dissolved Metals	Dissolved Metals	Dissolved Metals	Total Metals	Total Metals
Sulphate	-	-	-	-	-	-	-	100
Fluoride	-	2.5 to 10.0	-	-	-	-	-	0.3 ^a
Copper	0.3	0.05 to 0.3	0.05	0.05	0.05	0.05	0.002 ^a	0.0032 ^a
Zinc	0.5	0.2 to 1.0	0.2	0.2	0.2	-	0.03	0.033a
Cadmium	-	0.01 to 0.1	0.01	0.01	10.0	-	0.000017 ^a	0.000017 ^a
Molybdenum	-	0.5 to 5.0	-	-	-	0.5	0.073	1
Chromium	-	0.05 to 0.3	-	-	-	-	0.001	0.001
Cobalt	-	0.5 to 1.0	-	-	-	-	-	0.004
Selenium	-	0.05 to 0.5	-	-	-	-	0.001	0.002
Arsenic	0.5	0.1 to 1.0	0.1	0.05	0.05	0.1	0.005	0.005
Lead	0.2	0.05 to 0.2	0.005	-	-	0.05	0.004 ^a	0.011 ^a
Mercury	-	0 to 0.005	-	-	-	-	0.000026	0.0001
Nickel	0.5	0.2 to 1.0	0.2	-	-	-	0.065	0.065
Aluminum	-	0.5 to 1	-	-	-	-	0.1	-
Antimony	-	0.25 to 1	-	-	-	-	-	0.02
Manganese	-	0.1 to 1	-	-	-	-	-	1.5
Nitrate-N	-	10	-	-	-	-	2.93	40
Nitrite	-	10	-	-	-	-	0.06	0.02
Ammonia	-	1.0 to 10.0	-	8	15	-	0.86	0.71
Phosphate	-	2.0 to 10.0	-	-	-	-	-	-
Iron	-	0.3 to 1.0	-	-	-	-	0.3	0.3
Silver	-	0.05 to 0.5	-	-	-	-	0.0001	0.003
TSS	15	25 to 75	75	50	50	-	25	-
pH	6 to 9	6.5 to 8.5	6 – 10	-	6.5 to 9.0	7.5 to 11.5	6.5 to 9.0	-
TDS	-	2500 to 5000	-	-	-	-	-	-
Cyanide	1.0	0.1 to 0.5	-	-	-	-	0.005	0.01
Radium ₂₂₆	0.37 ^c	10 ^d	-	-	-	-	-	-

a. Criteria vary depending on hardness of water and or pH and temperature. Values calculated using an assumed hardness of 120 mg/L.

b. Un-ionized

c. Units for Radium are Bg/L

d. Units for Radium are pCi/L

2. Physical Setting and TSF Pond Design Details

The location of the main mining infrastructure at the Project is shown in Figure 2-1. The proposed Project site is on the east side of Morrison Lake in the eastern side of the Babine Range in north-central BC.

This section of the report outlines the physical setting of the proposed Project site (in terms of watersheds, streams, and lakes potentially affected by the proposed Project) and provides an overview of the proposed water management plan for the site. More details of the water management plan including a quantitative assessment are provided in Chapter 3.

2.1 Physical Setting

The Project is in north-central BC approximately 65 km northeast of the town of Smithers. The Project area lies on the east side of Morrison Lake in the Babine Lake watershed. The southeast side of Morrison Lake is dominated by a ridge, which includes Hearne Hill. East of this ridge, there is a lake/wetland/river complex that drains around Hearne Hill to Morrison Lake and Babine Lake. The location of the proposed Project site is at the base of the ridge, in the valley close to Morrison Lake.

2.1.1 Location of TSF

The TSF will be constructed within the watershed of a small stream, MCS-7 (see Section 7.5 and Rescan 2008b), which is a tributary of Morrison Lake. The pre-development watershed is shown in Figure 2.1-1 and has an area of around 12.7 km² at the outlet of the stream into Morrison Lake. The watershed's topography is relatively steep, draining a line of hills that bound Morrison Lake to the northeast. The topographic relief varies approximately 400 m from the highest point in the catchment to Morrison Lake over a distance of 4 km. However, the TSF will be on an area of high elevation and low relief.

The location of the TSF and the post-development watersheds are shown in Figure 2.1-2. During operations, the majority of the watershed area lying upstream of the pond will be allowed to report to the TSF to maintain a net positive TSF water balance to provide sufficient pond water for reclaim to the process plant.

The variation in watershed areas (and pond area) within the MCS-7 watershed during different periods of operation (Klohn Crippen Berger 2009) are outlined in Table 2.1-1. For the water quality prediction modelling carried out by Rescan, a variation of these values is used and will be discussed further in Chapter 4.

**Table 2.1-1
Details of Catchment within MCS-7**

Year	Pond Area (km²)	Watershed flowing to pond (km²)	Diverted watershed (km²)	Total upstream pond (km²)	Downstream of pond (km²)
^{a,b} Starter Dam	1.2	4.6	5.5	11.3	1.4
^{a,b} Year 10	4.1	0.6	6.6	11.3	1.4
^{a,b} Year 20	5	0.6	5.7	11.3	1.4
^a Closure	4.5	5.3	0	9.8	1.4
^b Closure (used in model)	5	6.3	0	11.3	1.4

a Values taken from Klohn (2009).

b Used in the model presented in this report. Note the Klohn (2009) values for closure did not produce the same total watershed area as during operations and as a result values in the final row in the table were used in the model.

2.1.2 Location of Process Plant Site, Waste Rock Storage Area, Low Grade Ore Stockpile and Open Pit

The process plant site, waste rock storage area, low grade ore stockpile, and open pit lie to the southwest of the TSF, on the lower slopes adjacent to Morrison Lake. This mine infrastructure lies within the MCS-4, MCS-5, and MCS-6 watersheds. All three watersheds are on the east side and drain into Morrison Lake.

Diversion channels will be constructed upstream of the process plant site and open pit, which will receive and direct “non-contact” water away and around the mine infrastructure. However, a watershed area, of approximately 2 km² during the early years of operations increasing to 3 km² by mid-operations, will remain within the mine footprint and surface water runoff and seepage will drain to the pit (Klohn Crippen Berger 2009).

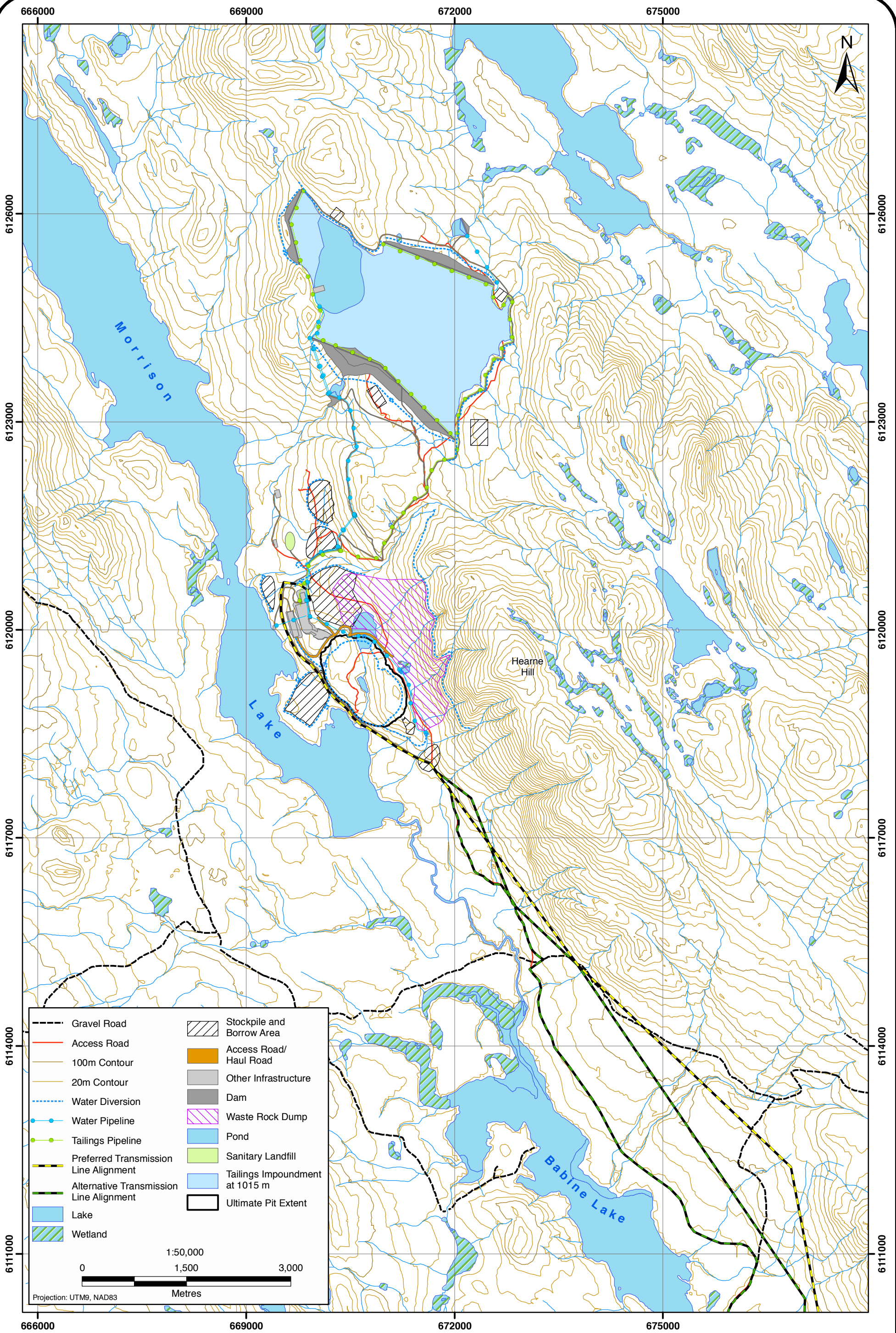
2.1.3 Downstream Streams and Lakes

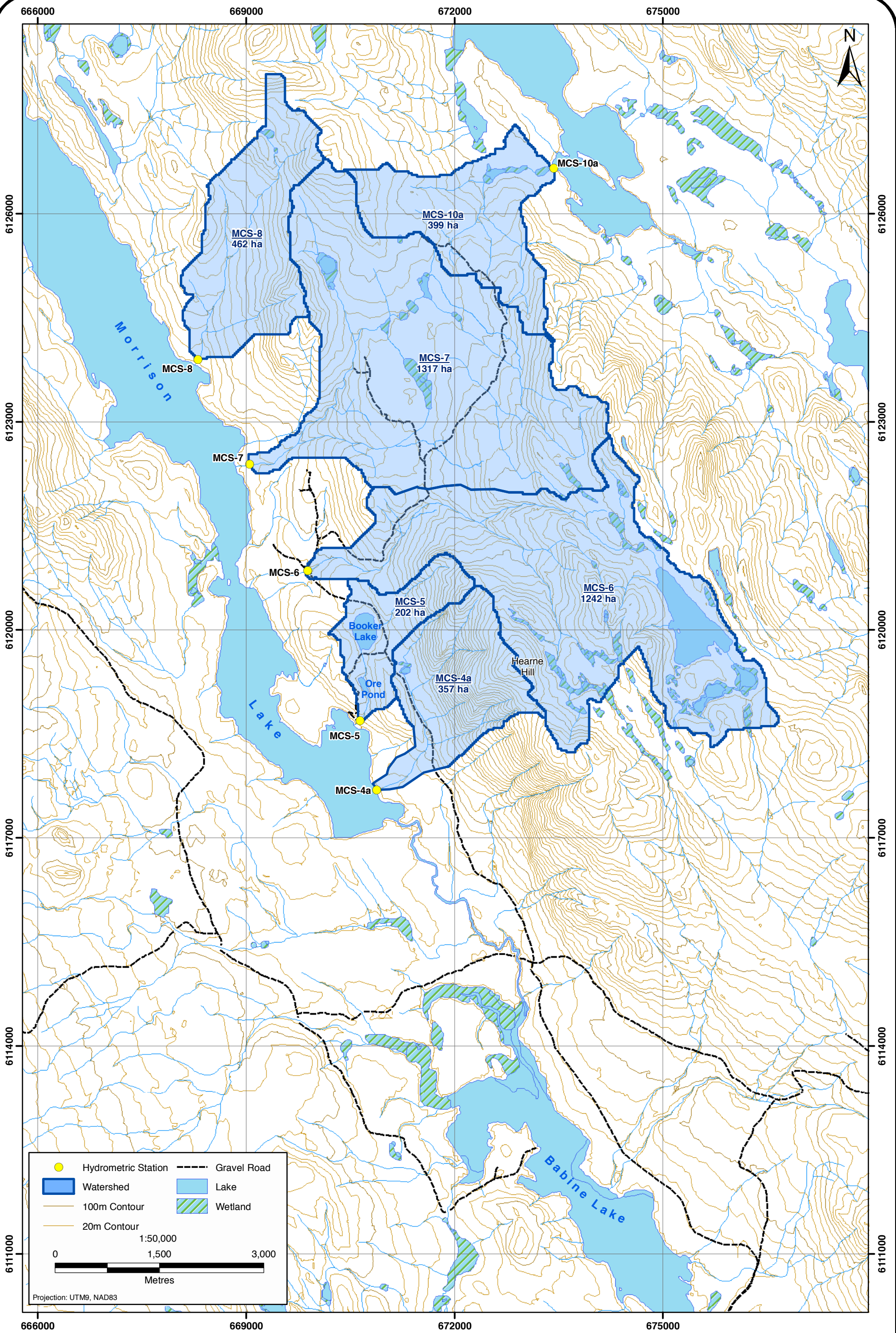
All watercourses affected by the Project site infrastructure (i.e., TSF, process plant site, waste rock storage area, low grade ore stockpile, and open pit) drain into Morrison Lake and Nakinilerak Lake. This report considers effects to water quality in streams MSC-7, MSC-8, MSC-10, and Morrison Lake.

Morrison Lake has a natural outflow point at the southeast end of the lake. A short stream section (Morrison Creek) links Morrison Lake with the much larger Babine Lake. Details of the lakes and watershed areas are provided in Table 2.1-2. Babine Lake flows into Babine River, which then joins the Skeena River. The Skeena River enters the Pacific Ocean just south of Prince Rupert.

2.2 Outline of Site Water Management Plan and TSF Details

The site Water Management Plan has been developed by Klohn (2009) and updated by Rescan according to the results of modelling carried out in this report as well as groundwater modelling (Rescan 2009b).





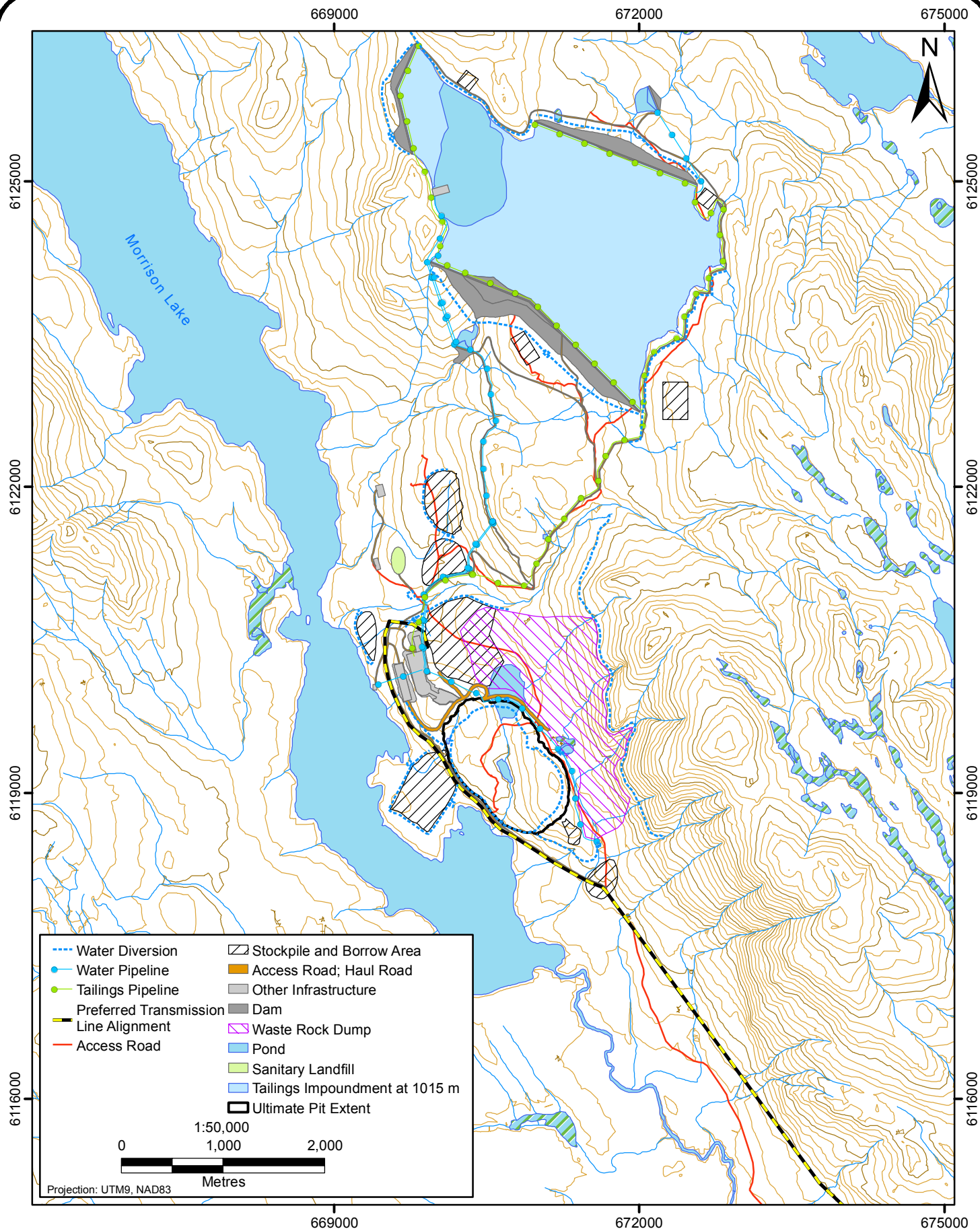


FIGURE 2.1-2

Table 2.1-2
Watershed Areas and Lake Areas Downstream of the Site

Watershed or Lake	Lake Area (km ²)	Watershed Area at mouth (km ²)
Morrison Lake	13.2	490
Babine Lake	n/a	~6,800
Skeena River	n/a	~54,400

During operations, the main objective of the Water Management Plan is zero surface water discharge from the TSF. As a result, all water entering the TSF during operations will be stored and/or re-used, primarily as reclaim water for the process plant. Through achieving this objective, the surface water and groundwater quality effects of the Project mine plan is limited through:

- efficiently using and reusing TSF pond water and collection of “contact” surface water runoff and seepage for use within the process plant;
- a Water Management Plan that integrates the management of all mine waters from the TSF, open pit and other mine components;
- diverting natural surface water runoff from upstream of the process plant site, open pit, and waste rock storage and low grade ore stockpile area to minimize “contact” surface water runoff in disturbed areas within the Project mine footprint.

A main TSF dam and smaller satellite dams (west and north) will be constructed to ensure that the available storage volume in the TSF is sufficient to contain both the tailings solids. The dams will be raised throughout the operational mine life using a centre-line construction method using coarse sands cycloned from the tailings for each successive dam raise. The dam will be raised at a rate sufficient to maintain the dam crest and spillway above the TSF pond level at all times. A series of emergency spillways will be constructed as the TSF dams are raised.

There will be some seepage through the TSF dams during operations, surface water runoff from the face of the TSF dams and excess porewater seepage from the coarse cycloned tailings sand on the face of the TSF dams. Most of these surface water releases will be captured by two seepage collection structures located in surface water drainages at the foot of the main and north dams, and recycled back to the TSF. However, there will also be some seepage losses through the bottom of the TSF that will enter the local groundwater aquifer and flow towards down gradient streams (e.g., MCS-7, MCS-8, MCS-10), and to Morrison Lake.

A diversion ditch will be constructed on the east side of the TSF. This ditch will be actively managed through operations, allowing additional surface water runoff from the upstream watershed area into the TSF, or diverting it around the TSF as necessary. Active management of this ditch will be key to achieving the management objectives of maintaining the TSF pond at a level that submerges the majority of the tailings below a water cover, while also maintaining necessary freeboard based on the dam raise schedule, and not requiring surface discharge.

Physical Setting and TSF Pond Design Details

At the end of operations, the management objective will be to fill the TSF to its spillway elevation (1,013 masl) as soon as possible. This will ensure water cover over the tailings, and best possible water quality by minimizing ML/ARD. During this time, the diversion channel will direct all upstream catchment runoff into the TSF. Modelling results indicate that there will be a period of approximately three years as the TSF pond level rises where there will be no discharge via the closure spillway. During this period, the quality of water in the pond will be monitored. Once the TSF is full, any excess TSF pond water will flow over the spillway, then be directed via gravity-fed pipeline to the open pit and contribute to pit filling.

Alternately, depending on water quality observed in the full TSF, it would be possible to continue actively managing the diversion channel to achieve a net zero water balance in the TSF (i.e., inflow is balanced by seepage) such that there is no surface discharge out of the TSF post-closure. This alternative has not been pursued at this time, as the current plan has been optimized based on producing the best water quality in both the TSF and the pit based on available data. However, potential benefits of this scenario include minimizing the volume of water that needs to be treated at the pit, as well as diverting more flow to the MCS-7 channel below the dam. Pacific Booker Minerals will continue to evaluate closure options through the life of the Project as new data becomes available to determine the best ultimate closure scenario.

At closure, the diversion ditch upstream of the waste rock storage area directing runoff to MCS-6 will be maintained to limit “contact” water entering the waste rock storage area. In addition, a cover will be placed on the waste rock storage area to limit infiltration. Runoff from and infiltration through the waste rock storage area will contribute to the pit filling.

Limited amounts of freshwater will be pumped from Morrison Lake for potable water at the Project site.

Key physical details for the TSF are provided in Table 2.2-1. A more quantitative assessment of the site water balance is provided in Chapter 4 and in Klohn (2009).

Table 2.2-1
Key Physical Data for the Tailings Pond

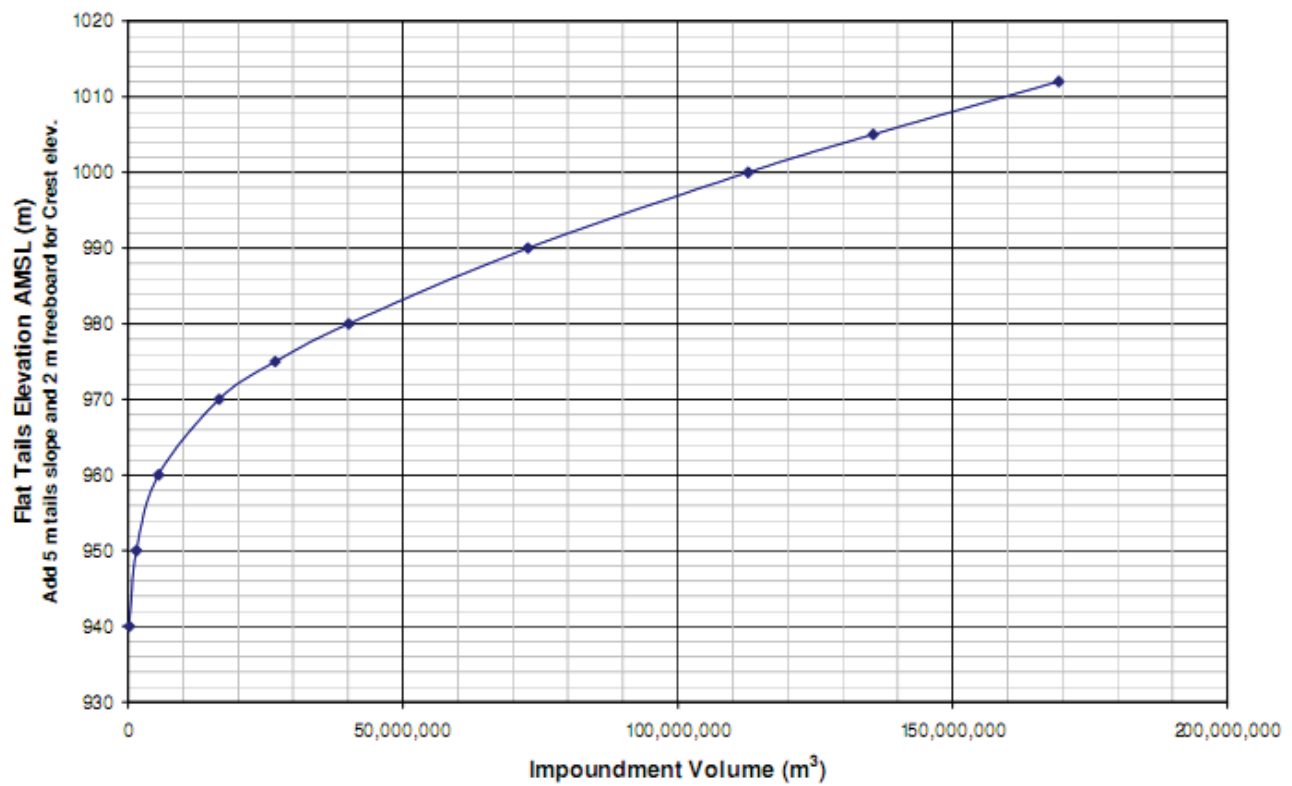
Input	Source	Value or assumption
<u>Pond Details</u>		
Pond Storage Volume	Klohn (2009)	Storage elevation curve shown in Figure 2.2-1.
Pond Area at closure	Klohn (2009)	1.2 km ² (Starter) - 5 km ² (Closure)
Pond Dimensions at closure	Klohn (2009)	Approx. 1.5 km x 1.3 km
<u>Key Design Elevations</u>		
• Dam crest elevation at closure	Klohn (2009)	1,015 m
• Dam spillway elevation at post-closure	Klohn (2009)	1,013 m
• Tailings elevation at closure	Klohn (2009)	1,008 m (with tailings slope rising another 5 m)
• Pond depth at closure	Klohn (2009)	Approximately 5 m
Catchment areas	Klohn (2009)	See Table 2.1-1

(continued)

Physical Setting and TSF Pond Design Details

Table 2.2-1
Key Physical Data for the Tailings Pond (completed)

Input	Source	Value or assumption
<u>Tailings Details</u>		
Total Tailings Production	Klohn (2009)	224 Mt
Tailings to pond (direct discharge and cyclone overflow)	Klohn (2009)	193 Mt
Tailings for dam construction (cyclone underflow)	Klohn (2009)	31 Mt
Slurry from process plant	Klohn (2009)	30,000 t/day; 33.9 % solids by weight
Consolidated tailings density	Klohn (2009)	1.3 t/m ³ – 1.5 t/m ³ quoted. It should be noted that a value of 1.3 t/m ³ is required to produce final tailings level of 1,008 m for 193 Mt tailings in pond
<u>Hydrological Design Conditions</u>		
Normal flows		
• Operations	Rescan (2009)	Zero discharge from pond during operations
• Closure	PBM (2009)	At closure overflow pumped to the open pit
Flood flows		
• Operations	Rescan (2008)	Storage of 2 week 200 year rain on snow event = 3.4 Mm ³ + 1 m freeboard. Emergency spillway raised as dam is built to allow water in excess of this to pass over spillway.
• Closure		At closure permanent bedrock spillway designed to pass PMF
<u>Seepage</u>		
Seepage through the TSF bottom	Rescan (2008)	Operations 1: 112 m ³ /hr Operations 2: 151 m ³ /hr Operations 3: 183 m ³ /hr Operations 4: 197 m ³ /hr Post-closure: 208 m ³ /hr
Seepage reclaim	Klohn (2009)	4 m ³ /hr



Source: KCBL, 2009.

3. Mine Plan

The following information is referenced from Klohn (2009) and Wardrop (2009).

3.1 Materials Excavation

The Project is a proposed conventional open pit development at an approximate rate of 30,000 t/d (11 Mt/yr) ore throughput. Stripping ratios range between 0.44, in the early years of the mine life, and 1.99 in the latter years, total waste destined for the waste rock storage area, overburden stockpile, and low grade ore stockpile are approximately 151 Mt, 15 Mt, and 51 Mt, respectively (Figure 3.1-1 and Figure 3.1-2). Note that because of ongoing stockpile recovery, the low grade ore stockpile maximum tonnage will reach a maximum size of 36 Mt. Any low grade ore remaining in the last two years of the operating mine life will be milled (Table 3.1-1)

On closure, the WRD area (171 ha of the total footprint) is scheduled to be reclaimed with a 30-cm soil cover underlain by a 1-m low permeability glacial till layer (Klohn Crippen Berger 2009 and Chapter 16 of the EA).

3.2 Process Plant and Tailings Storage Facility

Wardrop (2009) has described the milling processes. Ore will be processed through a conventional milling circuit consisting of a primary crusher, secondary cone crusher, followed by high pressure grinding rolls (HPGR), primary ball mills, and flotation circuit including regrinding tower mills. Copper will be concentrated by flotation in large tank cells then cleaned and filtered to achieve acceptable shipping moistures without thermal drying. A molybdenum concentrate will be produced from the ore zones containing significant amount of molybdenite.

Tailings will be produced at an annual rate of approximately 10.95 Mt. Tailings slurry (i.e., solids with process waters) will be pumped to the TSF, where the slurry stream will be cycloned to produce coarse sand for the main, north, and west dams construction purposes. Although the TSF will operate as a “zero” surface discharge facility, seepage recovery ponds will be constructed downstream of the main and north dams. Total seepage losses estimated by Klohn (2009) are 10 m³/hr with a 40% seepage recovery efficiency. Note that TSF seepage has been modelled using MODFlow (Rescan 2009b), and results indicate TSF seepage rates are controlled by the hydraulic conductivity of an underlying till layer with an average hydraulic conductivity of 2.7x10⁻⁷ m/s. TSF seepage rates are expected to increase through the life of the mine as the TSF pond area and elevation (hydraulic head) increases. During operations, the majority of the tailings will be submerged by TSF pond water, as determined by the annual TSF water balance and the dam heights. Upon closure, the TSF pond water level will be allowed to rise to an elevation of 1,013 masl, the ultimate TSF spillway elevation.

3.3 Pit Wall and Waste Rock Storage Area Rock

Pit wall rock will be exposed to varying degrees throughout all phase of the mine life. For water quality modelling purposes, pit wall rock was divided into four adjusted sulphide-based net potential ratios (SNPRs) intervals according to Table 3.3-1 and illustrated in Figure 3.3-1. The

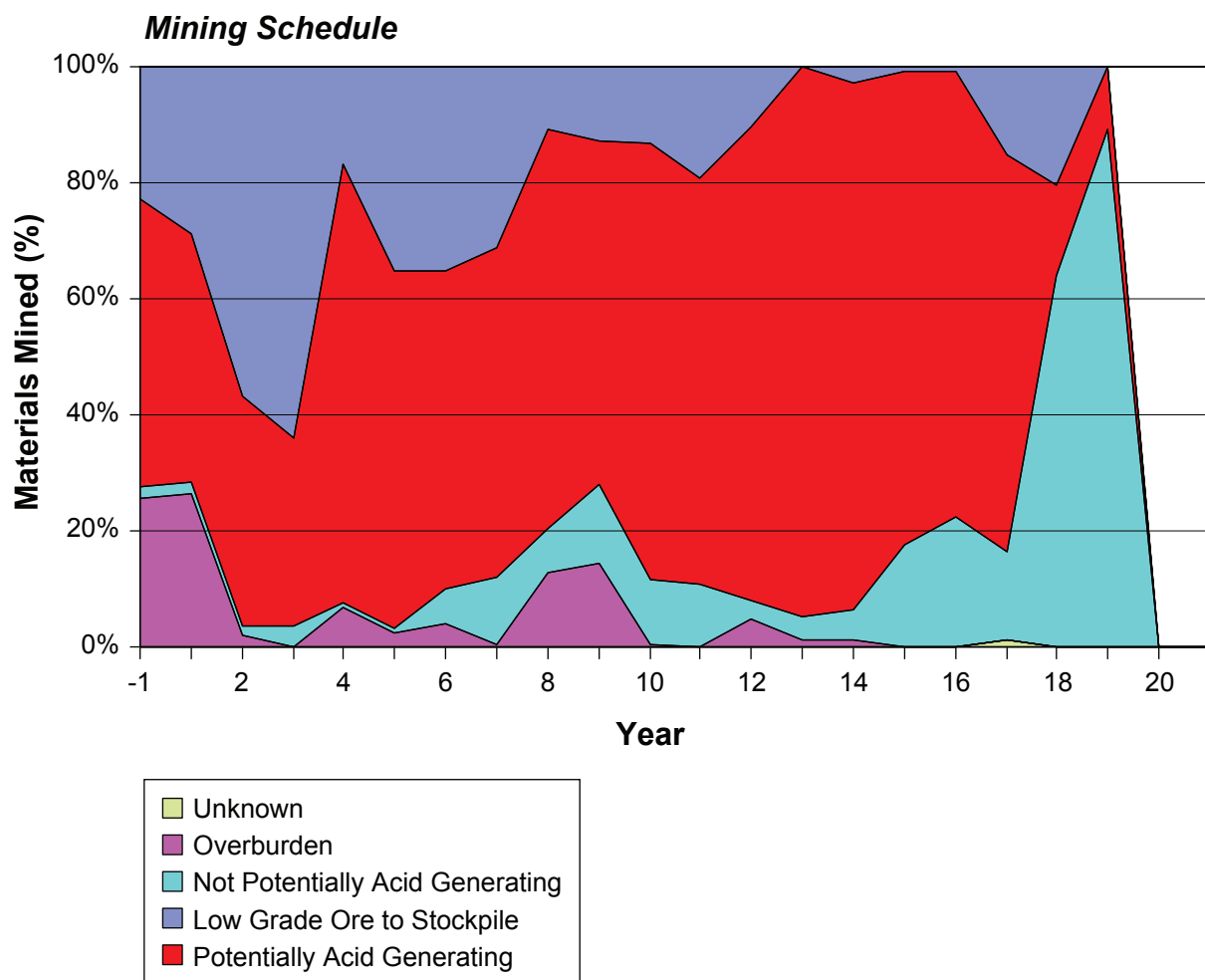
adjusted SNPR values used for the pit wall are weighted values derived from a Deposit Geochemical Block Model (DGBM) developed using GEMCOM SurpacTM software. Total sulphur (assumed to equal sulphide+del sulphur) and adjusted Sobek neutralization potential (NP) values from the deposit rock Acid Base Accounting (ABA) data are discussed in Recan's ML/ARD report (2009d). Adjusted SNPR values were then calculated for each block according to:

$$\text{Adjusted SNPR} = (NP-13)/(\text{Total Sulphur} \times 31.25) \quad \text{Eqn 3.3-1}$$

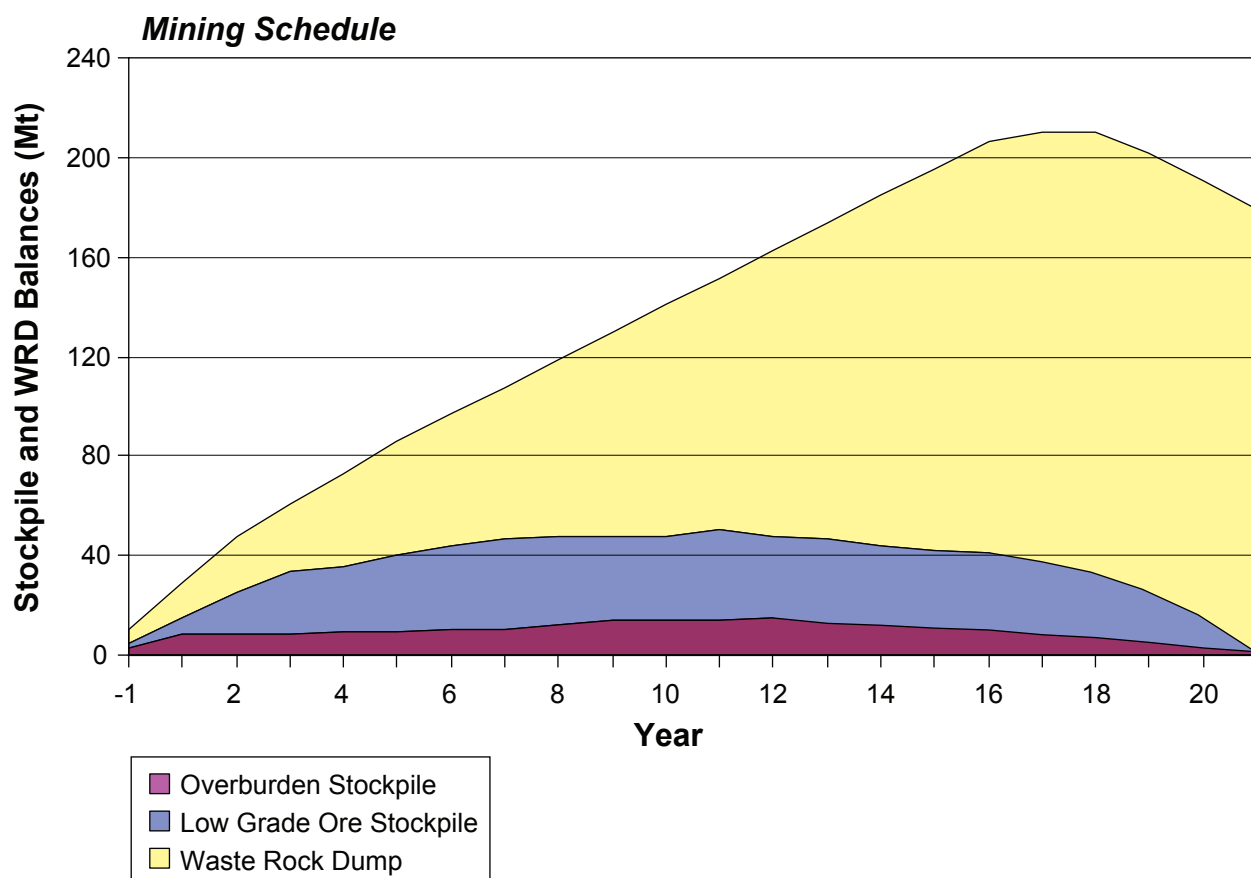
The sulphur estimation for each block used an anisotropic search ellipsoid, which is the same as that used for copper grade estimation (Wardrop 2009). The NP interpolation used an isotropic search. The maximum search distance was initially 200 m but expanded later to 250 m after the pit limits were increased in 2008. Although in most areas of the pit walls the confidence of the estimation is low, as there are few nearby data points to rely on, the majority of the entire pit wall rock (~56%) is classified as having adjusted SNPRs below 1.5. This proportion increases to 80% for the exposed pit wall on closure after the final pit lake elevation has been established at 728 masl (3.5 metres of freeboard). An important distinction to be made is that the blocks with measured ABA data were weighted and applied to surrounding blocks throughout the DGBM.

Waste rock was assigned adjusted SNPR values according to the method outlined above. Areas were assumed to be proportional to the tonnage of each adjusted SNPR category.

Table 3.3-2 provides a mine schedule showing the change in surface area based on ABA screening criteria applied to the adjusted SNPR from the DGBM. Note that Year 16 is the last year of substantial waste excavation, and therefore the area of geochemical influence as determined by adjusted SNPRs is assumed to be proportional to waste rock tonnage excavated during this year for the remainder of waste rock produced during the final three years of mining. For the purposes of water quality modelling (i.e., area of contact water), adjusted SNPR areas are assumed to be distributed equally over the entire footprint for each year. Waste rock production after Year 16 is assumed to increase each adjusted SNPR category equally until the ultimate WRD area of 175 ha footprint is reached.



Morrison Copper/Gold Project
Relative Percentage of Materials Mined
throughout Mine Life



Note: Overburden Stockpile will be reduced as reclamation proceeds.

Table 3.1-1
Morrison Copper/Gold Project: Mine Schedule

Materials	Units	Year -1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Total
Phase I																								
Mill Feed	t	2,299,000	14,366,000	21,340,000	19,104,000	8,943,000	10,328,000	7,533,000	3,188,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	87,101,000
Waste Rock	t	7,701,000	14,834,000	7,860,000	4,621,000	1,793,000	1,301,000	75,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38,185,000
Phase II																								
Potential Mill Feed	t	0	0	0	0	2,671,000	5,143,000	6,816,000	10,378,000	9,244,000	6,962,000	9,496,000	9,195,000	0	0	0	0	0	0	0	0	0	0	59,905,000
Waste Rock	t	0	0	0	0	10,318,000	6,953,000	7,476,000	8,334,000	3,732,000	1,111,000	393,000	0	0	0	0	0	0	0	0	0	0	0	38,317,000
Phase III																								
Potential Mill Feed	t	0	0	0	0	0	0	0	0	673,000	1,910,000	1,832,000	3,856,000	7,969,000	9,709,000	8,030,000	7,839,000	5,120,000	1,867,000	0	0	0	0	48,805,000
Waste Rock	t	0	0	0	0	0	0	0	0	8,251,000	11,918,000	10,179,000	8,850,000	5,981,000	3,647,000	1,457,000	394,000	229,000	128,000	0	0	0	0	51,034,000
Phase IV																								
Potential Mill Feed	t	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34,000	811,000	5,420,000	9,625,000	10,884,000	1,607,000	0	0	28,381,000
Waste Rock	t	0	0	0	0	0	0	0	0	0	0	0	0	7,950,000	8,544,000	12,379,000	12,856,000	11,071,000	2,880,000	616,000	289,000	0	0	56,585,000
Total Potential Mill Feed	t	2,299,000	15,803,000	21,340,000	19,104,000	13,371,000	15,471,000	15,022,000	14,747,000	12,388,000	12,850,000	12,547,000	13,051,000	12,562,000	10,951,000	11,335,000	11,075,000	10,966,000	11,492,000	11,109,097	10,950,000	10,950,000	6,345,000	275,728,097
Total Waste Rock	t	7,701,000	14,834,000	7,860,000	4,621,000	12,111,000	8,254,000	7,551,000	8,334,000	11,983,000	13,029,000	10,572,000	8,850,000	13,931,000	12,191,000	13,836,000	13,250,000	11,300,000	3,008,000	616,000	289,000	0	0	184,121,000
Total	t	10,000,000	30,637,000	29,200,000	23,725,000	25,482,000	23,725,000	22,573,000	23,081,000	24,371,000	25,879,000	23,119,000	21,901,000	26,493,000	23,142,000	25,171,000	24,325,000	22,266,000	14,500,000	11,725,097	11,239,000	10,950,000	6,345,000	459,849,097
Cumulative Potential Mill Feed	t	2,299,000	18,102,000	39,442,000	58,546,000	71,917,000	87,388,000	102,410,000	117,157,000	129,545,000	142,395,000	154,942,000	167,993,000	180,555,000	191,506,000	202,841,000	213,916,000	224,882,000	236,374,000	247,483,097	258,433,097	269,383,097	275,728,097	
Cumulative Waste Rock	t	7,701,000	22,535,000	30,395,000	35,016,000	47,127,000	55,381,000	62,932,000	71,266,000	83,249,000	96,278,000	106,850,000	115,700,000	129,631,000	141,822,000	155,658,000	168,908,000	180,208,000	183,216,000	183,832,000	184,121,000	184,121,000	184,121,000	
Cumulative Total	t	10,000,000	40,637,000	69,837,000	93,562,000	119,044,000	142,769,000	165,342,000	188,423,000	212,794,000	238,673,000	261,792,000	283,693,000	310,186,000	333,328,000	358,499,000	382,824,000	405,090,000	419,590,000	431,315,097	442,554,097	453,504,097	459,849,097	
Stockpile Recovery	t	0	1,437,000	0	0	1,757,000	0	673,000	1,181,000	2,471,000	3,978,000	1,219,000	0	4,593,000	1,242,000	3,271,000	2,425,000	426,000	0	225,097	9,343,000	10,950,000	6,345,000	51,536,097
Cumulative Stockpile Recovery	t	0	1,437,000	1,437,000	1,437,000	3,194,000	3,194,000	3,867,000	5,048,000	7,519,000	11,497,000	12,716,000	12,716,000	17,309,000	18,551,000	21,822,000	24,247,000	24,673,000	24,673,000	24,898,097	34,241,097	45,191,097	51,536,097	
Stockpile Balance	t	2,299,000	6,810,000	17,200,000	25,354,000	26,018,000	30,539,000	33,938,000	36,554,000	35,521,000	33,443,000	33,821,000	35,922,000	32,941,000	31,700,000	28,814,000	26,514,000	26,164,000	26,706,000	26,640,000	17,297,000	6,347,000		
Potential Total Stockpile (Recovery+Balance)	t		8,247,000	17,200,000	25,354,000	27,775,000	30,539,000	34,611,000	37,735,000	37,992,000	37,421,000	35,040,000	35,922,000	37,534,000	32,942,000	32,085,000	28,939,000	26,590,000	26,706,000	26,865,097	26,640,000	17,297,000	6,345,000	
Actual To Mill	t		9,855,000	10,950,000	10,950,000	10,950,000	10,950,000	10,950,000	10,950,000	10,950,000	10,950,000	10,950,000	10,950,000	10,950,000	10,950,000	10,950,000	10,950,000	10,890,000	10,950,000	10,950,000	10,950,000	10,950,000	6,347,000	224,192,000
Actual to LGO		2,299,000	5,948,000	10,390,000	8,154,000	2,421,000	4,521,000	4,072,000	3,797,000	1,438,000	1,900,000	1,597,000	2,101,000	1,612,000	1,000	385,000	125,000	76,000	542,000	159,097	0	0	-2,000	51,536,097
Mill Feed	t	2,299,000	15,803,000	21,340,000	19,104,000	13,371,000	15,471,000	15,022,000	14,747,000	12,388,000	12,850,000	12,547,000	13,051,000	12,562,000	10,951,000	11,335,000	11,075,000	10,966,000	11,492,000	11,109,097	10,950,000	10,950,000	6,345,000	275,728,097
Overburden	t	2,551,000	5,468,000	343,000	0	973,000	329,000	482,000	36,000	1,699,000	2,120,000	66,000	0	720,000	164,000	192,000	0	0	0	0	0	0	0	15,143,000
Unknown	t	8,000	0	0	0	0	0	0	0	3,000	0	0	0	0	0	0	0	0	43,000	0	0	0	0	54,000
Potentially Acid Generating Waste	t	4,936,000	8,932,000	7,186,000	4,182,000	11,029,000	7,858,000	6,395,000	6,858,000	9,254,000	8,839,000	9,172,000	7,655,000	12,662,000	11,564,000	12,922,000	10,907,000	8,751,000	2,427,000	119,000	31,000	0	0	151,679,000
Not -Potentially Acid Generating Waste	t	206,000	433,000	330,000	439,000	110,000	67,000	674,000	1,440,000	1,027,000	2,069,000	1,334,000	1,195,000	549,000	462,000	723,000	2,343,000	2,549,000	537,000	497,000	258,000	0	0	17,242,000
Total Waste	t	7,701,000	14,833,000	7,859,000	4,621,000	12,112,000	8,254,000	7,551,000	8,334,000	11,983,000	13,028,000	10,572,000	8,850,000	13,931,000	12,190,000	13,837,000	13,250,000	11,300,000	3,007,000	616,000	289,000	0	0	184,118,000

Notes: Modified from Wardrop (2009) and Klohn (2009).

Table 3.3-1
Morrison Copper/Gold Project: Pit Wall Adjusted SNPRs

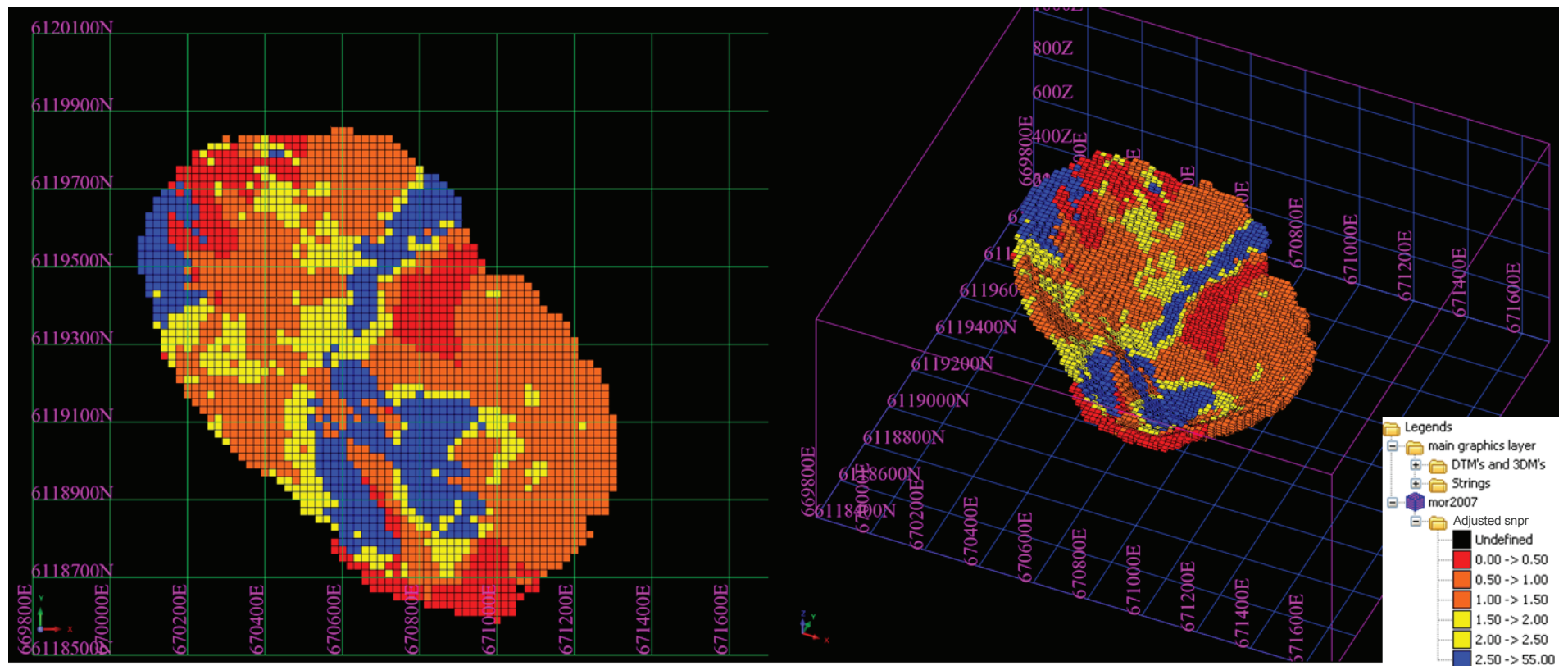
Elevation (masl)	Units	Adjusted SNPR (n)					Areas by Adjusted SNPR (m ²)					Cumulative Areas by Adjusted SNPR (m ²)				
		0-0.5	0.5-1.5	1.5-2.5	2.5+	Total	0-0.5	0.5-1.5	1.5-2.5	2.5+	Total	0-0.5	0.5-1.5	1.5-2.5	2.5+	Total
486		0	18	42	36	96	0	4,320	10,080	8,640	23,040	0	4,320	10,080	8,640	23,040
498		0	28	53	39	120	0	6,720	12,720	9,360	28,800	0	11,040	22,800	18,000	51,840
510		1	61	44	71	177	240	14,640	10,560	17,040	42,480	240	25,680	33,360	35,040	94,320
522		0	67	27	50	144	0	16,080	6,480	12,000	34,560	240	41,760	39,840	47,040	128,880
534		0	96	30	67	193	0	23,040	7,200	16,080	46,320	240	64,800	47,040	63,120	175,200
546		0	78	30	62	170	0	18,720	7,200	14,880	40,800	240	83,520	54,240	78,000	216,000
558		3	94	51	70	218	720	22,560	12,240	16,800	52,320	960	106,080	66,480	94,800	268,320
570		7	95	38	42	182	1,680	22,800	9,120	10,080	43,680	2,640	128,880	75,600	104,880	312,000
582		16	123	52	49	240	3,840	29,520	12,480	11,760	57,600	6,480	158,400	88,080	116,640	369,600
594		15	106	44	34	199	3,600	25,440	10,560	8,160	47,760	10,080	183,840	98,640	124,800	417,360
606		24	130	65	56	275	5,760	31,200	15,600	13,440	66,000	15,840	215,040	114,240	138,240	483,360
618		18	106	62	28	214	4,320	25,440	14,880	6,720	51,360	20,160	240,480	129,120	144,960	534,720
630		23	153	71	44	291	5,520	36,720	17,040	10,560	69,840	25,680	277,200	146,160	155,520	604,560
642		23	129	44	39	235	5,520	30,960	10,560	9,360	56,400	31,200	308,160	156,720	164,880	660,960
654		32	170	50	68	320	7,680	40,800	12,000	16,320	76,800	38,880	348,960	168,720	181,200	737,760
666		28	120	61	56	265	6,720	28,800	14,640	13,440	63,600	45,600	377,760	183,360	194,640	801,360
678		35	171	72	49	327	8,400	41,040	17,280	11,760	78,480	54,000	418,800	200,640	206,400	879,840
690		30	135	65	34	264	7,200	32,400	15,600	8,160	63,360	61,200	451,200	216,240	214,560	943,200
702		47	192	73	46	358	11,280	46,080	17,520	11,040	85,920	72,480	497,280	233,760	225,600	1,029,120
714		46	153	54	30	283	11,040	36,720	12,960	7,200	67,920	83,520	534,000	246,720	232,800	1,097,040
726		72	202	65	34	373	17,280	48,480	15,600	8,160	89,520	100,800	582,480	262,320	240,960	1,186,560
738		60	156	42	26	284	14,400	37,440	10,080	6,240	68,160	115,200	619,920	272,400	247,200	1,254,720
750		105	209	51	34	399	25,200	50,160	12,240	8,160	95,760	140,400	670,080	284,640	255,360	1,350,480
762		78	154	35	29	296	18,720	36,960	8,400	6,960	71,040	159,120	707,040	293,040	262,320	1,421,520
774		93	186	51	45	375	22,320	44,640	12,240	10,800	90,000	181,440	751,680	305,280	273,120	1,511,520
786		86	112	27	56	281	20,640	26,880	6,480	13,440	67,440	202,080	778,560	311,760	286,560	1,578,960
798		119	121	16	71	327	28,560	29,040	3,840	17,040	78,480	230,640	807,600	315,600	303,600	1,657,440
810		92	114	8	29	243	22,080	27,360	1,920	6,960	58,320	252,720	834,960	317,520	310,560	1,715,760
822		104	80	6	10	200	24,960	19,200	1,440	2,400	48,000	277,680	854,160	318,960	312,960	1,763,760

(continued)

Table 3.3-1
Morrison Copper/Gold Project: Pit Wall Adjusted SNPRs (completed)

Elevation (masl)	Units	Adjusted SNPR (n)					Areas by Adjusted SNPR (m ²)					Cumulative Areas by Adjusted SNPR (m ²)				
		0-0.5	0.5-1.5	1.5-2.5	2.5+	Total	0-0.5	0.5-1.5	1.5-2.5	2.5+	Total	0-0.5	0.5-1.5	1.5-2.5	2.5+	Total
834		66	74	3	1	144	15,840	17,760	720	240	34,560	293,520	871,920	319,680	313,200	1,798,320
846		49	37	1	0	87	11,760	8,880	240	0	20,880	305,280	880,800	319,920	313,200	1,819,200
858		16	7	0	0	23	3,840	1,680	0	0	5,520	309,120	882,480	319,920	313,200	1,824,720
870		0	1	0	0	1	0	240	0	0	240	309,120	882,720	319,920	313,200	1,824,960
Blocks with Attribute	(n)	1,288	3,678	1,333	1,305	7,604										
Pit Wall Block Area	(m ²)						309,120	882,720	319,920	313,200	1,824,960					
Pit Wall Block Percentage	(%)						17	48	18	17	100					
Area Below Morrison Lake Level	(m ²)											108,000	601,200	267,360	244,080	1,220,640
Percentage Below Morrison Lake Level	(%)											9	49	22	20	100
Area Above Morrison Lake Level	(m ²)											201,120	281,520	52,560	69,120	604,320
Percentage Above Morrison Lake Level	(%)											33	47	9	11	100

Notes: Morrison Lake Level ~ 732 masl.



4. Tailings Pond Water Balance

The TSF water balance is outlined in this section. This includes a description of model inputs, results of the modelling exercise and a discussion of the implications of the results and the assumptions inherent in the modelling work. General conceptual models for the TSF and site-wide water balance during operations and at closure are shown in Figure 4-1 and Figure 4-2.

4.1 Water Balance Model Inputs and Outputs

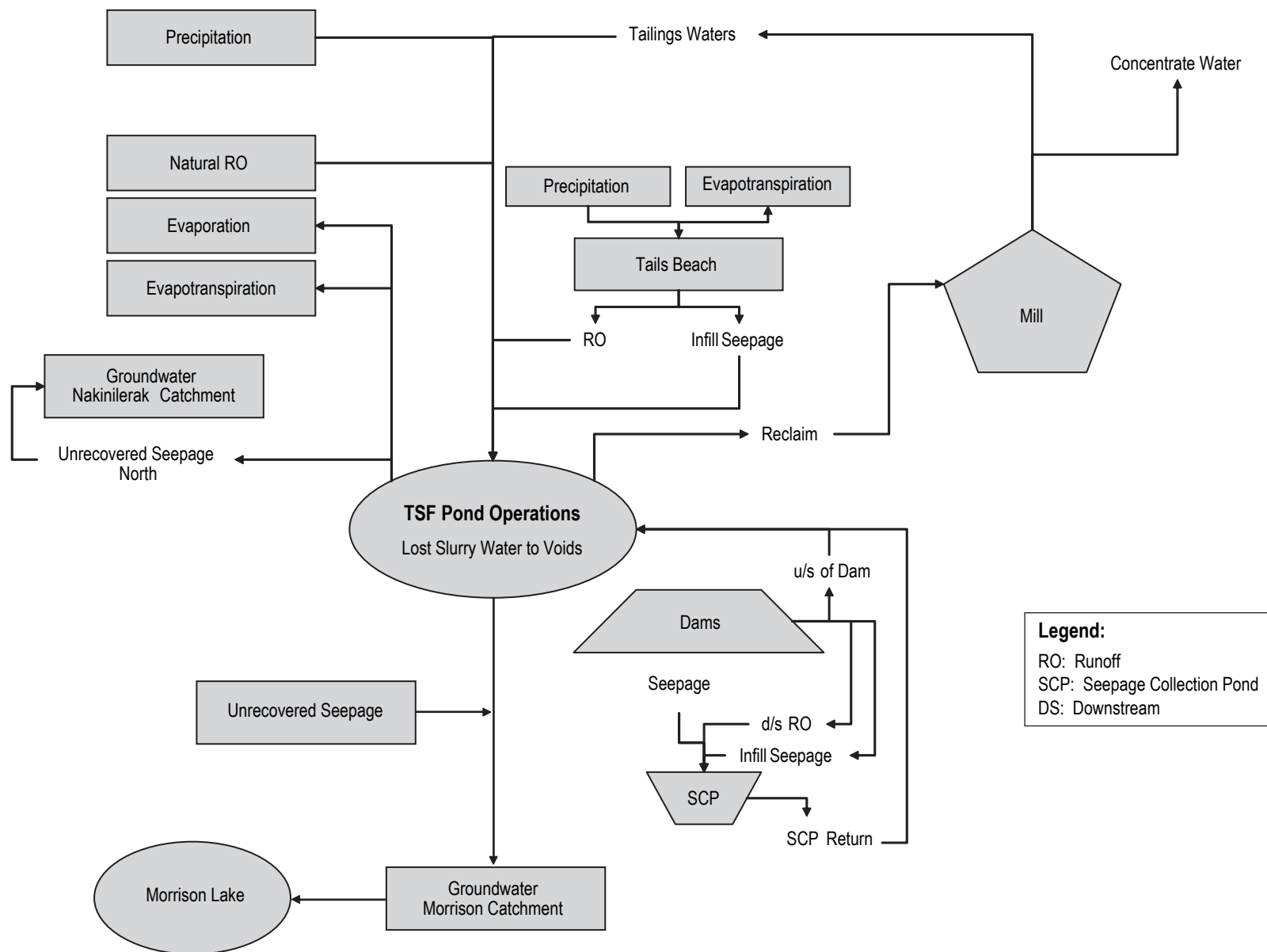
The key inputs and outputs to the water balance model are indicated below.

- an initial pond volume of 750,000 m³;
- precipitation falling onto the pond;
- surface water runoff from the watershed areas upstream and entering the TSF;
- surface water runoff from the beached tailings (i.e., upstream slopes) directed into the TSF pond;
- evaporation from the pond;
- tailings porewater seepage from the base of the TSF into the underlying groundwater aquifer;
- tailings porewater and pond water seepage through the dam and lost to the groundwater system;
- tailings porewater and pond water seepage through the dam, captured at the seepage collection ponds and directed back into the TSF pond;
- tailings slurry (solids and process waters) entering the TSF;
- surface water runoff over the downstream dam face, collected at seepage ponds and directed back into the TSF pond;
- TSF pond reclaim directed to the process plant;
- downstream flows.

4.1.1 Precipitation

4.1.1.1 Annual Totals

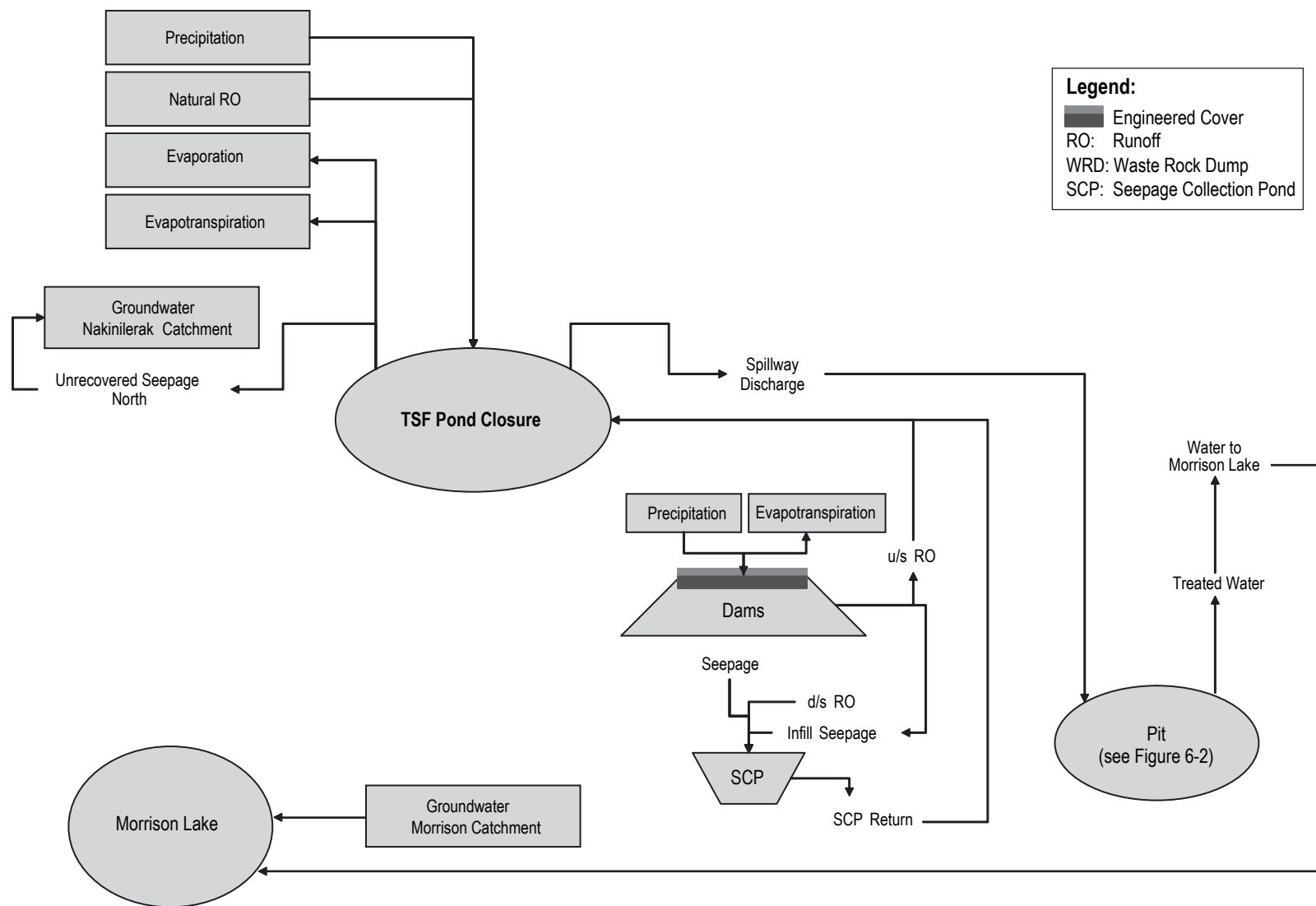
Total annual precipitation estimates for the Project are based on statistical analysis of observed precipitation at nearby Environment Canada meteorological stations, as shown in Table 4.1-1. There are five stations reasonably close to Morrison Lake. The average annual precipitation from these sites is approximately 535 mm (Klohn Crippen Berger 2009). The study site is at a higher elevation (approximately 950 masl for the median elevation of MCS-7 watershed) than the Environment Canada stations (average 700 masl) with precipitation expected to increase with elevation. As a result, to estimate precipitation at the site, a precipitation gradient was applied to the data.



Morrison Copper/Gold Project
TSF Pond Water Balance during Operations

FIGURE 4-1





**Morrison Copper/Gold Project
TSF Pond Water Balance at Closure**

FIGURE 4-2

Table 4.1-1
Comparison of Estimates of Average Annual Precipitation for the Site

Source	Average Annual Precipitation (mm)
Klohn Model	550
Prism Model	750
Rescan Baseline Estimate	620
^a Observed Site Data	575 to 620

a Observed data scaled by precipitation gradient as outlined in report text.

Klohn (2009) use a near-flat precipitation gradient (i.e., 1% increase for every 100 m rise in elevation) that is based on analysis of the Environment Canada station data. This provides an estimate of average annual precipitation at the site of 550 mm. Rescan (2008b) used a higher precipitation gradient (6% per 100 m rise in elevation) based on recent experience with data obtained from other sites within northern BC. This provides an estimate of average annual precipitation at the site of 620 mm.

Rescan (2008b) also presented data from PRISM (Parameter-elevation Regression on Independent Slopes Model) data set (PRISM Group 2001), which provides estimates of annual precipitation for all locations in BC. This dataset presents results based on analysis of available Environment Canada data and application of a precipitation gradient. A value of 750 mm for the site was obtained from the PRISM dataset.

A meteorological station was set up and operated on-site by Rescan and is at an elevation 800 masl. Between March 1, 2007 and March 1, 2008, 628 mm of precipitation was measured at the site. It is noted in Rescan (2008b) that the summer of 2007 was approximately 22% wetter than average based on analysis of Environment Canada data. Hence, reducing observed summer precipitation at the site gauge by 22% resulted in an adjusted annual precipitation value of 566 mm. Adding a suitable precipitation gradient to estimated values at 950 masl (i.e., median elevation for MCS-7) results in an annual precipitation total between 575 and 620 mm for precipitation gradients between 1% and 6% for every 100-m elevation increase.

To be consistent with the Klohn (2009) engineering report, the modelling was undertaken using an annual precipitation value of 550 mm. However, based on Rescan's evaluation of this and other data as described above, this precipitation value may be lower than expected for the Project. For more detail regarding the derivation of hydrological inputs to the model, refer to the *Morrison Copper/Gold Project: Hydrology Baseline Report* (Rescan 2008b).

4.1.1.2 Inter-annual Variability and Return Period Values

The annual precipitation total at the Project site will vary year-to-year because of climatic variability. This variability can be expressed as return period annual totals, with each return period representing a precipitation total with a given likelihood of occurrence in any one year (e.g., a 1-in-100 year wet year runoff total has a 1% probability of occurring in any one year).

Return period precipitation totals were calculated based on scaling factors developed for annual runoff totals. The methodology used to calculate these scaling factors is provided in Section 4.1.2.3. The same scaling factors for precipitation as runoff were used because of the larger runoff datasets available and to provide consistency between the model inputs.

Return period precipitation values are provided in Table 4.1-2.

Table 4.1-2
Return Period Runoff and Precipitation Totals

Return Period	Runoff – based on Klohn annual average (mm)	Ppt – based on Klohn annual average (mm)	Runoff – based on Rescan annual average (mm)	Ppt – based on Rescan annual average (mm)
100 year dry	109	217	150	245
50 year dry	128	256	177	289
25 year dry	150	300	207	338
10 year dry	183	367	253	413
Average	275	550	380	620
10 year wet	367	733	507	827
25 year wet	400	800	553	902
50 year wet	422	844	583	951
100 year wet	441	883	610	995

Data are based on a normal distribution with parameters calculated from analysis of available regional data sets. Standard deviations are estimated to be $0.26 \times \text{mean}$.

4.1.1.3 Monthly Distribution

The monthly precipitation distribution used in the model is shown in Table 4.1-3. Klohn (2009) and Rescan (2008b) provide monthly percentage values based on analysis of available Environment Canada data. For the purposes of modelling, an “Effective” precipitation distribution that differs from the distributions provided in Klohn (2009) and Rescan (2008b) was developed. During months where the average monthly temperature is <zero (based on on-site data) the effective precipitation is set to zero, i.e., precipitation is assumed stored as snow. This winter precipitation then melts during May and June (freshet).

4.1.2 Surface Water Runoff

Surface water runoff is a measure of stream flow and is presented in terms of millimetre per unit area of watershed to allow a direct comparison between surface water runoff and precipitation. Surface water runoff values are lower than precipitation totals because of losses resulting from evaporation, sublimation, uptake by plants, storage within soils, and discharge (i.e., infiltration) to groundwater. The ratio of surface water runoff to total precipitation is termed the runoff coefficient. For the purposes of the water balance modelling, the full upstream catchment area of 11.1 km² is input into the TSF (e.g., no diversion around TSF) throughout the mine life. This is necessary in early years of operation to ensure that there is sufficient pond water volume available for reclaim to the process plant. Maintaining the maximum water level in the TSF

Table 4.1-3
Morrison Copper/Gold Project: Comparison of Monthly Percentage Precipitation

	% of annual precipitation in each month											
	January	February	March	April	May	June	July	August	September	October	November	December
Klohn Model	10.2	7.0	5.4	4.2	6.8	9.4	8.8	8.5	8.8	10.0	10.2	10.7
^a Rescan	10.4	6.7	5.1	4.4	6.6	9.4	8.8	8.3	9.1	10.1	10.2	10.7
Effective precipitation	0	0	0	9.3	45.2	9.4	8.8	8.5	8.8	10	0	0

^a Average of local regional Environment Canada weather stations.

Highlighted data are used in the model. Precipitation during months where average daily temperature <0 is assumed to be held as snow and ice and is available as runoff in April and May.

through operation also enables the TSF to fill to spillway elevation upon closure at the quickest rate. The net watershed area that will contribute surface runoff to the TSF given the increasing area of the TSF pond is shown in Figure 4.1-1.

4.1.2.1 Annual Totals

Klohn (2009) estimates average annual surface water runoff at the site by applying a runoff coefficient of 0.5 to the annual precipitation total of 550 mm. This provides an estimate of annual runoff of 275 mm.

Rescan (2008b) analyzed annual surface water runoff data from the Water Survey of Canada monitoring stations close to the Project site. Average annual surface water runoff values from the dataset were approximately 380 mm. In addition, Rescan (2008) considered a runoff coefficient of 0.65 for the site (Coulson 1991), which combined with the Rescan annual precipitation estimate of 620 mm, this provided a range of annual surface water runoff estimates of around 400 mm. Surface water runoff values are summarized in Table 4.1-4.

**Table 4.1-4
Comparison of Estimates of
Average Annual Runoff for the Project Site**

Source	Average Annual Runoff (mm)
Klohn Model	275
Rescan Baseline	400
Regional WSC stations (<500 km²)	380

The model run is undertaken using an annual runoff value of 275 mm for consistency with the Klohn report (2009). However, based on Rescan's evaluation of this and other data as described above, this runoff value may be lower than expected for the Project.

4.1.2.2 Monthly Distribution

The monthly distribution of annual surface water runoff is shown in Table 4.1-5. Klohn (2009) provided a monthly distribution based on data from selected Water Survey of Canada monitoring stations. Rescan (2008) provided alternative values based on data from Water Survey of Canada monitoring stations that were selected to be hydrologically similar to the watersheds represented on the Project site. Also provided in the table are results for observed site data from Station MCS-7.

The results indicate that the Rescan (2008) values are similar to those from Station MCS-7, in that they show the highest monthly flows early in freshet (i.e., May). In addition, the results indicate an elevated hydrograph response to snow melt (i.e., for Station MCS-7 over half of the annual runoff occurs during May, indicating rapid snowmelt). This is to be expected for a small upland catchment. In contrast, the Klohn (2009) data show a more even distribution of flows throughout the summer months. It is Rescan's opinion that such a pattern is more representative

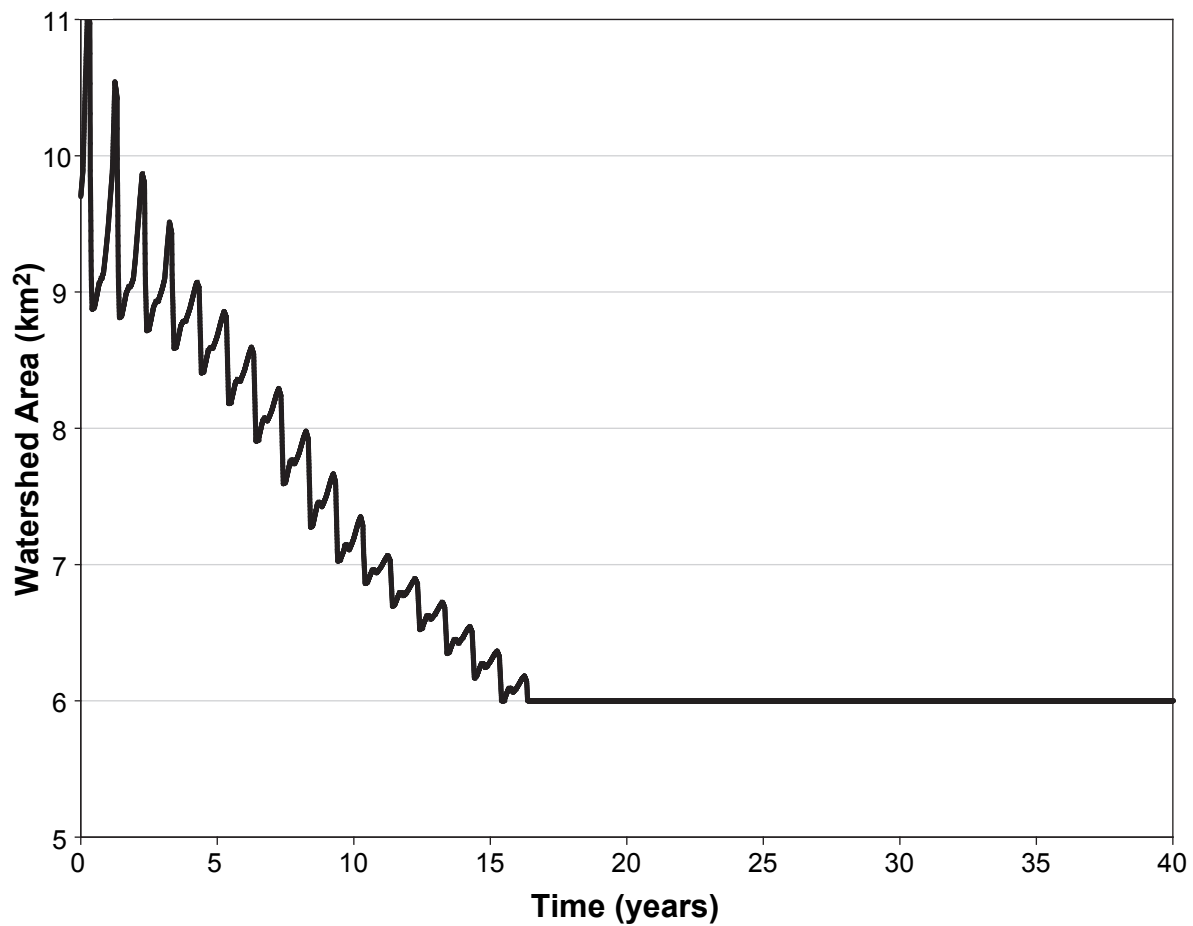


Table 4.1-5

Morrison Copper/Gold Project: Comparison of Monthly Percentage Runoff Applied to the Project Site

	% of annual runoff in each month											
	January	February	March	April	May	June	July	August	September	October	November	December
Klohn Model	5.0	4.0	4.0	3.0	10.0	20.0	16.0	12.0	8.0	6.0	6.0	6.0
^a Average for regional WSC stations (<500 km ²)	2.6	2.1	2.7	10.6	23.2	19.5	13.2	7.6	5.5	5.5	4.5	3.1
Rescan MCS-7	1.3	1.2	1.6	7.7	58	10	3.9	2.3	3.8	3.8	3.5	2.9

^a Average of local regional Environment Canada weather stations.
Highlighted data are used in the model.

of a large watershed and is not considered suitable for the watersheds in this Project study area, as the seasonal hydrologic variability is not accurately represented.

For the purposes of this modelling, the Project site dataset is used.

4.1.2.3 Inter-annual Variability and Return Period Values

Surface water runoff experienced at the Project site will vary year-on-year due to climatic variability. An assessment of the return period surface water runoff totals was made following statistical analysis of all observed annual surface water runoff data for selected Water Survey of Canada stream flow monitoring stations close to the Project site. For each station, the available data were fit to a normal distribution. Chow et al. (1988) notes that a normal distribution is acceptable for annual surface water runoff totals. For each station, a standard deviation was derived and converted to a scaling factor that related standard deviation to the average. The average scaling factor was then applied to the annual surface water runoff values for the station. This assumes an annual surface water runoff of 275 mm or 380 mm depending on the assumed surface water runoff total and results in estimates of the standard deviation of annual surface water runoff at the station.

4.1.3 Evaporation

4.1.3.1 Annual Total

The annual lake evaporation for the Project site was estimated based on data from the Meteorological Survey of Canada station at Topley Landing. The conditions at Topley Landing are expected to be similar to those at the Project site as both sites are within a 100-m elevation of each other and lie on the shores of large lakes (Babine Lake and Morrison Lake, respectively). The annual lake evaporation at Topley landing (based on 30 years of record) is 389 mm. For the purposes of this modelling, the value 389 mm for annual lake evaporation is used. Further details regarding Morrison site evaporation estimates can be found in Rescan's meteorology baseline report (Rescan 2009e).

4.1.3.2 Monthly Total

Klohn (2009) and Rescan (2008) calculated monthly evaporation totals from available data for the station at Topley Landing. The results are presented in Table 4.1-6 and are very similar. The model run is undertaken using the Klohn (2009) monthly evaporation data for consistency.

4.1.3.3 Return Period

There was insufficient information on lake evaporation to make an estimate of the inter-annual variations in evaporation. It is likely that the annual evaporation would be inversely related to precipitation, so that in drier years with low precipitation, evaporation rates would be higher. However, a number of other factors will affect evaporation such as sunshine hours and wind. As a result, the model run considered a constant annual evaporation total in all years, irrespective of changes in annual precipitation totals.

Table 4.1-6
Morrison Copper/Gold Project: Comparison of Monthly Percentage Evaporation Applied to the Project Site

	% of annual evaporation in each month											
	January	February	March	April	May	June	July	August	September	October	November	December
Klohn Model	0.0	0.0	0.0	0.0	19.8	25.2	25.2	20.3	9.3	0.0	0.0	0.0
^a Rescan	0	0	0	0	21.5	23.1	24.7	19.9	10.8	0	0	0

^a Average of local regional Environment Canada weather stations.

4.1.4 TSF Seepage to Groundwater

Seepage rates from the TSF during operations were calculated by Rescan (2009b). This seepage rate is shown graphically in Figure 4.1-2. Because of the large seepage rate, which differs from Klohn (2009), runoff from the upstream watershed area must be directed into the TSF to prevent the TSF from drying in the early years of operations, provide sufficient water for process plant reclaim requirements, and to keep the tailings submerged under a pond water cover at closure and during post-closure to minimize neutral pH metal leaching.

4.1.5 Tailings Water

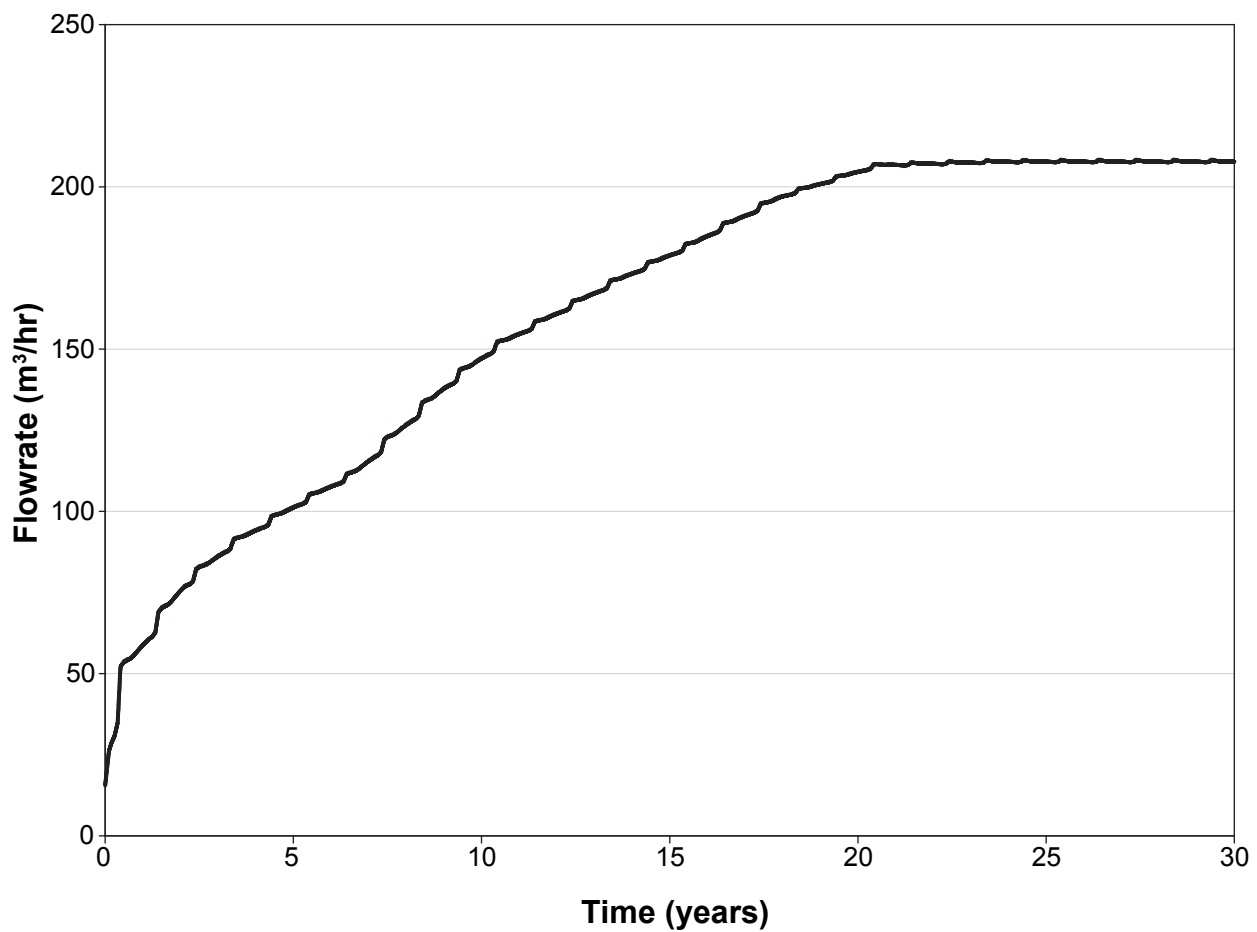
Klohn (2009) reports that the process plant will produce 30,000 tonne/day tailings solids with the tailings slurry at 33.9% solids. This will result in 58,500 tonne/day tailings water. The tailings will be:

- Discharged as total tailings to the TSF for four months per year (winter months).
- Discharged to the cyclones, located along the crest (i.e., top) of the tailings dams, for eight months per year (spring, summer, autumn months) with the tailings solids coarse fraction used for tailings dam construction and the tailings solids fine fraction reporting to the TSF.
- Tailings will then be discharged into the impoundment as either total tailings directly from the plant site, or as part of the operation of the cyclones during the 8 month dam construction period.
- During dam construction, it is assumed that whole tailings will be discharged to the impoundment for 15% of the time due to periodic cyclone plant maintenance.
- Approximately 24% of the tailings solids will pass out of the cyclone underflow as a coarse fraction and be used for dam construction. Water will be released from the underflow as the solids settle on the dam surfaces. On the tailings dam downstream slopes, this water is assumed to reach the seepage collection structures as surface water runoff or porewater seepage to surface and be pumped back to the TSF.
- Approximately 76% of the tailings solids will be too fine and will pass through the cyclone overflows and be directed into the TSF.
- During cyclone operation, approximately 164 m³/hour of tailings pond water will be pumped to the cyclones.

4.1.6 Reclaim and the Process Plant Water Balance

Water within the process plant will be provided through a combination of:

- reclaim from the tailings pond;
- pit de-watering water from the pit;
- intermittent freshwater pumped from Morrison Lake as required;



“Contact” water from the process plant area, pit area, and waste rock storage and low grade ore stockpile area will be collected and directed to the pump box at the inlet of the process plant where it will be mixed with tailings and sent via the tailings pipeline to the TSF.

Freshwater use from Morrison Lake is expected to be limited to potable water use (3 m³/hr). In the feasibility study, Wardrop identified the need for 87 m³/hr of freshwater for use in the processing plant that included the potable water. However, it is expected that most of this estimated water volume will be provided by pumping from pit dewatering. Depending on specific needs within the processing plant, there may be freshwater requirements for reagent mixing that pit dewatering water may not be of sufficient quality to supply. This is not currently specifically accounted for in the water balance, but it is expected that this would be a relatively small volume, and that the difference could easily be balanced through diversion around the TSF or other means as required.

The reclaim water will be used as make-up water with pumping rates varying from month to month depending on the volume provided through other sources.

Figure 4-1 and Figure 4-2 provide a breakdown of the various water flow paths within the mine site and process plant system.

4.1.7 Surface Water Runoff Over the Tailings Dam Face

Surface water runoff over the tailings dam face is assumed to be collected within the seepage collection structures at the foot of the north and main dams. The model assumes 50% of the precipitation falling on the tailings dam downstream face is collected and pumped back into the TSF. The remaining surface water runoff is either un-captured or lost through seepage to groundwater or evaporation. The area of the tailings dam face at any time is based on a tailings dam slope of 1V:3H and tailings dam heights and lengths, which are provided in Klohn (2009). Simple calculations indicate a tailings dam face surface area of approximately 60,000 m² for the starter dam and 350,000 m² at closure. The tailings dam surface area is assumed to increase linearly through time between these two values.

It is further assumed that 10 years after the end of operations, pumping from the seepage collection ponds to the TSF ceases as the quality of the surface water runoff from the downslope face is assumed to improve with tailings dam face reclamation. Modelling assumes surface water runoff from the downslope dam face flows to the receiving environment after 10 years from the end of operations.

4.1.8 Solids Balance

The water balance model also contains a solids balance component that models the infilling of the TSF with tailings solids. The solids balance model predicts the mass of tailings solids entering the TSF. The model was run considering settled tailings densities between 1.3 to 1.5 t/m³, which have water content from 72% to 77% as outlined in Klohn (2009). Based on data provided in Klohn (2009), a settled density of 1.3 t/m³ is likely more representative of recently deposited tailings. Tailings that have had a number of years to settle might be expected to have a settled density of 1.5 t/m³.

The predicted TSF pond water level is calculated by considering the combined volume of solids and free water at every time step. For volume calculations, the model assumes a horizontal tailings surface, in that all the solids are assumed to be underwater, except for beached tailings estimated at 10% for the TSF pond area during operations.

4.1.9 Tailings Storage Facility Outflows

During operations, the pond will be operated as a “zero” surface discharge facility with no surface water released from the TSF. The tailings main dam will be constructed so that all tailings slurry (solids and water) entering the TSF is retained.

At the end of mining operations, tailings discharge to the TSF will cease and the pond will be allowed to fill. Once full, the TSF pond water overflow will be directed to the open pit via the closure spillway and a gravity-fed pipeline to contribute to pit filling. The model also assesses whether the design conditions (i.e., “zero” surface discharge) can be met assuming average annual precipitation.

4.2 Water Balance Results

Water balance results are presented in this section. During operations, sufficient water is available from the sources described in Section 4.1 above for reclaim purposes and the pond will fill to the ultimate level at 1,013 masl, which is reached in Year 24 from the start of operations (i.e., 3 years after closure at Year 21). As discussed above, following this the TSF pond will discharge via the closure spillway and be directed to the pit via a gravity-fed pipeline.

4.2.1 Klohn Crippen Berger Ltd. Water Balance

Klohn (2009) presented water balance results within their Feasibility Study for the TSF. The water balance input parameters were outlined in Section 4.1. Key assumptions include average precipitation and runoff in selected years of operations. Table 4.2-1 provides a summary of the main inputs and outputs from the TSF for the Klohn water balance. Figure 4.2-1 illustrates the relative contribution to the pond from various inflows. It is clear that inflows to the TSF pond are dominated by tailings slurry water, which forms approximately 90% of the inflows to the pond in an average year.

Notably, Klohn’s water balance was developed for the purpose of feasibility study level design and as a result the assumptions used in their feasibility study report are relevant for the intended purpose. However, for the current report and the Environmental Assessment Application, there is a need for a more detailed analysis of the site-wide water balance to assess potential effects to the environment. A major difference between the Rescan water balance (higher estimate) and the Klohn water balance (lower estimate) is the difference in groundwater seepage from the TSF (Rescan 2009b). The higher TSF seepage rate to groundwater used in the Rescan water balance results in a much larger volume of water required as input to the TSF from the upstream watershed to maintain pond water levels. Therefore, for the purposes of this modelling, there is a key difference in the Water Management Plan from Klohn’s water balance and the Water Management Plan outlined in their Feasibility Study Report. The TSF requires more upstream surface water runoff to maintain a positive water balance during the early years of operations and

during closure and post-closure phases of the mine life. Therefore, less upstream surface water runoff will be diverted around the TSF than described in Klohn's Feasibility Study Report.

Table 4.2-1
Summary of Pond Water Balance

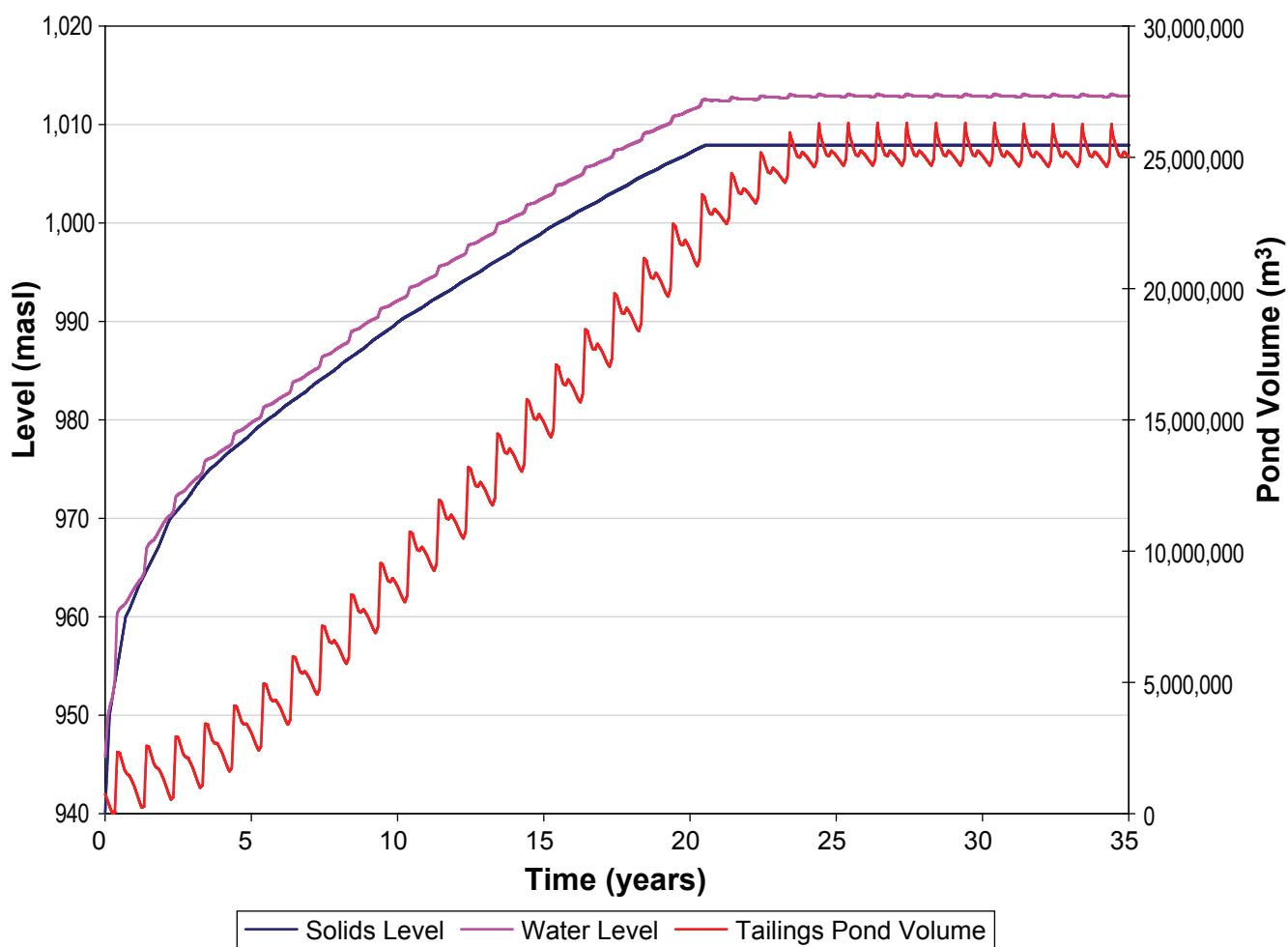
	Average annual flows (m ³ /hr)		
	Starter Dam	Pre-closure	Closure
Inflows to Tailings Pond			
Tailings water (all sources)	2,545	2,547	0
Precipitation on pond	76	318	286
Runoff to pond	145	19	167
Seepage Reclaim	4	4	0
Total inflows	2,770	2,888	453
Losses from Tailings Pond			
Evaporation from Pond	54	225	202
Loss to tailings voids	471	371	0
Seepage	10	10	10
Pump to cyclones	109	109	0
Reclaim	2,126	1,983	0
Total losses	2,770	2,698	212
Net Water Balance	0	190	241

Based on Klohn Crippen Berger Ltd. Water Balance.

4.2.2 Rescan Water Balance

A detailed description of annual flows entering and exiting the TSF can be found in Table 4.2-2. As discussed above, variations between the Rescan and Klohn water balances can be primarily attributed to the higher predicted seepage rates exiting the base of the TSF and into the underlying groundwater aquifer (Rescan 2009b). As a result, in order to achieve the management objectives of zero surface discharge through operations, while maximizing water cover over the tailings, additional surface runoff must be allowed into the TSF. Therefore, the diversion ditch on the east side of the TSF will be actively managed throughout operations. The upstream catchment area to this diversion ditch is 355 ha (which represents 111 m³/hr of the total "runoff from the undiverted catchment area" in Table 4.2-2). The ditch will be fitted with a flow control structure so that, as necessary, water can be diverted into or around the TSF to achieve management objectives.

Figure 4.2-1 shows the predicted evolution of the tailings water level and solids level over time within the TSF. If all of the catchment area upstream of the TSF remains undiverted (i.e., all surface water runoff is directed into the TSF), the tailings will have a water cover for both the operational and post-closure phases of the mine life. During the closure and post-closure phases, the TSF will fill to maximum capacity (i.e., the closure spillway elevation of 1,013 masl) in three years (Year 24). Because of the elevated seepage rates exiting the TSF, an initial pond volume of approximately 750,000 m³ is required with an undiverted TSF watershed area to prevent the pond from drying up during the first several years of operations.



Morrison Copper/Gold Project
Predicted Evolution of Tailings Solids
and Water Level for Water Balance

Tailings Pond Water Balance

Table 4.2-2
Summary of Site Water Balance During Operations and at Closure

Average Annual Flows (m³/hr)							
Plant Area	Year 2	Year 7	Year 11	Year 17	Year 19	Early Closure (Pit Re-Filling)	Full Closure (TSF and Pit Full)
Water Inputs							
Reclaim to process plant	2,066	1,966	1,928	1,875	1,875	--	--
Groundwater pumping for pit dewatering	100	200	238	291	291	245	151
Direct precipitation on pit	69	69	69	69	69	69	69
Runoff from waste rock piles and plant area	132	132	132	132	132	77	77
Ore void water	39	39	39	39	39	--	--
Freshwater from Morrison Lake	3	3	3	3	3	--	--
Subtotal	2,409	2,409	2,409	2,409	2,409	391	297
Water Losses							
Tailings transport water	2,405	2,405	2,405	2,405	2,405	--	--
Concentrate loadout	1	1	1	1	1	--	--
Potable water	3	3	3	3	3	--	--
Evaporation from pit lake	--	--	--	--	--	24	24
Subtotal	2,409	2,409	2,409	2,409	2,409	24	24
Net Plant Area Balance (Inputs – Losses)	0	0	0	0	0	367	273
<u>Tailings Storage Facility</u>							
Water Inputs							
Whole tailings water	1,062	1,062	1,062	1,062	1,062	--	--
Cyclone overflow	1,416	1,416	1,416	1,416	1,416	--	--
Cyclone underflow	67	67	67	67	67	--	--
Direct precipitation on pond	123	201	266	320	320	320	320
Runoff from undiverted catchment area	287	248	215	188	188	188	188
Seepage Reclaim	4	4	4	4	4	4	--
Subtotal	2,959	2,998	3,030	3,058	3,058	512	508
Water Losses							
Pond evaporation	86	142	188	226	226	226	226
Storage in tailings voids	171	171	171	171	171	--	--
Storage in cyclone overflow voids	169	169	169	169	169	--	--
Storage in cyclone underflow voids	30	30	30	30	30	--	--
Seepage from bottom of TSF	81	121	158	194	203	208	208
Seepage through dam	4	4	4	4	4	4	4
Pump to cyclowash	109	109	109	109	109	--	--
Reclaim to process plant	2,066	1,966	1,928	1,875	1,875	--	--
Subtotal	2,716	2,712	2,757	2,778	2,787	438	438
Net TSF Balance (Inputs – Losses)	243	286	273	279	270	74	70
Accumulation as TSF Storage	243	286	273	279	270	0	0
Accumulation as Pit Lake Storage	0	0	0	0	0	441	0
Site Wide Water Balance	0	0	0	0	0	0	343

In addition, Figure 4.2-2 shows the spillway overflow rate that will be directed into the open pit when the TSF reaches the ultimate volume in Year 24 and beyond. As noted in Section 2, once the TSF is full, it would be possible to continue active management of the diversion channel to achieve a net zero TSF balance (i.e., inputs equal losses). The current modelling does not include this scenario, as the current scenario (no diversion around TSF at closure) produces the best water quality conditions in both the TSF and pit at closure. However, when additional water quality data is available later in the mine life, this scenario should be re-evaluated, as it would minimize water volumes required to be managed at the pit into closure, and would increase stream flow to the MCS-7 channel below the dam.

The total volume of tailings discharged to the TSF is 193 Mt from the total tailings mass of 224 Mt, with the balance used to build the cycloned tailings sand dam. To reach a final tailings level of 1,008 masl, 20.5 years of operations is required with a density of settled tails at 1.3 t/m^3 . Based on data provided in Klohn (2009), a settled density of 1.3 t/m^3 is more representative of recently deposited tailings. Tailings that have had a number of years to settle might be expected to have a settled density of 1.5 t/m^3 . If a density of 1.5 t/m^3 is used for 193 Mt tailings, then the tailings level at closure is likely to be closer to 1,004 masl, providing additional pond water storage capacity. Notably, applying a settled density of 1.5 t/m^3 to all the tailings (224 Mt—this includes cycloned sand that is used to construct the dams) entering the TSF results in final tailings volume equivalent to that required to fill the pond to 1,008 masl. The assessment outlined in this report uses the more conservative settled density value (1.3 t/m^3). In addition, an operational period of 20.5 years was also used for all subsequent model runs.

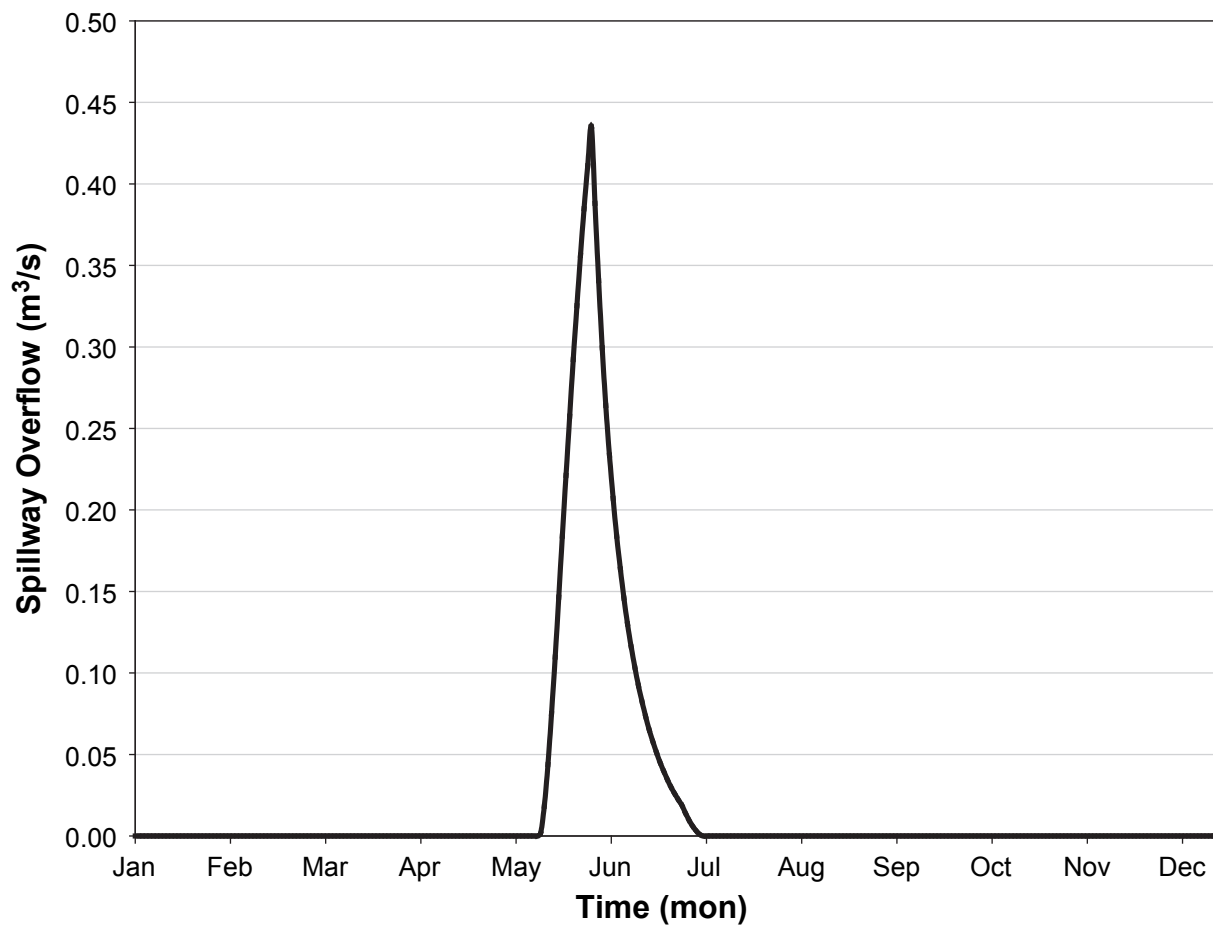
4.2.3 Summary of Water Balance Results

The modelling exercise presented above indicates that under design conditions the TSF will operate as a “zero” surface discharge facility throughout the operations phase. To achieve this, the diversion channel on the east side of the TSF will be actively managed to maintain maximum water levels in the pond (e.g., within dam freeboard requirements), without the need for a surface discharge.

From the end of operations (Year 21), it will take approximately three years after the end of operations (Year 24) for the TSF to reach the final spillway elevation (1,013 masl). Once full, an average of $70 \text{ m}^3/\text{hr}$ of excess water will be directed from the TSF to the pit lake.

It is recommended that a more rigorous analysis be undertaken to understand the sensitivities of the water balance to changes in the individual inputs described above.

There is the potential for revising the water balance using more site-specific climatic and design data during the construction and operations of the Project mine plan and for adjusting water management plans (i.e., adaptive management) accordingly. For example, the discussion provided above regarding precipitation inputs indicates the potential for higher precipitation rates than modelled. However, it is important to note that the water balance as summarized in Table 4.2-2 is based on maximum surface runoff input to the TSF (e.g., no diversion around TSF



from upstream catchment area). If higher precipitation/runoff rates were encountered, these additional volumes could be offset through management of the diversion channel by increasing diversion around the TSF. The balance can also be reviewed as TSF seepage estimates are verified through the collection of additional field information.

Adaptive water management, water management planning, and monitoring programs during the mine life will allow for opportunities for adjustments to be made to the Water Management Plan when and as needed.

Overall, inflows to the TSF on an annual basis are dominated by tailings slurry water. The location of the pond in the headwaters of a small watershed and the relatively low annual precipitation totals in the Project site area, results in the tailings slurry water accounting for approximately 90% of the inflows to the TSF. Regardless of the uncertainty in natural inflow rates to the pond, the key inflow parameter to the TSF water balance remains the tailings slurry water.

The provision for adequate freeboard of the TSF pond through the mine life of the facility is not considered in detail in this report, but should be reviewed by the design engineers. Under normal operating conditions, the proposed contingency in the case of an extreme wet precipitation events is for the TSF pond level to be held at a level that provides storage of 3.4 Mm³ or 1-m freeboard before any TSF pond water can spill from the pond.

The TSF is designed to operate as a “zero” surface discharge facility during operations and until Year 24, when the TSF pond elevation would reach the closure spillway elevation. The dam crests and closure spillway elevation for the TSF has been designed by Klohn (2009) using estimated precipitation and surface water runoff values. In addition, the design calculations consider average annual precipitation and runoff in every year of operations. Based on the design parameters, the model presented in this report confirms that the TSF can operate as a “zero” surface discharge facility during operations and into post-closure until Year 24.

An alternative closure scenario depending on water quality observed in the full TSF that has not been modeled, would be to possibly continue actively managing the diversion channel to achieve a net zero water balance in the TSF (i.e., inflow is balanced by seepage) such that there is no surface discharge out of the TSF into post-closure. This alternative has not been pursued at this time, as the current plan has been optimized based on producing the best water quality in both the TSF and the pit based on available data. However, potential benefits of this scenario include minimizing the volume of water that needs to be treated at the pit, as well as diverting more flow to the MCS-7 channel below the dam. PBM will continue to evaluate closure options through the life of the Project as new data becomes available to determine the best ultimate closure scenario.

There are many uncertainties associated with water balance calculations associated with the availability of and variability in water balance input values. Given the length of time of Project operations (21 years) there is the opportunity for adjustments to be made to the water balance and site water management during the mine life, as additional input data become available and input parameters are refined.

5. Waste Rock Storage Area Water Balance

The water balance of the waste rock storage area is described in this section. This includes a description of model inputs to the waste rock storage area.

5.1 Waste Rock Storage Area Water Balance Model Inputs

The key inputs and outputs to the waste rock storage area water balance model are:

- precipitation falling on the waste rock storage area
- surface water runoff from the waste rock storage area
- surface water runoff infiltration into the waste rock storage area

5.1.1 Precipitation

5.1.1.1 Annual Totals

As described in Section 4.1.1.1, the total annual precipitation estimates for the Project are based on statistical analysis of observed precipitation at nearby Environment Canada meteorological stations. The precipitation estimates for the waste rock storage area are identical to those for the tailings pond and open pit, and for further explanation of this please refer to Section 4.1.1.1 of this report. As stated previously, an annual precipitation value of 550 mm was used in the modelling work to be consistent with Klohn (2009).

5.1.1.2 Inter-annual Variability; Return Period Values

The methodology and values used for calculating return period precipitation totals is the same as the tailings pond, and is explained in Section 4.1.2.2. The return period precipitation values are provided in Table 4.1-2.

5.1.1.3 Monthly Distribution

The monthly distribution of precipitation for the waste rock storage area is identical to that used for the tailings pond, and is summarized in Section 4.1.1.3. The effective precipitation value was used for the modelling runs, and is shown in Table 4.1-3.

5.1.2 Runoff

The annual runoff coefficient of the waste rock storage area is assumed to be 0.5 during operations (50% infiltration), and 0.7 upon closure (30% infiltration). As discussed previously, this change in runoff coefficient upon closure is to account for the construction of a cover on the final waste rock storage area to reduce the amount of contact infiltration water. All surface water runoff and contact water from the waste rock storage area is assumed to report to the open pit during operations and closure. Thus, during operations, 275 mm of precipitation reports as surface water runoff from the waste rock storage area to the pit, and 275 mm infiltrates into the waste rock. At closure, 385 mm of water reports as surface water runoff over the waste rock storage area to the pit, and 165 mm infiltrates the waste rock. A diversion ditch is maintained

Waste Rock Storage Area Water Balance

indefinitely upstream of the waste rock storage area to prevent natural surface water runoff from entering into the waste rock and subsequently flowing into the open pit. Thus the watershed area of the waste rock storage area is limited to the footprint of the waste rock. Runoff coefficients were chosen based on professional judgment and are considered suitable for representing the hydrology of the waste rock storage area.

The waste rock storage area footprint increases throughout the operational mine life in accordance with the mine plan and schedule and waste management schedule. This increase in footprint results in progressively more surface water runoff associated with the waste rock storage area throughout the operational mine life. Klohn (2009) presented a final footprint for the waste rock storage area of 175 ha. For the purposes of the water balance and water quality prediction modelling, it was assumed that the area increased linearly throughout the life of the mine (Table 5.1-1).

**Table 5.1-1
Waste Rock Storage Area Growth during Operations**

Year	Waste Rock Storage Area (ha)
0	17.5
1	26.3
2	35
3	43.8
4	52.5
5	61.3
6	70
7	78.8
8	87.5
9	96.3
10	105
11	114
12	123
13	131
14	140
15	149
16	158
17	163
18	169
19	175

5.1.2.1 Monthly Distribution

The monthly distribution of annual runoff is assumed to be consistent with the tailings pond and open pit and is shown in Table 4.1-4.

5.1.3 Outflows from the Waste Rock Storage Area

All precipitation onto the waste rock storage area will flow either as surface water runoff or as infiltrated water into the open pit. During operations, this surface water runoff and a portion of the infiltrate that daylights as seepage water will be collected in sumps and pumped to the process plant. At mine closure, this water will contribute to the filling of the pit lake. As the estimation of evaporation from the WRD was difficult to predict, it was assumed that 30% of the total precipitation is lost as evaporation.

6. Open Pit Water Balance

The open pit water balance is described in this section. This includes a description of model inputs to the pit, and the results of the modelling exercise. Key assumptions used throughout the modelling exercises are also described. General conceptual models for the open pit water balance during operations and at closure are shown in Figure 6-1 and Figure 6-2.

6.1 Open Pit Water Balance Model Inputs

The key inputs and outputs to the open pit water balance model are:

- precipitation falling on the open pit (both on the pit walls and on the pit lake as it fills during operations and closure);
- surface water runoff from the waste rock storage area during operations, closure, and post-closure;
- seepage from the waste rock storage area during operations and closure;
- evaporation from the waste rock storage area;
- groundwater inflows to the pit during operations, closure, and post-closure;
- spillway overflow from the TSF starting at Year 24;
- evaporation from the open pit lake as it fills;
- pumped outflow required to maintain the pit water level at 728 masl or 4 m below Morrison Lake (732 masl).

6.1.1 Precipitation

6.1.1.1 Annual Totals

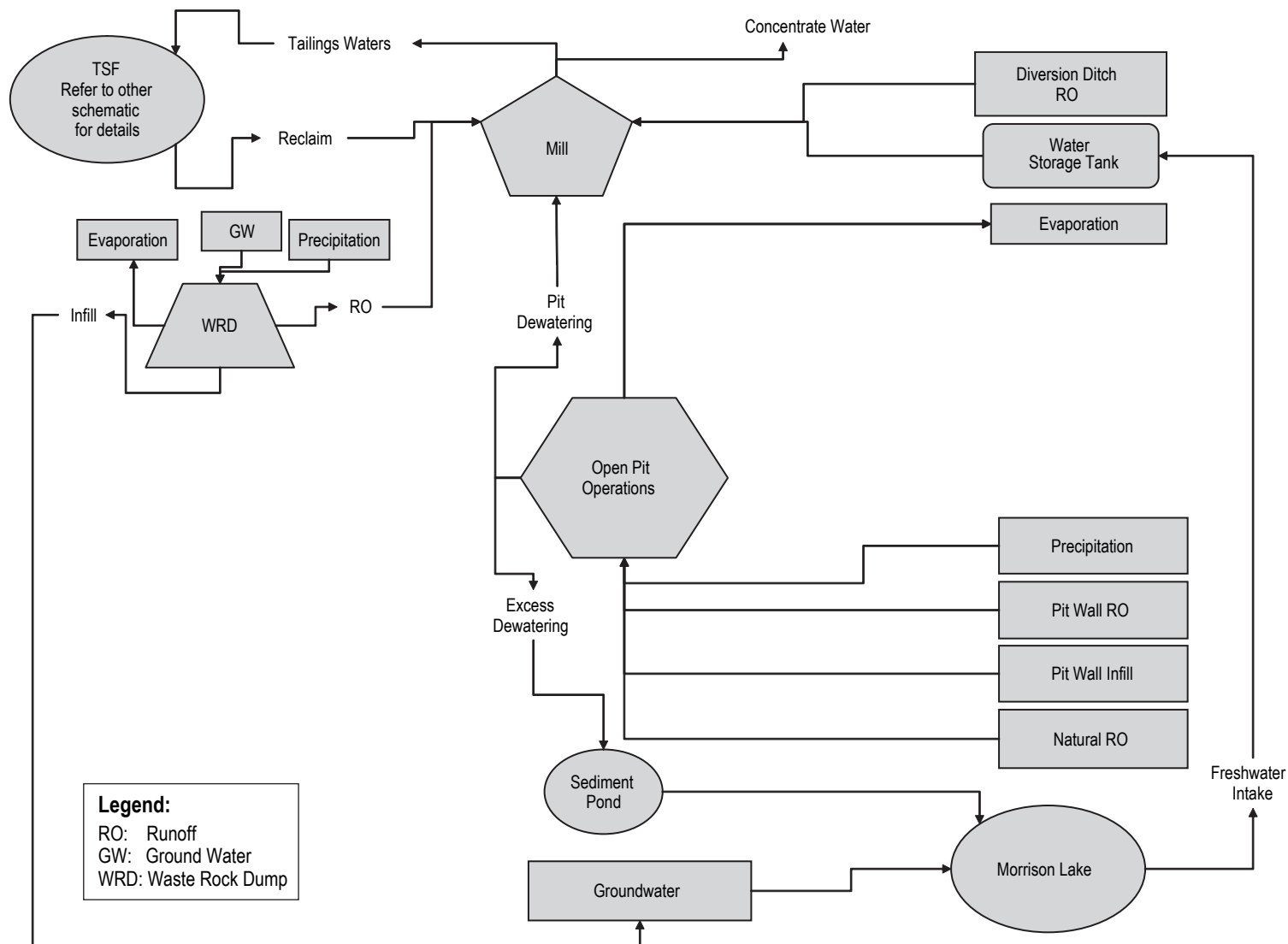
As described in Section 4.1.1.1, the total annual precipitation estimates for the Project are based on statistical analysis of observed precipitation at nearby Environment Canada meteorological stations. The precipitation estimates for the open pit area are identical to those for the TSF, and for further explanation of this please refer to Section 4.1.1.1 of this report. As stated previously, an annual precipitation value of 550 mm was used in the modelling work for consistency with Klohn (2009).

6.1.1.2 Monthly Distribution

The monthly distribution of precipitation for the open pit is identical to that used for the TSF, and is summarized in Section 4.1.1.3. The effective precipitation value was used for the modelling runs, and is shown in Table 4.1-3.

6.1.2 Runoff

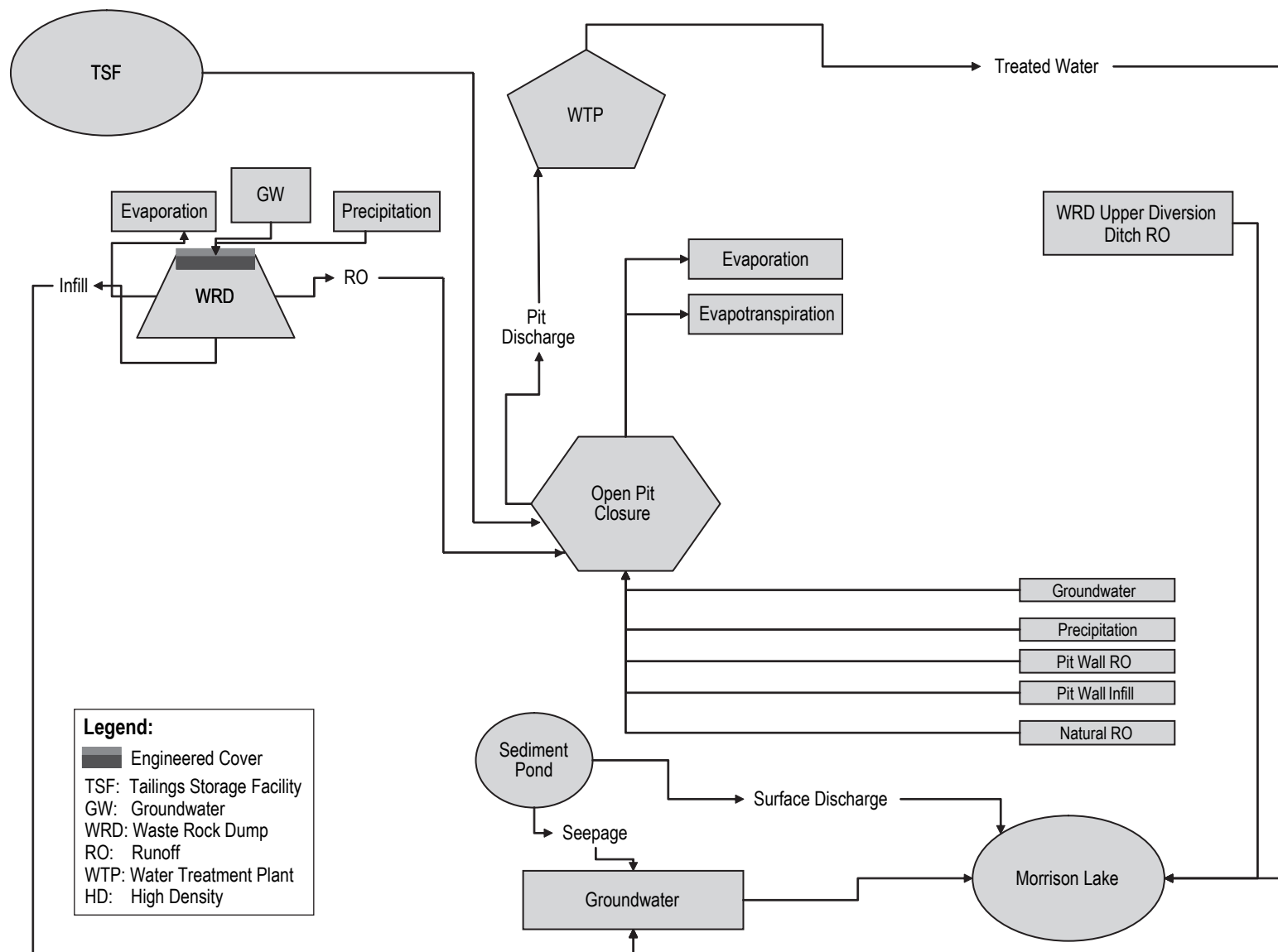
The annual surface water runoff of the open pit surrounding natural watersheds was assumed to be consistent with the surface water runoff used in the TSF water balance.



Morrison Copper/Gold Project
Open Pit Water Balance during Operations

FIGURE 6-1





**Morrison Copper/Gold Project
Open Pit Water Balance at Closure**

FIGURE 6-2



6.1.2.1 Annual Totals

Klohn (2009) estimates average annual surface water runoff at the site by applying a runoff coefficient of 0.5 to the annual precipitation total of 550 mm. This provides an estimate of annual surface water runoff of 275 mm. This value was used for diverted and natural watersheds surrounding the open pit, as with the TSF, and is summarized in Table 4.1-6. It was assumed that all precipitation landing on the pit walls and within the pit area would flow into the pit and contribute to pit dewatering during operations and pit filling on closure. Additionally, all precipitation (less evaporation) landing on the waste rock storage area is assumed to report to the pit, as previously described in Section 5.1.2. The natural watershed area was assumed to be the ultimate footprint of the waste rock storage area, process plant, and open pit area, which decreases throughout the mine life as the waste rock storage area increases.

6.1.2.2 Monthly Distribution

The monthly distribution of annual surface water runoff is assumed to be consistent with the TSF and is shown in Table 4.1-4. As described in Section 4.1.2.2, for the purposes of modelling, the on-site dataset was used.

6.1.2.3 Inter-annual Variability; Return Period Values

Inter-annual surface water runoff return period values are consistent with those derived for the TSF and are presented in Section 4.1.2.3.

6.1.3 Evaporation

The value for evaporation of the pit lake and methodology of derivation is the same as that used for the TSF evaporation, and is described in detail in Section 4.1.3.

6.1.3.1 Annual Total

The annual lake evaporation for the site was estimated based on data from the Meteorological Survey of Canada station at Topley Landing and is 389 mm. This value is used for the open pit water balance and rationale for its use is described in Section 4.1.3.1.

6.1.3.2 Monthly Total

As with the TSF water balance, Klohn (2009) and Rescan (2008) calculated monthly evaporation totals from available data for the station at Topley Landing. The results are presented in Table 4.1-5 and are very similar.

To be consistent with Klohn (2009) engineering report, model runs are undertaken using the Klohn monthly evaporation data.

6.1.3.3 Return Period

As stated in Section 4.1.3.3, there were insufficient data to derive a return period evaporation value, and therefore a constant value for evaporation is used in all model runs.

6.1.4 Groundwater Inflow to Pit

Average annual groundwater dewatering rates during construction and operations and groundwater filling rates to the open pit during closure and post-closure were derived by Rescan (2009b). This is summarized in Table 6.1-1 for the mine life.

**Table 6.1-1
Groundwater Dewatering and Filling to the Open Pit**

Mine Phase	Year	Pit Dewatering or Filling	Flow Rate (m³/hr)
Construction	0	Dewatering	50
I	1	Dewatering	50
I	3	Dewatering	100
I-II	5	Dewatering	150
I-II	7	Dewatering	200
II-III	11	Dewatering	238
II-IV	17	Dewatering	291
IV	19	Dewatering	291
Closure	21	Filling	245
21 years post-closure ¹	44	Near Full	151

Notes: ¹ For modelling purposes, this date was chosen and does not correspond to the time at which pit filling is completed.

6.1.5 TSF Spillway Overflow to Pit

Approximately three years following the end of operations (Year 24), the TSF spillway will overflow. This spillway overflow will be transferred to the pit via gravity-fed pipeline to contribute to pit filling and improve the water quality within the pit through dilution, because of the differences of relative mass loadings from the TSF pond and pit wall and waste rock contact waters.

6.1.6 Outflows from Open Pit

During operations, water flowing into the open pit will be pumped out and transferred to the mill for process water usage and ultimately delivered to the TSF as tailings slurry water. At closure, the pit will begin to fill and allowed to fill to a level of 728 masl, at which time the pit lake water must be pumped from the pit to maintain a reverse hydraulic gradient towards the pit lake. Based on the predicted pit lake water quality, the pit lake water will be pumped to a water treatment plant for treatment to a level that meets regulatory requirements for discharge to Morrison Lake.

6.1.7 Final Pit Lake Elevation

To determine a reasonable estimate of the final pit lake elevation that included an allowance for additional storage capacity in the pit caused by an extreme precipitation event, a 1-in-200 wet precipitation year was considered. Various precipitation sources were considered for a full comparison of results. Table 6.1-2 shows that a probable maximum flood would cause a water level in the pit lake of approximately 3.3 m, assuming 70% of water reporting to the pit catchment area (418 ha) occurs during the months between May and June and a runoff coefficient of 1. Thus,

a freeboard of approximately 3 to 4 m would be sufficient for storage of a 1-in-200-year wet precipitation event and maintain a reverse hydraulic gradient towards the pit lake. Notably, this evaluation assumes that the Morrison Lake level will not rise above 732 masl.

Table 6.1-2
Evaluation of Probable Maximum Flood Event within the Open Pit

	Klohn 1 in 200 wet year (0.5 runoff coef)	Klohn 1 in 200 wet year (0.7 runoff coef)	Rescan 1 in 200 wet year (0.5 runoff coef)	Klohn 30 day ^a PMP (1.0 runoff coef)	Klohn 7 day ^a PMP (1.0 runoff coef)	Klohn 2 week, 200 year rainstorm (1.0 runoff coef)
Runoff (mm)	460	640	635	540	350	320
^b Freshet Volume (Mm ³)	1.3	1.9	1.9	-	-	-
^c Event Volume	-	-	-	2.3	1.5	1.3
Water Level rise from 732 (m)	~ 1.9	~2.7	~2.7	~3.3	~2.2	~ 1.9

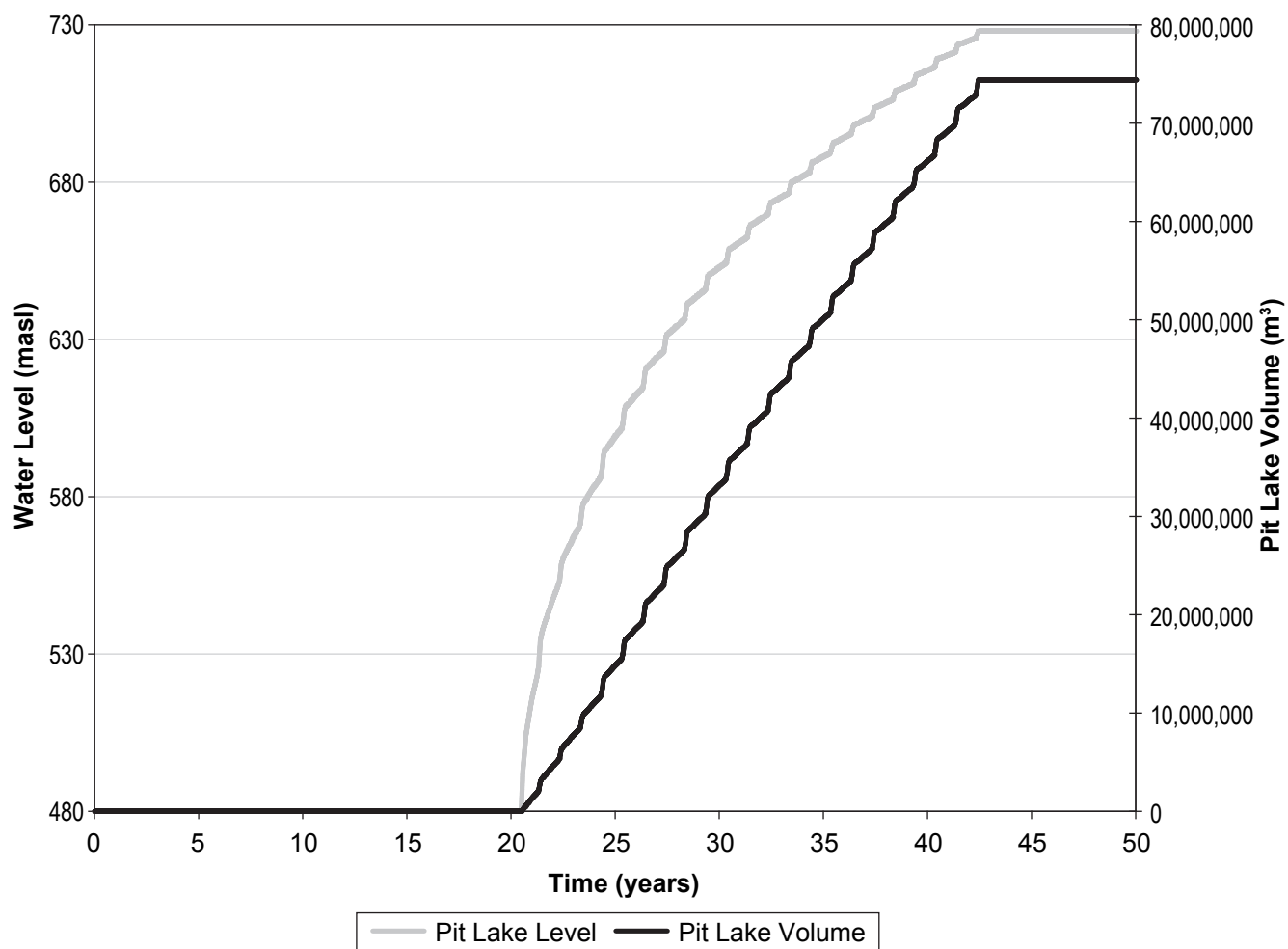
^a Probable Maximum Precipitation

^b Catchment 418 ha, 70% of annual flow in freshet

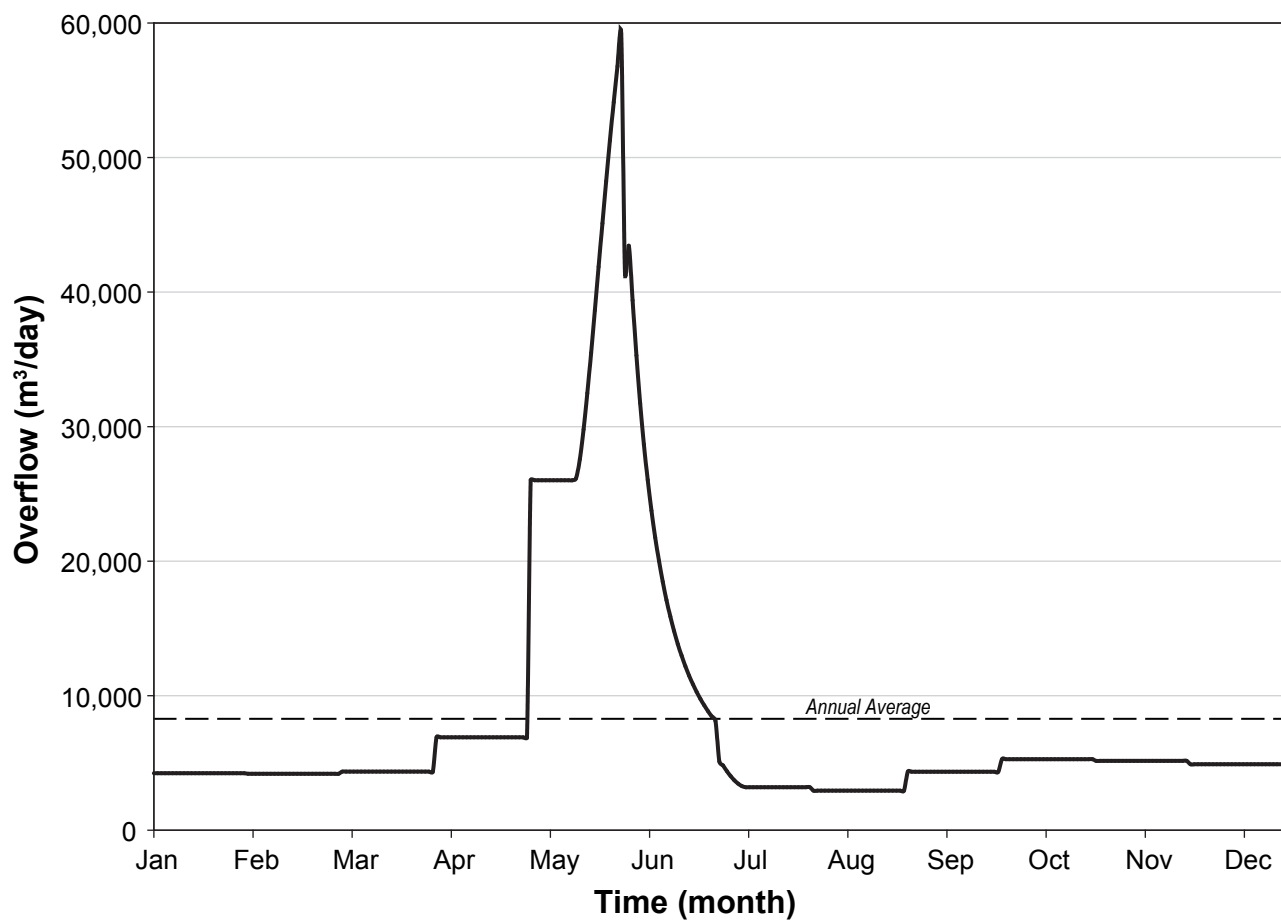
^c Catchment 418 ha

6.2 Water Balance Results

Figure 6.2-1 shows the expected pit lake filling curve and time to the final pit lake elevation (728 masl). Overflow from the TSF enters the open pit in Year 24. Although this increases pit filling, the overall contribution of water after 100 years of pumping is less than 20% of the total water entering the pit. A longer period to pit refill is possible if the TSF is operated as zero discharge post closure or TSF pond water quality is acceptable for direct discharge post closure. This will result in poorer water quality as pit walls are exposed for a longer period contributing loadings to the pit lake and also due to the relatively better water quality of the TSF pond water that provides a dilution to the pit lake. Figure 6.2-2 shows that the average year pit overflow rate that will require pumping and a water treatment plant before discharge upon final pit lake elevation.



**Morrison Copper/Gold Project
Predicted Evolution of Pit Lake
Water Level for Water Balance**



7. Tailings Pond Water Quality

7.1 Water Quality Inputs

Key sources of water quality loadings to the TSF:

- natural water inflows (surface water runoff and precipitation on the TSF)
- tailings slurry water
- surface water runoff over beached (exposed) tailings
- surface water runoff over dam face
- suspended solids

The water quality associated with each of the sources is developed as a concentration (in mg/L) for each parameter as an input to the model. The loadings are coupled with the water balance for a given surface area to produce a mass inflow of mg/hr. The general mass and water balance calculation used to derive resultant concentrations is shown below.

Equations 7.1-1a and b General Mass and Water Balance Equation for Water Quality Predictions

$$\text{Mass Loading (mg/hr)} = (\text{Concentration (mg/L)} \times \text{Flow Rate (m}^3\text{/hr)} \times 1,000 \text{ L/m}^3) \quad \text{Eqn 7.1a}$$

$$C_{final} = C_{in} \times (1 - e^{-1/\tau}) + C_{initial} \times e^{-1/\tau} \quad \text{Eqn 7.1b}$$

Where C_{final} is the final concentration within the TSF pond; C_{in} is the inflow concentration to the pond; τ is the residence time of the body of water; and $C_{initial}$ is the initial concentration of the TSF pond.

The model predicts concentrations of dissolved parameters; however, an estimation of the contribution from totals is also provided in Section 7.1-6. Selected predicted water quality concentrations within the TSF pond are compared to relevant BC water quality guidelines provided by the British Columbia Ministry of the Environment (BC MOE).

The reader is encouraged to read Chapter 6 of Rescan's *Morrison Copper/Gold Project: Prediction of Metal Leaching and Acid Rock Drainage* (2009d) and references therein for the development and assignment of mine component source term water quality used in predictive water quality modelling reported in the following sections.

7.1.1 Natural Water Inflows

Natural water inflows include surface water runoff from watersheds adjacent to and upstream of the TSF (termed natural runoff) and precipitation falling directly onto the pond surface. Precipitation is assumed to be pure water with zero loadings of all parameters as the mass loading contributions from this source is considered negligible.

The chemistry of natural runoff is based on data obtained during the baseline monitoring program for the Project (Rescan 2008a, 2008b, 2009a). Natural water quality used in the model is based on average concentrations of chemical constituents from all samples for stream MCS-7. The water quality sampling point was within the same watershed as the TSF and downstream of the location of the main dam. The natural water quality used in the model is shown in Table 7.1-1.

Natural water in the MCS-7 watershed is of good quality. As is shown in Table 7.1-1, the concentrations of selected parameters are well below CCME (CCME 1999) water quality guideline values.

Table 7.1-1
Water Quality of Natural Runoff Compared to BC and CCME
Guideline Values

	BC Freshwater Aquatic Life Guideline (mg/L)	CCME Freshwater Aquatic Life Guideline (mg/L)	Natural Runoff (mg/L)
Acidity			2.2
Alkalinity			61.4
Sulphate	100		7.1
TDS			86.3
Fluoride	0.3		0.048
Chloride	600		0.25
Ammonia			0.0043
Nitrite	0.06 ^A	0.06	0.0018
Nitrate	200		0.45
Dissolved Metals			
Aluminum	0.1	0.1	0.035
Antimony	0.02		0.00005
Arsenic	0.005	0.005	0.000207
Barium	5		0.022
Beryllium	0.0053		0.00025
Bismuth	--		0.00025
Cadmium	0.000048	0.00001	0.0001
Calcium	--		18.8
Chromium	0.001	0.0089	0.00025
Cobalt	0.11		0.00005
Copper	0.008 ^B	0.002 ^B	0.00072
Iron	1	0.3	0.04
Lead	0.043 ^B	0.001 ^B	0.000032
Lithium	5		0.0025
Magnesium	--		3.09
Manganese	1.201		0.0005
Mercury	0.0001	0.000026	0.000006
Molybdenum	2	0.073	0.000055
Nickel	0.025 ^B	0.025 ^B	0.00026

(continued)

**Table 7.1-1
Water Quality of Natural Runoff Compared to BC and CCME
Guideline Values (completed)**

	BC Freshwater Aquatic Life Guideline (mg/L)	CCME Freshwater Aquatic Life Guideline (mg/L)	Natural Runoff (mg/L)
Potassium	--		0.268
Selenium	0.002	0.001	0.000281
Silicon	--		2.43
Silver	0.0001 ^B	0.0001	0.000006
Sodium	--		3.27
Tin	--		0.000056
Titanium	0.1		0.005
Vanadium	--		0.0005
Zinc	0.033 ^B	0.03	0.00062

Notes:

All values measured below the method detection limit is listed as one half the method detection limit.

Guidelines are based on total metals (with the exception of the BC Guideline for Aluminum)

A: guideline dependant on Chloride concentration.

B: guideline hardness dependant, calculated based on hardness of 60.

7.1.2 Tailings Supernatant

Tailings slurry water quality is based on results of tailings supernatant aging test work reported by SGS Lakefield (2007). Tailings supernatant quality used in the model is based on the aging test data at Day 1 as a conservative approach and assumes tailings are composed of a 65% to 35% mix of coarse and fine tailings fractions, respectively. The proportions of coarse and fine tailings are from Klohn (2009). Source term water quality for tailings supernatant is provided in Table 7.1-2.

**Table 7.1-2
Results of Test Work on Tailings from Morrison Project**

Parameter	Aging Tests (Supernatant)
	Average Aged (65% coarse and 35% fine)
pH	8.44
Conductivity	476
Sulphate	83
Acidity	1
Alkalinity	114
Aluminum	0.056
Antimony	0.00438
Arsenic	0.00251
Barium	0.142
Beryllium	0.00002
Bismuth	0.000062

(continued)

**Table 7.1-2
Results of Test Work on Tailings from Morrison Project
(completed)**

Parameter	Aging Tests (Supernatant)
	Average Aged (65% coarse and 35% fine)
Boron	0.0298
Cadmium	0.000304
Calcium	38.9
Chromium	0.000664
Cobalt	0.000372
Copper	0.00498
Iron	0.0546
Lead	0.000373
Lithium	0.001
Magnesium	11.4
Manganese	0.0378
Mercury	0.000343
Molybdenum	0.0825
Nickel	0.00476
Phosphorus	
Potassium	16.3
Selenium	0.000825
Silicon	2.37
Silver	0.0000703
Sodium	31.4
Strontium	
Thallium	
Tin	0.00328
Titanium	0.00203
Uranium	
Vanadium	0.000722
Zinc	0.00259
TDS	463
Fluoride	0.393
Chloride	33.6
Ammonia	0.0072
Nitrite	0.46
Nitrate	217

Notes: All values measured below the method detection limit is listed as one half the method detection limit.
Data from SGS Lakefield 2007.

7.1.3 Runoff Over Tailings Beaches

During operations tailings will be spigotted from the dams at the TSF, forming shallowly sloping (i.e., 1°) tailings beaches. Part of the beaches will be exposed above the surface of the pond water, with the exposed beached area assumed to vary over time in response to a number of factors including pond water level, location of spigotting point, and the storage/elevation curve for the TSF pond. At the end of operations, there will be areas of tailings beaches exposed on the fringes of the TSF pond. However, as the pond fills up to the spillway level the exposed tailings beaches will decrease in area and any remaining exposed areas of beached tailings will have a cover placed overtop to limit the risk of oxidization and metal leaching.

Precipitation falling directly onto exposed beached tailings could:

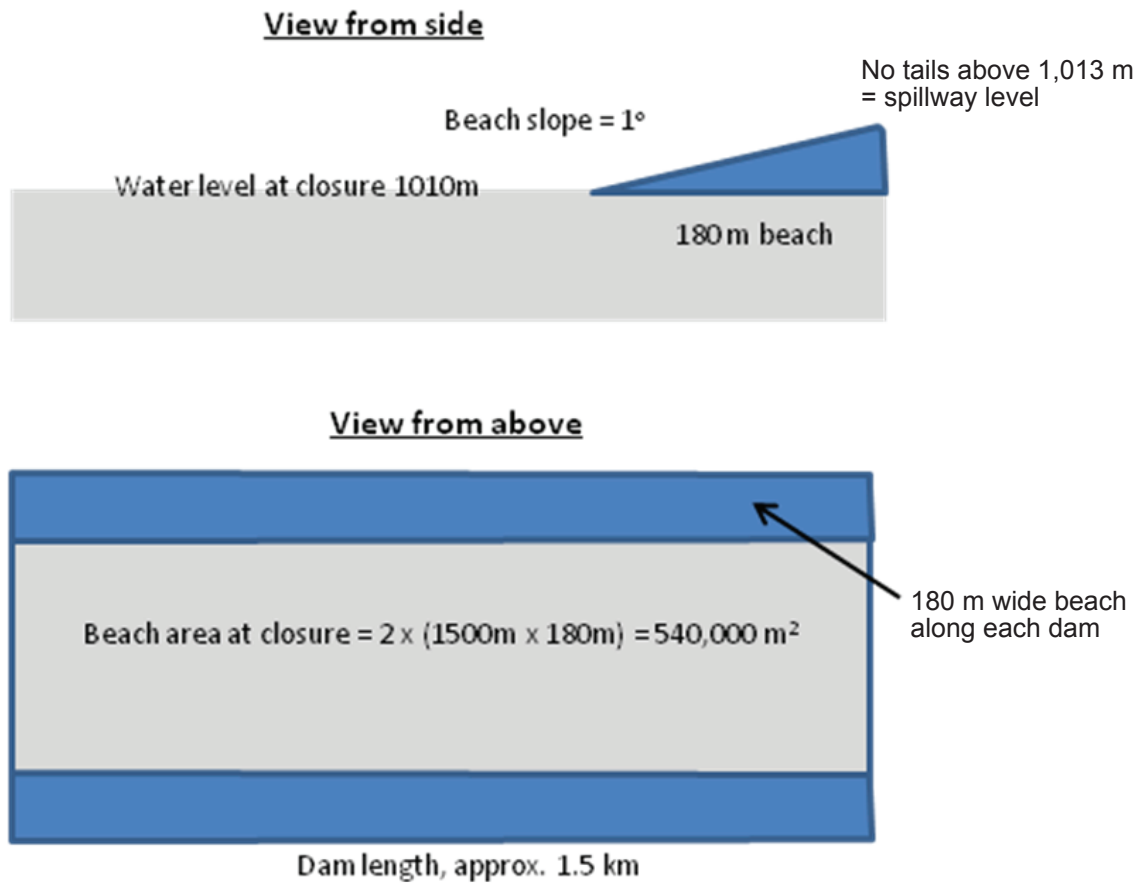
- obtain loadings from the surface of the beached tailings as it flows over the surface of the beached tailings;
- infiltrate into and flow through the beached tailings and into the TSF pond obtaining loadings from the beached tailings and/or displacing porewater.

For modelling purposes, a conservative water quality was used for the beached tailings and the water quality assigned is equivalent to that of waste rock with an adjusted SNPR pH of 7. This assignment is based on the characterization of the tailings as not potentially acid-generating (not-PAG) but a near-neutral pH metal leaching potential (Rescan 2009d). This source term water quality is shown in Table 9.1-1 below.

At present, the beached tailings area exposed at any one time during operations is not known. The beached tailings area exposed relative to the TSF pond area is assumed to decrease over time as the TSF pond water volume increases. An estimate of beached tailings area at the end of operations is shown in Figure 7.1-1. The assumptions are:

- beach slope at 1°;
- top beach level = 1,013 m, which is the spillway elevation;
- pond water level at closure = 1,010 m, from Klohn (2009);
- beached tailings extend along the length of the main and north dams, approximate length 1.5 km for each.

This results in a beached tailings area at end of operations of 540,000 m². For modelling purposes, this area is assumed to decrease linearly with increasing pond level until it reaches zero at 1,013 m. During operations as the TSF pond fills, a beached tailings area of 10% of the total pond area is assumed.



7.1.4 Other Inflows

7.1.4.1 Internal Loadings from Process Plant

The modelling work assumes that tailings slurry water quality from the process plant remains constant over time and is not affected by the chemistry from other sources (e.g., pit de-watering water). Hence, the process plant produces constant mass loadings according to Table 7.1-2 over time during operations and any mass loading inputs into the process plant (i.e., pit dewatering) are assumed to be treated to achieve acceptable water quality for process plant usage.

7.1.4.2 Runoff from Disturbed Areas

The modelling work assumes that surface water runoff from disturbed areas surrounding the TSF do not generate any additional loadings to the TSF. Surface water runoff to the pond is assumed to have the chemistry of natural runoff.

7.1.4.3 Blast Residues or Mine Site Additives

The tailings slurry water nitrogen species water quality used in the modelling is summarized in Table 7.1-2. Further explanations regarding the development of this water quality can be found in Rescan's ML/ARD report (Rescan 2009d).

7.1.4.4 Runoff Over the Dam Face

For a conservative estimate of TSF dam runoff water quality, it was assumed that loadings from the dam face contained similar water chemistry to the SNPR >2.5 waste rock, summarized in Table 9.1-1 later in this report.

7.1.5 Discussion of pH within Inflows to TSF

The mass balance model used in this study does not predict the pH within the TSF pond water directly. However, the pH is an important control on loadings (e.g., from dissolution of re-suspended sediment within the pond and in surface water runoff and infiltration to the pond). Low pH will tend to promote metal leaching from the suspended sediment and additional leaching from beached tailings.

Based on available data and test work, typical pH values are shown in Table 7.1-3

Table 7.1-3
pH of Key Inflows to the TSF

Source	pH
Tailings supernatant test work (for tailings slurry inflows)	~8.2 to 8.5
Natural water	8.0

In addition, as alkalinity and acidity are inputs to the mass-balance modelling, the net result of the balance of these two parameters from the mass-balance modelling was checked against the

Granisle empirical drainage chemistry model (EDCM) to back out a pH value for the TSF pond (see Section 6.9.2 of Rescan 2009d).

During mine operations the water balance for the TSF pond will be dominated by tailings slurry water. In addition, as the TSF pond water will also be used as reclaim water for the process plant any natural water entering the pond will also be cycled through the process plant over time. As a result it is expected that the pH within the TSF pond will be strongly influenced by to the pH of the tailings slurry water.

At closure and into post-closure, the TSF pond water will be diluted by natural runoff and precipitation entering the TSF pond. Over time the pH would decrease towards the pH of natural runoff water quality.

Based on the assumptions outlined above and given that the pH values of the main inputs to the tailings pond are within a relatively narrow range of slightly alkaline to near-neutral pH values, the tailings have been classified as not-PAG and the water management strategy is to maintain a water cover at closure, the risk of acidification of the TSF pond water is low.

7.1.6 Geochemical Reactivity

Geochemical reactivity within the model is taken into account and discussed in Section 6.9 of Rescan's ML/ARD report (2009d). Briefly, credible equilibrium phases calcite, gypsum, goethite, gibbsite, cupricferrite, and barite were allowed to precipitate if saturation was achieved. In addition, metal(loid) adsorption onto goethite was taken into account. Both of these geochemical processes provide natural attenuating mechanisms that limit the dissolved and total metal(loid) concentrations in predicted water quality.

7.2 TSF Pond Water Quality Results

The TSF pond water quality was predicted using the water balance model and mass balance outlined in previous sections. Model predictions are provided:

- during operations
- post-operations into the closure period

7.2.1 Predicted Water Quality

The input parameters are summarized in Table 7.2-1.

Time series of key parameters are shown in Figures 7.2-1 to 7.2-5. All parameters are summarized in Table 7.2-2. The results indicate:

- oscillations in predicted concentrations early in operations as TSF pond volume tends to zero in low precipitation months;
- monthly variations in predicted concentrations indicating the effect of variation in monthly flow rates on concentrations in the TSF pond;

- predicted concentrations tend to tailings slurry water quality during operations due to dominance of tailings slurry water within TSF pond water balance;
- water quality begins to improve at end of operations as tailings slurry inflows cease and the TSF pond water is diluted by natural runoff;
- over time concentrations in TSF pond tends towards natural runoff water quality.

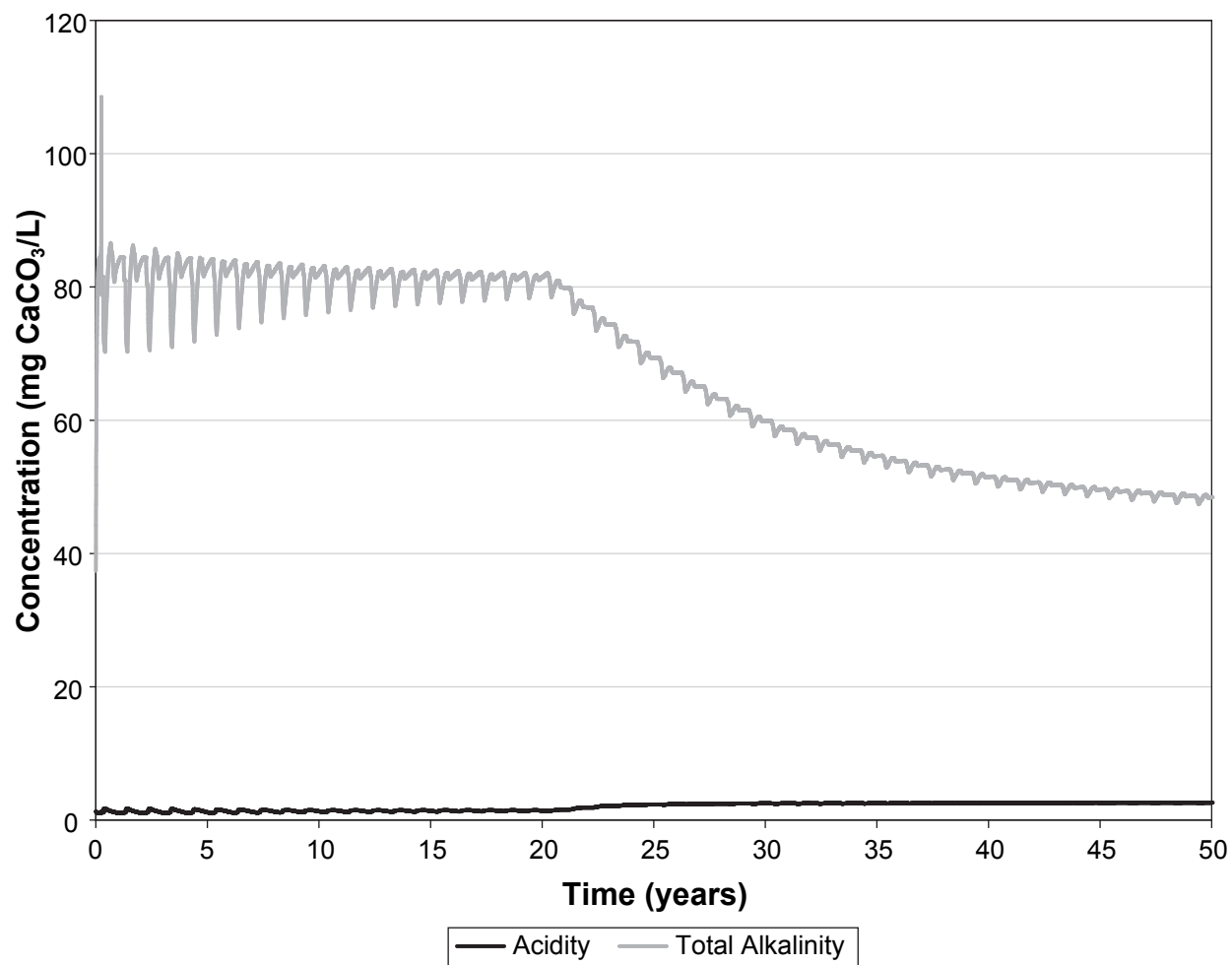
Table 7.2-1
Summary of Water Quality Inputs

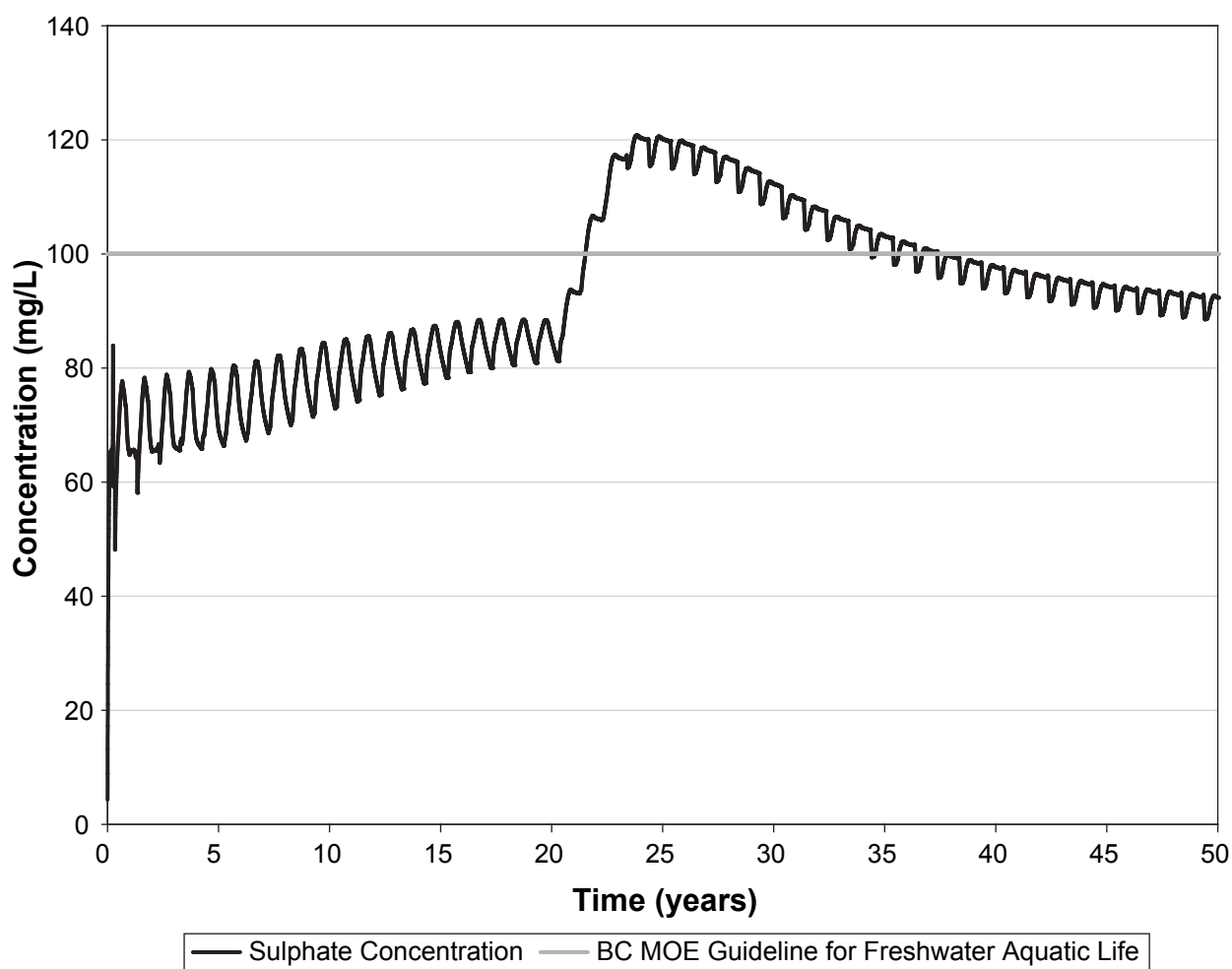
Input	Modelling approach / data
Precipitation directly on pit lake	Assumed to be pristine water
Natural runoff directly entering pit lake from upstream watersheds	Assumed equal to typical natural stream water from Baseline monitoring dataset
Runoff from disturbed areas within mine area	No additional loadings assumed water is passed through Process Plant
Tailings Slurry Water	Ageing supernatant data from SGS Lakefield test work.
Leachate from waste rock storage area	Assumed collected and becomes part of the pit dewatering stream. Does not enter TSF
Leaching from pit walls	Assumed collected and becomes part of the pit dewatering stream. Does not enter TSF
Leaching of submerged tailings material	None, once tailings are submerged there is zero additional loading
Leaching from exposed beached tailings	Assumed to be equal to adjusted SNPR 2.5+ assigned pH 7 loadings according to the Granisle EDCM
Leaching from runoff over dam face	Assumed to be equal to adjusted SNPR 2.5+ assigned pH 7 loadings according to the Granisle EDCM
Pit de-watering	Assumed collected and sent to Process Plant were water assumes tailings supernatant water quality
Residual mine related chemicals (ANFO)	Assumed analogue mine water quality
Geochemical Reactions	Solid-phase precipitation upon saturation for calcite, gypsum, gibbsite, goethite, cupricferrite and barite with metal(loid) adsorption onto goethite

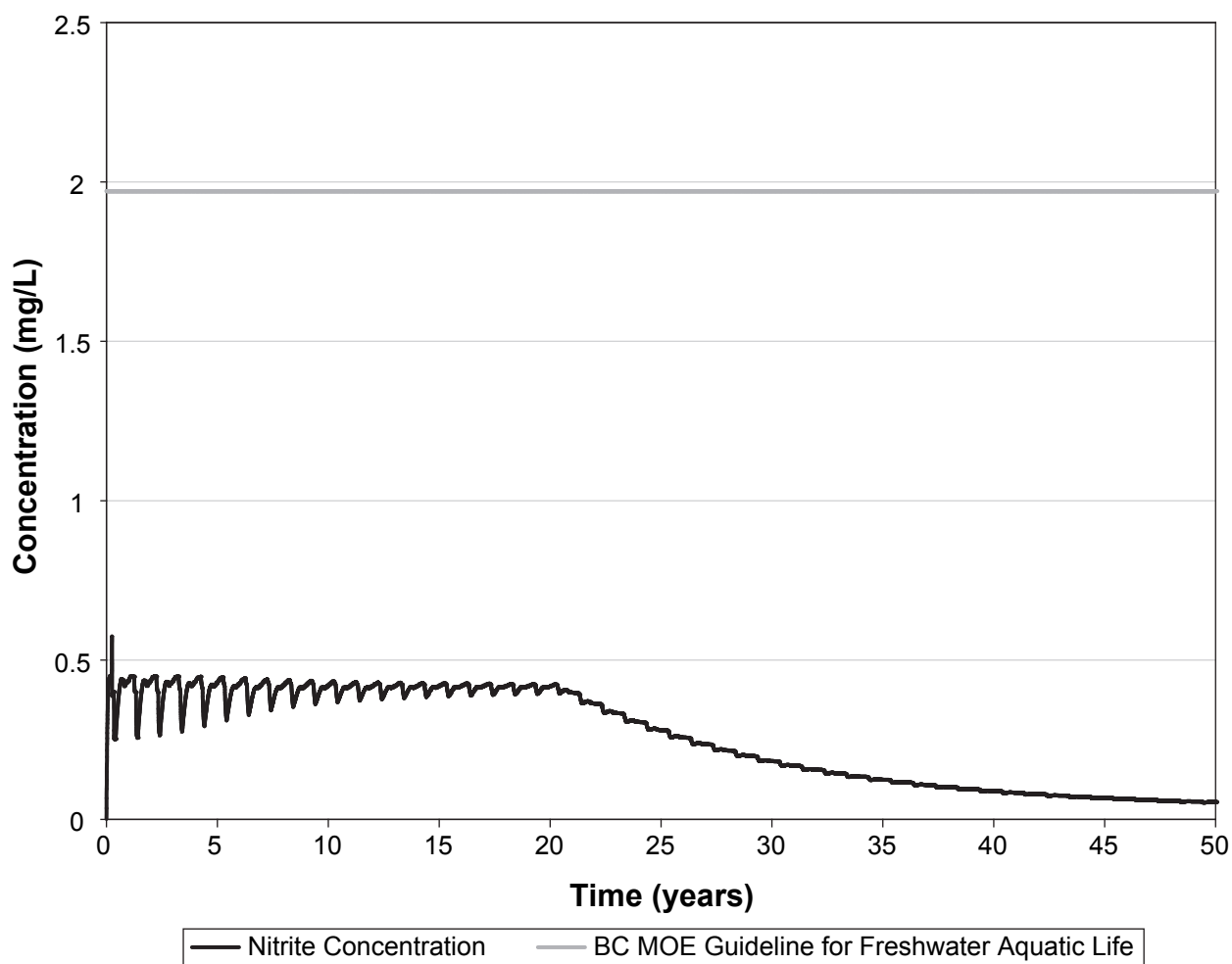
Predicted concentrations of key parameters at TSF overflow (predicted at Year 24) and at steady state (Year 99) are provided in Table 7.2-2 where they are compared to CCME and BC water quality guideline values as well as to tailings slurry water quality.

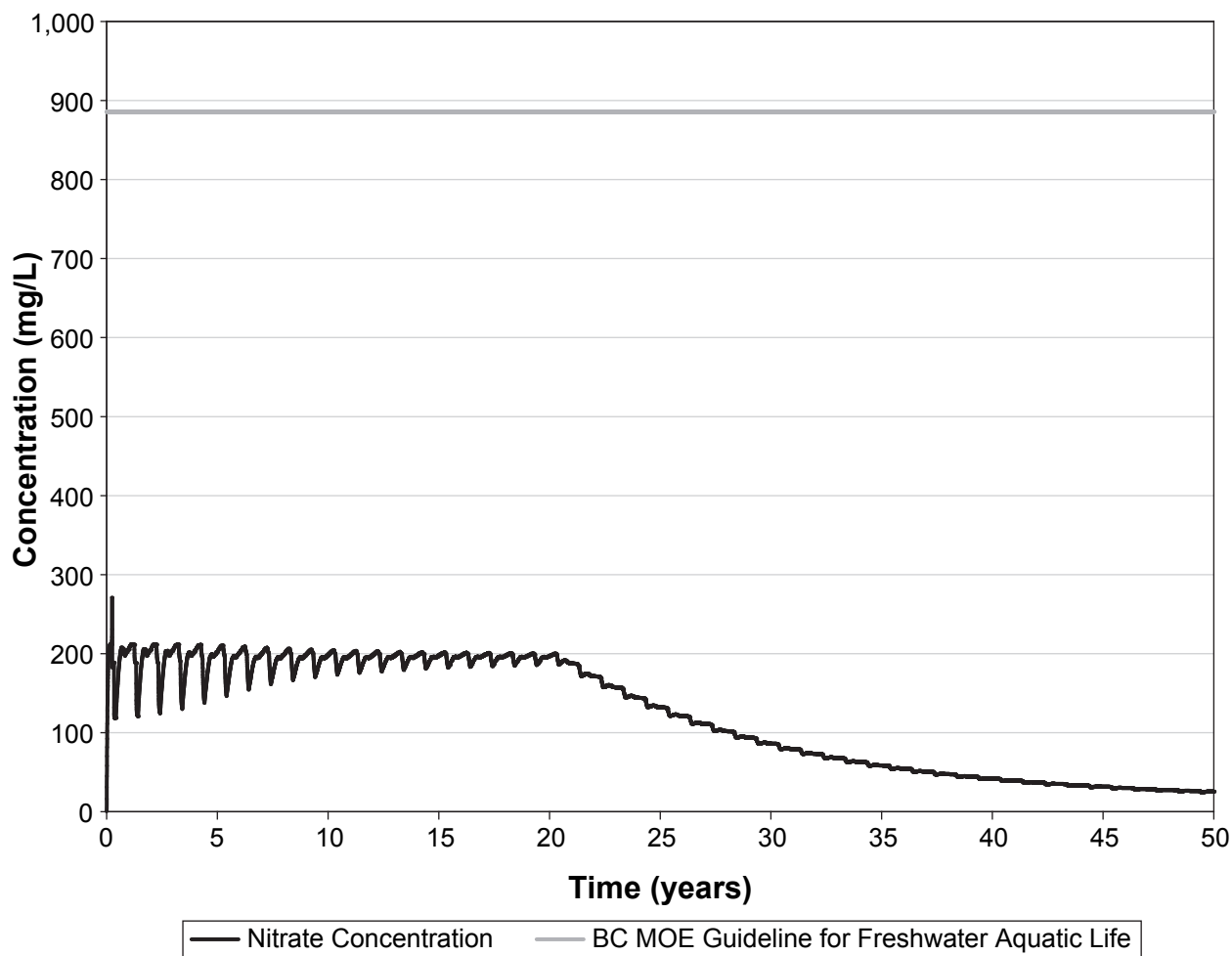
During operations, the dominant inflow to the pond is tailings slurry water. In addition, as the TSF pond water is used for reclaim water and is cycled through the process plant, the water chemistry in the TSF pond tends to tailings slurry water quality. The results in Table 7.2-2 illustrate that varying inputs to the TSF pond water balance does little to change the predicted chemistry within the TSF pond. The only means of changing the chemistry in the TSF pond significantly would be to vary the tailings slurry water quality.

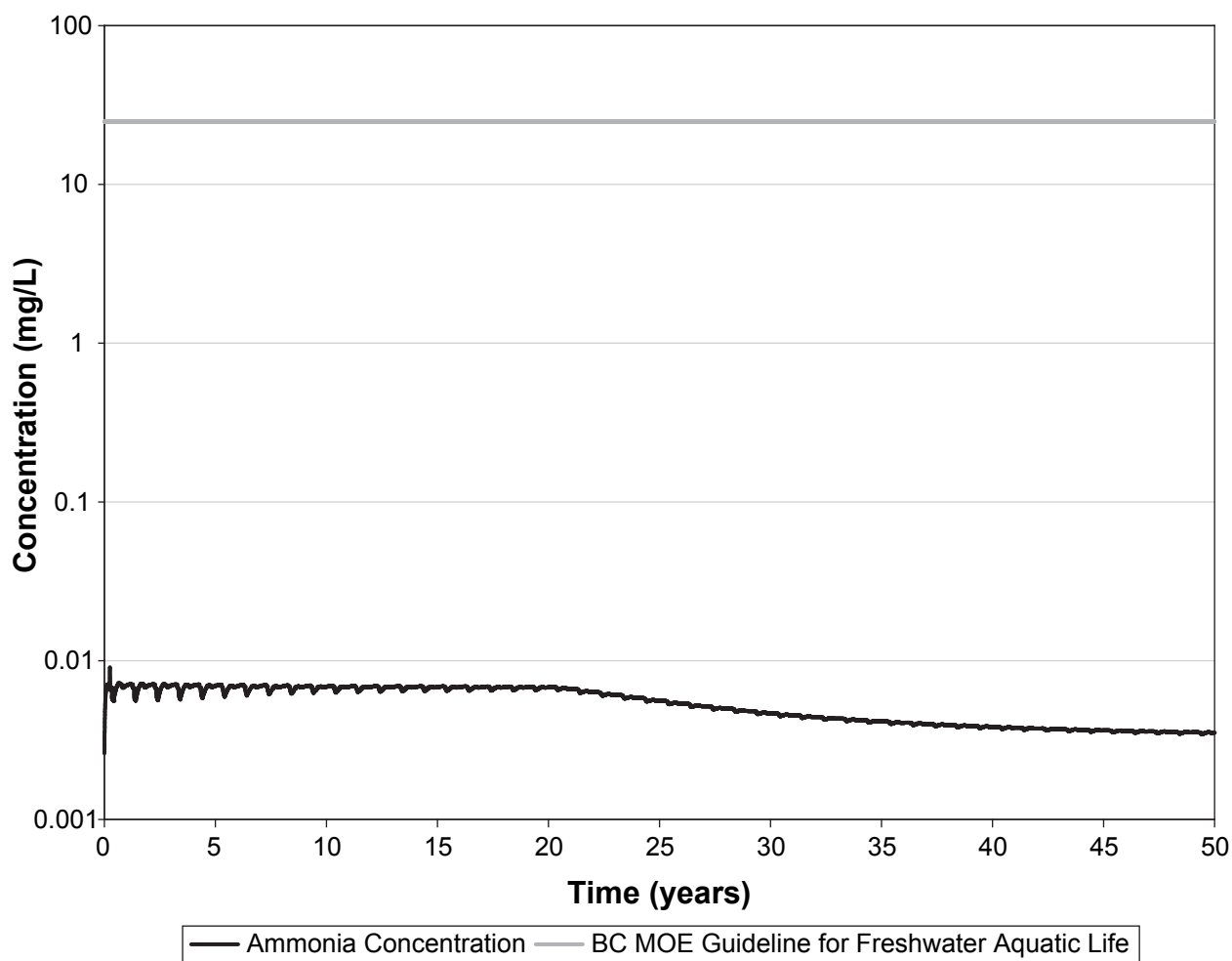
In summary, during operations the TSF pond water quality can be approximated to be equivalent to tailings slurry water quality. At the end of mining operations, tailings slurry discharges to the











Tailings Pond Water Quality

TSF will cease. At this time, the TSF pond water level would be expected to be below the final closure spillway elevation and there would be a period of time when the TSF pond fills up to the closure spillway level before water is able to discharge from the TSF.

Table 7.2-2
Model Water Quality Results for the TSF

Parameter	Type	Concentration at TSF Spill at 1013masl (year 24)	Concentration at Steady State at 1013masl (year 99)	BC Freshwater Aquatic Life Guideline	CCME Freshwater Aquatic Life Guideline
Sulphate	[Dissolved] [mg/L]	121	90	100	--
TDS	[Dissolved] [mg/L]	314	187	--	--
Fluoride	[Dissolved] [mg/L]	0.39	0.21	0.3	--
Chloride	[Dissolved] [mg/L]	23	2.4	600	--
Nitrite	[Dissolved] [mg/L]	0.31	0.034	0.6 / 0.12 ^a	0.06
Nitrate	[Dissolved] [mg/L]	144	16	200	2.9
Aluminum	[Dissolved] [mg/L]	0.0013	0.0013	0.1	--
	[Total] [mg/L]	0.026	0.025	--	0.1
Antimony	[Dissolved] [mg/L]	0.0081	0.0057	--	--
	[Total] [mg/L]	0.0078	0.0055	0.02	--
Arsenic	[Dissolved] [mg/L]	0.0066	0.0057	--	--
	[Total] [mg/L]	0.011	0.0091	0.005	0.005
Barium	[Dissolved] [mg/L]	0.015	0.018	--	--
	[Total] [mg/L]	0.022	0.026	5	--
Beryllium	[Dissolved] [mg/L]	0.00018	0.00025	--	--
	[Total] [mg/L]	0.00024	0.00033	0.0053	--
Bismuth	[Dissolved] [mg/L]	0.0028	0.003	--	--
	[Total] [mg/L]	0.0028	0.003	--	--
Cadmium	[Dissolved] [mg/L]	0.0004	0.00023	--	--
	[Total] [mg/L]	0.00057	0.00032	0.000048	0.000048
Calcium	[Dissolved] [mg/L]	42	28	--	--
	[Total] [mg/L]	46	31	--	--
Chromium	[Dissolved] [mg/L]	0.00068	0.00051	--	--
	[Total] [mg/L]	0.0044	0.0033	0.001	0.001
Cobalt	[Dissolved] [mg/L]	0.00095	0.00078	--	--
	[Total] [mg/L]	0.0019	0.0015	0.11	--
Copper	[Dissolved] [mg/L]	0.0013	0.0011	--	--
	[Total] [mg/L]	0.015	0.013	0.016 / 0.012 ^B	0.003 / 0.002 ^B
Iron	[Dissolved] [mg/L]	0.0000018	0.0000018	--	--
	[Total] [mg/L]	0.00027	0.00028	1	0.3
Lead	[Dissolved] [mg/L]	0.00097	0.00099	--	--
	[Total] [mg/L]	0.038	0.038	0.141 / 0.088 ^B	0.004 / 0.002 ^B
Lithium	[Dissolved] [mg/L]	0.0018	0.0022	--	--
	[Total] [mg/L]	0.0018	0.0022	5	--
Magnesium	[Dissolved] [mg/L]	12	8.7	--	--
	[Total] [mg/L]	13	9.3	--	--
Manganese	[Dissolved] [mg/L]	0.066	0.048	--	--
	[Total] [mg/L]	0.21	0.15	2.237 / 1.704 ^B	--

(continued)

**Table 7.2-2
Model Water Quality Results for the TSF (completed)**

Parameter	Type	Concentration at TSF Spill at 1013masl (year 24)	Concentration at Steady State at 1013masl (year 99)	BC Freshwater Aquatic Life Guideline	CCME Freshwater Aquatic Life Guideline
Mercury	[Dissolved] [mg/L]	0.00021	0.0000096	--	--
	[Total] [mg/L]	0.000087	0.000004	0.0001	0.000026
Molybdenum	[Dissolved] [mg/L]	0.033	0.0023	--	--
	[Total] [mg/L]	0.029	0.0021	2	0.073
Nickel	[Dissolved] [mg/L]	0.0043	0.0015	--	--
	[Total] [mg/L]	0.013	0.0046	0.11 / 0.065 ^B	0.11 / 0.065 ^B
Potassium	[Dissolved] [mg/L]	8.3	0.72	--	--
	[Total] [mg/L]	8.3	0.72	--	--
Selenium	[Dissolved] [mg/L]	0.00046	0.00046	--	--
	[Total] [mg/L]	0.00068	0.00068	0.002	0.001
Silicon	[Dissolved] [mg/L]	1.9	1.9	--	--
	[Total] [mg/L]	3.4	3.3	--	--
Silver	[Dissolved] [mg/L]	0.0055	0.0057	--	--
	[Total] [mg/L]	0.013	0.013	0.003 ^B	0.0001
Sodium	[Dissolved] [mg/L]	24	7.1	--	--
	[Total] [mg/L]	26	7.8	--	--
Tin	[Dissolved] [mg/L]	0.01	0.0086	--	--
	[Total] [mg/L]	0.01	0.0086	--	--
Titanium	[Dissolved] [mg/L]	0.057	0.06	--	--
	[Total] [mg/L]	0.057	0.06	0.1	--
Vanadium	[Dissolved] [mg/L]	0.019	0.02	--	--
	[Total] [mg/L]	0.22	0.23	--	--
Zinc	[Dissolved] [mg/L]	0.0044	0.0031	--	--
	[Total] [mg/L]	0.082	0.058	0.081 / 0.045 ^B	0.03
Acidity	[Dissolved] [mg/L]	2.3	2.6	--	--
Alkalinity	[Dissolved] [mg/L]	72	47	--	--
TSS	[Dissolved] [mg/L]	95	4.7	--	--
Ammonia	[Dissolved] [mg/L]	0.0058	0.0034	0.681	0.019
pH		7	7	--	6.5 to 9

Notes:

Bold values exceed BC and/or CCME Guideline

A: Guideline is based on Chloride concentration (Year 24 / Year 99)

B: Guideline is hardness dependant. Based on hardness of 154 for Year 24, and 106 for Year 99 (Year 24 / Year 99)

7.2.2 Summary of TSF Water Quality Results

The key conclusions for the TSF water quality modelling are:

- During operations TSF pond water quality will be controlled by the tailings slurry water quality because of the dominant influence of tailings slurry water on the annual TSF pond water balance. Predictions of tailings slurry water quality are based on the results of laboratory aging tests.
- Following the end of operations there will be a period of time when natural runoff to the TSF pond will provide some level of dilution to the TSF pond water before the TSF pond

water levels reach the closure spillway elevation, and the TSF pond water discharges and is transferred to the pit for pit filling.

- Over time the TSF pond water quality will improve because of dilution from natural runoff to the TSF. After 50 years post-closure, TSF pond water quality would be expected to improve to the point that the majority of water quality parameters would be below water guideline values, as presented in the results for Year 99. However, steady state predictions for a number of parameters (e.g., As, Cu, Ag, Zn) remain above guideline levels, and may not be suitable for direct discharge to the environment. Instead, any excess TSF pond water will be directed to the pit lake for further management. Directing TSF pond water to the pit will improve pit water quality by providing dilution, and also will contribute to faster filling of the pit. Submerging pit walls more rapidly will minimize ML/ARD.
- The potential for re-suspension (and therefore increased total metal concentrations in TSF pond water) of deposited tailings solids is present. Initial calculations (Appendix A) indicate that the TSF pond should be deep enough to avoid widespread re-suspension. This should be confirmed by the design engineers.
- During operations, the TSF pond will be operated as a “zero” surface discharge facility. As a result, there will be time during operations to collect data and to assess the evolving pond and porewater water quality within the TSF. Additional monitoring undertaken during operations will allow for changes to the ML/ARD Prediction and Prevention Plan (Section 13.17 of the EA) and Water Management Plan (Section 13.3 of the EA) to be adapted and implemented. These changes will also be reflected in the Mine Closure and Reclamation Plan (Chapter 16 of the EA) developed during the operational mine life to allow mitigation to be implemented in the event that TSF water quality deteriorates or is poorer than predicted.

8. Waste Rock Storage Area Water Quality

8.1 Water Quality Inputs

The only source of inflows to the waste rock storage area is direct precipitation. Precipitation is assumed to have pristine water quality, and therefore the flows exiting the waste rock storage area assume loadings from the waste rock that will contribute to the pit load balance.

As with the previous calculations of loadings, the water quality of each of the rock types of the waste rock storage area are developed as a concentration (in mg/L) for each parameter as an input to the model. The loadings are coupled with the precipitation and runoff coefficient for a given area to produce a mass inflow of mg/hr.

8.1.1 Natural Water Loadings

The precipitation that lands outside the progressively increasing waste rock dump footprint and does not infiltrate (50% during operations and 70% at closure) is assumed to have the water quality of the natural watershed areas, as previously described in Section 7.1.1.

8.1.2 Waste Rock Loadings

The remaining precipitation that enters the waste rock storage area as runoff or infiltration during operations is assumed to take on the water quality of the waste rock types (i.e., adjusted SNPRs categories with their assigned source term water qualities) on which it falls. This water will eventually enter into the pit load balance as an inflow. The water quality of the waste rock types is summarized in Section 9.1.2 of this report.

8.1.3 Waste Rock Storage Area Fractional Rock Types

The fractional area of each rock type within the waste rock storage area will dictate the loadings leaving the waste rock storage area. In general, a larger amount of PAG rock will generate more constituents with elevated concentrations than a lesser amount of PAG rock. Therefore, the breakdown of the volume and aerial extent of various waste rock types present in the waste rock storage area with respect to the mine life must be considered within the water quality prediction model. This proportional relationship of each adjusted SNPR category of rock in the waste rock storage area is a function of the tonnage mined. As described further in Section 9.1.3, the geochemical block model was combined with the mine schedule to produce the tonnage of each adjusted SNPR type of rock mined per year and the percent contribution to the overall waste rock storage area. The fractional amount of each adjusted SNPR rock type is shown in Table 8.1-1 during mining operations. The assigned source term water quality for each adjusted SNPR category of rock is presented in Section 9, Table 9.1-1.

Table 8.1-1
Fractional Waste Rock Type Areas in the Waste Rock Storage Area
During Mining Operations

Year	Adj-SNPR 0 to 0.5	Adj-SNPR 0.5 to 1.5	Adj-SNPR 1.5 to 2.5	Adj-SNPR >2.5
1	0.016	0.11	0.49	0.39
2	0.017	0.086	0.4	0.5
3	0.082	0.045	0.17	0.7
4	0.0066	0.026	0.69	0.27
5	0.0023	0.053	0.75	0.19
6	0.022	0.22	0.4	0.36
7	0.067	0.2	0.21	0.53
8	0.058	0.13	0.22	0.6
9	0.14	0.15	0.42	0.3
10	0.081	0.18	0.56	0.18
11	0.092	0.24	0.58	0.086
12	0.032	0.12	0.79	0.062
13	0.024	0.11	0.77	0.098
14	0.032	0.12	0.65	0.19
15	0.14	0.17	0.51	0.19
16	0.2	0.12	0.49	0.18
17	0.21	0.12	0.49	0.19
18	0.21	0.13	0.48	0.19
19	0.21	0.13	0.47	0.19

9. Open Pit Water Quality

9.1 Water Quality Inputs

Key sources of mass loadings to the open pit include:

- natural watershed inflows
- waste rock storage area surface water runoff
- waste rock storage area infiltration emanating from the toe as seeps or contribution to groundwater
- precipitation directly onto pit walls and associated runoff
- groundwater pit inflows

The water quality associated with each of the sources is developed as a concentration (in mg/L) for each parameter as an input to the model. The loadings are coupled with the water balance for a given area to produce a mass inflow of mg/hr. The general mass and water balance calculation used to derive resultant concentrations is shown below.

$$\text{Mass Loading (mg/hr)} = (\text{Concentration (mg/L)} \times \text{Flow Rate (m}^3\text{/hr)} \times 1000 \text{ L/m}^3) \quad \text{Eqn9.1-1a}$$

$$C_{\text{final}} = C_{\text{in}} \times (1 - e^{-1/\tau}) + C_{\text{initial}} \times e^{-1/\tau} \quad \text{Eqn9.1-1b}$$

Where C_{final} is the final concentration within the pit lake; C_{in} is the inflow concentration to the pit; τ is the residence time of the body of water; and C_{initial} is the initial concentration of the pit lake.

The model predicts concentrations of dissolved parameters; however, an estimation of the contribution from totals is also provided from the Granisle EDCM (Section 9.1.2) and is generally equal to the dissolved prediction. Selected predicted water quality concentrations within the pit are compared to relevant BC water quality guidelines provided by BC MOE.

The reader is encouraged to read Chapter 6 of Rescan's ML/ARD report (2009d) and references therein for developing and assigning mine component source term water quality used in predictive water quality modelling reported in the following sections.

9.1.1 Natural Water Inflows

Natural water inflows include surface water runoff from watersheds upstream of the open pit (termed natural runoff). The water quality of natural runoff upstream of the pit assumes the same water quality as the natural watersheds surrounding the pit, data obtained during the baseline monitoring program for the Project (Rescan 2008a, 2008b, 2009a), and summarized and described in Section 7.1.1.

Precipitation onto the pit lake is assumed to have a negligible effect to water quality for all modelled parameters.

9.1.2 Pit Wall and Waste Rock Storage Area Loadings

The water quality of contact water associated with the waste rock storage area and pit walls are summarized in Table 9.1-1 for the four adjusted SNPR criteria.

Analogue water quality for contact water from waste rock and pit wall rock was sourced from the Granisle mine site EDCM (Morin and Hutt 2007). The EDCM for Granisle was developed using approximately 1,200 water analyses taken between February 1980 and May 1999. The Granisle mine site was selected as an appropriate analogue because of the geological, mineralogical, and geochemical similarities to the Project and because this water quality is considered to be at equilibrium, meaning loadings will not change with time. Additionally, over one decade of post-closure water quality was collected for use in the Granisle mine site EDCM. Because the EDCM requires pH as an input for calculating water quality, reasonable and conservative pHs (Table 9.1-1) were selected that correspond to the relative reactivity of the four different adjusted SNPR categories discussed in Chapter 3. Further detail regarding the derivation of the waste rock and pit wall water quality can be found in Rescan's ML/ARD report (2009d).

**Table 9.1-1
Waste Rock and Pit Wall Water Quality**

Parameter	Units	SNPR <0.5	SNPR 0.5 to 1.5	SNPR 1.5 to 2.5	SNPR >2.5
		pH 3	pH 4.5	pH 5.5	pH 7
Sulphate	mg/L	10,814	2,111	1,834	1,486
TDS	mg/L	12,760	2,820	2,441	2,001
Fluoride	mg/L	3	3	3	3
Chloride	mg/L	30	30	30	30
Ammonia	mg/L	0.0072	0.0072	0.0072	0.0072
Nitrite-N	mg/L	0.46	0.46	0.46	0.46
Nitrate-N	mg/L	217	217	217	217
Aluminum	mg/L	738	5.94	1.34	0.143
Antimony	mg/L	0.1	0.1	0.1	0.1
Arsenic	mg/L	2.74	0.1	0.1	0.1
Barium	mg/L	0.032	0.032	0.032	0.032
Beryllium	mg/L	0.0143	0.00702	0.00438	0.00216
Bismuth	mg/L	0.05	0.05	0.05	0.05
Cadmium	mg/L	0.0242	0.0121	0.00766	0.00384
Calcium	mg/L	275	275	275	275
Chromium	mg/L	0.0782	0.0299	0.0158	0.00604
Cobalt	mg/L	7.19	0.156	0.0579	0.0131
Copper	mg/L	162	1.15	0.399	0.0811
Iron	mg/L	83.4	1.16	0.338	0.0533
Lead	mg/L	0.283	0.0991	0.0492	0.0172
Lithium	mg/L	0.0579	0.0291	0.0184	0.00927
Magnesium	mg/L	522	298	204	116
Manganese	mg/L	14.2	4.89	2.4	0.83
Mercury	mg/L	0.00001	0.00001	0.00001	0.00001

(continued)

Table 9.1-2
Waste Rock and Pit Wall Water Quality

Parameter	Units	SNPR <0.5	SNPR 0.5 to 1.5	SNPR 1.5 to 2.5	SNPR >2.5
		pH 3	pH 4.5	pH 5.5	pH 7
Molybdenum	mg/L	0.1	0.1	0.1	0.0275
Nickel	mg/L	2.67	0.129	0.0636	0.022
Potassium	mg/L	6.25	6.25	6.25	6.25
Selenium	mg/L	0.1	0.1	0.1	0.1
Silicon	mg/L	18.7	3.7	3.7	3.7
Silver	mg/L	0.0075	0.0075	0.0075	0.0075
Sodium	mg/L	80	80	80	80
Tin	mg/L	0.15	0.15	0.15	0.15
Titanium	mg/L	0.5	0.5	0.5	0.5
Vanadium	mg/L	0.35	0.35	0.35	0.35
Zinc	mg/L	15.7	0.222	0.119	0.0465
Acidity	mg CaCO ₃ /L	3,443	128	62.2	21.2
Alkalinity	mg CaCO ₃ /L	0	2.94	11.3	84.7

Notes:

1 – Metal(loid) values are for dissolved.

2 – Source of EDCM (Morin and Hutt 2007).

3 – TDS calculated from sum of listed ions.

4 - Values in orange indicated maximum concentrations from the Granisle site wide water quality (Morin and Hutt 2003).

Morin and Hutt (2007) compared both Bell Mine EDCM data and Granisle EDCM data to available Morrison kinetic data at equilibrium and concluded that both the Bell and Granisle EDCM can be used as predictors of Morrison drainage chemistry for acidic and alkaline pH. Justification for the use of the Granisle EDCM as an analogue for the Morrison project include the following.

- Similar geology and mineralogy between Granisle and Morrison rock.
- The majority of Granisle data supporting the EDCM is from post-closure which assists in modelling the Morrison Pit Lake water quality (WQ).
- A larger list of predictable parameters is available in the Granisle EDCM as presented in Morin and Hutt (2007).
- The Granisle EDCM provides a conservative (i.e., worst case higher concentration) prediction of rock drainage chemistry at a range of pHs.

Two conservative assumptions for the prediction of water quality were employed and include:

1. Acidic pH from rock with adjusted SNPRs less than 2.5 develops as soon as materials are excavated from the pit, pit walls are exposed, and materials are placed in the waste rock dump.
2. Contact water from waste rock or pit walls collected during operations and directed to the process plant for process purposes takes on the water quality characteristics of tailings slurry water (aging test supernatant data) discussed in Section 7.1-2.

Approximately 0.24 kg of ammonia nitrate fuel oil (ANFO) per tonne of ore and waste rock will be used in materials blasting throughout the operational mine life when conditions are dry or if the blasthole can be pumped and lined. It is anticipated that approximately 5% of the blast holes will be “wet” where emulsion explosives will be used. An alternative explosive is a 70/30 ANFO-Emulsion blend that can be used in wet or dry blast holes.

The generation of nitrogen species at a mine site is generally governed by detonating ANFO during blasting activities, producing oxides of nitrogen as unwanted by-products from incomplete blasting reactions. Nitrogen species (i.e., nitrate, ammonia, and nitrite) concentrations in contact water were estimated using analogue water quality data from a BC mine with one important assumption listed below.

1. Ammonia in waste rock and pit wall contact water is assumed to mostly volatilize under aerobic conditions in runoff or in pit lake mixing.

9.1.3 Pit Wall Runoff

The proportions of each adjusted SNPR rock type area at a certain elevation within the pit were derived as described in Chapter 3 as a means of determining the proportion and volume of associated contact water quality as the pit fills on closure. On closure, the pit wall above 728 masl will be exposed indefinitely to maintain a reverse groundwater hydraulic gradient into the pit. The amount of exposed pit wall rock consists of all four adjusted SNPR rock types, and depending on the level of the water within the pit, a different total loading from each rock type will contribute to pit lake water quality. A pit lake elevation related to the proportion of exposed rock type relationship was developed to take this into account. The cumulative pit wall adjusted SNPR rock type proportions are shown in Table 9.1-2.

Table 9.1-2
Cumulative Proportions of Adjusted SNPR Areas per 12 m Bench

Elevation (masl)	SNPR 0 to 0.5	SNPR 0.5 to 1.5	SNPR 1.5 to 2.5	SNPR >2.5
486	0.00	0.00	0.01	0.00
498	0.00	0.01	0.01	0.01
510	0.00	0.01	0.02	0.02
522	0.00	0.02	0.02	0.03
534	0.00	0.04	0.03	0.03
546	0.00	0.05	0.03	0.04
558	0.00	0.06	0.04	0.05
570	0.00	0.07	0.04	0.06
582	0.00	0.09	0.05	0.06
594	0.01	0.10	0.05	0.07
606	0.01	0.12	0.06	0.08
618	0.01	0.13	0.07	0.08
630	0.01	0.15	0.08	0.09
642	0.02	0.17	0.09	0.09
654	0.02	0.19	0.09	0.10

(continued)

Table 9.1-2
Cumulative Proportions of SNPR Areas Per 12 m Bench (completed)

Elevation (masl)	SNPR 0 to 0.5	SNPR 0.5 to 1.5	SNPR 1.5 to 2.5	SNPR >2.5
666	0.02	0.21	0.10	0.11
678	0.03	0.23	0.11	0.11
690	0.03	0.25	0.12	0.12
702	0.04	0.27	0.13	0.12
714	0.05	0.29	0.14	0.13
726	0.06	0.32	0.14	0.13
738	0.06	0.34	0.15	0.14
750	0.08	0.37	0.16	0.14
762	0.09	0.39	0.16	0.14
774	0.10	0.41	0.17	0.15
786	0.11	0.43	0.17	0.16
798	0.13	0.44	0.17	0.17
810	0.14	0.46	0.17	0.17
822	0.15	0.47	0.17	0.17
834	0.16	0.48	0.18	0.17
846	0.17	0.48	0.18	0.17
858	0.17	0.48	0.18	0.17
870	0.17	0.48	0.18	0.17

Although pit lake water quality is assumed to be at equilibrium, pit walls cannot provide an infinite source of elemental loadings. Assuming a 20-m blast influence, adjusted SNPR areas above the final pit lake elevation shown in Chapter 3, an average rock density of 2.7 tonne/m³, and the 25th percentile solid-phase elemental concentrations, a finite source of loadings from pit wall runoff is shown in Table 9.1-3. The 25th percentile was chosen because of the expected decrease in elements such as copper, molybdenum, and zinc outwards from the ore zone. Similar estimates using average whole crustal abundance from Price (1997) are also provided for comparison, and show an order of magnitude difference for copper, molybdenum, arsenic, and two orders (marginal) of magnitude differences for selenium. This is not unreasonable for the fringes of a copper-porphyry deposit. Long-term post-closure water quality predictions are checked against these elemental values, and it was determined that predictions do not approach depleting this elemental reservoir.

9.1.4 Groundwater Loadings

Groundwater quality data were obtained through monitoring groundwater wells near the open pit throughout 2007 and 2008 (37 sampling events were performed; Rescan 2009c). Data from six groundwater wells were used to represent the groundwater quality for incorporation into the pit lake water quality prediction model (i.e., MW-01 A and B, MW-02 A and B, MW-05 A and B, MW-06 A and B, MW-07 A and B, and MW-08 A and B). Further details regarding the locations of these groundwater wells can be found in Rescan (2009c). The water quality associated with the groundwater inflows are summarized in Table 9.1-4.

9.1.5 Geochemical Reactivity

Geochemical reactivity within the model is taken into account and discussed in Section 6.9 of Rescan's ML/ARD report (2009d). Briefly, credible equilibrium phases calcite, gypsum, goethite, gibbsite, cupricferrite, and barite were allowed to precipitate if saturation was achieved. In addition, metal(loid) adsorption onto goethite was taken into account. Both of these geochemical processes provide natural attenuating mechanisms that limit the dissolved and total metal(loid) concentrations in predicted water quality.

9.1.6 Pit Lake Mixing

A major assumption of the water quality prediction model is a fully mixed pit lake. The model assumes instantaneous full mixing and further investigations into the evolution of a stratified pit lake are recommended verify this assumption.

The stratification of lakes is important in evaluating water quality, and it is necessary to determine whether or not stratification will occur in the pit lake at the Project. For lakes and reservoirs already in existence, stratification can be evaluated through using vertical profiles for temperature and water quality. However, for proposed projects such as the Project, it is necessary to use an analytical method to estimate the potential for stratification.

Stratification is a function of several factors, which include heat exchange, depth of the lake, bathymetry, in and out flows, and wind effects. In general, lakes tend to stratify when their mean depths are exceed 10 m and the mean annual residence times are greater than 20 days. The Froude number (F_d) provides a general indication of potential stratification within the proposed Morrison pit lake and is governed by the following relationship:

$$F_d = \sqrt{\frac{1}{ge}} \frac{LQ}{D_m V}$$

Where g is acceleration because of gravity (9.81 m/s^2), e is a dimensionless density gradient (10^{-6} m^{-1}), L is the pit lake length ($\sim 1000 \text{ m}$), Q is the average discharge from the pit lake ($\sim 0.100 \text{ m}^3/\text{s}$, an estimate of the average volume of water to be pumped from the pit to maintain), D_m is the mean depth of the pit lake (120 m), and V is the pit lake final volume ($\sim 77 \text{ Mm}^3$). Notably, the pit lake depth is actually 250 m , but a value of 120 m was used to account for the conical shape of the open pit to produce an average depth. Evaluating the above relationship yields a value of 1.5×10^{-7} . When the value of $F_d \gg 1/\pi$, it can be assumed that the reservoir is very well mixed. Furthermore, when $F_d \ll 1/\pi$, the reservoir is expected to be very well stratified. Based on this assessment, the pit lake could become stratified, at least for a portion of the year. The above assessment does not consider the stability of the stratification once it is produced.

The potential for stratification and stability at other mine sites was investigated as a means of further understanding the potential for stratification at the Project. Morin and Hutt (2003) found that the temperature profiles in the Granisle pit indicated a minor chemocline was present at approximately 8-m depth. This was also associated with a significant thermocline, in which surficial temperatures of approximately 18°C decreased to 4.5 to 5.0°C as depth increased.

Because water reaches a maximum temperature of 4°C, the deeper water with the higher conductivity was considered more stable than the shallow water. Thus, the potential in August (i.e., the warmest seasonal temperatures) for any instability, turnover, and deep mixing was considered to be very low. However, the very consistent chemistry below the chemocline, which extended through greater than 40 m of the water column, indicates that there is some mechanism present for thorough mixing in the Granisle mine site pit lake. As a result, it is not possible to reliably explain the complex hydrodynamics of the Granisle mine site pit lake.

In addition to the Granisle mine site pit lake, the Bell mine site pit lake was assessed by Morin and Hutt (2003). In August 2002, the Bell mine site pit lake contained very acidic water with a fairly high level of dissolved solids. No significant chemoclines or thermoclines were present in both field and laboratory data at depths greater than 7 m extending to the ultimate depth of data measurement of 152 m. The bottom depth of the pit lake was estimated at 162 m. However, it was found that above 7 m depth, there were warmer temperatures and variability in the conductivity, both above and below the deeper value. This was attributed to pumping acidic and highly concentrated metal contact water from the mine site collection ponds into the pit during the non-winter months. In general, the overall trends in August indicate that each year's pumping volume will be stratified at the surface initially, and eventually mixing with the remainder of the water column will occur.

The above discussion of nearby Granisle and Bell mine site pit lakes indicate “remnants” of stratification and suggest the proposed Project pit lake will stratify with periods of stability. Water quality of the surface of the pit lake will respond to the physical behaviour of the lake. In addition, the geochemical nature of the initial pit lake will determine salinity, and therefore density behaviour. Future water treatment plant designs need to consider the geochemical and physical behaviour of the pit lake.

9.2 Water Quality Results

Table 9.2-1 shows the pit water quality at final pit lake elevation, occurring in Year 42, and at steady state after closure. The steady state values were selected 100 years after the start of the mine life and indicate that parameters will level off to a constant value provided that inflows remain constant, the pit lake remains fully mixed, and no major fluctuations in source loadings occur. Figures 9.2-1 to 9.2-5 show the water quality of non-metals throughout the Project life with comparisons to BC MOE freshwater aquatic life guidelines. Several parameters are elevated (e.g., copper and sulphate) and in general are caused by the net acidity in the pit lake generated by the large proportions of reactive wall rock exposed on closure that are assigned Granisle EDCM equilibrium water quality source terms. Note that at the predicted pH, backed out from the Granisle EDCM acidity-alkalinity mass balance, reactive geochemical processes (i.e., cupricferrite precipitation and goethite adsorption) provide minimal modelled natural attenuation.

Table 9.2-1
Predicted Pit Lake Water Quality at Final Pit Lake Elevation (728 masl)
and at Steady State

Parameter	Type	Concentration at Pit "Spill" at Final Lake Elevation 728masl (year 42)	Concentration at Steady State at Final lake Elevation 728masl (year 99)
Sulphate	[Dissolved] [mg/l]	1,704	1,873
TDS	[Dissolved] [mg/l]	2,503	2,671
Fluoride	[Dissolved] [mg/l]	1.5	1.5
Chloride	[Dissolved] [mg/l]	18	16
Nitrite	[Dissolved] [mg/l]	0.22	0.21
Nitrate	[Dissolved] [mg/l]	98	90
Aluminum	[Dissolved] [mg/l]	72	86
	[Total] [mg/l]	72	86
Antimony	[Dissolved] [mg/l]	0.041	0.041
	[Total] [mg/l]	0.20	0.20
Arsenic	[Dissolved] [mg/l]	0.036	0.35
	[Total] [mg/l]	0.036	0.35
Barium	[Dissolved] [mg/l]	0.0029	0.0030
	[Total] [mg/l]	0.0029	0.0030
Beryllium	[Dissolved] [mg/l]	0.0035	0.0036
	[Total] [mg/l]	0.0035	0.0036
Bismuth	[Dissolved] [mg/l]	0.021	0.021
	[Total] [mg/l]	0.021	0.021
Cadmium	[Dissolved] [mg/l]	0.0052	0.0055
	[Total] [mg/l]	0.0052	0.0055
Calcium	[Dissolved] [mg/l]	152	149
	[Total] [mg/l]	152	149
Chromium	[Dissolved] [mg/l]	0.015	0.016
	[Total] [mg/l]	0.015	0.016
Cobalt	[Dissolved] [mg/l]	0.72	0.86
	[Total] [mg/l]	0.72	0.86
Copper	[Dissolved] [mg/l]	16	19
	[Total] [mg/l]	16	19
Iron	[Dissolved] [mg/l]	4.7	10
	[Total] [mg/l]	4.7	10
Lead	[Dissolved] [mg/l]	0.048	0.052
	[Total] [mg/l]	0.048	0.052
Lithium	[Dissolved] [mg/l]	0.020	0.020
	[Total] [mg/l]	0.020	0.020
Magnesium	[Dissolved] [mg/l]	135	140
	[Total] [mg/l]	135	140
Manganese	[Dissolved] [mg/l]	3.2	3.4
	[Total] [mg/l]	3.2	3.4

(continued)

Table 9.2-1
Predicted Pit Lake Water Quality at Final Pit Lake Elevation (728 masl)
and at Steady State (completed)

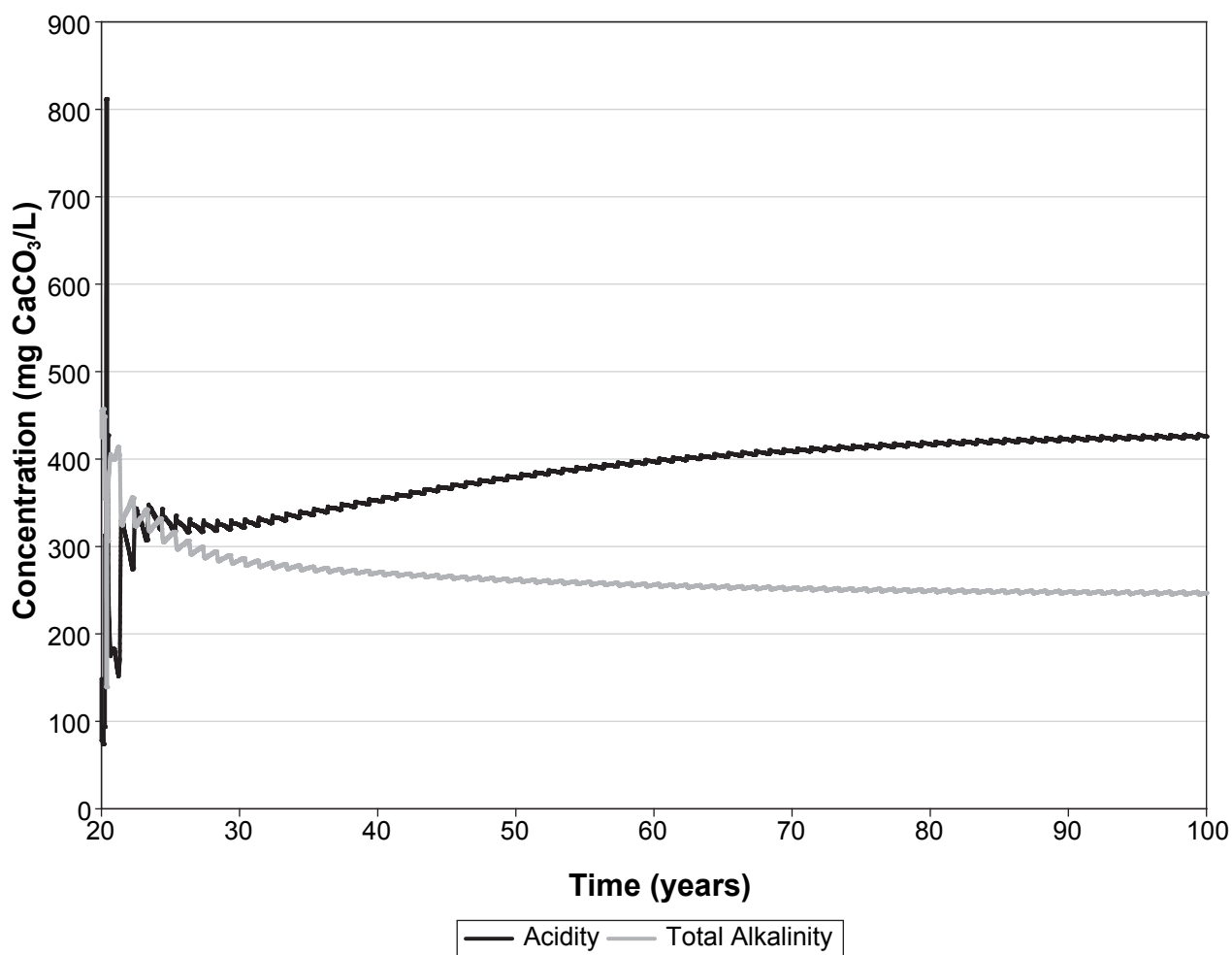
Parameter	Type	Concentration at Pit "Spill" at Final Lake Elevation 728masl (year 42)	Concentration at Steady State at Final lake Elevation 728masl (year 99)
Mercury	[Dissolved] [mg/l]	0.000028	0.000014
	[Total] [mg/l]	0.000028	0.000014
Molybdenum	[Dissolved] [mg/l]	0.044	0.042
	[Total] [mg/l]	0.044	0.042
Nickel	[Dissolved] [mg/l]	0.29	0.34
	[Total] [mg/l]	0.29	0.34
Potassium	[Dissolved] [mg/l]	5.2	4.5
	[Total] [mg/l]	5.2	4.5
Selenium	[Dissolved] [mg/l]	0.040	0.041
	[Total] [mg/l]	0.040	0.041
Silicon	[Dissolved] [mg/l]	6.6	6.7
	[Total] [mg/l]	6.6	6.7
Silver	[Dissolved] [mg/l]	0.040	0.040
	[Total] [mg/l]	0.040	0.040
Sodium	[Dissolved] [mg/l]	120	111
	[Total] [mg/l]	120	111
Tin	[Dissolved] [mg/l]	0.061	0.061
	[Total] [mg/l]	0.061	0.061
Titanium	[Dissolved] [mg/l]	0.41	0.41
	[Total] [mg/l]	0.41	0.41
Vanadium	[Dissolved] [mg/l]	0.14	0.14
	[Total] [mg/l]	0.14	0.14
Zinc	[Dissolved] [mg/l]	1.6	1.9
	[Total] [mg/l]	1.6	1.9
Acidity	[Dissolved] [mg/l]	363	428
Alkalinity	[Dissolved] [mg/l]	269	248
TSS	[Dissolved] [mg/l]	283	252
Ammonia	[Dissolved] [mg/l]	0.083	0.076
pH		4.5	4.0

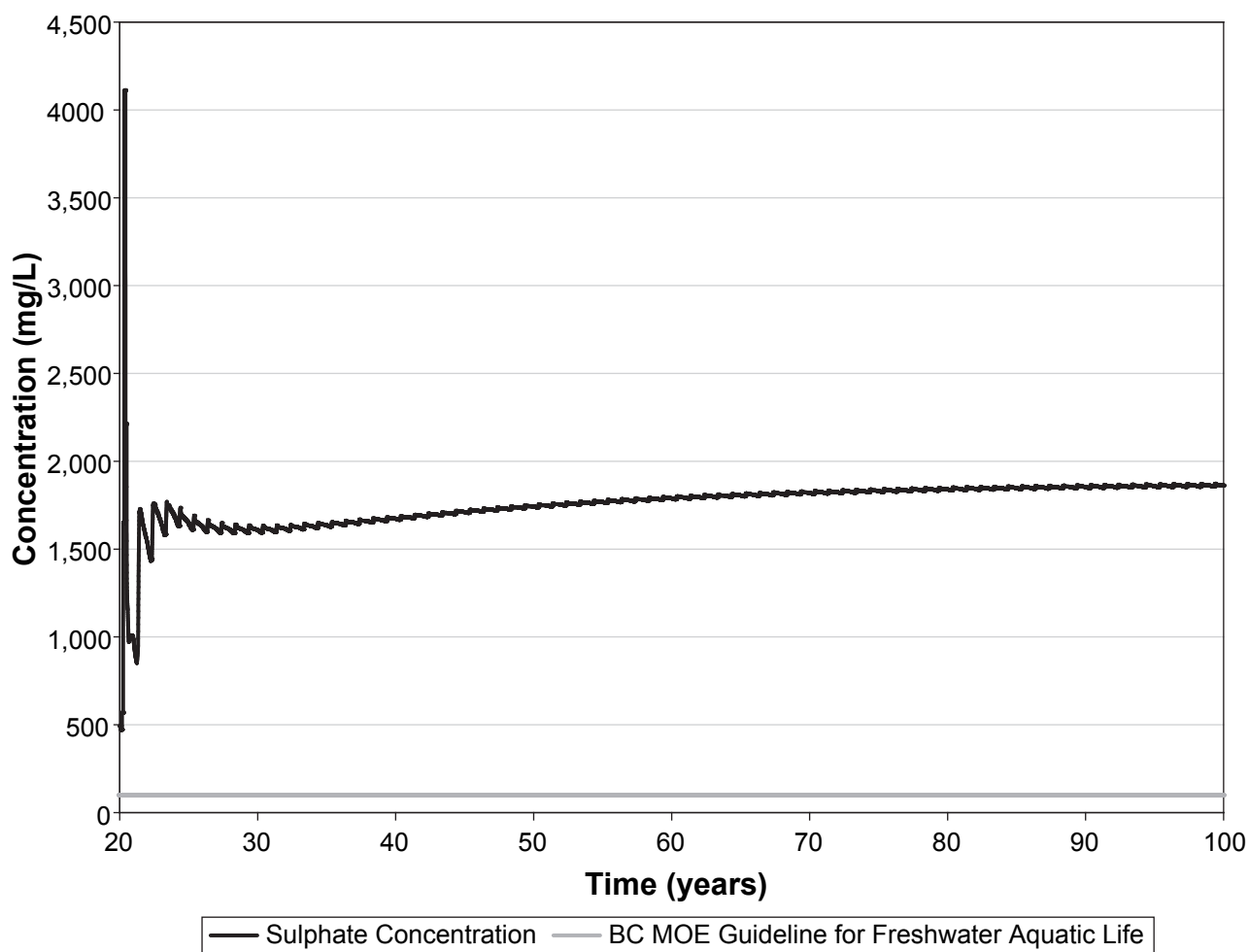
Table 9.2-2
Morrison Copper/Gold Project: Solid-Phase Elemental Reservoirs in 20 m of Pit Wall Rock

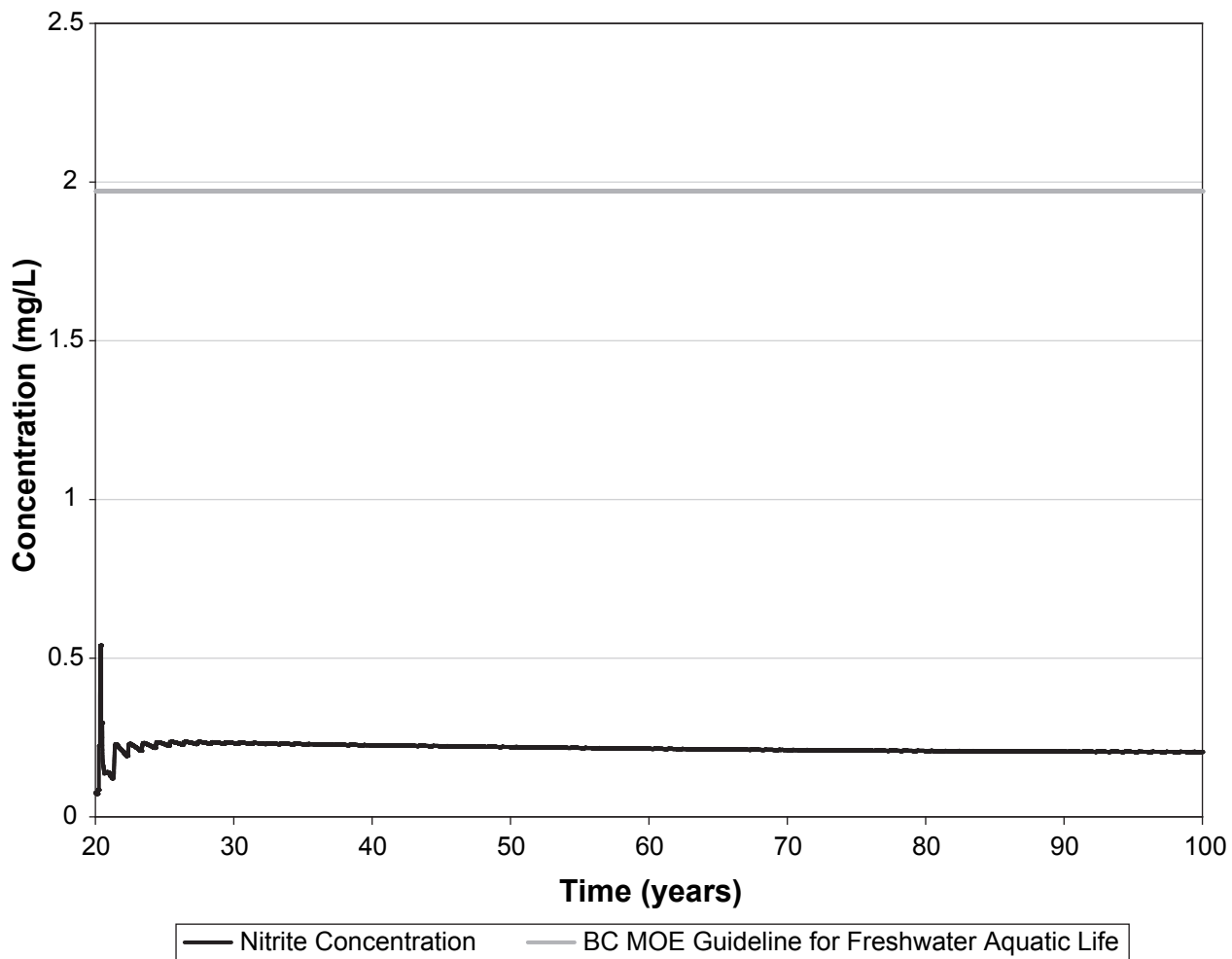
Parameter	Average Whole Crustal (ppm)	Adj-SNPR <0.5 25 th Percentile (ppm)	Adj-SNPR 0.5 to 1.5 25 th Percentile (ppm)	Adj-SNPR 1.5 to 2.5 25 th Percentile (ppm)	Adj-SNPR>2.5 25 th Percentile (ppm)	Adj- SNPR<0.5 Solid-phase (tonnes)	Adj-SNPR 0.5 to 1.5 Solid-phase (tonnes)	Adj-SNPR 1.5 to 2.5 Solid-phase (tonnes)	Adj-SNPR >2.5 Solid-phase (tonnes)	Adj-SNPR Total Solid-phase (tonnes)	Average Crustal Solid-phase (tonnes)
Ag	0.080	0.30	0.70	0.81	0.51	6	9	8	3	27	2.6
Al	83,600	78,375	74,300	74,850	77,775	844,674	812,907	806,934	851,190	3,621,005	2,728,142
As	1.8	13	3.4	5.3	11	121	57	37	137	385	59
Ba	390	333	360	353	183	1,982	3,828	3,910	3,611	14,559	12,727
Be	2.0	1.2	1.1	0.99	1.00	11	11	12	13	50	65
Bi	0.0082	0.18	0.14	0.16	0.15	2	2	2	2	7.5	0.27
Ca	46,600	1,850	10,100	15,250	24,425	265,267	165,622	109,691	20,092	612,297	1,520,711
Cd	0.16	0.058	0.10	0.10	0.090	1	1	1	1	4.1	5.2
Co	29	15	14	13	12	132	140	154	166	647	946
Cr	122	69	70	68	62	676	739	760	749	3,193	3,981
Cu	68	306	1,445	1,555	1,134	12,313	16,888	15,693	3,321	52,655	2,219
Fe	62,200	29,300	29,700	29,425	29,400	319,298	319,570	322,556	318,212	1,397,461	2,029,790
Hg	0.086	0.060	0.040	0.033	0.020	0	0	0	1	1.8	2.8
K	18,400	10,975	7,300	6,525	6,825	74,123	70,865	79,282	119,194	375,088	600,452
Li	18	22	18	18	15	168	194	195	240	871	587
Mg	27,640	3,675	6,900	7,075	9,050	98,287	76,838	74,937	39,912	316,675	901,984
Mn	1,060	172	226	247	209	2,273	2,677	2,454	1,865	10,123	34,591
Mo	1.2	1.8	3.5	6.6	7.8	85	72	38	20	234	39
Na	22,700	800	600	500	1,025	11,132	5,430	6,516	8,688	34,692	740,775
Ni	99	44	41	45	49	531	492	447	483	2,134	3,231
P	1,120	298	550	520	828	8,987	5,647	5,973	3,231	26,034	36,549
Pb	13	5.1	6.4	6.8	6.8	74	74	70	55	298	424
S	340	5,250	5,500	6,450	7,725	83,897	70,050	59,733	57,018	295,622	11,095
Sb	0.20	1.2	0.62	0.68	0.51	6	7	7	13	36	6.5
Se	0.050	2.0	2.0	2.0	3.0	33	22	22	22	107	1.6
Sn	2.1	1.3	1.4	1.5	1.8	20	16	15	14	71	69
Sr	384	153	195	156	275	2,984	1,697	2,112	1,662	9,233	12,531
Ti	6,320	3,120	3,250	3,325	3,500	38,012	36,111	35,297	33,885	156,499	206,242
Tl	0.72	0.56	0.33	0.35	0.28	3	4	4	6	18	23
U	2.3	1.4	1.3	1.3	1.1	12	14	14	15	60	75
V	136	115	111	116	116	1,260	1,260	1,206	1,246	5,429	4,438
Zn	76	41	54	66	68	739	720	586	445	2,719	2,480

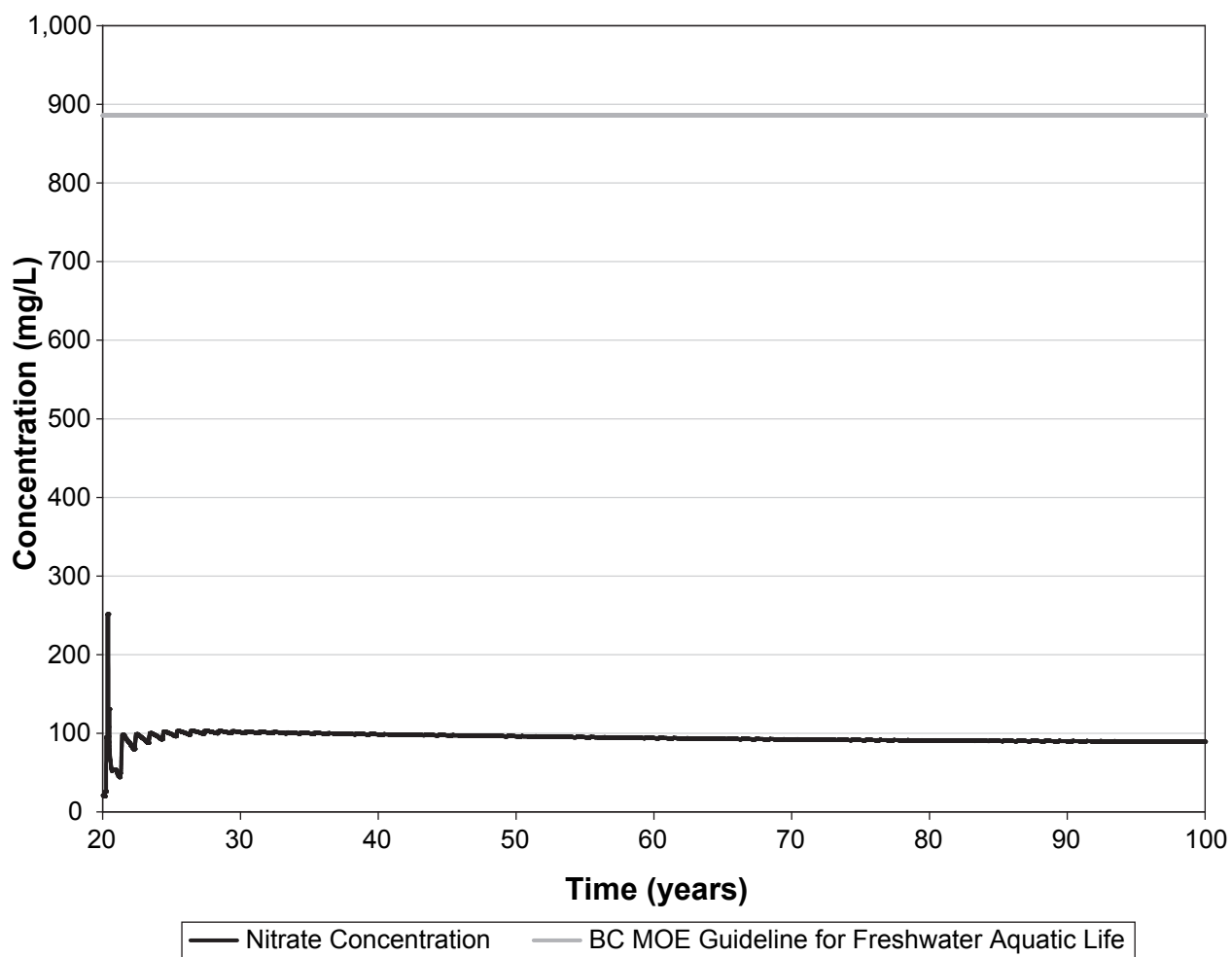
Table 9.2-3
Average Groundwater Quality near the Proposed Morrison
Copper/Gold Project Pit

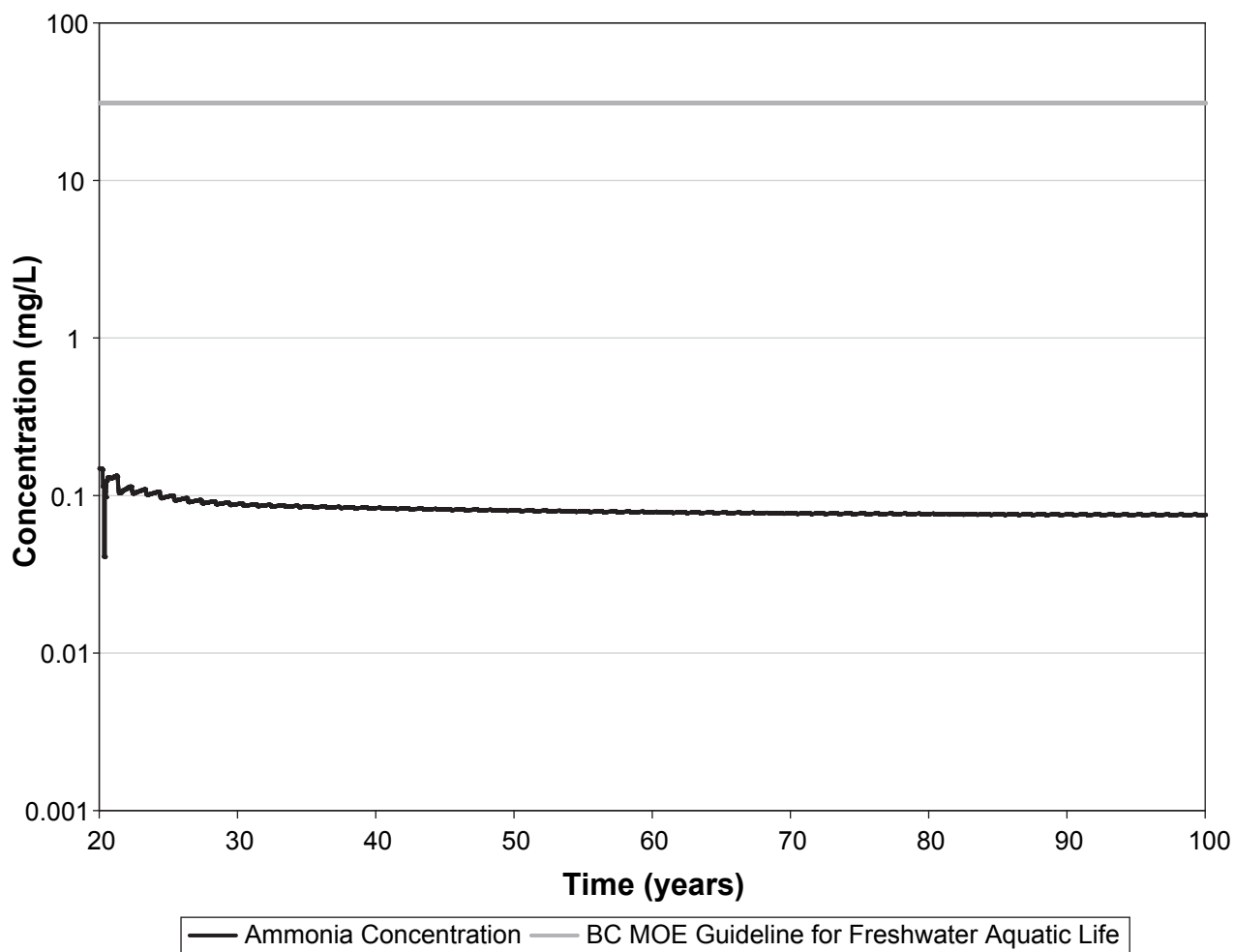
Parameter	Units	Concentration
Sulphate	mg/L	165
TDS	mg/L	762
Fluoride	mg/L	0.49
Chloride	mg/L	8.2
Nitrite	mg/L	0.0084
Nitrate	mg/L	0.034
Aluminum	mg/L	0.37
Antimony	mg/L	0.0021
Arsenic	mg/L	0.019
Barium	mg/L	0.12
Beryllium	mg/L	0.00083
Bismuth	mg/L	0.00083
Cadmium	mg/L	0.000096
Calcium	mg/L	70
Chromium	mg/L	0.0019
Cobalt	mg/L	0.0029
Copper	mg/L	0.0034
Iron	mg/L	0.74
Lead	mg/L	0.00020
Lithium	mg/L	0.014
Magnesium	mg/L	25
Manganese	mg/L	1.7
Mercury	mg/L	0.0000098
Molybdenum	mg/L	0.013
Nickel	mg/L	0.0050
Potassium	mg/L	4.0
Selenium	mg/L	0.00057
Silicon	mg/L	5.8
Silver	mg/L	0.000020
Sodium	mg/L	172
Tin	mg/L	0.00042
Titanium	mg/L	0.0069
Vanadium	mg/L	0.0042
Zinc	mg/L	0.0076
Acidity	mg CaCO ₃ /L	12
Alkalinity	mg CaCO ₃ /L	484
TSS	mg/L	546











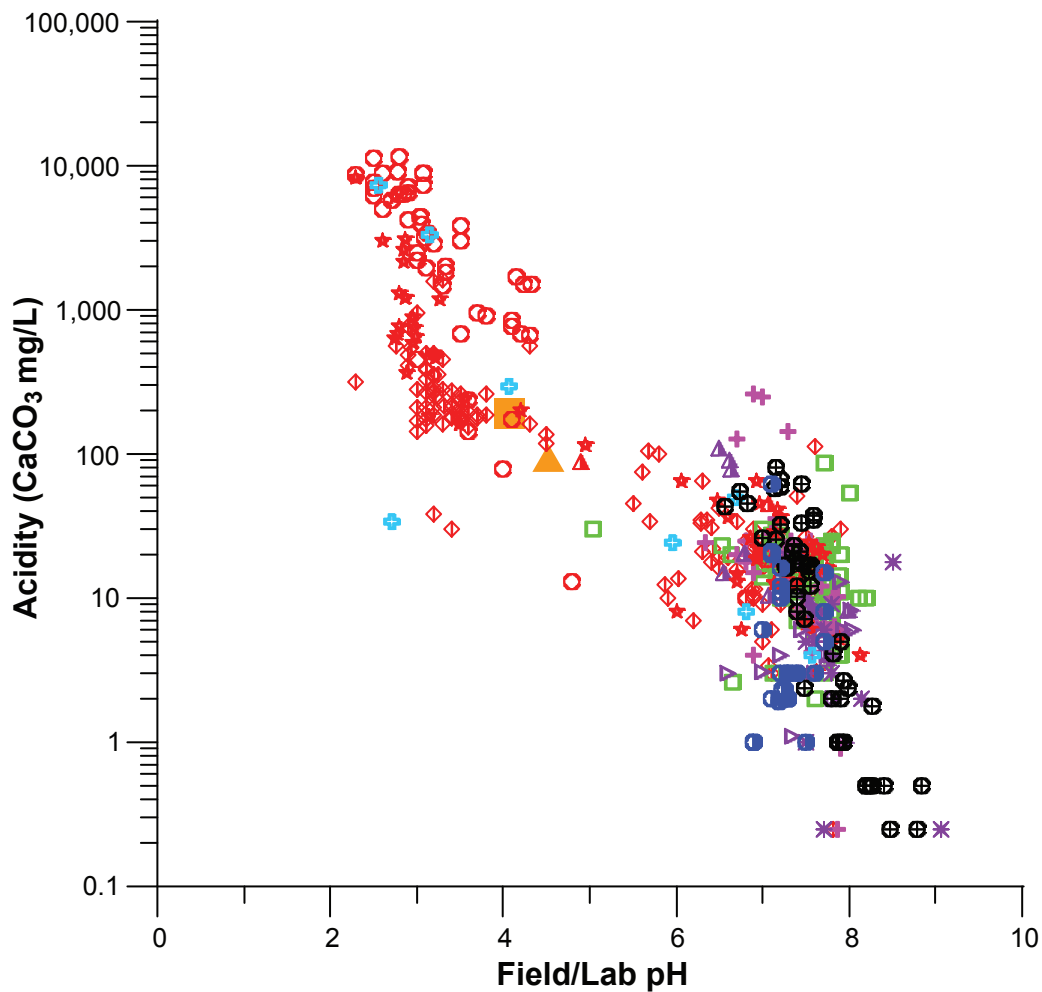
10. Comparison of Water Quality Predictions with Existing Projects

10.1 Summary of Projects

The water quality predictions presented in the previous sections of this report were compared to existing projects that are considered to have similar geology, mineralogy and geochemistry and are within a reasonable comparable climatic zone. It was found that predictions fell within similar ranges of those determined at various locations within the Granisle mine site. Figures 10.1-1 to 10.1-7 show a graphical representation of the comparison between the Granisle mine site and the predicted water quality of the Project for both pit and TSF water quality. In the absence of sufficient site-specific ML/ARD prediction data for the Project for predicting water/drainage quality, conservatism is built into assigning adjusted SNPR values to the waste rock storage area materials and pit wall rock and assigned analogue water quality. The predictive modeling shows results are conservative with respect to acidity and pH predictions when compared to measured Granisle mine site pit lake quality.

Morin and Hutt (2007) compared both Bell Mine EDCM data and Granisle EDCM data to available Morrison kinetic data at equilibrium and concluded that both the Bell and Granisle EDCM can be used as predictors of Morrison drainage chemistry for acidic and alkaline pH. Justifications for the use of the Granisle EDCM as an analogue for the Morrison project include the following.

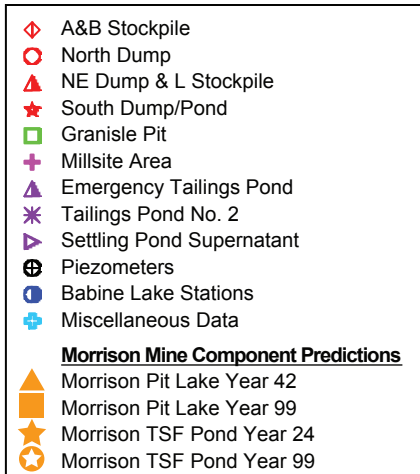
- Similar geology and mineralogy between Granisle and Morrison rock.
- The majority of Granisle data supporting the EDCM is from post-closure which assists in modelling the Morrison Pit Lake water quality (WQ).
- A larger list of predictable parameters is available in the Granisle EDCM as presented in Morin and Hutt (2007).
- The Granisle EDCM provides a conservative (i.e., worst case higher concentration) prediction of rock drainage chemistry at a range of pHs.

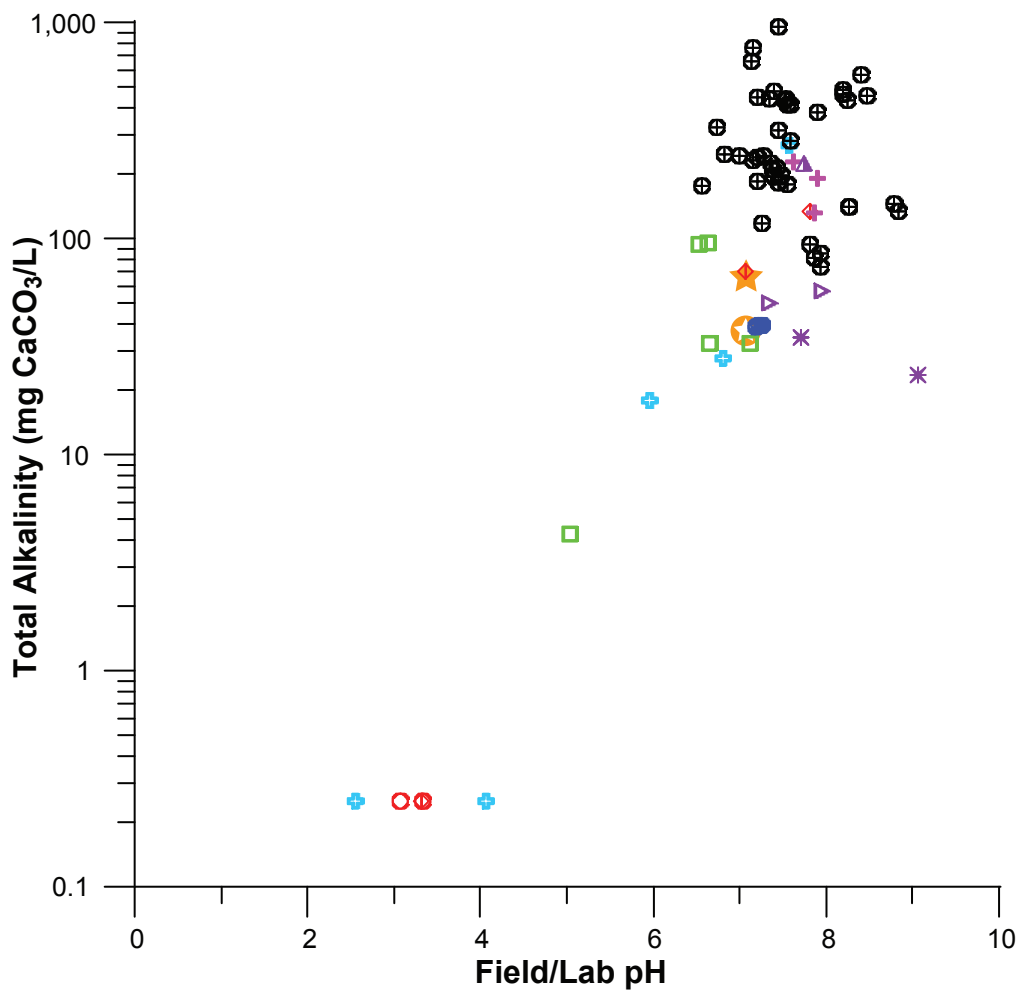


Source: Morin & Hutt, 2002

Note: Field pH was used if available otherwise lab pH was used.

If data was reported as < detection limit then half the detection limit was used.



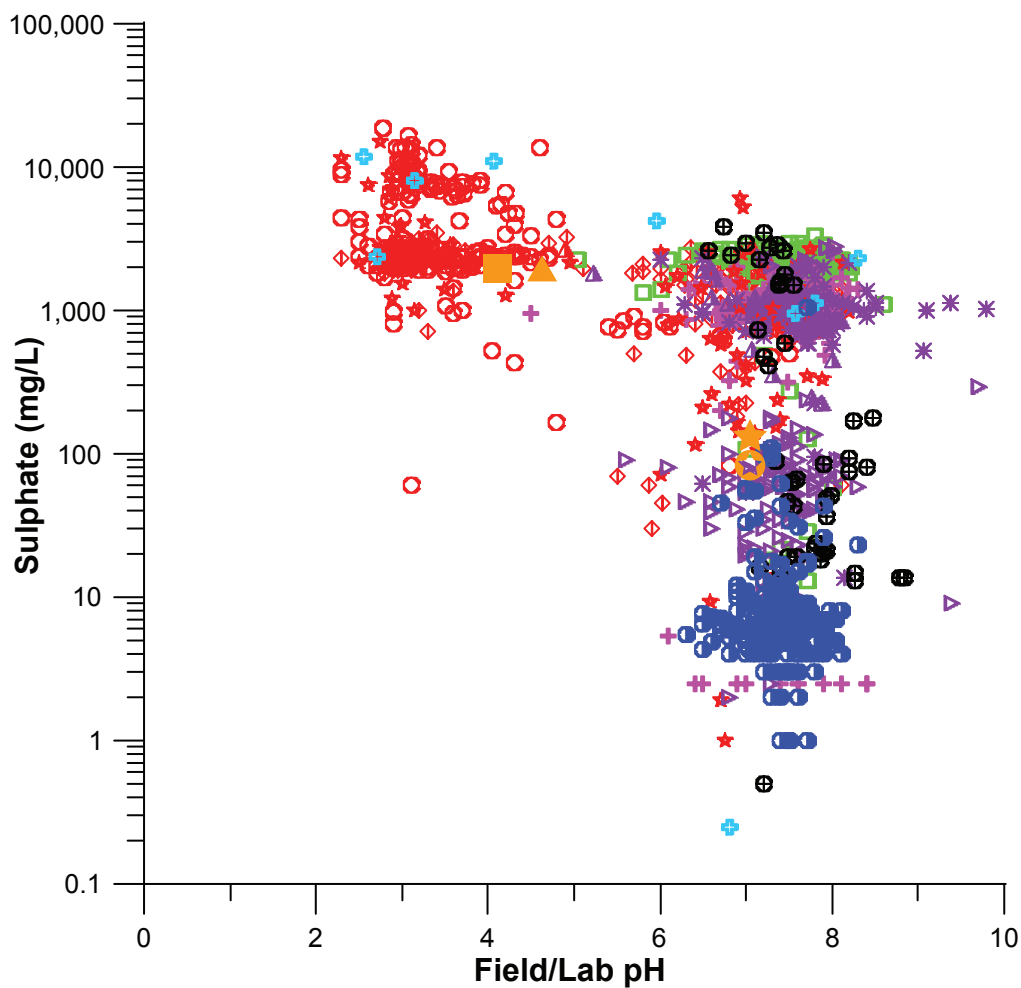


Source: Morin & Hutt, 2002

Note: Field pH was used if available otherwise lab pH was used.

If data was reported as < detection limit then half the detection limit was used.

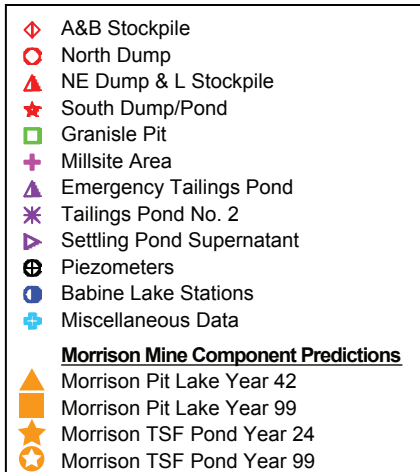
- ◇ A&B Stockpile
- North Dump
- △ NE Dump & L Stockpile
- ★ South Dump/Pond
- Granisle Pit
- + Millsite Area
- △ Emergency Tailings Pond
- * Tailings Pond No. 2
- ▽ Settling Pond Supernatant
- ⊗ Piezometers
- Babine Lake Stations
- + Miscellaneous Data
- Morrison Mine Component Predictions**
- ▲ Morrison Pit Lake Year 42
- Morrison Pit Lake Year 99
- ★ Morrison TSF Pond Year 24
- ★ Morrison TSF Pond Year 99

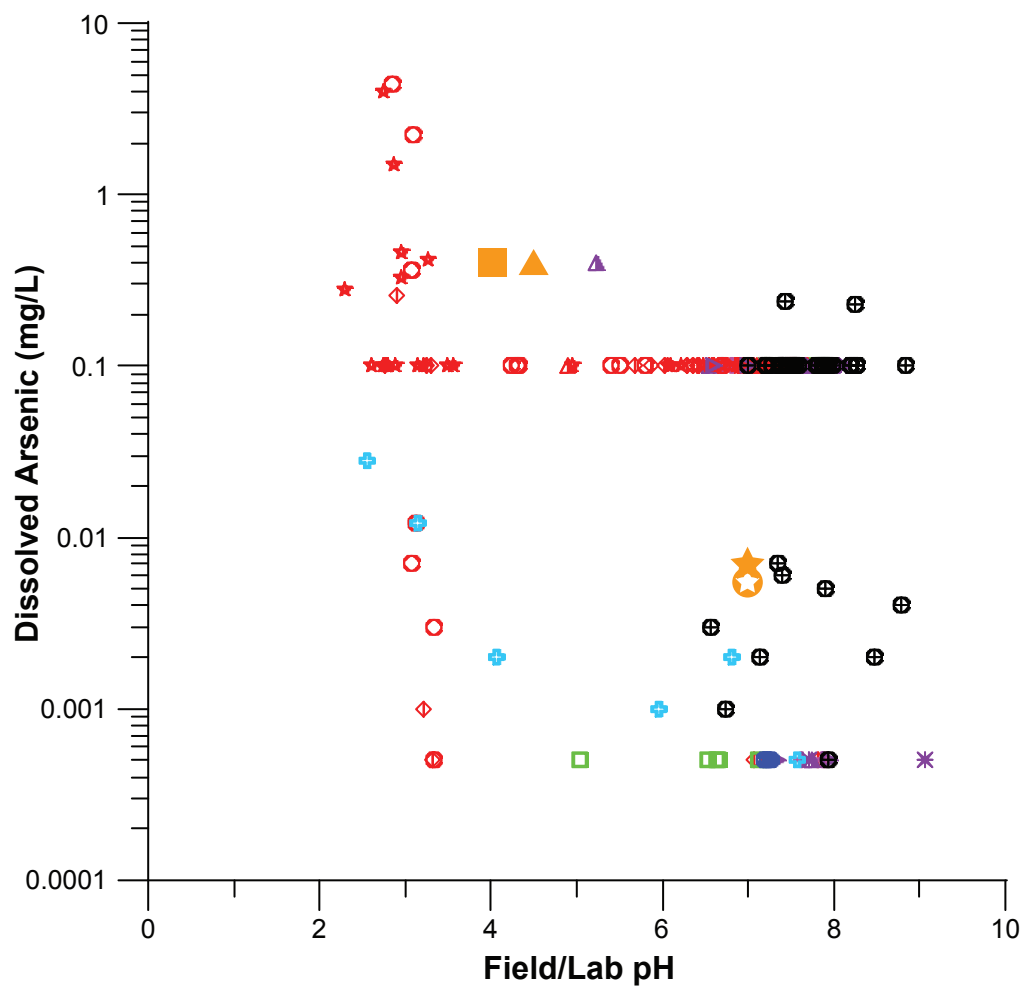


Source: Morin & Hutt, 2002

Note: Field pH was used if available otherwise lab pH was used.

If data was reported as < detection limit then half the detection limit was used.



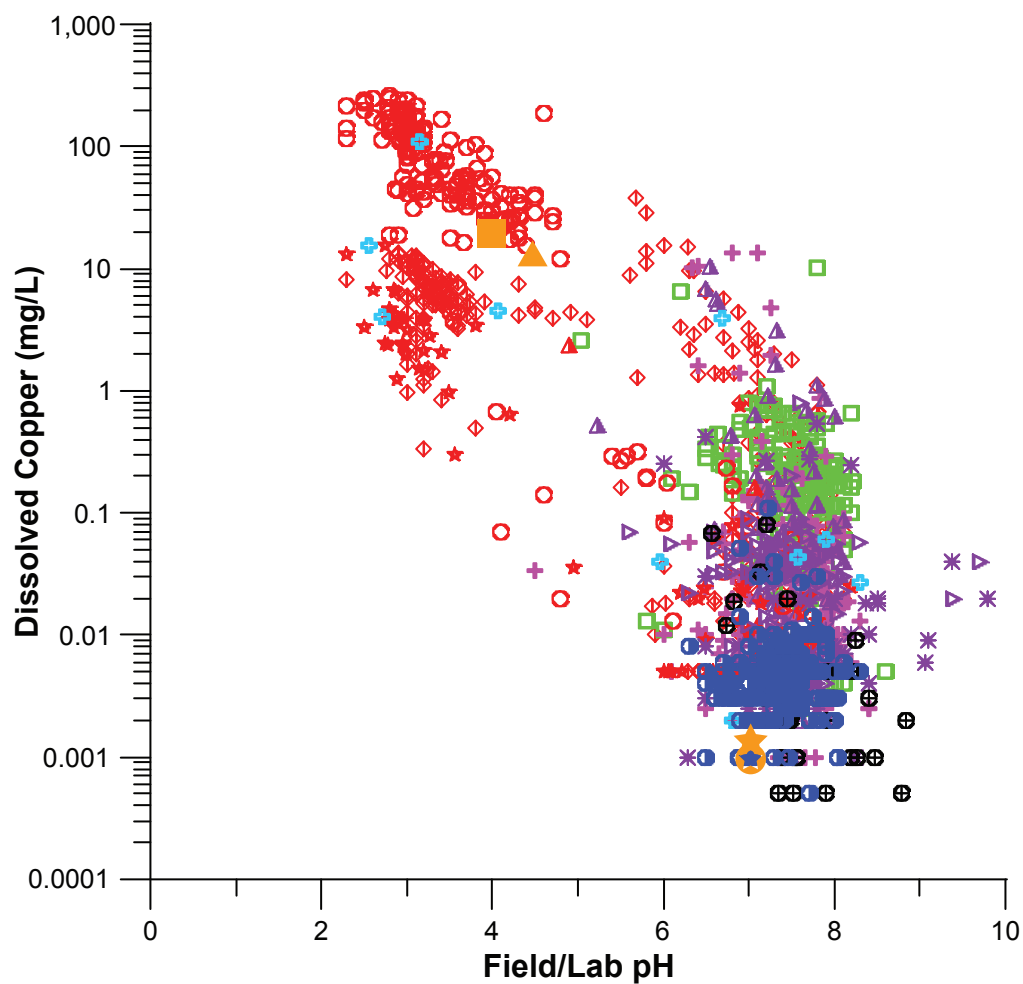


Source: Morin & Hutt, 2002

Note: Field pH was used if available otherwise lab pH was used.

If data was reported as < detection limit then half the detection limit was used.

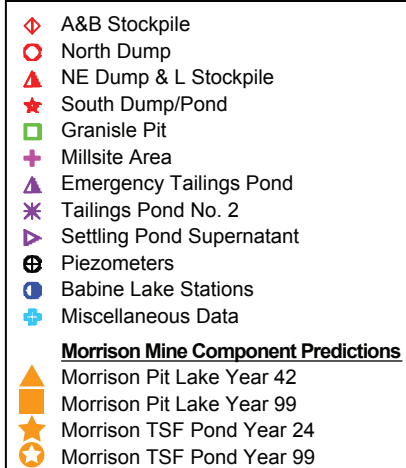
- ◇ A&B Stockpile
- North Dump
- △ NE Dump & L Stockpile
- ★ South Dump/Pond
- Granisle Pit
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- △ Emergency Tailings Pond
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- ▽ Settling Pond Supernatant
- ⊕ Piezometers
- Babine Lake Stations
- ✚ Miscellaneous Data
- Morrison Mine Component Predictions**
- ▲ Morrison Pit Lake Year 42
- Morrison Pit Lake Year 99
- ★ Morrison TSF Pond Year 24
- ✱ Morrison TSF Pond Year 99

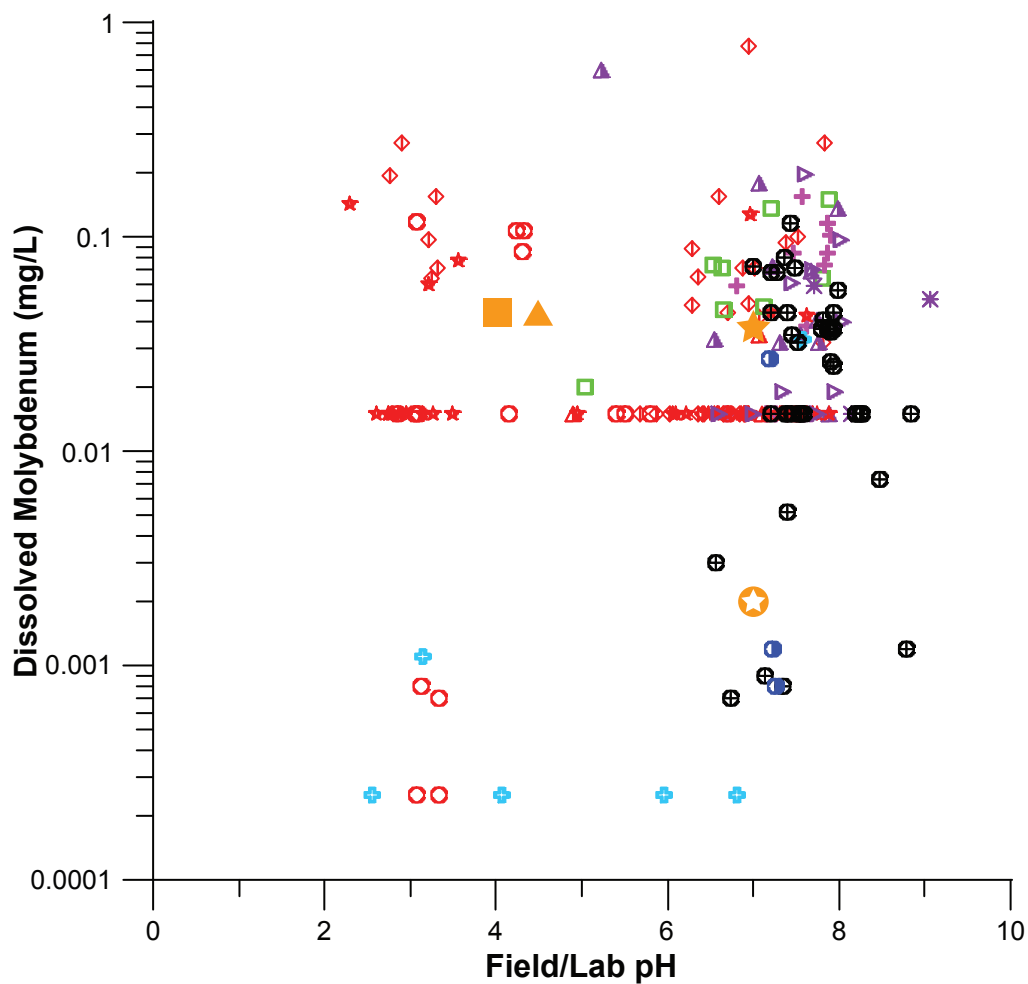


Source: Morin & Hutt, 2002

Note: Field pH was used if available otherwise lab pH was used.

If data was reported as < detection limit then half the detection limit was used.

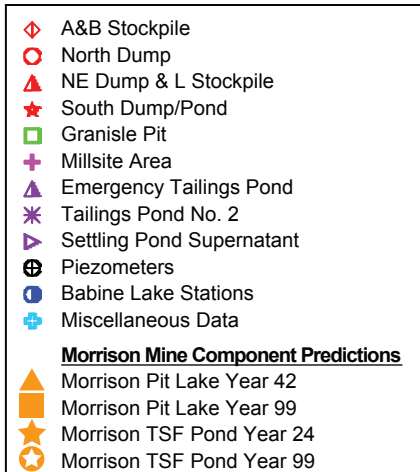


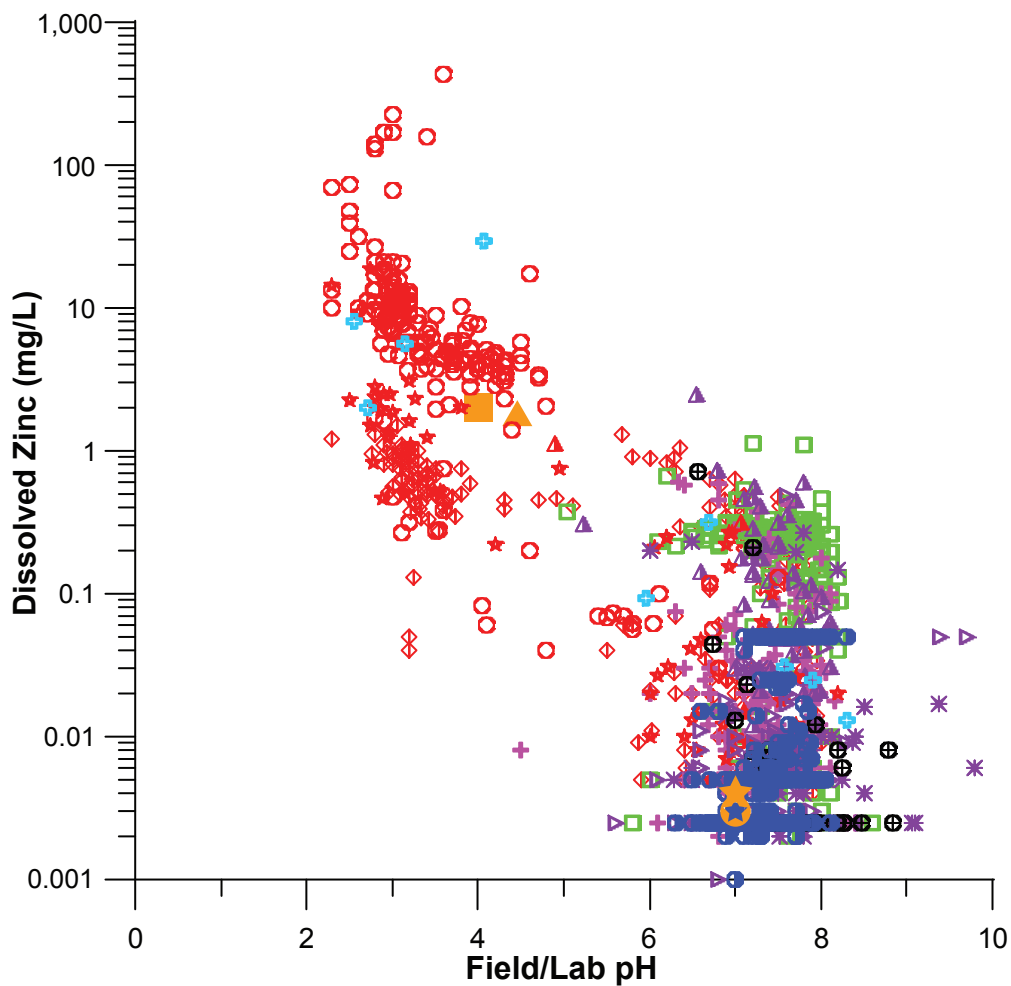


Source: Morin & Hutt, 2002

Note: Field pH was used if available otherwise lab pH was used.

If data was reported as < detection limit then half the detection limit was used.

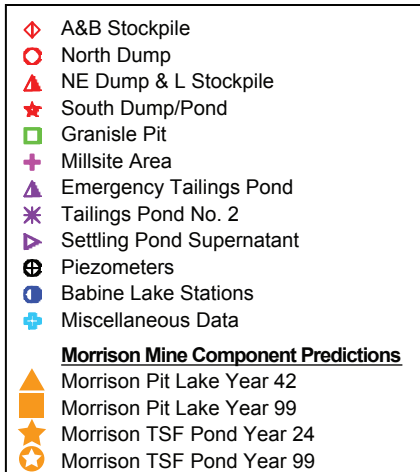




Source: Morin & Hutt, 2002

Note: Field pH was used if available otherwise lab pH was used.

If data was reported as < detection limit then half the detection limit was used.



11. Downstream Water Quality Effects

Groundwater contaminant transport and particle tracking modelling (Rescan 2009b; Section 5 and Section 4) shows that TSF seepage reaches downstream receptors such as streams MCS-7, MCS-8, and MCS-10 and Morrison Lake. Mass balance water quality modelling was done to determine the potential water quality at MCS-7, MCS-8, and MCS-10. In addition, a dilution volume of Morrison Lake was estimated based on the flux of seepage surfacing at the bed of Morrison Lake.

11.1 TSF Seepage

The TSF lies within the watersheds of streams MCS-7, MCS-8, and MCS-10. Seepage from the TSF has been modelled and is discussed in Section 4.1-4. Contaminant transport modelling indicates the relative concentrations from the TSF source (i.e., in this case estimated tailings porewater quality seepage to groundwater (see Chapter 6 of Rescan 2009d) at different reaches of streams are varied. A summary of the relative concentrations is presented in Table 11.1-1 for different sections of streams affected by TSF seepage. Source term water qualities used as input for water quality modelling are shown in Table 11.1-2. Water quality data available for MCS-10 were sparse, and therefore the water quality from MCS-7 was used instead.

Additional assumptions in water quality modelling include:

1. All upstream mass loadings report to MCS-7, MCS-8, and MCS-10.
2. Groundwater contaminant transport and relative source concentrations in the seepage plume are at maximum TSF pond volume.
3. Average seepage concentrations relative to the source are used (e.g., for 0 to 20%, 10% was used).
4. Mass contributions from seepage are weighted according to stream length affected.
5. The leachate originating from the different source components are at equilibrium and do not change with time (i.e., constant loading rates with no kinetic constraints) and are removed quantitatively from the sources.
6. The software PHREEQC (Parkhurst and Appelo 1999) was employed for reactive geochemical modelling after an initial estimate of solution chemistry was provided from the mass-balance modelling. Credible minerals at equilibrium (Early 1999; Agbenin and Felix-Henningsen 2004) were included to limit concentrations of sulphate, aluminum, barium, calcium, and copper only if saturation was achieved (i.e., $SI > 0$) and included:
 - a. Barite ($BaSO_4$)
 - b. Calcite ($CaCO_3$)
 - c. Geothite ($FeOOH$)
 - d. Gibbsite [$Al(OH)_3$]
 - e. Gypsum ($CaSO_4$)

f. Cupricferrite (CuFe_2O_4)

7. Modelling included metal(loid) adsorption onto iron (hydr)oxides, in this case the amount of precipitated goethite caused by saturation. As a conservative approach, goethite, was the iron (hydr)oxides of choice due to an order of magnitude fewer adsorption sites compared to other phases, such as ferrihydrite (Appelo and Postma 2007).
8. No solid-aqueous interaction such as buffering or cation exchange was considered.
9. Redox conditions at solution mixing in the surface stream are moderate (i.e., $\text{pe} = 8$).
10. Once TSF seepage to groundwater discharges to (i.e., surfaces and comes into contact with) surface water is assumed to be well-mixed and at equilibrium with atmospheric carbon dioxide.
11. Average temperatures are assumed to be 10°C .
12. Estimates for total metals were based on average measured laboratory tailings aging test total to dissolved ratios (see Section 5.2.1.5 of Rescan 2009d) and average surface water total to dissolved ratios weighted according to the groundwater or surface water flux component.

As sensitivity analyses, low and average surface flow at MCS-7, MCS-8, and MCS-10 were used as dilution sources once TSF seepage discharges at their respective streams (Table 11.1-3). Low flow occurs approximately in March before freshet. Note that the majority of the MCS-7 watershed catchment upstream of the TSF reports to the TSF to maintain a TSF pond water cover.

Table 11.1-1
Predicted Relative Concentrations of Seepage in Stream Lengths
Downstream from the TSF

Concentration Relative to the Source	MCS-7 Downstream (m)	MCS-7i West Tributary (m)	MCS-7ii East Tributary (m)	MCS-8 (m)	MCS-10 (m)
0–20%	0	0	1,255	183	2,055
20–40%	730	0	641	312	136
40–60%	299	73	233	1,524	98
60–80%	0	660	238	733	141
80–100%	0	655	0	0	0
Total	1,029	1,388	2,367	2,752	2,429

Table 11.1-2
Source Term Input Water Quality used in Water Quality Modelling

Parameter	Units	Aging Test Day One	Average Surface Water Quality	Average Surface Water Quality
		65:35 Coarse Fraction:Fine Fraction Tailings Porewater	MCS-7	MCS-8
			n = 19	n = 6
pH		8.31	7.96	7.95
Alkalinity	mgCaCO ₃ /L	84	72	88
F	mg/L	0.36	0.064	0.086
Cl	mg/L	86	0.25	0.25
Sulphate	mg/L	67	8.8	6.2
Nitrite	mg/L	1.0	0.00057	0.00050
Nitrate	mg/L	22	0.15	0.14
Ammonia	mg/L	54	0.0044	0.0064
Hg	mg/L	0.000050	0.0000055	0.0000050
Ag	mg/L	0.000064	0.0000067	0.0000050
Al	mg/L	1.9	0.046	0.022
As	mg/L	0.0050	0.00026	0.00038
Ba	mg/L	0.33	0.025	0.041
Be	mg/L	0.000046	0.00025	0.00025
B	mg/L	0.027	0.0078	0.016
Ca	mg/L	38	21	27
Cd	mg/L	0.00041	0.000010	0.000010
Co	mg/L	0.0013	0.000050	0.000050
Cr	mg/L	0.0079	0.00025	0.00025
Cu	mg/L	0.033	0.00088	0.00091
Fe	mg/L	3.8	0.051	0.023
K	mg/L	14	0.29	0.32
Li	mg/L	0.0010	0.0025	0.0025
Mg	mg/L	10	4.0	4.6
Mn	mg/L	0.072	0.00060	0.0021
Mo	mg/L	0.049	0.000053	0.00014
Na	mg/L	31	5.2	4.4
Ni	mg/L	0.012	0.00026	0.00050
Pb	mg/L	0.0018	0.000039	0.000050
Sb	mg/L	0.0044	0.000050	0.000050
Se	mg/L	0.00083	0.00030	0.00033
Si	mg/L	2.4	2.7	3.9
Sn	mg/L	0.0040	0.000061	0.000050
V	mg/L	0.0087	0.00050	0.00050
Zn	mg/L	0.011	0.00061	0.00066
Hardness (calc)	mg CaCO ₃ /L	138	68	86

Notes: Measured values below detection are listed as one half the method detection values.

**Table 11.1-3
Surface Flow Conditions and Seepage Contributions at MCS-7,
MCS-8, and MCS-10**

	Flow Condition	Surface Flow (L/s)	Groundwater Contribution (L/s)	Total Flow (L/s)
MCS-7 + i + ii	Low Flow	0	19.7	19.7
	Average Flow	19.2	19.7	38.9
MCS-8	Low Flow	0	36.2	36.2
	Average Flow	32	36.2	68.2
MCS-10	Low Flow	0	9.5	9.5
	Average Flow	21	9.5	30.5

11.1.1 TSF Seepage Effects on Surface Water Quality

Table 11.2-1 presents the predicted water quality at MCS-7, MCS-8, and MCS-10 for low and average surface flow conditions. Predicted results compared against average surface water quality for MCS-7 indicate increase in several parameters with higher predictions for the low flow condition caused by the absence of surface dilution. Note that predicted increases in mercury are partly caused by modelling artifacts as source term from laboratory tailings aging test data showed mercury was below the method detection (0.001 mg/L) and modelling used one half the method detection limit as a conservative approach to mass balance calculations.

Table 11.2-1
Morrison Copper/Gold Project: Surface Water Quality Predictions at MCS-7, MCS-8, and MCS-10

Parameter	Units	MCS-7 Measured		MCS-7		MCS-8		MCS-10		MCS-7		MCS-8		MCS-10	
		Average Dissolved	Average Total	Dissolved Metals						Total Metals					
		n = 19		Low Surface Flow	Average Surface Flow	Low Surface Flow	Average Surface Flow	Low Surface Flow	Average Surface Flow	Low Surface Flow	Average Surface Flow	Low Surface Flow	Average Surface Flow	Low Surface Flow	Average Surface Flow
pH		8.0		7.7	8.1	7.5	7.8	7.1	7.8						
Alkalinity	mgCaCO ₃ /L	72		36	94	28	56	9.6	52						
F	mg/L	0.064		0.23	0.15	0.18	0.14	0.058	0.062						
Cl	mg/L	0.25		55	28	43	38	14	21						
Sulphate	mg/L	8.8		43	26	34	21	11	9.5						
Nitrite	mg/L	0.00057		0.64	0.33	0.50	0.27	0.16	0.051						
Nitrate	mg/L	0.15		14	7.2	11	6.0	3.6	1.2						
Ammonia	mg/L	0.0044		35	18	27	14	8.8	2.7						
Hg	mg/L	0.0000055	0.0000053	0.000032	0.000019	0.000025	0.000016	0.0000081	0.0000063	0.000013	0.000017	0.000010	0.000014	0.0000034	0.0000056
Ag	mg/L	0.0000067	0.0000064	0.000041	0.000024	0.000032	0.000019	0.000010	0.0000078	0.000095	0.000067	0.000074	0.000053	0.000023	0.000027
Al	mg/L	0.046	0.061	0.0017	0.0032	0.0015	0.0022	0.0012	0.0021	0.034	0.067	0.030	0.049	0.024	0.045
As	mg/L	0.00026	0.00027	0.00069	0.00049	0.00053	0.00049	0.00012	0.00018	0.0011	0.0010	0.00085	0.0011	0.00020	0.00046
Ba	mg/L	0.025	0.026	0.037	0.058	0.044	0.070	0.053	0.034	0.052	0.11	0.062	0.13	0.075	0.075
Be	mg/L	0.00025	0.0025	0.00000024	0.0000025	0.00000025	0.0000024	0.00000049	0.000019	0.00000032	0.0000046	0.00000033	0.0000044	0.00000066	0.0000039
B	mg/L	0.0078	0.0078	0.017	0.012	0.013	0.015	0.0043	0.0067	0.018	0.019	0.014	0.023	0.0046	0.012
Ca	mg/L	21	20	24	23	19	23	6.2	16	26	36	20	35	6.6	29
Cd	mg/L	0.000010	0.000010	0.00026	0.00013	0.00021	0.00011	0.000066	0.000028	0.00037	0.00026	0.00030	0.00021	0.000094	0.000059
Co	mg/L	0.000050	0.000050	0.00084	0.00044	0.00066	0.00038	0.00021	0.000100	0.0017	0.0011	0.0013	0.0010	0.00041	0.00033
Cr	mg/L	0.00025	0.00025	0.0043	0.0027	0.0032	0.0021	0.0010	0.00057	0.028	0.019	0.021	0.015	0.0067	0.0040
Cu	mg/L	0.00088	0.00088	0.00011	0.000078	0.00013	0.000089	0.00045	0.000090	0.0013	0.00097	0.0016	0.0011	0.0054	0.0011
Fe	mg/L	0.051	0.068	0.00000041	0.00000018	0.00000051	0.00000027	0.0000014	0.00000028	0.000062	0.000028	0.000077	0.000042	0.00021	0.000044
K	mg/L	0.29	0.29	8.8	4.6	6.9	3.8	2.2	0.89	9.1	7.0	7.2	5.8	2.3	1.7
Li	mg/L	0.0025	0.0025	0.00064	0.0016	0.00050	0.0014	0.00016	0.0018	0.00064	0.0024	0.00050	0.0021	0.00016	0.0030
Mg	mg/L	4.0	4.0	6.7	5.4	5.3	4.9	1.7	3.3	7.1	8.4	5.6	7.5	1.8	5.9
Mn	mg/L	0.00060	0.027	0.046	0.024	0.036	0.020	0.012	0.0041	0.15	0.13	0.12	0.13	0.038	0.17
Mo	mg/L	0.000053	0.000052	0.032	0.016	0.025	0.013	0.0080	0.0025	0.029	0.022	0.022	0.018	0.0071	0.0043
Na	mg/L	5.2	5.3	20	13	16	10	5.1	5.2	21	20	17	15	5.4	9.1
Ni	mg/L	0.00026	0.00028	0.0075	0.0039	0.0060	0.0034	0.0020	0.00080	0.023	0.014	0.018	0.012	0.0062	0.0032
Pb	mg/L	0.000039	0.000026	0.000060	0.000021	0.000099	0.000019	0.00016	0.000026	0.0024	0.00084	0.0039	0.00075	0.0065	0.0011
Sb	mg/L	0.000050	0.000050	0.0028	0.0015	0.0022	0.0012	0.00071	0.00026	0.0027	0.0021	0.0021	0.0017	0.00068	0.00043
Se	mg/L	0.00030	0.00040	0.00053	0.00041	0.00042	0.00038	0.00013	0.00025	0.00075	0.00085	0.00059	0.00067	0.00018	0.00053
Si	mg/L	2.7	2.7	0.70	0.98	0.56	1.2	0.18	0.89	1.3	2.3	1.0	2.7	0.32	2.2
Sn	mg/L	0.000061	0.000057	0.0026	0.0013	0.0020	0.0011	0.00065	0.00025	0.0063	0.0039	0.0049	0.0033	0.0016	0.00078
V	mg/L	0.00050	0.00050	0.0030	0.0014	0.0025	0.0015	0.00092	0.00056	0.034	0.017	0.029	0.019	0.011	0.0068
Zn	mg/L	0.00061	0.00062	0.0066	0.0034	0.0054	0.0031	0.0019	0.00099	0.13	0.066	0.10	0.061	0.036	0.020
Hardness (calc)	mgCaCO ₃ /L	68		87	80	69	78	22	54						

12. Summary and Conclusions

12.1 TSF Summary and Conclusions

The modelling exercise presented above indicates that under design conditions the TSF will operate as a “zero” surface discharge facility throughout the operations phase. To achieve this, an initial TSF pond volume of 750,000 m³ is required to maintain sufficient water for reclaim purposes in early years. Further, the diversion channel on the east side of the TSF will be actively managed throughout operations to maintain maximum water levels in the pond (e.g., within dam freeboard requirements), without the need for surface discharge.

The TSF will fill to the closure spillway elevation of 1013 masl at approximately three years following closure (Year 24). Conservative water quality predictions indicate that even once at steady state, TSF water quality will exceed guideline levels for some parameters, and therefore may not be suitable for direct discharge to the environment. Therefore, after Year 24, any excess TSF pond water will flow over the spillway and then be directed to the open pit and contribute to pit filling. This water management strategy eliminates any discharge to the receiving environment from the TSF, and thus only requires one treatment location for discharge water located close to the pit lake. Should water quality observed during operation of the mine be better than predicted, alternate management strategies could be investigated.

In general, the water quality of the TSF is of better quality than that of the pit, and therefore the inflow from the TSF will aid in diluting the concentrations of parameters within the pit lake. It should be noted that the model results are conservative and thus generate high loadings of parameters for a worst case water quality prediction. Based on the modelling results, it was found that the majority of copper, zinc, molybdenum, arsenic, and the nitrogen species loadings are from the tailings slurry water discharged to the TSF from the process plant. Percentage contributions from each source entering the TSF are summarized in Tables 12.1-1 to 12.1-5.

12.2 Open Pit Summary and Conclusions

It was concluded that the water quality of the pit is governed primarily by the reactivity of the waste rock and pit wall rock types and their assigned water quality mass loadings. As a result, larger exposed rock volumes will result in mass loadings entering the open pit. As with the TSF water quality predictions, the model results are conservative and produce elevated loading levels for a worst case water quality prediction. Based on conservative predictions of pit lake water quality, it was determined that any “overflow” in excess of the final pit lake elevation (~728 masl) would require post-closure treatment in a water treatment plant to meet applicable federal and provincial regulatory discharge criteria (such as copper and others).

The water quality modelling results show that the majority of loadings of metal(loids) came from the leaching of the SNPR 0-0.5 rock from either the open pit walls or the waste rock dump. Nitrate and nitrite entered the pit primarily through TSF overflow and SNPR 0.5-1.5 rock, with smaller contributions from groundwater and the other rock types. The percentage load contributions to the pit lake are summarized in Tables 12.2-1 to 12.2-11.

Table 12.1-1
Percent Contribution of TSF Dam Seepage Reclaim Loadings to TSF Water Quality

	Sulphate	Acidity	Alkalinity	Nitrite	Nitrate	Ammonia	Copper	Zinc	Molybdenum	Arsenic
Year 1	0.16%	0.13%	0.17%	0.18%	0.18%	0.17%	0.14%	0.16%	0.18%	0.14%
Year 20	0.19%	0.17%	0.31%	0.35%	0.35%	0.32%	0.13%	0.22%	0.36%	0.12%
TSF Spill Year 24	0.78%	0.45%	2.47%	14.88%	15.06%	2.89%	0.37%	1.00%	24.77%	0.35%
Steady State Year 99	1.07%	0.54%	2.58%	19.48%	19.89%	3.02%	0.51%	1.35%	31.51%	0.49%

Table 12.1-2
Percent Contribution of Tailings Water Loadings to TSF Water Quality

[illegible]

Table 12.1-3
Percent Contribution of Watershed Loadings to TSF Water Quality

	Sulphate	Acidity	Alkalinity	Nitrite	Nitrate	Ammonia	Copper	Zinc	Molybdenum	Arsenic
Year 1	1.26%	20.69%	9.01%	0.06%	0.03%	7.57%	4.04%	2.59%	0.01%	1.06%
Year 20	0.96%	16.82%	10.59%	0.07%	0.03%	8.93%	2.41%	2.19%	0.02%	0.60%
TSF Spill Year 24	3.87%	46.16%	83.91%	2.81%	1.48%	81.12%	6.95%	10.05%	1.26%	1.72%
Steady State Year 99	5.32%	54.63%	87.31%	3.69%	1.96%	85.05%	9.48%	13.51%	1.60%	2.41%

Table 12.1-4
Percent Contribution of TSF Dam Face Loadings to TSF Water Quality

[illegible]

Table 12.1-5
Percent Contribution of TSF Beach Area Loadings to TSF Water Quality

	Sulphate	Acidity	Alkalinity	Nitrite	Nitrate	Ammonia	Copper	Zinc	Molybdenum	Arsenic
Year 1	9.21%	7.11%	0.44%	0.48%	0.48%	0.44%	16.02%	6.81%	0.26%	17.87%
Year 20	34.22%	28.05%	2.49%	2.79%	2.79%	2.54%	46.39%	28.06%	1.53%	49.02%
TSF Spill Year 24	66.93%	37.47%	9.56%	57.74%	58.58%	11.23%	65.02%	62.40%	51.93%	68.71%
Steady State Year 99	93.62%	44.83%	10.11%	76.83%	78.15%	11.93%	90.01%	85.14%	66.89%	97.10%

Table 12.2-1
Percent Contribution of Groundwater Loadings to Open Pit Filling

	Sulphate	Acidity	Alkalinity	Nitrite	Nitrate	Ammonia	Copper	Zinc	Molybdenum	Arsenic
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Year 25	5.17%	1.82%	88.44%	6.59%	0.06%	94.39%	0.01%	0.28%	13.67%	3.47%
Pit Spill Year 42	3.89%	1.20%	87.67%	6.91%	0.06%	93.90%	0.01%	0.18%	13.38%	2.34%
Steady State Year 99	3.88%	1.20%	87.94%	7.23%	0.07%	94.00%	0.01%	0.18%	13.71%	2.32%

Table 12.2-2
Percent Contribution of Pit Wall Loadings (SNPR 0–0.5) to Open Pit Filling

	Sulphate	Acidity	Alkalinity	Nitrite	Nitrate	Ammonia	Copper	Zinc	Molybdenum	Arsenic
Year 25	45.42%	71.59%	0.00%	12.32%	13.20%	0.57%	78.74%	76.94%	14.27%	67.91%
Pit Spill Year 42	55.56%	76.98%	0.00%	21.06%	22.63%	0.93%	82.02%	80.80%	22.73%	74.33%
Steady State Year 99	55.71%	76.98%	0.00%	22.02%	23.85%	0.93%	82.02%	80.81%	23.38%	74.36%

Table 12.2-3
Percent Contribution of Pit Wall Loadings (SNPR 0.5–1.5) to Open Pit Filling

	Sulphate	Acidity	Alkalinity	Nitrite	Nitrate	Ammonia	Copper	Zinc	Molybdenum	Arsenic
Year 25	20.24%	6.08%	0.16%	28.13%	30.12%	1.31%	1.28%	2.48%	32.59%	5.66%
Pit Spill Year 42	15.57%	4.11%	0.17%	30.23%	32.52%	1.33%	0.84%	1.64%	32.63%	3.89%
Steady State Year 99	15.51%	4.09%	0.17%	31.64%	34.02%	1.33%	0.83%	1.63%	33.36%	3.88%

Table 12.2-4
Percent Contribution of Pit Wall Loadings (SNPR 1.5–2.5) to Open Pit Filling

	Sulphate	Acidity	Alkalinity	Nitrite	Nitrate	Ammonia	Copper	Zinc	Molybdenum	Arsenic
Year 25	5.43%	0.91%	0.19%	8.68%	9.30%	0.40%	0.14%	0.41%	10.05%	1.75%
Pit Spill Year 42	2.60%	0.38%	0.12%	5.78%	6.23%	0.25%	0.06%	0.17%	6.24%	0.74%
Steady State Year 99	2.57%	0.38%	0.12%	6.00%	6.48%	0.25%	0.05%	0.17%	6.34%	0.74%

Table 12.2-5
Percent Contribution of Pit Wall Loadings (SNPR 2.5) to Open Pit Filling

	Sulphate	Acidity	Alkalinity	Nitrite	Nitrate	Ammonia	Copper	Zinc	Molybdenum	Arsenic
Year 25	3.75%	0.27%	1.24%	7.41%	7.93%	0.34%	0.02%	0.14%	2.36%	1.49%
Pit Spill Year 42	2.64%	0.16%	1.15%	7.30%	7.86%	0.32%	0.01%	0.08%	2.17%	0.94%
Steady State Year 99	2.64%	0.16%	1.16%	7.63%	8.24%	0.32%	0.01%	0.08%	2.22%	0.94%

Table 12.2-6
Percent Contribution of Waste Rock Storage Area Loadings (SNPR 0–0.5) to Open Pit Filling

	Sulphate	Acidity	Alkalinity	Nitrite	Nitrate	Ammonia	Copper	Zinc	Molybdenum	Arsenic
Year 25	11.30%	17.82%	0.00%	3.06%	3.28%	0.14%	19.60%	19.13%	3.55%	16.89%
Pit Spill Year 42	11.44%	15.83%	0.00%	4.33%	4.66%	0.19%	16.89%	16.61%	4.67%	15.28%
Steady State Year 99	11.44%	15.85%	0.00%	4.55%	4.92%	0.19%	16.89%	16.62%	4.81%	15.30%

Table 12.2-7
Percent Contribution of Waste Rock Storage Area Loadings (SNPR 0.5–1.5) to Open Pit Filling

	Sulphate	Acidity	Alkalinity	Nitrite	Nitrate	Ammonia	Copper	Zinc	Molybdenum	Arsenic
Year 25	1.36%	0.41%	0.01%	1.90%	2.03%	0.09%	0.09%	0.17%	2.20%	0.38%
Pit Spill Year 42	1.38%	0.36%	0.01%	2.68%	2.89%	0.12%	0.07%	0.15%	2.90%	0.35%
Steady State Year 99	1.38%	0.36%	0.01%	2.81%	3.04%	0.12%	0.07%	0.15%	2.97%	0.35%

Table 12.2-8
Percent Contribution of Waste Rock Storage Area Loadings (SNPR 1.5–2.5) to Open Pit Filling

	Sulphate	Acidity	Alkalinity	Nitrite	Nitrate	Ammonia	Copper	Zinc	Molybdenum	Arsenic
Year 25	4.29%	0.72%	0.15%	6.86%	7.35%	0.32%	0.11%	0.32%	7.94%	1.38%
Pit Spill Year 42	4.32%	0.64%	0.21%	9.69%	10.41%	0.43%	0.09%	0.28%	10.47%	1.25%
Steady State Year 99	4.35%	0.64%	0.21%	10.18%	10.99%	0.43%	0.09%	0.28%	10.78%	1.25%

Table 12.2-9
Percent Contribution of Waste Rock Storage Area Loadings (SNPR 2.5) to Open Pit Filling

	Sulphate	Acidity	Alkalinity	Nitrite	Nitrate	Ammonia	Copper	Zinc	Molybdenum	Arsenic
Year 25	1.41%	0.10%	0.46%	2.77%	2.97%	0.13%	0.01%	0.05%	0.88%	0.56%
Pit Spill Year 42	1.42%	0.09%	0.62%	3.93%	4.22%	0.17%	0.01%	0.04%	1.16%	0.51%
Steady State Year 99	1.42%	0.09%	0.63%	4.13%	4.43%	0.17%	0.01%	0.04%	1.20%	0.51%

Table 12.2-10
Percent Contribution of TSF Overflow Loadings to Open Pit Filling

	Sulphate	Acidity	Alkalinity	Nitrite	Nitrate	Ammonia	Copper	Zinc	Molybdenum	Arsenic
Year 25	2%	0%	5%	22%	24%	1%	0%	0%	12%	1%
Pit Spill Year 42	1%	0%	5%	8%	8%	1%	0%	0%	4%	0%
Steady State Year 99	1%	0%	4%	4%	4%	1%	0%	0%	1%	0%

Table 12.2-11
Percent Contribution of Waste Rock Runoff (Non-infiltrated) Loadings to Open Pit Filling

	Sulphate	Acidity	Alkalinity	Nitrite	Nitrate	Ammonia	Copper	Zinc	Molybdenum	Arsenic
Year 25	0.08%	0.12%	4.14%	0.14%	0.08%	0.94%	0.00%	0.01%	0.02%	0.01%
Pit Spill Year 42	0.08%	0.11%	5.53%	0.19%	0.11%	1.26%	0.00%	0.01%	0.03%	0.01%
Steady State Year 99	0.08%	0.11%	5.56%	0.20%	0.11%	1.27%	0.00%	0.01%	0.03%	0.01%

The contribution of the TSF overflow into the pit serves to improve the water quality within the pit lake; however, it does not eliminate the need for a water treatment plant to be designed and included in the mine plan. It is expected that the pit will reach the maximum level of 728 masl approximately 22 years following closure or at Year 43. Beyond Year 43, an average net water balance of 343 m³/hr (8,232 m³/day) will require management through treatment prior to discharge to Morrison Lake.

12.3 Recommendations

The water quality modelling work resulted in a number of recommendations.

Note that the GoldSim water quality prediction modelling software assumes perfectly mixed reservoirs, and does not account for stratification or variation in concentrations throughout lakes (i.e., Morrison Lake and the pit lake). As a result, water quality predictions presented in this report should be considered as reasonable predicted perfectly mixed concentrations, based on the data and information available for modelling at this time. Further investigations into the chemical and physical behaviour of the potential pit lake stratification and stability, and their effects on the water quality over the long term should be investigated as part of monitoring programs during a future phase of the Project.

The water quality predictions presented in this report assume an average annual precipitation of 550 mm annually. Notably, no sensitivity analysis considering conservative conditions, such as higher annual precipitation and runoff rates, leakage from diversion channels, inter-annual variability in precipitation and surface water runoff rates, were performed. It is recommended that a more rigorous analysis be undertaken to understand the sensitivities of the water balance to changes in the individual inputs describe above. Furthermore, the water quality predictions are based upon the data provided from the Bell and Granisle projects, which are in close proximity to the proposed Morrison Project and have similar rock composition and characteristics.

A main strategy of the proposed water management plan (Section 13.4 of the EA) and ML/ARD Prediction and Prevention Plan (Section 13.17 of the EA) to minimize ML/ARD from the waste rock and pit walls and contain ML/ARD seepage and runoff from these components, includes maintaining the pit lake below Morrison Lake elevation (732 masl) to maintain a reverse groundwater hydraulic gradient toward the pit lake. If post-closure, a wet year results in the pit lake elevation rising above the elevation of Morrison Lake (732 masl), it would be necessary to revise the water management plan and reduce the ultimate pit lake level to a lower level. However, based on the justification provided in Chapter 6, the pit lake level of 728 masl was concluded to be suitable for these mass-water balance modelling purposes. Additionally, the hydraulic conductivity and connectivity between the pit lake and Morrison Lake should be investigated at a future phase of the Project to improve understanding of pit dewatering and refilling (Section 8.6, Section 8.7 of the EA and Rescan 2009c).

A monitoring program should be developed for the pit lake on closure (Sections 13.4 and 13.17 of the EA). In the event that water quality appears to be unacceptable, a detailed water treatment plan should be developed well before pit lake water reaches an elevation that would potentially release pit lake water to the receiving environment.

Summary and Conclusions

Conservatism is built into assigning adjusted SNPR values to the waste rock and pit wall rock and subsequent assigned leachate quality results in conservative acidity and pH predictions, when compared to measured Granisle mine site pit lake and TSF pond water quality. In the absence of site-specific ML/ARD prediction data (e.g., field-measured leachate water quality that approaches or represents equilibrium conditions), this conservatism is considered appropriate at this time.

References

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MORRISON COPPER/GOLD PROJECT
APPENDIX 1
POTENTIAL FOR RE-SUSPENSION OF TAILINGS SOLIDS

Appendix 1: Potential for Re-suspension of Tailings Solids

At closure the proposals are for the tailings within the storage facility to be submerged under water. Based on information from Klohn Crippen the depth of the pond is expected to range from 0 to 5 m. The main tailings surface is predicted to be at 1,008 m, with tailings beaches rising 5 m to the edge of the pond. The pond spillway elevation is at 1,013 m and during closure the water level in the pond will be retained close to the spillway level.

Wind waves cause shear stresses on the bed of any waterbody with the magnitude of the shear stress depending on a number of factors including water depth, local wind speed and fetch length. If the shear stress generated by wind is in excess of the critical shear stress required for re-suspension of sediment that sediment will be released into the water column. The critical shear stress of sediment is dependant on its grain-size and consolidation properties.

This assessment considers the potential for re-suspension under ‘normal’ wind conditions, such as those that might be expected to occur weekly or monthly and which could affect much of the pond area. Under these conditions, re-suspension could cause issues related to compliance of the outlet discharge from the pond in terms of TSS or total metals concentrations. It should be noted that local re-suspension events could occur near the edge of the pond (shallows) and/or for short period due to extreme wind events (e.g., 1 in 100 year storm), but that the effect of these on the outlet water quality would be low, assuming that:

- outlet is located away from areas of low water depth; and
- regulatory regime allows for some intermittent failures of TSS or total metals concentrations as a result of extreme events.

This assessment is based on:

- significant wave heights, wave periods, and wavelengths are obtained from the ACES method; and
- bed shear stress and critical shear stress from a methodology outlined in Adu-Wusu et al. (2001).

The assessment provides an initial assessment of the potential for wind waves to produce re-suspension of tailings solids within the final (closure) tailings pond at the Morrison Project.

Inputs

The input variables for the assessment are summarised in Table 1 and are based on data obtained from Klohn Crippen’s Draft Geotechnical Report for the site.

Wind action on a waterbody can also produce wind-induced currents; however, bed shear stresses caused by these currents are generally much less than those generated by wind waves.

Appendix 1: Potential for Re-suspension of Tailings Solids

As a result they are not considered in this assessment. In addition, this assessment does not consider the effect of stream flows entering the tailings pond, which could cause re-suspension at local points where the streams enter the pond.

Table 1
Input Parameters

Parameter	Value and Comment
Fetch Length	4,750 m based on Figure 1
Water Depth	Range from 0.5 to 5 m considered
Wind Speed	Range from 2 to 10 m/s considered
Density Dry Sediment	2,760 kg/m ³
Density settled sediment	1,500 kg/m ³
Grain size of tailings	D50 = 0.07 mm

A review of the wind speed data from the Rescan meteorological station at the Morrison site was undertaken (10m tower). This did not involve a full statistical analysis of the data, but the review indicated:

- Predominant wind directions in the area (from site wind rose) are from west to west-south-west and from east and east-south-east. This wind directions are consistent with the main fetch length shown in Figure 1.
- The 2 minute average data for the site (2006 to 2008) show that wind speeds rarely exceed 6 m/s, with maximum speeds around 3 to 4 m/s for this duration (gust speeds are higher). As the maximum fetch length is around 4,750 m, high wind speeds would need to occur over a reasonable length of time to generate larger waves (e.g., 15-minutes of wind speed of 5 m/s would be required to generate a 5 m/s significant wave height). The assessment was undertaken considering wind speeds of between 2 and 10 m/s

It is notable that the maximum hourly wind speeds for regional meteorological stations (e.g., Smithers airport and Babine Lake at Pinkut Creek) are substantially higher than those observed at the site (e.g., 13 to 18 m/s at Smithers Airport and 10 to 15 m/s at Babine Lake). We assume that the site is located in a low wind area compared to the regional stations.

Results

Graphs of bed shear stress for a range of water depths and wind speeds are shown in Figure 4. The assessment assumes that the wind gusts for the time required to generate fully formed waves across the fetch length of 4,750 m.

The critical shear stress for the D50 grainsize is shown in Figure 4. For a wind speed of 6 m/s the figure shows that for water depths greater than 2 m the bed shear stress generated by wind waves is predicted to be less than the critical shear stress for the tailings. For depths less than 2 m re-suspension can occur. Once the pond depth is in excess of around 3 m the bed shear stress generated by the wind waves tends to near zero for wind speeds up to 10 m/s.

Appendix 1: Potential for Re-suspension of Tailings Solids

The assessment considers wind data from the Morrison meteorological station which shows high short-term gusts, but relatively low wind speeds when averaged over 2 minutes. The wind speeds at the site are significantly lower than those recorded at the Environment Canada meteorological stations, indicating that the site is located in an area of low wind speed.

The assessment indicates that if water depth on the final pond is 3 m or deeper there will be very low bed shear stresses acting on the tailings surface on the pond and limiting the potential for re-suspension.

Reference

C Adu-Wusu, E K Yanful and M H Mian, 2001. Field evidence of re-suspension in a mine tailings pond. Canadian Geotechnical Journal, v 38, p. 796 – 808.

Appendix 1: Potential for Re-suspension of Tailings Solids

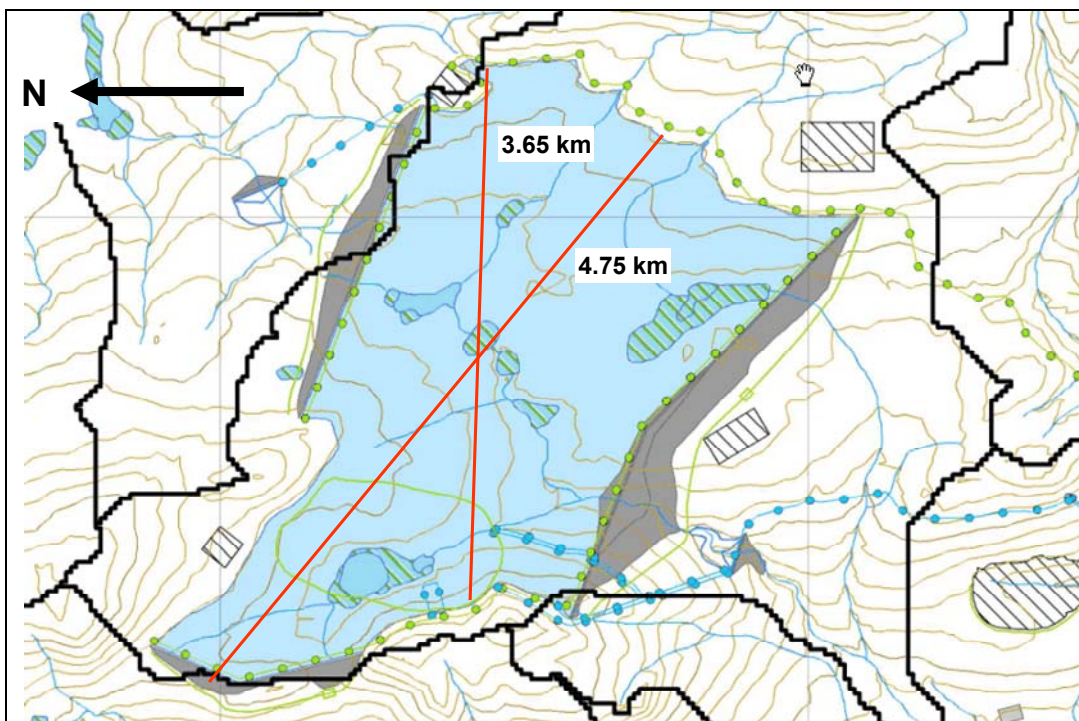


Figure 1. Longest Fetch Lengths at Morrison Tailings Facility at Closure

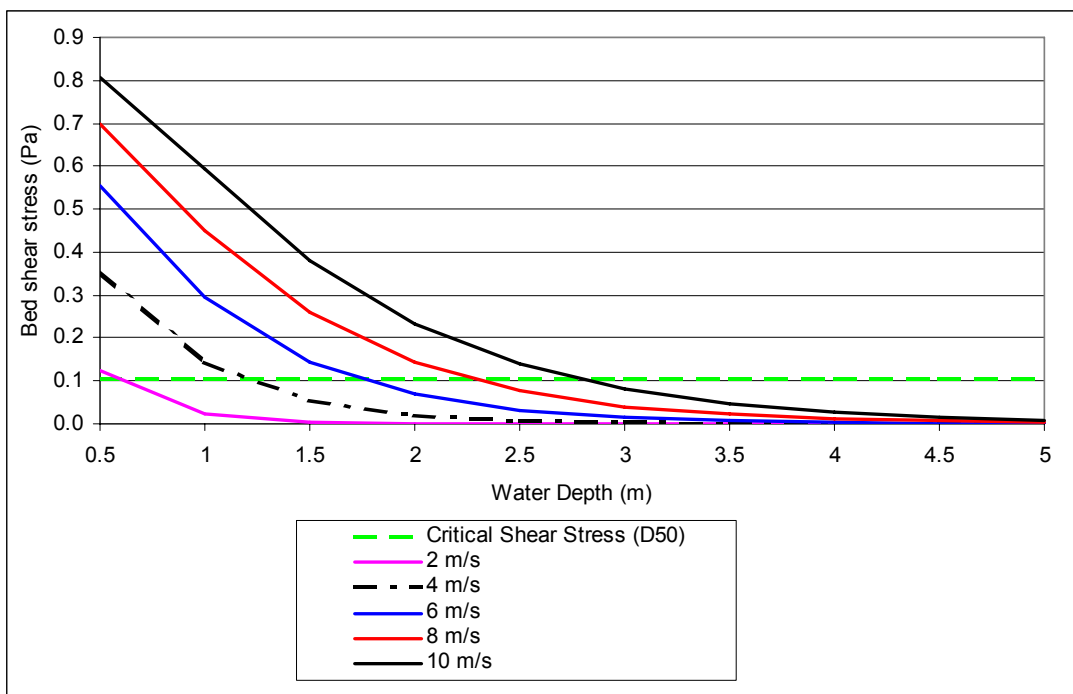


Figure 2. Comparison of Bed Shear Stress and Critical Shear Stress for Fetch Length 4,750 m, D50 Grain Size