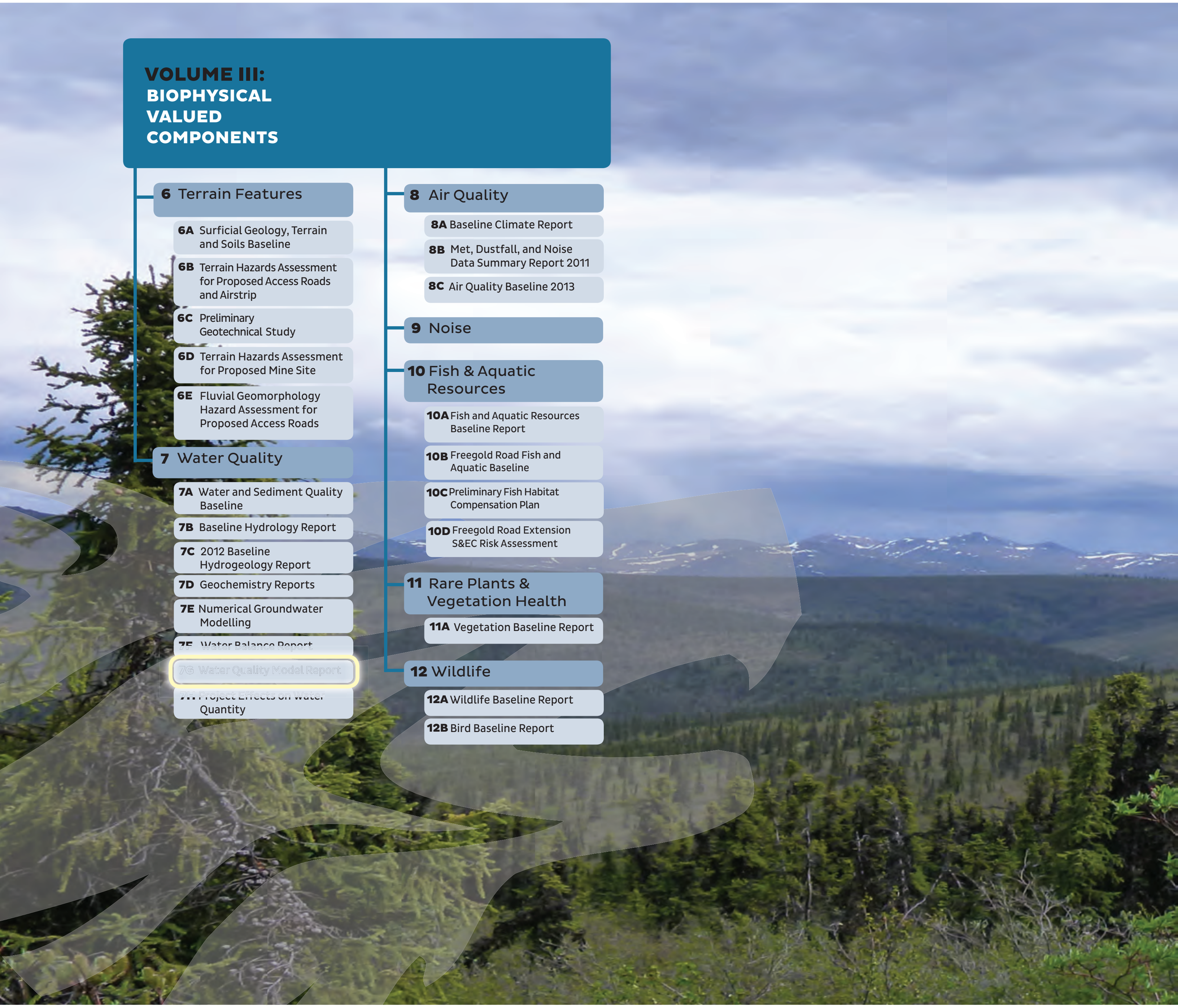
APPENDIX 7G: WATER QUALITY MODEL REPORT



Casino Project

Water Quality Predictions

Prepared for:

CASINO
COPPER AND GOLD

Prepared by**:**

Source
ENVIRONMENTAL ASSOCIATES INC.

December 2013

Executive Summary

Introduction

A site-wide water quality model was developed for the proposed Casino Project. The model simulated water quality in the mine discharge and receiving environment. The water quality model was also used as a planning tool to help select water quality mitigations. This report documents the predicted water quality resulting from the mine design developed for the YESAB submission.

The site-wide water quality model is organized by the following six model components:

- Open Pit Lake
- Ore Stockpile Drainage
- Heap Leach Facility
- TMF Pond and Treatment Wetlands
- Seepage management pond
- Receiving environment

The model was developed with a monthly time step and was run using monthly average flows. The water quality model was built within the GoldSim modelling platform, and was run for a simulation timeline of 200 years. The GoldSim model included 29 water quality parameters.

A water balance model was developed by Knight Piésold Limited (KPL) and was used as the basis for the water quality model. The water balance and the water quality models were fully integrated. Source terms for the water quality model were developed by Lorax Environmental Services (Lorax) and are incorporated into the GoldSim model.

Geochemical modelling has been integrated into the site-wide water quality model by use of dynamic links to PHREEQC. The model nodes with geochemical solubility controls include the following:

- Pit Lake
- TMF pond
- Seepage pond release mixed with TMF pond discharge
- Casino Creek at H18

These nodes are locations where mixing of water streams occurs and solubility controls affect the concentrations of some water quality parameters (such as aluminum, copper and iron).

The YESAB water quality model included the mine designed with seasonal variation and without reference to the variability associated with higher and lower flows. It is critical to formulate an acceptable mine design before considering statistical variations in detail.

As there will be no sources of contaminants in the Canadian Creek catchments, model nodes are limited to the Casino and Dip Creek Catchments.

Water Quality Mitigations

The water quality model results were used as a rationale for the implementation of a number of Project mitigations. Initially, copper was used as the constituent of concern (COC) for the mitigation planning as copper was predicted to exceed water quality targets by orders of magnitude in the source terms. Once desired copper concentrations were achieved, mitigations were considered for other COCs including cadmium, sulphate, selenium, molybdenum, uranium, cyanide and iron.

Key Project mitigation plans for the Open Pit are as follows:

- The North TMF wetland was designed to passively treat the Pit Lake discharge. The water quality model of the Pit Lake indicates that the discharge will be at acceptable concentrations and pH for successful treatment in the North TMF wetland.

- The runoff from the upper Canadian Creek catchment (upslope from water quality monitoring station W7) will flow to the Pit Lake in perpetuity to increase the alkalinity entering the Pit Lake.

Key Project mitigation plans for the Heap Leach Facility (HLF) are as follows:

- Following HLF operations, surplus water will be treated and pumped to the Open Pit until the HLF cover is in place in year 29. Treatment includes cyanide destruction and removal of selenium and mercury in a bioreactor. Cyanide degradation of the HLF discharge will occur as the Open Pit is filled.

- Following draindown, the HLF will be recontoured to promote runoff. The soil cover placed on the HLF reduces seepage from the toe of the HLF to 20% of the net surplus water.

Key Project mitigation plans for the TMF are as follows:

- The upward migration of porewater through the submerged waste rock in the TMF negatively affected the TMF Pond water. Hence the South TMF wetland was identified as being a necessary component of the Project.

- TMF pumping to the Pit Lake will lower the water level in the TMF and will create suitable working conditions for the construction of the TMF wetlands.

- The placement of waste rock within the TMF has been the subject of numerous design changes and the resulting design is the optimal strategy as the waste rock is in the upper part of the TMF where there is minimal loading contribution to the foundation seepage.

The wetland passive treatment systems were designed by Clear Coast Consulting Inc. Passive treatment by the North and South wetlands was modelled as follows:

- The wetlands treat Cd, Cu, Mo, Hg, Ag, Zn to the CCME guideline;

- The wetlands treat SO4 to 85% of the inflow concentration (i.e., 15% removal).

Key Project mitigation plans for seepage from the TMF and Ore Stockpiles:

- Source control for one of the six ore stockpiles was identified as an appropriate Project mitigation. The groundwater seepage pathway from the southern-most ore pile was estimated to be the most influential on Casino Creek water quality. As a result, the Project proposal incorporates mitigation (e.g., groundwater seepage collection) to intercept 90% of potentially contaminated seepage. The collected discharge will be directed to the TMF pond.

- Some of the waste rock generated during initial mine operations will be acidic supergene rock. This rock was initially planned to be disposed of within the TMF and has subsequently been relocated to a temporary surface ore stockpile. When this waste rock was going to be submerged and placed without neutral hypogene rock, the modelled seepage from the TMF was not acceptable for release to the environment. The relocation allows for passive management of the source loadings as the rock is disposed of into the open pit after Operations.

- Water collected in the WSMP will be pumped back into the TMF Pond until initial discharge of the TMF Pond.

- The Winter Seepage Mitigation Pond (WSMP) will store winter seepage and release it during the open water season when it will be mixed with the TMF Pond discharge prior to release to Casino Creek. Mixing the discharges will allow dissolved iron to precipitate when the discharges mix. This mitigation measure also avoids discharging seepage in winter when there is no other flow available for mixing and dilution, and avoids the potential for long-term pump back.

Model Results

The water quality model results for Casino Creek and Dip Creek are summarized by COC and compared to CCME water quality guidelines. As there is no CCME water quality guideline for sulphate, the BC Water Quality Guideline (BCWQG) was adopted. The water quality results do not represent an impact assessment. Palmer Environmental Consulting Group has completed the aquatic impact assessment of the Casino Project including the effects of the Project on the receiving environment downstream of the Project. EDI Consulting Services has completed the wildlife impact assessment of the Casino Project including the effects of the Project resulting from the two long-term wetlands and two lakes at post-closure.

While the treatment wetlands have improved the water quality for a number of parameters, the release of seepage from the WSMP downstream of the Project results in some exceedances of water quality guidelines in Casino Creek. The parameters in exceedance include: cadmium, copper, selenium, sulphate, uranium, molybdenum, and iron. As such, these seven COCs are described in detail herein and baseline water quality is included for comparison to the predicted water quality and the guideline values.

Water quality was evaluated in Dip Creek, just downstream of the confluence with Casino Creek. In Dip Creek, there is sufficient dilution that the water quality guidelines are met with the exception of cadmium, copper, selenium and iron. For iron, the baseline water quality is higher than the predicted water quality. The significance of cadmium, copper and selenium are discussed in more detail in the impact assessment.

Table of Contents

List of Tables

List of Figures

List of Appendices

Glossary

Abbreviation	Definition
BCL	Brodie Consulting Ltd
CAP	Leached cap
CCME	Canadian Council of Ministers of the Environment
CMC	Casino Mining Corporation
COC	Contaminant of concern
HLF	Heap Leach Facility
HYP	Hypogene
KPL	Knight Piésold Ltd.
Lorax	Lorax Environmental Services Ltd.
mbgs	Metres below ground surface
MMER	Metal Mining Effluent Regulations
NAG	Non-Acid Generating
PAG	Potentially Acid Generating
PECG	Palmer Environmental Consulting Group
Project	Casino Project
SART	Suphidization, acidification, recycling and thickening
SEA	Source Environmental Associates Inc.
SOX	Supergene oxide
SUS	Supergene sulphide
TDS	Total Dissolved Solids
TMF	Tailings Management Facility
WMP	Water Management Pond
WSMP	Winter Seepage Mitigation Pond
YESAB	Yukon Environmental and Socio-economic Assessment Board

1 Introduction

The Casino Project (the Project) is a proposed open pit copper-gold-molybdenum mine in the Yukon Territory by Casino Mining Corporation (CMC). The Project is located at 62.74°N and 138.82°W, approximately 300 km northwest of Whitehorse, Yukon. A location map is provided in Figure 1-1. The deposit will be mined by open pit methods and processed on-site using traditional flotation cell milling methods, with an estimated nominal mill throughput of 120,000 tonnes/day of ore, over a 22 year operating life. The Project also includes a heap leach facility for cyanide leaching of gold ore.

A water quality model was developed to predict mine drainage water quality in the receiving environment of the proposed Casino Mine. A water balance model was developed by Knight Piésold Limited (KPL, 2013a) and was used by Source Environmental Associates Inc. (SEA) as the basis for the water quality model. Mine drainage and naturally occurring sources of contaminants within the hydrologic system of the Project site were characterized, and the rate of mass transport (mass loading) from each source was estimated. Flow rate (hydrologic) estimates were combined with mass loading rates, to predict water quality concentrations of potential contaminants in the Project receiving waters.

This report presents the methodology and results of the water quality predictions. The main body of this report presents a summary of the water quality predictions in the mine drainage and in the receiving environment. Additional information related to modelling methodology and results are presented in Appendices to this report.

Source: M3 Engineering, 2013.

Figure 1-1. Location Map

2 Overview of the Proposed Mine Facilities

The following section provides a discussion of the proposed mine components and activities as they are relevant to water quality modelling. Additional information related to design and operation of the facility is provided in the *Casino Project Description* (KPL, 2013a) and the *Casino Water Management Plan* (KPL, 2013b).

2.1 Mine System Components

The following Project facilities are proposed for the Casino Project and are described in the following sub-sections:

- Open Pit;
- Ore Stockpiles;
- Processing Facility;
- Heap Leach Facility (HLF); and
- Tailings Management Facility (TMF).

2.1.1 Open Pit

Mining will be carried out by traditional open pit methods. The Open Pit will be situated between the headwaters of Casino Creek and Canadian Creek and will be up to 600 m deep and up to 2400 m wide, with an ultimate footprint area of approximately 3 km^2. The four main mineralization types found in the Open Pit are summarized in Table 2-1.

Table 2-1. Mineralization Types in the Open Pit

Mineralization Type	Acronym	Characteristics
Leached Cap (oxide gold zone)	(CAP)	Gold-enriched and copper-depleted. Forms the top layer (average 70 m thick) of the mineralization types in the Open Pit.
Supergene Oxide	(SOX)	Copper-enriched, with trace molybdenite. Generally occurs as a thin layer (10 m) above the Supergene Sulphide zone.
Supergene Sulphide	(SUS)	Copper mineralization occurs in an up to 200 m deep weathered zone below the leached cap and above the hypogene. Average thickness of 60 m.
Hypogene	(HYP)	Below the other mineralization types, also occurs throughout the various alteration zones as mineralized stock-work veins and breccias.

2.1.2 Ore Stockpiles

Temporary storage of ore will be required to provide a steady input to the mill and to the HLF throughout Operations. Ore types will be separated and placed into six stockpiles based on ore grade and mineralization type (Table 2-2).

Mitigation measures to reduce groundwater seepage will be installed for the Low Grade Supergene Oxide pile to reduce loading to the environment. The seepage reduction mitigation was assumed to have 90% load reduction efficiency in the water quality model.

Table 2-2. Casino Ore Stockpiles

Ore Stockpile Name	Project Years [1]	
	Stockpiling	Processing
Supergene Oxide Ore	-3 to 1	4 to 12
Gold[2]	-2 to 3	4 to 15
Low Grade Supergene Oxide	-1 to 15	19 to 22
Low Grade Hypogene	2 to 17	19 to 22
Low Grade Supergene Sulphide	-1 to 16	19 to 22
Marginal Grade	-1 to 16	Backfilled to Open Pit

1. Project Years are relative to the first year of ore processing in the Mill, described in Section 2.2.
2. Leached Cap (CAP) rock to be processed in the HLF.

2.1.3 Ore Processing Facility (Mill)

Ore processing is comprised of primary crushing followed by a mill circuit and conventional copper molybdenum flotation to produce molybdenum and copper concentrates. Process water will be supplied by reclaim from the TMF Pond with makeup water supplied from the Yukon River. The process will produce two tailings slurry streams: Non-Acid Generating (NAG) and Potentially Acid Generating (PAG). M3 Engineering (2013) estimated that 80% (by mass) of the total tailings will be NAG, and the remaining 20% will be PAG.

2.1.4 Heap Leach Facility (HLF)

The HLF will process crushed gold ore using a cyanide leachate system. The HLF will be constructed in a small valley upslope from Casino Creek, 1 km south of the Open Pit. An earthen embankment at the eastern end of the pad will provide structural support. A composite liner system will be constructed below the HLF to minimize seepage into the groundwater table. A spill and runoff control collection system (Events Pond) will be constructed immediately down slope from the heap leach pad. The completed HLF and associated infrastructure will encompass approximately 1.3 km^2 (KPL, 2013a).

2.1.5 Tailings Management Facility (TMF)

Tailings and waste rock will be stored in the TMF, located in the Casino Creek valley southeast of the open pit. Two embankments, the Main Embankment, and the West Saddle Embankment will be constructed across the Casino Creek valley to create the storage impoundment. The finished TMF will have a footprint area of approximately 11 km^2, and a final water surface elevation of approximately 990 m.

Waste rock and PAG tailings will be stored subaqueously to maintain a saturated state and inhibit oxidation and potential reactivity. A portion of the NAG tailings will be processed in the cyclone sand plant to produce material for construction of the TMF embankments. The remainder of the NAG tailings will be stored in the TMF.

The TMF Water Management Pond (WMP) and Winter Seepage Mitigation Pond (WSMP) will be constructed downstream from the embankments to recover seepage and runoff from the embankments. The recovered seepage will be pumped back into the TMF Pond during mine Operations.

2.2 Project Water Management Phases

The Casino Project life was sub-divided into five water management phases (Table 2-3) in this document. Project years are described relative to the beginning of milling Operations. For example, Year -2 refers to the second year before Operations begins, and Year 2 refers to the second year of Operations. Relevant information related to water quality modeling is provided in the following sub-sections.

Table 2-3. Water Management Phases

Water Management Phase	Abbreviation	Project Year
Construction Water Management	Construction	-4 to -1
Operations Water Management	Operations	1 to 22
North and South TMF Wetland Construction	Wetland Construction	23 to 30
TMF and WSMP Discharge	TMF Discharge	31 to 112
Pit Lake Discharge to North TMF Wetland	Pit Discharge	113 and beyond

2.2.1 Construction (Year -4 to Year -1)

Project construction is expected to take four years to complete. Activities relevant to water quality modelling include:

- Open Pit stripping of overburden and mining the top layer of ore;
- ore stockpile development;
- construction and operation of a fresh water supply pond (for interim use);
- construction of the fresh water supply pipeline from the Yukon River;
- construction of the Mill;
- construction and operation of the WMP downstream from the TMF footprint;
- construction of the cyclone sand plant;
- TMF embankment development; and
- construction and operation of the HLF.

Open Pit construction will begin by overburden stripping and stockpiling, followed by mining of the CAP rock from the Open Pit. The gold ore (from the CAP rock) that is removed from the Open Pit during the construction phase will be placed in a temporary stockpile (Gold Ore Stockpile), and processing by heap leaching will begin in Year -3.

The fresh water supply pipeline from the Yukon River will be constructed and operational by the end of the Construction Phase. While the water supply pipeline is under construction, a fresh water supply pond will be constructed on Casino Creek (at the north end of the TMF area) to provide an interim source of fresh water for use by the HLF.

Local borrow material and suitable waste rock from Open Pit stripping will be used for initial construction of the TMF starter Main Embankment and the West Saddle Embankment. A reclaim water pond upstream from the Main Embankment will collect surface runoff and precipitation to provide mill start-up water for initial ore processing.

2.2.2 Operations (Year 1 to Year 22)

Milling Operations will commence in Year 1 and will continue to the end of Year 22. A portion of the NAG tailings produced in the milling process will be cycloned in the Cyclone Sand Plant for construction of the TMF embankments. During Operations, unused NAG tailings (including overflow from the Cyclone Sand Plant), PAG tailings, and waste rock will be disposed of in the TMF. Waste rock will be placed at the north end of the TMF at an elevation above the design flood level of the supernatant pond to provide a dry, stable placement surface for machine access and waste rock deposition. Seepage water losses from the TMF will be collected in the WMP (downstream of the embankments) and pumped back to the TMF throughout Operations.

Mining of the Open Pit will be carried out from Year 1 until the end of Year 17. The pit will be dewatered by pump and pipeline systems and the water will be used as make-up water in the Mill.

The low grade ore stockpiles will be processed during the final four years of Operations (Year 19 to Year 22). The waste rock area will be covered by a layer (approximately 3 m thick) of NAG tailings produced by the processing of the low grade ore.

Ore stacked in the HLF will be processed until the end of Year 15. Crushed oxide gold ore sequentially piled in the HLF will be leached with an aqueous cyanide solution and the pregnant solution extracted for gold and copper using a SART facility until end of Year 18. Surplus barren solution will be treated in a cyanide destruction facility prior to re-use as leachate solution. Supplementary water will be supplied from the fresh water pipeline.

A general layout of the Project site in Year 19 is provided in Figure 2-1 to illustrate the site conditions during Operations.

2.2.3 Wetland Construction (Year 23 to Year 30)

The primary objective of the mine closure and reclamation initiative will be to achieve long-term physical and geochemical stability of the reclaimed mine components for acceptable water quality in the receiving environment. The proposed closure plan is to flood waste rock and tailings stored in the TMF and to allow the Open Pit to flood to create a Pit Lake. Additional information related to mine closure activities are provided in the *Casino Project Conceptual Reclamation and Closure Plan* (BCL, 2013).

The Wetland Construction Phase is presented in this document as the period of time immediately following ore processing, when water will be actively managed at some locations. However, some mine closure activities related to the Open Pit and HLF will begin prior to Year 23.

Closure of the Open Pit will begin prior to Year 23. Mining of the Open Pit will be completed by the end of Year 17. Dewatering will be discontinued, and the Open Pit will be allowed to fill with groundwater recharge, overland runoff, and direct precipitation.

Water from the TMF will be pumped to the Open Pit from Year 23 to Year 27 (inclusive) to expedite filling of the pit and minimize oxidation potential of the potentially reactive pit walls. Pumping to the Open Pit will stop at the beginning of Year 28, and the TMF Pond will be allowed to fill with surface runoff, precipitation and groundwater inflow to its maximum storage capacity. Filling of the TMF Pond was predicted by KPL (2013c) to be complete by the end of Year 30.

Closure of the HLF will begin before Year 23 with an ore rinsing process (Year 19 to Year 23), followed by drain down (Year 24 to Year 28). Surplus rinse water and drain down water will be treated in a cyanide destruction facility and then pumped to the Open Pit. The final slopes of the HLF ore will be graded, covered, and re-vegetated to provide adequate drainage and erosion protection from surface runoff. Surface runoff and seepage from the toe of the HLF will flow to the TMF beginning in Year 28.

Some residual ore may be present in the surface ore stockpiles following mine closure if the ore is not economical to process. Unprocessed ore will be placed in the Open Pit. For closure planning purposes, BCL (2013) assumed that the Gold Ore and Supergene Oxide Ore would be processed completely, while 5% of the low grade ores would remain at the end of mining, and none of the Marginal Ore would be processed. The 5% low grade ore remainder and 100% of the Marginal Grade Ore will be disposed of in the Open Pit. The reclaimed stockpile footprints will be covered with stockpiled overburden and re-vegetated.

Embankment seepage and runoff will be collected and pumped into the TMF Pond. Construction of two engineered wetlands within the TMF will begin. The wetlands are intended to perform as long-term passive water treatment systems for removal of contaminants by chemical precipitation and biological processes. The North TMF Wetland will be constructed for treatment of the discharge from the Pit Lake. The South TMF Wetland will be constructed immediately upstream of the TMF spillway for removal of contaminants from the TMF Pond prior to overflow to Casino Creek.

2.2.4 TMF Discharge (Year 31 to 112)

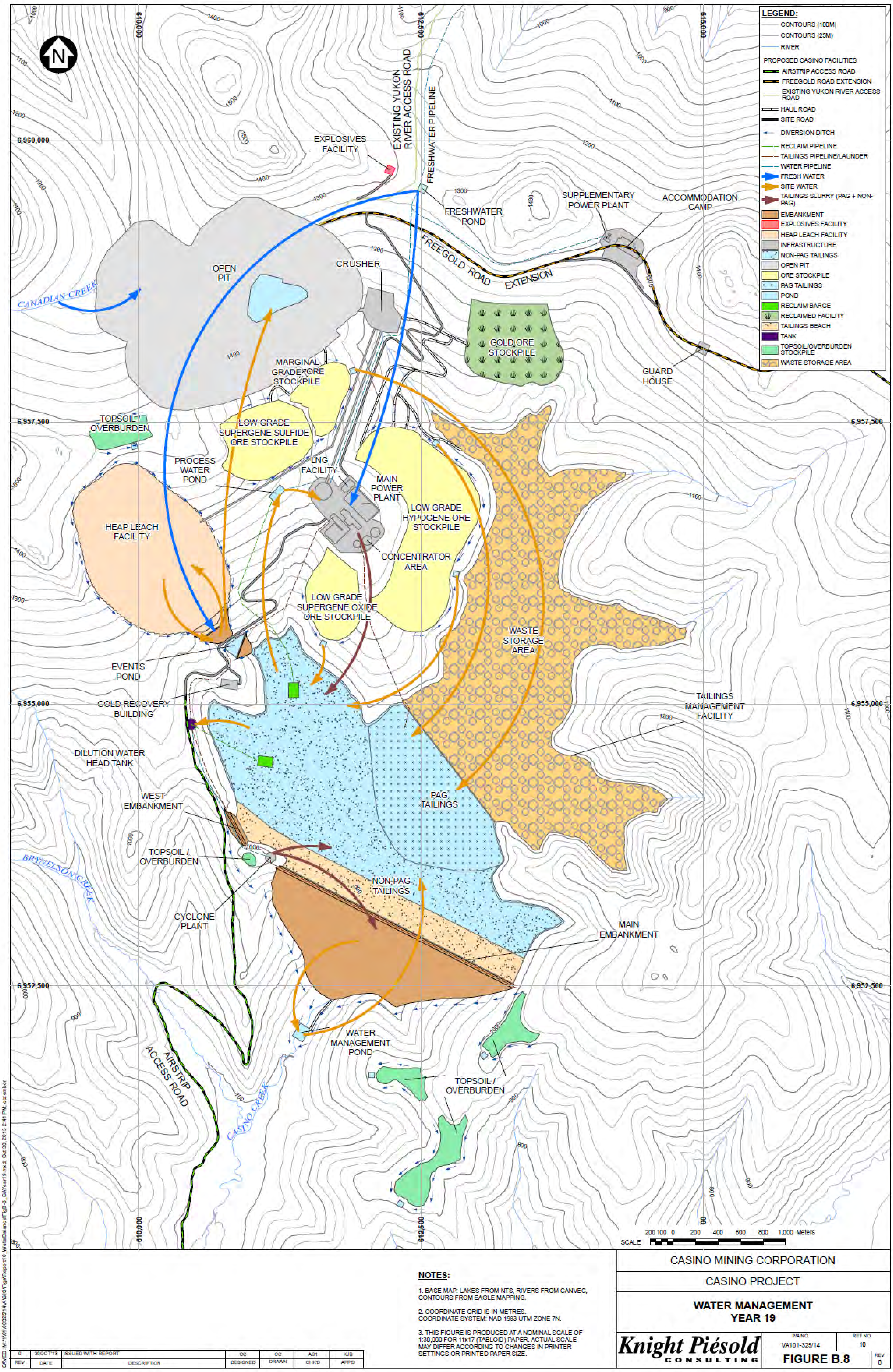
The TMF Discharge Phase will begin immediately after the TMF Pond reaches its maximum capacity and overflows to Casino Creek via the TMF Closure Spillway. KPL (2013c) predicted initial discharge of the TMF to occur during Year 31. The TMF Pond water will travel through the TMF South Wetland for passive treatment prior to release into Casino Creek.

Starting in year 31, seepage recovered downstream from the TMF embankments will be stored in the Winter Seepage Mitigation Pond (WSMP) through the low flow months of the year (winter), and released during the remaining months when the TMF Pond water discharges via the Closure Spillway, such that the seepage water quality will be less influential on the water quality in Casino Creek.

2.2.5 Pit Discharge (Year 113+)

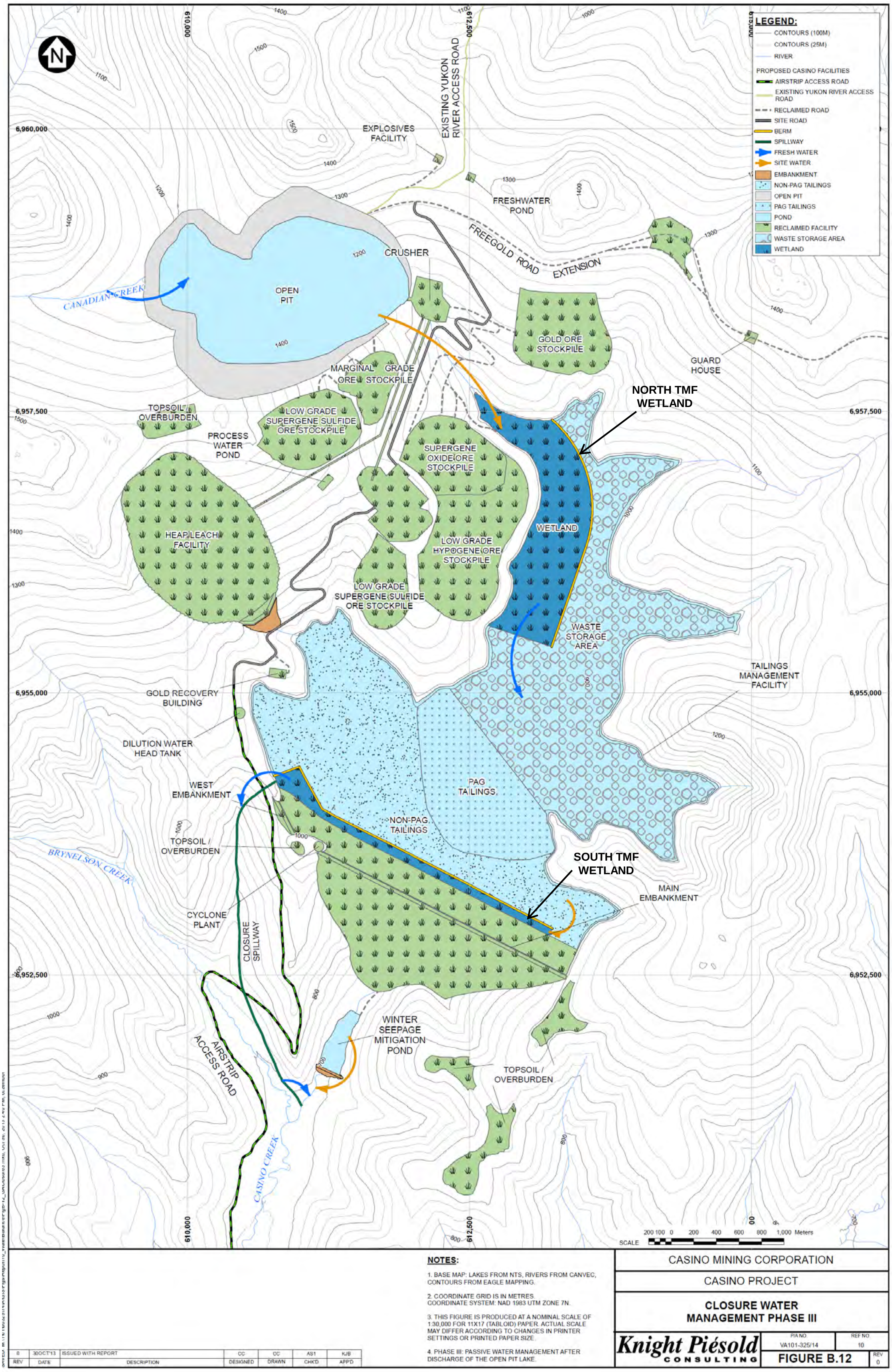
Eventually (approximately 90 years after Operations, Year 113), the Pit Lake will fill to its maximum water storage capacity and will discharge to the North TMF Wetland treatment system which will be constructed at the northern end of the TMF. Treated effluent from the wetland will discharge to the TMF Pond.

Layout of the Project site during Pit Discharge is provided in Figure 2-2 to illustrate the long-term site conditions including: the final Open Pit Lake, reclaimed HLF and stockpile areas, TMF pond, and wetland treatment systems.



Source: KPL, 2013c

Figure 2-1. Site Plan Showing Proposed Mine Components (Year 19 Operations)



Source: KPL, 2013c

Figure 2-2. Site Plan Showing Proposed Mine Components (Pit Discharge Phase)

3 Existing Site Conditions at the Casino Project

A discussion of the existing environmental conditions as they are relevant to water quality modelling are provided in the following section.

3.1 Physiography

The Casino Project property is located in the west central Yukon, in the north-westerly trending Dawson Range Mountains. The Dawson Range forms a series of rounded ridges and hills that reach a maximum elevation of 1675 m with moderate to deeply incised valleys. Major drainage channels extend below 1000 m elevation. The Yukon River is about 16 km north of the Project site and flows to the west. Most of the Casino Project lies between the 650 m elevation at Dip Creek and an elevation of approximately 1400 m on Patton Hill near the proposed open pit (M3 Engineering, 2013).

3.2 Climate

The climate at the Casino Project area is continental and cold. Winters are long, cold and dry, with snow typically on the ground from September through June. Summers are short, mild, and wet, with the greatest monthly precipitation falling in July.

Site weather data was collected by KPL (previously Hallam Knight Piesold) from 1993 to 1995. A new weather station was established in 2008 at approximately the same location at an elevation of approximately 1200 m (Figure 3-1) and has been operational since that time. Monthly average climate conditions at Casino (for an elevation of 1200 m) were derived by KPL (2013d), and are presented in Table 3-1.

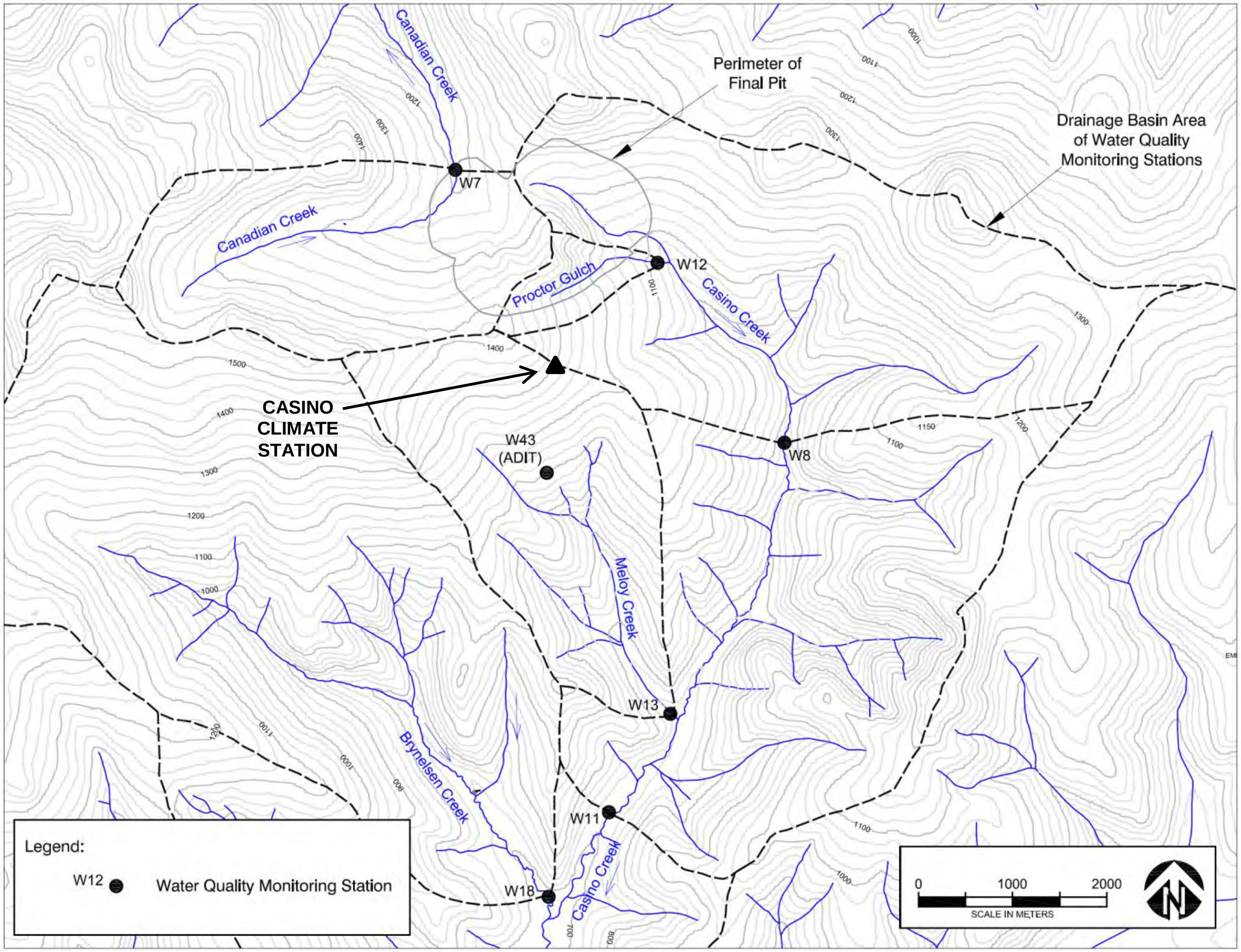


Figure 3-1. Climate and Water Quality Monitoring Stations at the Project Site

Table 3-1. Average Monthly Climate Conditions at the Casino Project Site

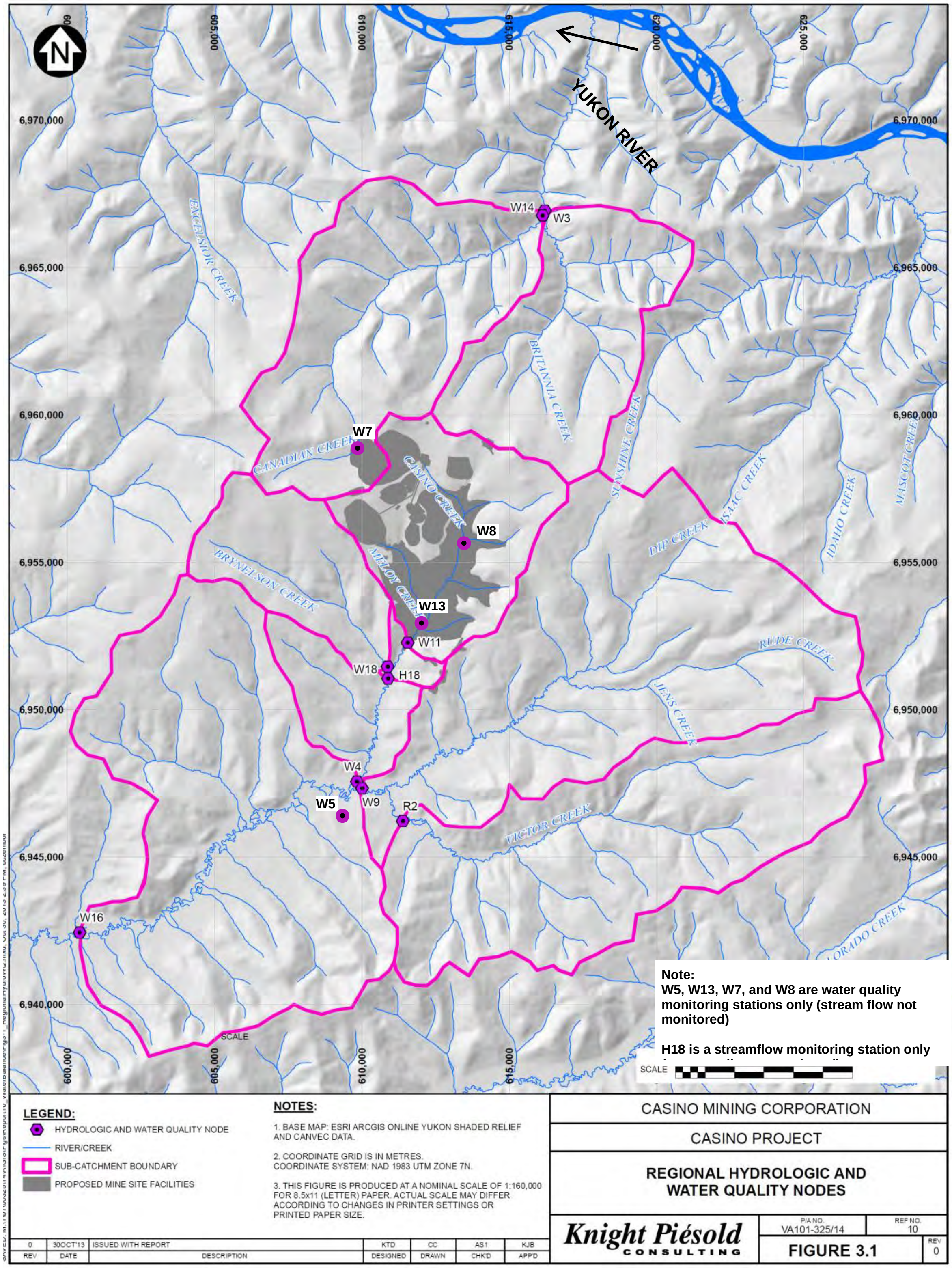
Month	Temp-erature (°C)	Evap-oration (mm)	Precip-itation (mm)	Rainfall (mm)	Snowfall (mm)	Snowmelt (mm)
Jan	-18.0	0	25	0	25	0
Feb	-14.2	0	19	0	19	0
Mar	-9.7	0	15	0	15	0
Apr	-1.9	2	13	0	13	15
May	4.9	43	37	37	0	85
Jun	9.9	72	62	62	0	0
Jul	11.4	79	91	91	0	0
Aug	9.0	68	67	67	0	0
Sep	3.7	37	48	48	0	0
Oct	-4.4	1	28	0	28	0
Nov	-12.1	0	31	0	31	0
Dec	-16.3	0	24	0	24	0
Average	**-3.2**		**38**			
Total		**303**	**460**	**305**	**155**	**100**

3.3 Hydrology

The property is within the Yukon River drainage basin. The Project is situated in the Dip Creek and Britannia Creek watersheds. Casino Creek is a tributary to Dip Creek. Dip Creek drains southwest, eventually flowing into the White River, a tributary of the Yukon River. Canadian Creek is a tributary to Britannia Creek. Britannia Creek drains north, and discharges into the Yukon River. The footprint of the proposed Open Pit is situated along the existing watershed divide between Canadian Creek and Casino Creek.

The majority of creeks in the area observe peak discharges during May, and daily fluctuations in discharge due to permafrost active layer melt, and rainfall events from June to September. The annual hydrograph typically has a bimodal shape, with high flows resulting from snowmelt in the spring freshet period and a secondary peak in mid-summer from rainfall and permafrost melt events.

Stream flow data were collected from 1993 to 1994, and 2008 to present at several locations around the Project area. Hydrometric (stream flow) monitoring station locations are presented on Figure 3-2. KPL combined site and regional hydrology data to characterise baseline hydrology conditions and summarized the results in the *Casino Baseline Hydrology Report* (KPL, 2013e).



Source: KPL, 2013c

Figure 3-2. Hydrology and Water Quality Monitoring Stations Surrounding the Project

3.4 Hydrogeology

The following section summarizes the results of *the 2012 Baseline Hydrogeology Report* that was completed by KPL (2013g). The Casino Project is situated within a region of discontinuous permafrost. Permafrost is inferred to be present at shallow depths on north-facing slopes and below organic soils in portions of the Casino Creek valley, and generally absent, or deeper, on south-facing slopes. The groundwater flow systems that develop within the Project area are controlled by the extent and spatial distribution of the permafrost in addition to topography and geology.

A surface and inferred groundwater flow divide bisects the deposit area, directing surface water and groundwater flow north toward Canadian Creek or south and east toward Casino Creek. Groundwater is inferred to discharge to surface throughout the year in creek valleys and sustains winter flows in Casino Creek and Canadian Creek. Four hydrostratigraphic units have been identified at the Project site, consisting of overburden, weathered bedrock, fresh bedrock, and fault zones. Each of the hydrostratigraphic units may be frozen or unfrozen based on the presence or absence of permafrost.

Groundwater elevations are lowest in April and May immediately preceding the spring freshet and are typically highest in August following snowmelt and summer rainfall. Relatively strong downward vertical hydraulic gradients have been observed within the upland areas of the proposed Open Pit where the water table is more than 100 m deep. Within the southeast lowlands of the proposed Open Pit, upward vertical hydraulic gradients and artesian conditions are present upslope of faults adjacent to Proctor Gulch at the head of Casino Creek. These artesian pressures suggest that faults may act as barriers to groundwater flow. Depth to groundwater along the hillslope is between 6 mbgs and 20 mbgs. Groundwater elevations are artesian within the Casino Creek valley.

3.5 Baseline Water Quality

Description of surface water quality was provided in the *Water and Sediment Quality Baseline Report* (PECG, 2013). Groundwater quality was summarized by KPL (2013g).

3.5.1 Surface Water Quality

A total of 26 sites were sampled for water quality between 2008 and 2012. Sites were concentrated in the Casino Creek (a tributary to Dip Creek) and Britannia Creek watersheds. Water quality station locations are shown on Figure 3-1 and Figure 3-2.

Water samples were collected and analyzed for the full suite of physical parameters, anions, nutrients and total and dissolved metals. Exceedences of the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of freshwater aquatic life were observed for a total of ten parameters (cadmium, copper, aluminum, iron, uranium, fluoride, zinc, lead, pH and silver) throughout the Project area. The number of exceedances was highest for aluminum, cadmium, copper and iron. With the exception of uranium, exceedances were most numerous in the summer season (May to October), indicating a seasonal trend related to hydrological factors such as snow melt and stream flow.

In general, hardness, conductivity and nitrogen based nutrients were higher in the winter months. Conversely, TSS, phosphorus based nutrients, organic matter and metal concentrations were higher in the summer months for all sites, indicating a seasonal trend most likely directly related to hydrological factors such as surface runoff and stream flow.

The 2008-2012 water quality program confirmed the unique water chemistry of Proctor Gulch (W12) as documented by Himmelright (1994). Exceedances of CCME guidelines for pH, copper, aluminum and iron were found in 100% of the 16 samples from Proctor Gulch. Fluoride, cadmium, lead and zinc were also elevated in samples from Proctor Gulch. Additionally, water quality at this site exhibited highest values for acidity (and lowest pH), hardness, conductivity, total dissolved solids and turbidity, as well as lowest values for alkalinity.

Spatially, it was observed that copper, aluminum and iron concentrations were highest at Proctor Gulch (W12) and decreased with successive sites downstream at W8, W11 and W4. This indicates that inflows from Casino Creek tributaries, Meloy Creek, Brynelsen Creek and Austin Creek, effectively dilute the Casino Creek water.

Proctor Gulch consistently showed higher concentrations in the winter than in the summer for all the metals when groundwater was the major source of flow in the winter months. Some effects from Proctor Gulch are observed in Dip Creek at site W5, just downstream of Casino Creek, particularly for copper, cadmium, lead and zinc, as background levels upstream in the Dip Creek watershed at sites W22, R2 and W9 had lower concentrations of those metals.

A historical adit established to access a lead/zinc/silver deposit in the upper Meloy Creek watershed discharges groundwater in the spring and summer months (approximately May to August). This site (W43) was found to have the highest concentrations of cadmium, lead, silver and zinc of all the sites sampled. Of these four metals, only one cadmium sample (0.00004 mg/L in April 2011) exceeded CCME guidelines in the lower reach of Casino Creek at W4, due to the small flow from the adit relative to the total Casino Creek discharge.

Table 3-2 provides a summary of parameters that exceeded CCME guidelines in the upper Dip Creek (including Casino Creek) drainage basin.

Table 3-2. Parameters with Median Water Quality Exceeding CCME Guidelines

Station	Watercourse	Water Quality Parameters Exceeding CCME Guidelines in Baseline Discharge		
		Summer	Winter	Year Round
W12	Proctor Gulch	Al, Cd, Cu, Fe, F, pH, Zn	Al, Cd, Cu, Fe, F, pH, U, Zn	Al, Cd, Cu, Fe, F, pH, Zn
W8	Casino Creek	Al, Cd, Cu, Fe	Al, Cd, Cu	Al, Cd, Cu, Fe
W43	Adit	Ag, Cd, Cu, Pb, Zn	(no flow)	Ag, Cd, Cu, Pb, Zn
W13	Meloy Creek	Cd, Pb	Cd, Cu, U	Cd
W11	Casino Creek	Al, Cd, Cu, Fe	Cd, Cu, U	Al, Cd, Cu, Fe
W18	Brynelsen	Al	-	-
W4	Casino Creek	Al, Cu	-	Cu
W5	Dip Creek	Al, Cu	-	Cu
W9	Dip Creek	Al	-	-

Summer was defined by PECG as May to October (inclusive) and winter was November to April.

Although less pronounced, an overall similar spatial pattern for cadmium, zinc, copper, aluminum, iron and lead were observed for Canadian Creek and Britannia Creek. The uppermost site on Canadian Creek (W7) is situated in close proximity to the ore body and therefore likely receives base flow with similar water quality to Proctor Gulch. This site exhibits the highest concentration of these metals in the Britannia Creek watershed, decreasing downstream to the Yukon River.

3.5.2 Groundwater Quality

Groundwater chemistry is variable throughout the Project area and has been characterized in terms of the proposed Open Pit area, the hillslope area, and the Casino Creek valley area. Groundwater samples from the proposed Open Pit area were dominantly calcium-sulphate type, and from the hillslope area were dominantly calcium-bicarbonate type. Groundwater chemistry of samples collected from the Casino Creek valley area can generally be interpreted as intermediate to that of the hillslope and proposed Open Pit areas. The groundwater types vary along the Casino Creek valley but are generally characterized as calcium-bicarbonate-sulphate in the upper limits of the valley, calcium-magnesium-bicarbonate-sulphate type through the middle of the proposed TMF area, and calcium-bicarbonate in the vicinity of the proposed TMF embankment.

The deposit area is a sulphidic ore body that has been subjected to considerable weathering and oxidation. Sulphate is present in the mineralization (as gypsum/anhydrite) and as a result sulphate has been measured at very high concentrations in this area (up to 1,100 mg/L). Mean total dissolved solids (TDS) concentrations are indicative of groundwater that is moderately to highly mineralized. In the proposed Open Pit area, significant variability in groundwater metals and metalloid concentrations was observed between samples collected from the Proctor Gulch monitoring wells and from monitoring well 94-337. The variability in the ore body geochemistry results in groundwater with low pH and low hardness in the vicinity of 94-337 and neutral pH and very hard water in the Proctor Gulch area. In the samples from 94-337, cadmium, cobalt, copper and zinc were detected at concentrations that exceeded the Yukon Contaminated Sites Regulation (YCSR) limits, and aluminum and iron were detected at concentrations that exceeded the CCME guidelines. In the Proctor Gulch area groundwater samples, cadmium and cobalt were detected at concentrations that exceeded the YCSR limits and arsenic, iron, uranium and zinc were detected at concentrations that exceeded the CCME limits.

In the hillslope area, mean TDS values in water collected from monitoring wells were indicative of slight to moderately mineralized groundwater. Samples from monitoring wells installed near the Historic Meloy Creek mine adit reported higher mean TDS values than others from the hillslope area.

Slightly higher mean TDS and higher concentrations of sulphate, sodium, fluoride, and chloride were reported in water samples obtained from the shallow groundwater well compared to the deep well. In samples from the hillslope area, cadmium, copper, and zinc were the only metals detected at concentrations that exceed the CCME guideline limits on a regular basis.

In the Casino Creek valley, mean TDS values for groundwater samples were indicative of slightly to highly mineralized conditions. Cadmium, copper, iron, and uranium were the only metals that were detected at concentrations exceeding the CCME guideline limits on a regular basis from the vicinity of the proposed TMF in the Casino Creek valley area. The elevated concentrations were not widespread and are reflective of relatively heterogeneous groundwater chemistry conditions that may result from localized variability in mineralization and from mixing with groundwater originating from the deposit area. Arsenic and zinc were also reported at concentrations that exceeded the CCME guideline limit, but the exceedances were infrequent.

4 Mine Sources of Geochemical Mass Loading

Development of the proposed mine is expected to introduce sources of geochemical mass loading to the hydrologic and water management system of the Project site and downstream environment. Sources of geochemical mass loading at the Casino Project are described in the following sections. Source terms were developed by Lorax to predict the rate of mass loading from each source into the water management system of the Casino Project (Lorax, 2013).

4.1 Open Pit Wall Rock

Blasting in the Open Pit leaves the wall rock fractured and exposed to weathering processes. The fractured rock will contribute mass loading into the Pit Lake via runoff from the pit walls. As the Pit Lake reaches its maximum storage capacity, exposed wall rock will be submerged, inhibiting potential oxidation and reactivity. A portion of the pit wall (i.e. the “high wall”) that is above the elevation of the final Pit Lake will remain un-submerged in perpetuity. Runoff from the high wall will be an on-going source of mass loading into the Pit Lake.

Pit wall runoff is expected to travel along preferential flow paths through the fractures of the unsubmerged pit wall rock. As a result, oxidation products could build-up on the the poorly drained wall rock surfaces. When the Pit Lake level rises and submerges the wall rock, those built-up oxidation products may be flushed into the Pit Lake. After submergence of the wall rock, oxidation products will no longer form on the saturated rock surfaces and no additional leaching is predicted to occur.

4.2 Ore Stockpiles

While the ore stockpiles are present during Operations, contact water (from rainfall and snowmelt) will drain from the rock as runoff or infiltration to groundwater. Runoff from the stockpiles will be captured by the TMF Pond. Hydrogeological modelling (KPL, 2013h) indicated that depending on the stockpile location, infiltrated contact water will flow to one or more of the following receptors: the TMF Pond, Open Pit, through the TMF Embankment, or through the TMF foundation.

Some residual ore may be present in the stockpiles following Operations if the ore is not economical to process. Unprocessed ore will be placed in the Open Pit at the end of Operations and during Closure. Upon submergence of the ore in the Pit Lake, the oxidation products that have built up on the ore during Operations are assumed to flush into the Pit Lake.

4.3 Processing Facility (Mill)

NAG and PAG tailings will be pumped from the Mill to the TMF as slurry. The water content of the tailings slurry will be process water from the Mill. Mass load in the slurry water will enter the TMF Pond.

Lorax (2013) assumed that select parameters (Sb, As, Mo, Se, and U) will accumulate in the process water throughout Operations. That is, those water quality parameters will continue to build up in the process water, while others will be removed from reclaim water in the milling process.

4.4 Heap Leach Facility

Ore contact water from the HLF will be a source of loading. During Operations and rinsing of the HLF, the ore contact water will be kept within a closed system and will therefore not be a source of loading to other Project components, or to the receiving environment. During rinsing and draindown, the contact water will be treated and pumped to the Pit Lake. Following draindown, HLF toe seepage and surface runoff will discharge to the TMF Pond.

4.5 TMF Waste Rock and Tailings

Tailings and waste rock will be deposited in the TMF for long-term storage. Temporary and perpetual mass loading mechanisms from the stored mine wastes are described in the following sections.

4.5.1 Unsaturated Tailings

NAG tailings will remain unsaturated in the tailings beach and the TMF embankments. Contact water (runoff) from the tailings beach will drain into the TMF Pond, and runoff from the downstream face of the TMF embankments will drain downstream to be collected in the WMP and later in the WSMP.

4.5.2 Unsaturated Waste Rock

Waste rock will be placed at the north end of the TMF. During Operations, the surface of the waste rock will be maintained above the operating level of the supernatant pond to provide a dry, stable placement surface for machine access to facilitate waste rock placement. Runoff from and infiltration through the unsubmerged portion of waste rock will carry a mass load into the TMF Pond.

Built up oxidation products that are not transported from the unsubmerged waste rock surfaces by runoff will be flushed into the TMF Pond when the supernatent pond level rises and submerges the waste rock.

4.5.3 Saturated Tailings and Waste Rock

Tailings and waste rock that are stored below the water surface in the TMF will be in chemical equilibrium with their porewater. Fluxes of water through the stored mine waste will lead to displacement of the porewater and mass transport from the deposited material into the TMF Pond, groundwater table, or TMF embankment.

4.6 Summary of Mine Loading Sources by Project Phase

Table 4-1 illustrates the mine sources of loading by Project phase. Following closure of the mine the following loading sources are expected to contribute some mass loading in perpetuity: Open Pit high wall rock, tailings beach runoff, TMF embankment runoff, runoff from spent HLF ore and displaced porewater from saturated tailings and waste rock.

Table 4-1. Loading Sources by Project Phase

Source of Loading	Casino Project Water Management Phase				
	Construction	Operations	Wetland Construction	TMF Discharge	Pit Discharge
Open Pit wall rock (runoff)					
Open Pit wall rock (flushing upon submergence)					
Ore Stockpile (runoff and infiltration)				(note 2)	
Ore Stockpile (flushing)					
Heap Leach Facility (rinsing and drain down)					
Heap Leach Facility (runoff from covered ore)					
Saturated Tailings and Waste Rock (TMF seepage)					
Unsaturated (NAG) Tailings (embankment and beach runoff)					
Unsaturated Waste Rock (runoff and flushing)					

1. Shaded cells indicate a loading source during that Project phase.
2. Because ore stockpile seepage will enter the groundwater table, a lag time can be expected from when the contact water enters the groundwater and when it reaches its point of discharge.

5 Water Quality Model Overview

A water quality model was developed to predict mine drainage water quality for various components for each Project phase to evaluate the potential impact on water quality in the receiving environment. Mass transport (mass loading) rates were estimated for potential sources of contamination within the water management system. Flow rate (water balance) estimates were combined with mass loading rates, to predict water quality concentrations of substances at the Project site and in the receiving waters of the Project site. An overview of the modelling is provided in the following sections.

5.1 Water Balance Model

A site-wide water balance model was developed by KPL. The predicted flow rates from the water balance were used by SEA as the basis for the Casino Project water quality predictions. Development of the model, and model results are provided in KPL (2013c).

5.2 Water Quality Model

A mass load balance was developed to predict the rate of contaminant transport through the modelled system. Source terms (Lorax, 2013) were combined with flow rates from the water balance to predict contaminant concentrations throughout the mine water management system and in the receiving (downstream) environment of the Casino Project.

A total of 29 water quality parameters (i.e. potential contaminants) were modelled and the full set of water quality model input values and results are provided in the Appendices of this document. This document summarizes input and output values for cadmium, copper, iron, molybdenum, selenium, sulphate, and zinc to illustrate modelling methodology and results. Modelling results for the full set of water quality parameters are presented in the Appendices of this report.

5.3 Modelling Time-Steps and Timeline

The model simulation was run for a time period beginning a few years prior to Construction, and continued for 200 years following the beginning of Operations using monthly time steps. Average monthly environmental conditions were assumed. The Project timeline with respect to relevant Project activities are provided in Table 5-1.

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Table 5-1. Milestone Dates for Water Quality Modelling

Project Year	Project Activity
-4	start of construction
-3	start of HLF processing and mining the Open Pit
1	start of milling (start of Operations)
18	Last year of Open Pit mining
19	Open Pit dewatering stops, Pit Lake begins to form
19	end of waste rock placement and begin covering waste rock with tailings layer
19	begin rinsing HLF (pump surplus water to Open Pit)
22	final year of milling (end of Operations)
23	start of pumping TMF Pond to Open Pit
24	end of HLF rinsing and start of HLF drain down (pump to Open Pit)
26	transition from the WMP to the WSMP
27	end of pumping TMF to Open Pit
28	start of TMF filling by natural recharge
28	end of HLF drain down
29	HLF drainage directed to TMF Pond
31	Initial discharge of TMF Pond and WSMP (seasonal) to Casino Creek
113	Initial discharge of Pit Lake to TMF (into North TMF Wetland)

5.4 Simplified Site-Wide Mass Loading Schematic

A simplified representation of the Casino Project water management system and receiving environment are presented schematically to illustrate the general flow paths of water and potential contaminants through the system during Operations (Figure 5-1) and for long-term conditions (Figure 5-2).

Descriptions of each of the drainage system components are presented in Section 6 (Open Pit), Section 7 (Heap Leach Facility), Section 8 (TMF Pond), Section 9 (Downstream Seepage), and Section 11 (Receiving Environment).

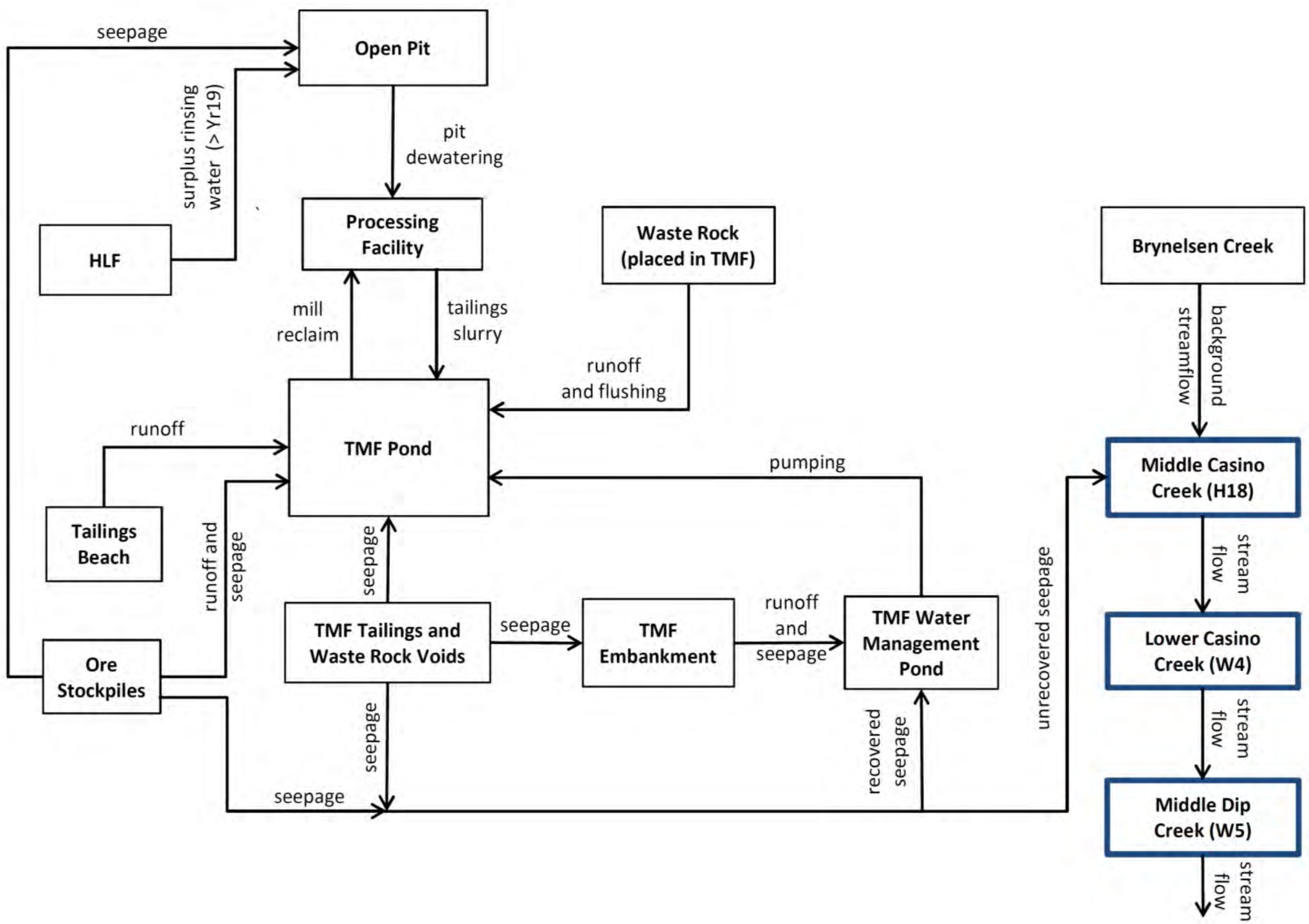


Figure 5-1. Simplified Mass Loading Schematic Casino Mine System (Operations)

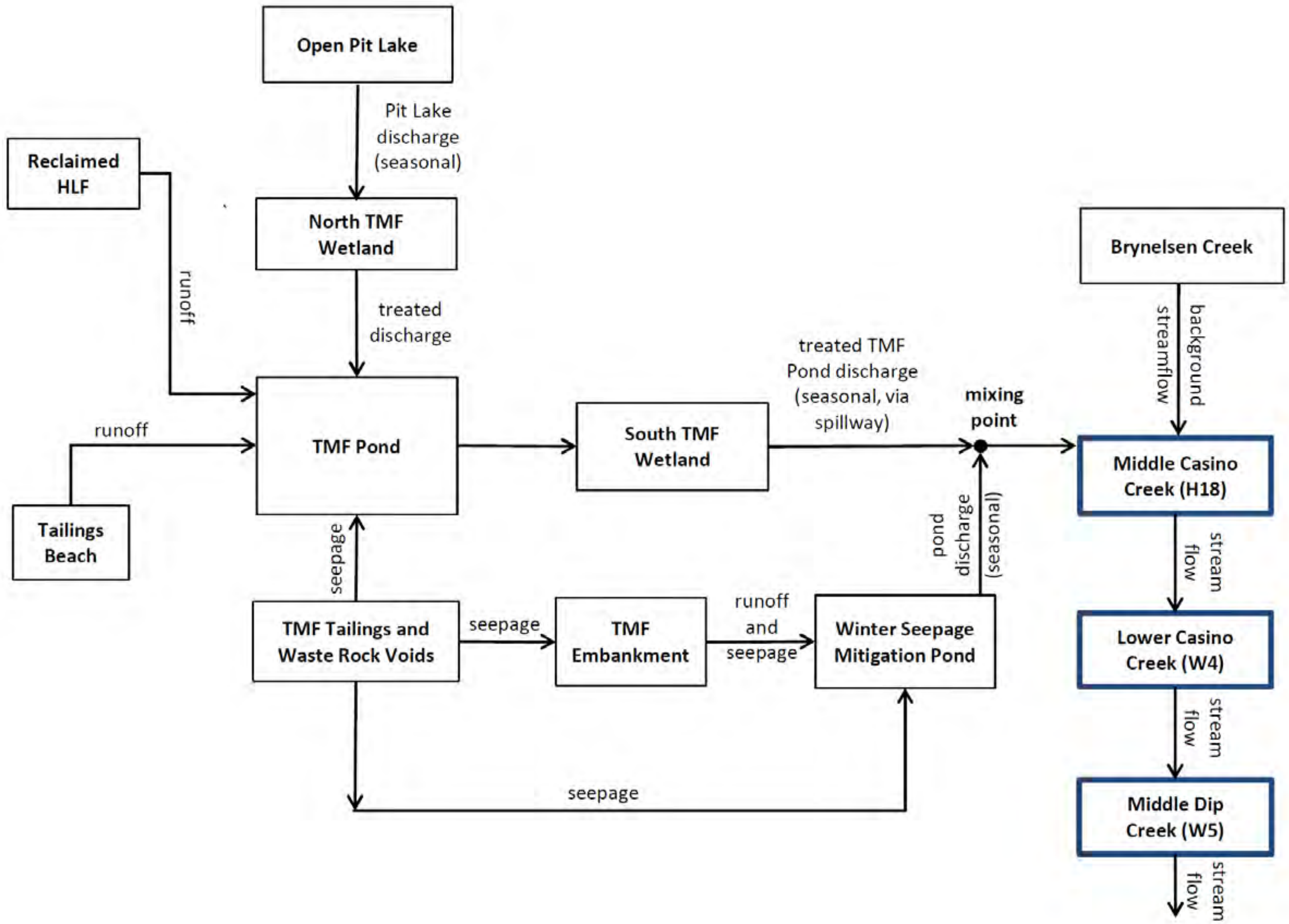


Figure 5-2. Simplified Mass Loading Schematic Casino Mine System (Pit Discharge Phase)

5.5 Modelling Platform

The model was developed using GoldSim modelling software. GoldSim is a standard platform for developing detailed water balance and water quality models for mine sites. A schematic view of one of the GoldSim model sub-components is provided in Figure 5-3 for illustration. The example includes four sub-containers (yellow boxes), one cell pathway (TMF_wq), four expressions ("f_x" icons), and one Dynamic Link Library element *("*DLL" icon). Other types of GoldSim elements are incorporated into the model but are not part of this particular example. Information about GoldSim software can be readily obtained (GoldSim Technology Group LLC, 2013).

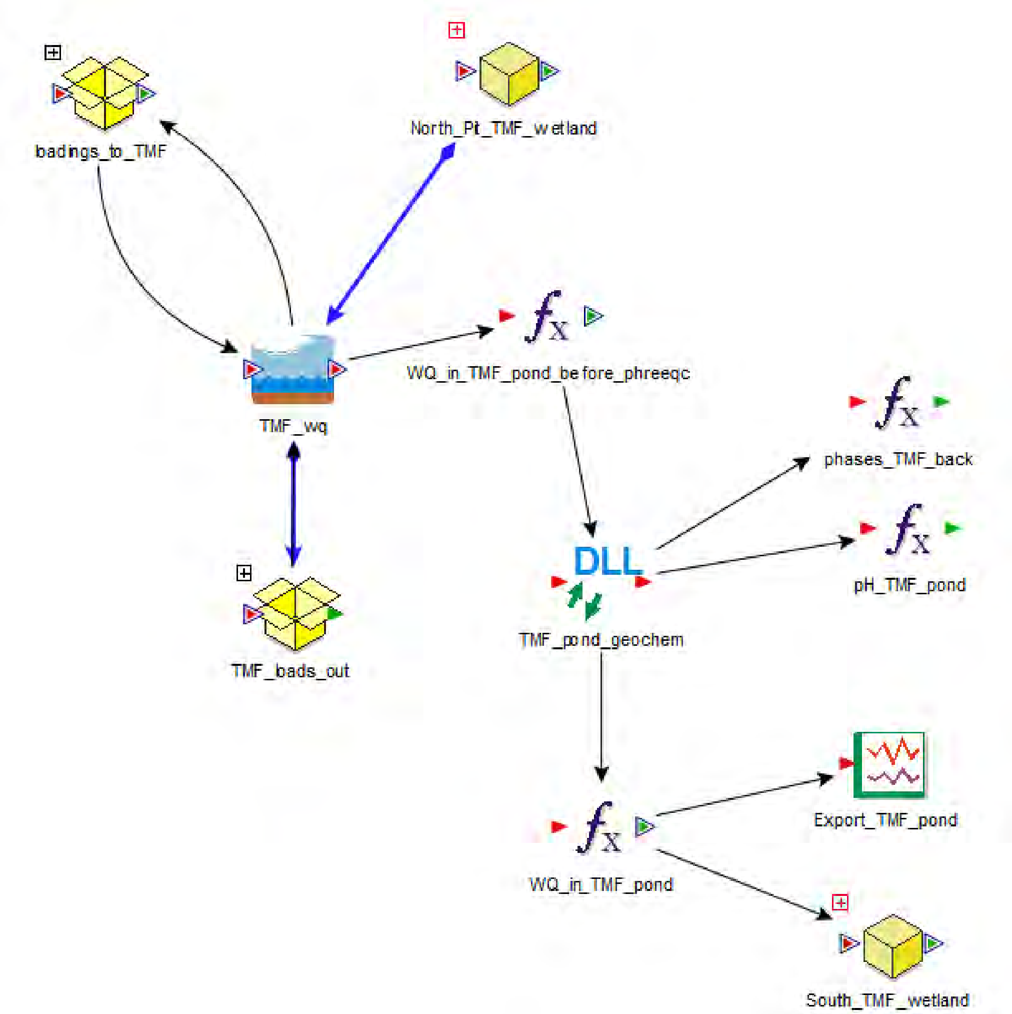


Figure 5-3. Example of the Casino Water Quality Model in GoldSim

5.6 GoldSim and PHREEQC Linkages

PHREEQC is a geochemical modelling software developed by the United States Geological Survey. The mixing model in GoldSim was linked dynamically with PHREEQC at four model nodes: the Pit Lake, the TMF Pond, the closure discharge, and in Casino Creek at H18. The closure discharge is a combination of TMF spillway discharge and the seepage and embankment runoff released from the WSMP. At each model node, a C++ DLL (dynamic link library) element was developed to represent the particular geochemical environment. Additional information related to geochemical modelling using PHREEQC are provided in Appendix I (Open Pit), Appendix IV (TMF Pond), Section 10 (post-closure mine discharge), and Section 11 (Casino Creek at H18).

During each timestep, Goldsim ran PHREEQC and the resulting concentrations returned from PHREEQC replaced the initial mixed concentrations. For example, as iron moves from a reducing enviromnment (groundwater seepage) to an oxiding environment (surface water), iron precipitates out of solution.

6 Open Pit Water Quality

Mining of the open pit will begin 4 years before the mill starts operating and will continue through the first 17 years of Operations. Dewatering will continue until Year 19 and collected water will be pumped to the mill as makeup. Pit water pumped to the Mill will take on the water quality of process water and will ultimately be discharged to the TMF Pond within the tailings slurry. Mill process water from the Open Pit dewatering was accounted for in TMF Pond water quality model (Section 8).

Following the cessation of dewatering in Year 19, the formation of Pit Lake will commence by groundwater recharge, overland runoff, and direct precipitation on the water surface in the Open Pit. During Wetland Construction (Year 23 to Year 30), unused ore present in the surface ore stockpiles will be placed in the pit and TMF Pond water will be pumped to the Open Pit. Eventually (approximately Year 113), the Pit Lake will fill to its maximum water storage capacity and discharge to the TMF North Wetland for treatment prior to discharge to the TMF Pond.

A water quality model was developed for the Pit Lake (Year 19 and beyond). Pit Lake inflow and outflow sources of mass loading are summarized in Figure 6-1.

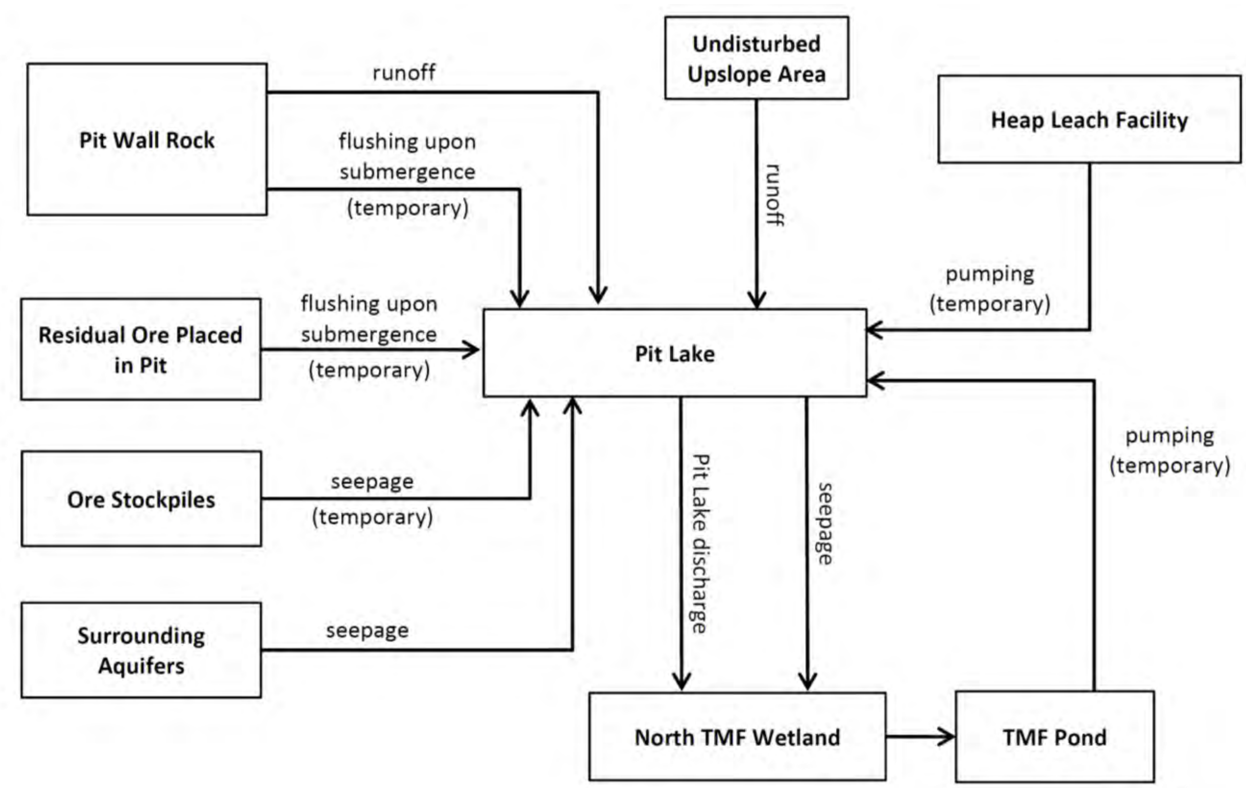


Figure 6-1. Mass Loading Flow Paths through the Pit Lake System

6.1 Water Balance Model Results

The KPL (2013c) water balance simulation showed that under average annual hydrologic conditions, the Pit Lake will fill to its maximum capacity approximately 90 years following the end of Operations (i.e. Project Year 113). Average annual Pit Lake inflows and outflows are presented in Table 6-1 for two conditions: 1) shortly following mine Operations (Year 24), and 2) long-term, following pit filling and discharge (Year 120).

Table 6-1. Pit Lake Water Balance Results

Water Balance Component	Average Annual Discharge (L/s)	
	Wetland Construction (Year 24)	Pit Discharge (Year 120)
Inflows		
Precipitation on Lake Surface	7	30
Groundwater Seepage	22	12
Ore Stockpile Seepage	< 1	0
Pit Wall Runoff	32	14
Upslope Overland Runoff	33	33
Pumping from TMF Pond	336	0
Pumping from the HLF	33	0
Total Inflow	463	89
Outflows		
Evaporation	4	19
Groundwater Seepage	0	11
Discharge	0	59
Total Outflow	4	89
Net (Inflow - Outflow)	459	0

According to the *Conceptual Reclamation and Closure Plan* (BCL, 2013), the total annual Pit Lake overflow volume will be discharged to the TMF wetland at a controlled rate during the warmest months of the year (June through September, inclusive) for optimal operation of the TMF wetland treatment system. KPL (2013c) modelled the discharge as a constant flow of approximately 180 l/s over the four month period.

6.2 Mass Load Balance and Water Quality Model Results

Water balance flows (KPL, 2013c) were combined with mine loading source terms (Lorax, 2013) and background water quality (from SEA) to predict mass loading rates of inflow and outflow of potential contaminants in the Pit Lake water. Water quality in the Pit Lake was calculated as the cumulative mass of a given substance in the Pit Lake water, divided by the water volume stored in the Pit Lake over a given time step interval. This section provides a summary of the Pit Lake water quality model results. Modelling methodology and results are provided in Appendix I of this report.

As the Pit Lake water level rises, all wall rock below the water surface will become submerged, and loading ceases for that submerged portion of the wall rock. The total planar area of un-submerged wall rock was calculated for each model time-step. From that, the relative proportions of acidic and neutral un-submerged wall rock were calculated, and their respective loading rates into the Pit Lake were applied.

The mass loading balance between Pit Lake acidity loading and available alkalinity in the water (including neutralization potential available from the submerged wall rock) indicated that over the duration of the model simulation, the available alkalinity exceeds the acidity. Geochemical modelling indicated the pH of the Pit Lake will be near neutral.

The Pit Lake will discharge to the North TMF Wetland, an engineered wetland for the removal of certain contaminants. The wetland layout was designed by BCL (2013) and is illustrated on Figure 2-2. Clear Coast Consulting Inc., (2013) provided maximum water quality concentrations for water quality parameters (Table 6-2) from the North TMF Wetland.

In the water quality modelling, if the modelled TMF Pond water quality in the North TMF Wetland discharge was higher than the maximum treatment system concentrations, then water quality in North TMF Wetland discharge was set equal to the maximum effluent water quality (Table 6-2). If no treatment was specified, the modelled water quality loading from the Open Pit was assumed to report to the TMF Pond via the wetland.

Table 6-2. North TMF Wetland Maximum Effluent Water Quality

Water Quality Parameter		Maximum Effluent Water Quality (mg/L)
Sulphate	(SO_4)	15% reduction
Cadmium	(Cd)	0.00012
Copper	(Cu)	0.0040
Molybdenum	(Mo)	0.073
Mercury	(Hg)	0.000026
Selenium	(Se)	-
Silver	(Ag)	0.00010
Uranium	(U)	0.015
Zinc	(Zn)	0.030

Average annual water quality in the Pit Lake, and predicted North TMF Wetland discharge concentrations are provided in Table 6-1 for intial discharge of the Pit Lake (Year 113), and long-term conditions (Year 200). Model output concentrations for all modelled water quality parameters are provided in Appendix I.

Table 6-3. Pit Lake Water Quality Model Results

Water Quality		Pit Lake Water Quality (mg/L)		North TMF Wetland Water Quality (mg/L)	
		Initial Pit Lake Discharge (Year 113)	Long-Term (Year 200)	Initial Pit Lake Discharge (Year 113)	Long-Term (Year 200)
Sulphate	(SO_4)	474	352	355	264
Cadmium	(Cd)	0.0039	0.0035	0.00012	0.00012
Copper	(Cu)	0.37	0.36	0.0040	0.0040
Iron	(Fe)	0.00014	0.00014	0.00013	0.00012
Molybdenum	(Mo)	0.18	0.099	0.073	0.072
Selenium	(Se)	0.0083	0.0052	0.0073	0.0046
Uranium	(U)	0.062	0.055	0.015	0.015

Individual contributions of each mass loading source are presented in Table 6-4 (initial pit discharge) and Table 6-5 for a typical year following discharge of the Pit Lake. Model output concentrations and individual contributions of mass loading sources are provided in Appendix I for all modelled water quality parameters.

Closure activities such as pumping from the HLF and TMF and disposal of residual ore stockpile rock will influence Pit Lake water quality upon initial discharge. However, those loading contributions will be temporary and will not affect the long-term water quality in the Pit Lake.

A portion of the pit wall (i.e. the "high wall") that is above the elevation of the final Pit Lake will remain un-submerged in perpetuity. Runoff from the high wall will be a perpetual source of mass loading into the Pit Lake. Generally, the acidic portion (Supergene Acidic or Hypogene Acidic) of the Open Pit high wall rock is expected to be the largest contributor of mass load into the Pit Lake in the long-term.

Table 6-4. Loading Source Contributions to the Pit Lake (Initial Discharge)

Pit Lake Loading Source	Fraction Contributing (%)						
	SO_4	Cd	Cu	Fe	Mo	Se	U
Runoff	3	1	0	0	0	0	0
Groundwater	21	8	1	27	1	0	9
Ore Stockpile Seepage	0	2	2	1	0	2	1
Pit Wall Rock	33	47	58	51	25	23	54
Ore Rock Flushing upon Submergence	12	35	38	19	6	58	26
TMF Pond Pumping	21	3	0	0	16	12	11
HLF Draindown	8	4	1	2	51	5	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Initial discharge occurred in the model at Year 113.
2. Shaded cells are for sources that contribute >10% to the overall load.
3. Values are rounded to the nearest 1 and the total of individual values may not add to exactly 100.

Table 6-5. Loading Source Contributions to the Pit Lake (Long-Term)

Pit Lake Loading Source	Fraction Contributing (%)						
	SO_4	Cd	Cu	Fe	Mo	Se	U
Runoff	8	2	0	0	1	1	0
Groundwater	40	10	1	28	15	1	13
Pit Wall Rock	52	88	99	72	84	98	87
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Year 200 was selected as the representative year for long-term conditions.
2. Shaded cells are for sources that contribute >10% to the overall load.
3. Values are rounded to the nearest 1 and the total of individual values may not add to exactly 100.

7 Heap Leach Facility Water Quality Model

Crushed oxide gold ore will be placed on the HLF until end of Year 15. The ore will be leached with an aqueous cyanide solution and the pregnant solution extracted for gold and copper. The leaching will continue until recovery is no longer profitable. For modelling purposes, KPL (2013c) assumed leaching would continue until end of Year 18 and predicted that during that time the system will operate in water deficit. That is, no surplus water will be produced by the HLF until after the end of Year 18.

After operations of the HLF, rinsing occurs from Year 19 to Year 23 and draindown occurs from Year 24 to Year 28. Surplus water will be directed to the Pit Lake, after treatment with a cyanide destruction circuit and a bioreactor for selenium and mercury (Clear Coast Consulting, 2013). The bioreactor is the preferred treatment method for selenium and mercury. Alternate treatment methods may also be considered to remove selenium and mercury during the rinsing and draindown phase.

Following draindown, the final slopes of the HLF will be graded, covered, and re-vegetated. The water quality model assumes that 20% of surplus water (i.e. 20% of net precipitation) infiltrates and becomes seepage at the toe of the HLF while the remaining 80% of surplus water is non-contact runoff. The non-contact runoff is modelled as background water quality (W13), similar to runoff from the land adjacent to the HLF. Both the toe seepage and the surface runoff from the HLF will be directed downslope to the TMF Pond. Table 7-1 provides a timeline of surplus HLF water management with predicted average annual flow rates from the KPL water balance (KPL, 2013c).

Table 7-1. HLF Surplus Water Management

Project Year	Activity	Average Annual Surplus Water (l/s)	Surplus Water Management
-3 to 18	Processing	0	-
19 to 23	Rinsing	1.6	Treated and Pump to Open Pit
24 to 28	Drain Down	33	Treated and Pump to Open Pit
29 and beyond	Reclaimed Site	10.4	Non-contact runoff to TMF Pond
29 and beyond	Reclaimed Site	2.6	HLF seepage to TMF Pond

The HLF will be underlain by a Linear Low Density Polyethylene (LLDPE) liner (KPL, 2013a). As a result, a groundwater pathway from the HLF was assumed to be negligible. Discharge from the HLF toe seepage is incorporated into the water quality model.

Lorax (2013) provided a source term for three time periods; 1) rinsing and draindown, 2) 10 years following draindown and 3) longterm. The first set of source terms was applied during the rinsing and drain down period. The second set was applied for ten years following drain down (Year 29 to Year 38) while the water quality stabilizes to long-term conditions. Long-term water quality was applied for Year 39 and beyond.

Mass loading from the HLF to the Pit Lake during rinsing and draindown was adjusted for treatment by the bioreactor (Table 7-2). Following treatment in the bioreactor, the selenium and mercury levels are reduced to 0.02 mg/L and 0.00026 mg/L, respectively. This mitigation was designed to reduce selenium levels in the North TMF wetland (Clear Coast Consulting, 2013).

The bioreactor treatment may also remove other constituents of concern in addition to selenium and mercury (e.g. uranium, silver, copper, cadmium, arsenic), however the water quality model did not account for these reductions to allow for flexibility in the treatment method as more detailed designs are developed. The cyanide destruction circuit was accounted for in the source terms provided by Lorax.

Mass loading from the HLF to the TMF Pond was accounted for by SEA in the water quality modelling by multiplying the estimated HLF toe seepage flow rate by the estimated water quality (Table 7-2). The full set of HLF surplus water quality data is provided in Appendix III.

Table 7-2. HLF Surplus Water Quality

Water Quality Parameter	HLF Surplus Water Quality (mg/L)			
	Rinsing and Draindown (Year 19 to 28)	Bioreactor Treatment* (Year 19 to 28)	10 Years Post Draindown (Year 29 to 38)	Long Term (Year 39 and beyond)
WAD-Cyanide	5.0	5.0	0.030	-
Sulphate (SO_4)	1,920	1,920	2,100	424
Cadmium (Cd)	0.0084	0.0084	0.0050	0.00028
Copper (Cu)	2.8	2.8	0.016	0.0011
Iron (Fe)	9.5	9.5	0.0040	0.0040
Molybdenum (Mo)	4.2	4.2	4.2	0.94
Selenium (Se)	0.40	0.02**	0.23	0.098
Uranium (U)	0.0018	0.0018	0.63	0.17

*Mercury is also treated for in the bioreactor to the CCME guideline level (0.026 ug/L)

**This treatment level is based on Yukon Zinc (2010)

8 TMF Pond Water Quality

The Tailings Management Facility (TMF) will be the primary water and waste management component of the Project, and was designed by Knight Piesold Ltd (KPL) to store approximately 956 million tonnes of tailings and up to 649 million tonnes waste rock and overburden (KPL, 2012). The TMF will be situated in the Casino Creek valley southeast of the Open Pit.

During Operations waste rock and tailings slurry will be deposited in the TMF with the tailings supernatant water reclaimed via the reclaim system for reuse by the mill or by the cyclone sand plant. Site runoff, including runoff from the ore stockpiles will drain to the pond. During Operations, the WMP will collect the TMF embankment runoff and seepage and pump it back to the TMF pond.

Starting in year 2023, the TMF Pond will be pumped to the Open Pit for a 5 year period and then the TMF will be allowed to refill by natural recharge. Next, the TMF Pond will discharge to Casino Creek and pumpback of the WMP to the TMF Pond will cease. The final phase will begin when the Open Pit discharges to the TMF Pond.

A water quality model was developed for the TMF Pond from Construction through to the Pit Discharge Phase. TMF Pond inflow and outflows of mass loading are summarized for Operations (Figure 8-1), and Pit Discharge (Figure 8-2).

8.1 Water Balance Model Results

The TMF Pond will be pumped to the Open Pit for five years during Wetland Construction, and will refill by natural recharge and discharge to Casino Creek by Year 31. Inflow from tailings pore water will be highest during Operations due to tailings consolidation, and will gradually reduce during closure and post-closure as the tailings consolidation process slows and eventually stops. After that time, tailings and waste rock pore water displacement will be the result of groundwater fluxes through the tailings and waste rock voids.

A summary of average annual inflows and outflows of water to the TMF Pond (derived from the KPL water balance model) is provided in Appendix IV (TMF Pond Water Quality Modelling).

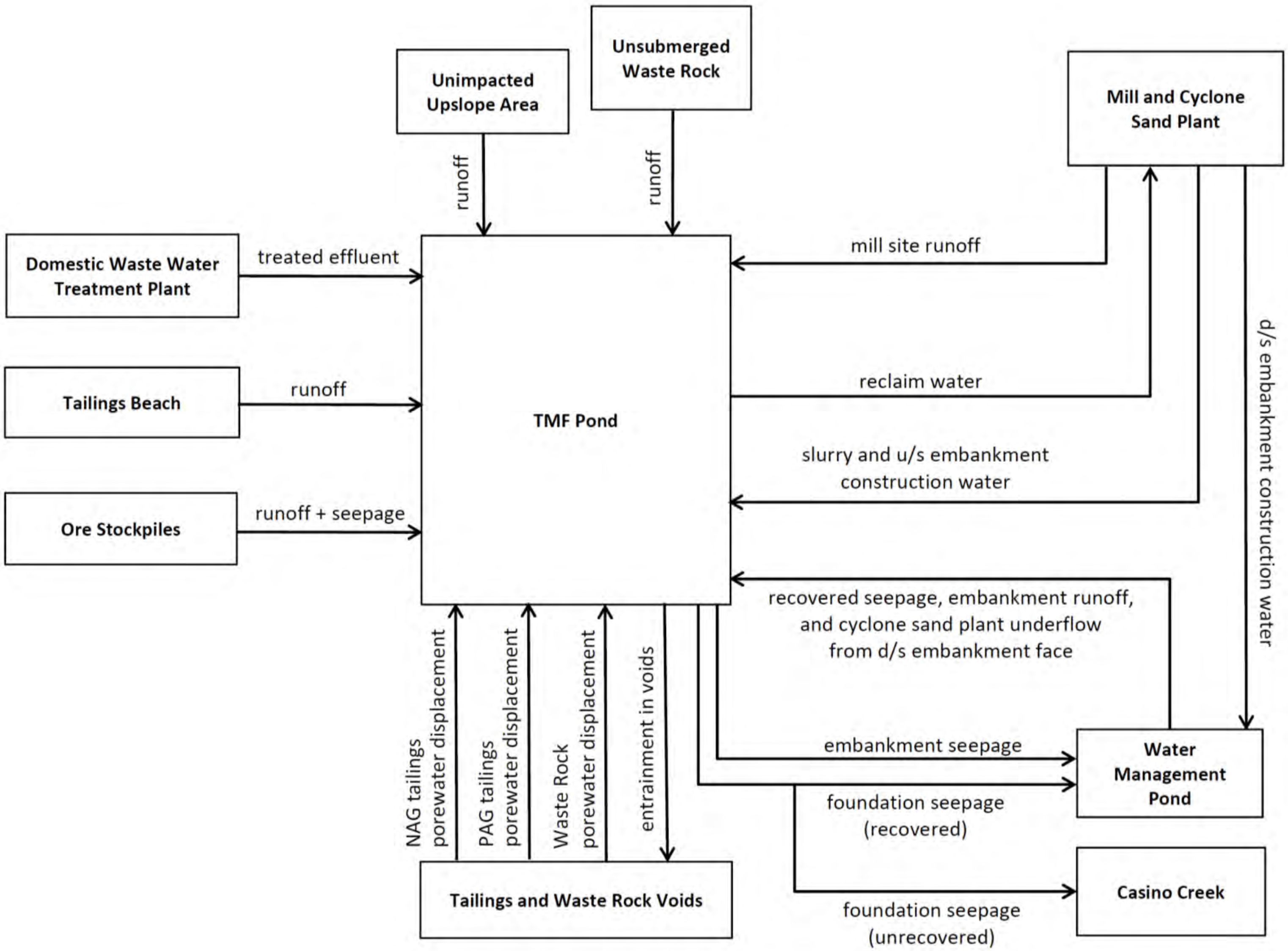


Figure 8-1. Mass Loading Flow Paths through the TMF Pond System (Operations)

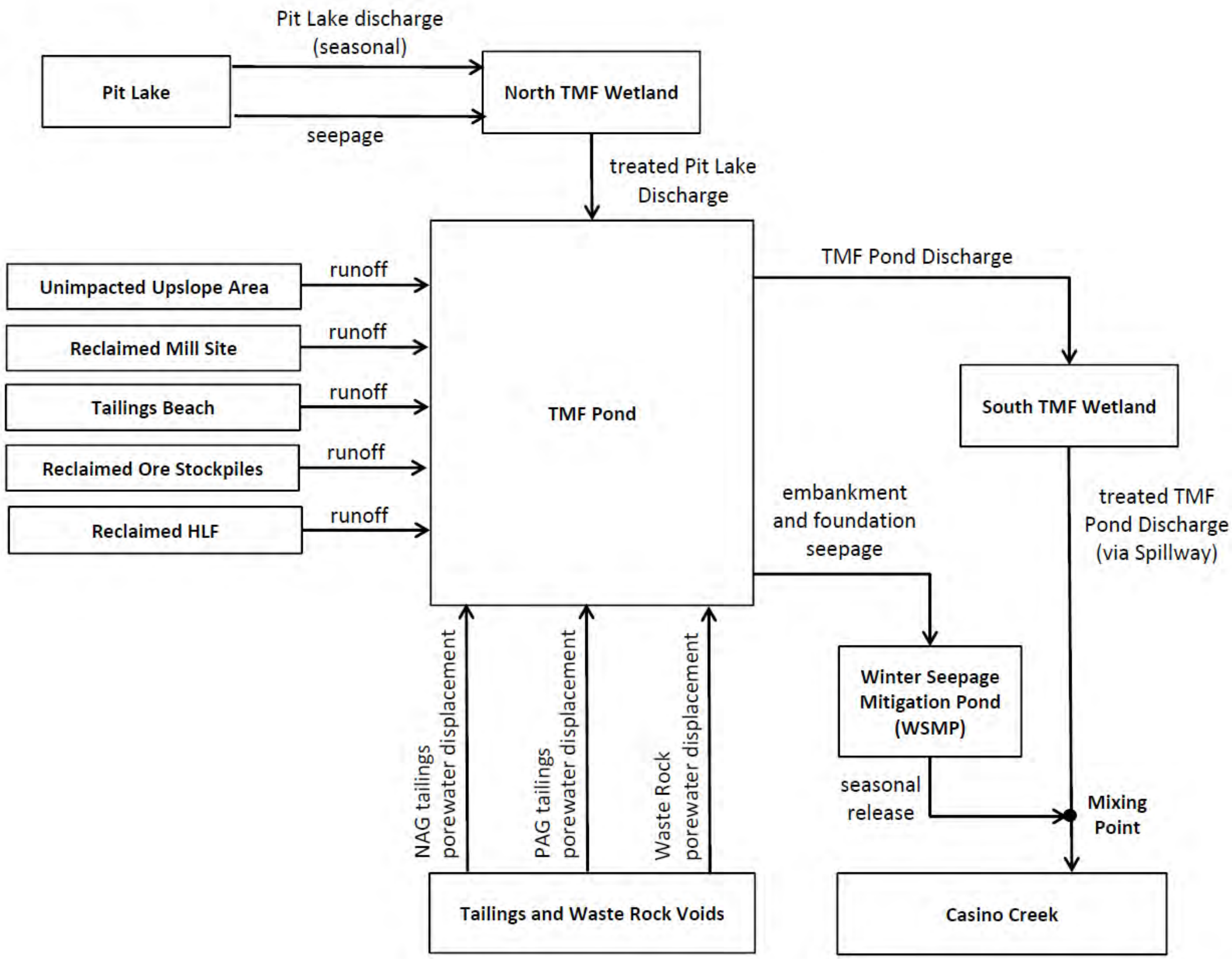


Figure 8-2. Mass Loading Flow Paths through the TMF Pond System (Pit Discharge)

8.2 Mass Load Balance and Water Quality Prediction

Water balance flows (KPL, 2013a) were combined with mine loading source terms (Lorax, 2013), and background water quality (from SEA) to predict mass loading rates of inflow and outflow of potential contaminants in the TMF Pond. Water quality in the TMF Pond was calculated as the cumulative mass of a given substance in the TMF Pond water, divided by the water volume stored in the TMF Pond over a given time step interval. This section provides a summary of the model results. Modelling methodology and results are provided in Appendix IV of this report.

After the Wetland Construction Phase, surplus TMF Pond water will discharge over the TMF spillway and into Casino Creek. Prior to discharge over the spillway, the TMF Pond water will travel through the South TMF Wetland, an engineered wetland for the removal of some contaminants. The wetland layout was designed by BCL (2013) and is illustrated on Figure 2-2.

Clear Coast Consultants (2013) provided maximum water quality concentrations for the South TMF Wetland effluent (Table 8-1). In the water quality modelling, if the modelled TMF Pond water quality in the spillway discharge was higher than the maximum treatment system concentrations, then water quality in the spillway discharge was set equal to the maximum water quality concentration of the wetland. If no treatment was specified, the modelled TMP Pond water quality was assumed to report to Casino Creek via the spillway.

Table 8-1. South TMF Wetland Maximum Effluent Water Quality

Water Quality Parameter		Maximum Effluent Water Quality (mg/L)
Sulphate	(SO_4)	15% reduction
Cadmium	(Cd)	0.00014
Copper	(Cu)	0.0040
Molybdenum	(Mo)	0.073
Mercury	(Hg)	0.000026
Selenium	(Se)	-
Silver	(Ag)	0.00010
Uranium	(U)	0.015
Zinc	(Zn)	0.030

Average annual TMF Pond water quality for select parameters are provided for a typical year during Operations (Year 15), initial discharge of the TMF to Casino Creek (Year 31), and long-term, post Pit Lake discharge (Year 120) conditions. Model output concentrations are provided in Appendix IV for all modelled water quality parameters.

Water quality is provided (Table 8-2) for the TMF Pond water, and TMF Spillway discharge to illustrate the modelled effects of the treatment wetland.

Table 8-2. TMF Pond Water Quality Model Results

Water Quality Parameter		TMF Pond Water Quality (mg/L)		
		Operations (Year 15)	Initial TMF Pond Discharge (Year 31)	Long-Term (Year 120)
Sulphate	(SO_4)	1,269	492	296
Cadmium	(Cd)	0.00067	0.00055	0.00018
Copper	(Cu)	0.33	0.073	0.086
Iron	(Fe)	0.0017	0.00034	0.00015
Molybdenum	(Mo)	0.34	0.13	0.067
Selenium	(Se)	0.017	0.0050	0.0046
Uranium	(U)	0.020	0.037	0.046
Water Quality Parameter		**TMF Spillway Water Quality (mg/L)**		
		Operations (Year 15)	**Initial TMF Pond Discharge (Year 31)**	**Long-Term (Year 120)**
Sulphate	(SO_4)	-	399	250
Cadmium	(Cd)	-	0.00014	0.00014
Copper	(Cu)	-	0.0040	0.0040
Iron	(Fe)	-	0.00033	0.00015
Molybdenum	(Mo)	-	0.073	0.066
Selenium	(Se)	-	0.0047	0.0046
Uranium	(U)	-	0.015	0.015

Individual contributions of each mass loading source are presented in Table 8-3 (typical year during Operations) and Table 8-4 (typical year following discharge from TMF and prior to Pit Lake discharge), and Table 8-5 (typical year followoing discharge of the Pit Lake). Individual contributions of mass loading sources are provided in Appendix IV for all modelled water quality parameters.

In general, during TMF Dsicharge, upward fluxes of porewater from the tailings and waste rock are the dominant loads to the TMF Pond. Once the Pit Discharge Phase begins, this source is a large proportion of the overall load to the TMF Pond for some water quality paramters.

Table 8-3. Loading Source Contributions to the TMF Pond (Operations)

Source of Loading	Fraction Contributing (%)						
	SO_4	Cd	Cu	Fe	Mo	Se	U
Background Runoff	0	1	0	0	0	0	3
Stockpile (runoff + seepage)	1	41	93	18	2	8	18
Waste Rock Runoff	0	9	0	0	0	11	8
Tailings Beach Runoff	0	1	0	0	1	0	0
HLF Drainage	0	0	0	0	0	0	0
Tailings Slurry	72	4	1	3	75	66	47
PAG Tailings Pore Water	1	1	0	3	1	1	2
NAG Tailings Pore Water	14	34	1	66	12	7	4
Waste Rock Pore Water	1	1	2	5	1	1	14
WMP Pump Back	9	6	0	5	8	5	3
North TMF Wetland Discharge	0	0	0	0	0	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Year 15 was selected as the representative year during Operations.
2. Shaded cells are for sources that contribute >10% to the overall load.
3. Values are rounded to the nearest 1 and the total of individual values may not add to exactly 100.

Table 8-4. Loading Source Contributions to the TMF Pond (TMF Discharge Phase)

Source of Loading	Fraction Contributing (%)						
	SO_4	Cd	Cu	Fe	Mo	Se	U
Background Runoff	6	22	1	3	0	1	16
Stockpile (runoff + seepage)	0	0	0	0	0	0	0
Waste Rock Runoff	0	0	0	0	0	0	0
Tailings Beach Runoff	1	1	0	0	4	1	2
HLF Drainage	3	4	0	0	20	37	7
Tailings Slurry	0	0	0	0	0	0	0
PAG Tailings Pore Water	1	1	0	1	1	1	0
NAG Tailings Pore Water	29	41	2	32	26	14	1
Waste Rock Pore Water	56	27	97	63	41	38	72
WMP Pump Back	0	0	0	0	0	0	0
North TMF Wetland Discharge	4	4	0	0	8	8	2
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Year 60 was selected as the representative year during the TMF Discharge Phase.
2. Shaded cells are for sources that contribute >10% to the overall load.
3. Values are rounded to the nearest 1 and the total of individual values may not add to exactly 100.

Table 8-5. Loading Source Contributions to the TMF Pond (Pit Discharge Phase)

Source of Loading	Fraction Contributing (%)						
	SO_4	Cd	Cu	Fe	Mo	Se	U
Background Runoff	5	25	1	5	0	0	14
Stockpile (runoff + seepage)	0	0	0	0	0	0	0
Waste Rock Runoff	0	0	0	0	0	0	0
Tailings Beach Runoff	1	1	0	0	4	1	1
HLF Drainage	2	4	0	0	16	23	6
Tailings Slurry	0	0	0	0	0	0	0
PAG Tailings Pore Water	0	0	0	0	0	0	0
NAG Tailings Pore Water	6	12	0	11	6	2	0
Waste Rock Pore Water	44	31	97	84	34	24	65
WMP Pump Back	0	0	0	0	0	0	0
North TMF Wetland Discharge	42	25	2	0	40	50	13
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Year 120 was selected as the representative year during the Pit Discharge Phase.
2. Shaded cells are for sources that contribute >10% to the overall load.
3. Values are rounded to the nearest 1 and the total of individual values may not add to exactly 100.

9 TMF Seepage Pond Water Quality Model

The Water Management Pond (WMP) will collect surface runoff and seepage from the TMF embankments and the collected water will be pumped back to the TMF Pond. Mass loading inflows and outflows to the WMP are presented in Figure 9-1.

The Winter Seepage Mitigation Pond (WSMP) will be constructed to replace the WMP. Starting in post-closure (Year 26), seepage recovered downstream from the TMF embankments will be stored in the WSMP through the low flow months of the year (winter), and released during those months when the TMF Spillway is discharging, and when Casino Creek flows are higher (spring, summer, and fall) such that the seepage water quality will be less influential on the water quality in Casino Creek. Mass loading inflows and outflows to the WSMP are presented in Figure 9-2.

9.1 Water Balance Model Results

A portion of the total seepage from the TMF tailings and waste rock voids, and ore stockpiles are expected to travel through the TMF embankment foundation. KPL (2013a) assumed that prior to the WSMP, 10% of the total TMF foundation seepage would be unrecovered by the WMP system in a given time-step, and would report to Casino Creek. The flow rate of unrecovered TMF foundation seepage at the end of operations was assumed to be 2.2 L/s. KPL assumed in the water balance that 100% of the total foundation seepage would be captured in the WSMP and released to Casino Creek during the summer months.

KPL modelled the WSMP coming online starting in Post-Closure (Year 26). However, the water collected in the WSMP was pumped to the TMF for the remainder of the Wetland Construction Phase.

KPL (2013a) estimated that for average annual conditions, water would be released from the WSMP at a controlled rate of 130 L/s from May to August (inclusive) and flows would be gradually reduced to approximately 50 L/s by November. After that time, the WSMP would collect seepage from December to April.

A summary of average annual inflows and outflows of water to the WMP / WSMP is provided in Appendix V.

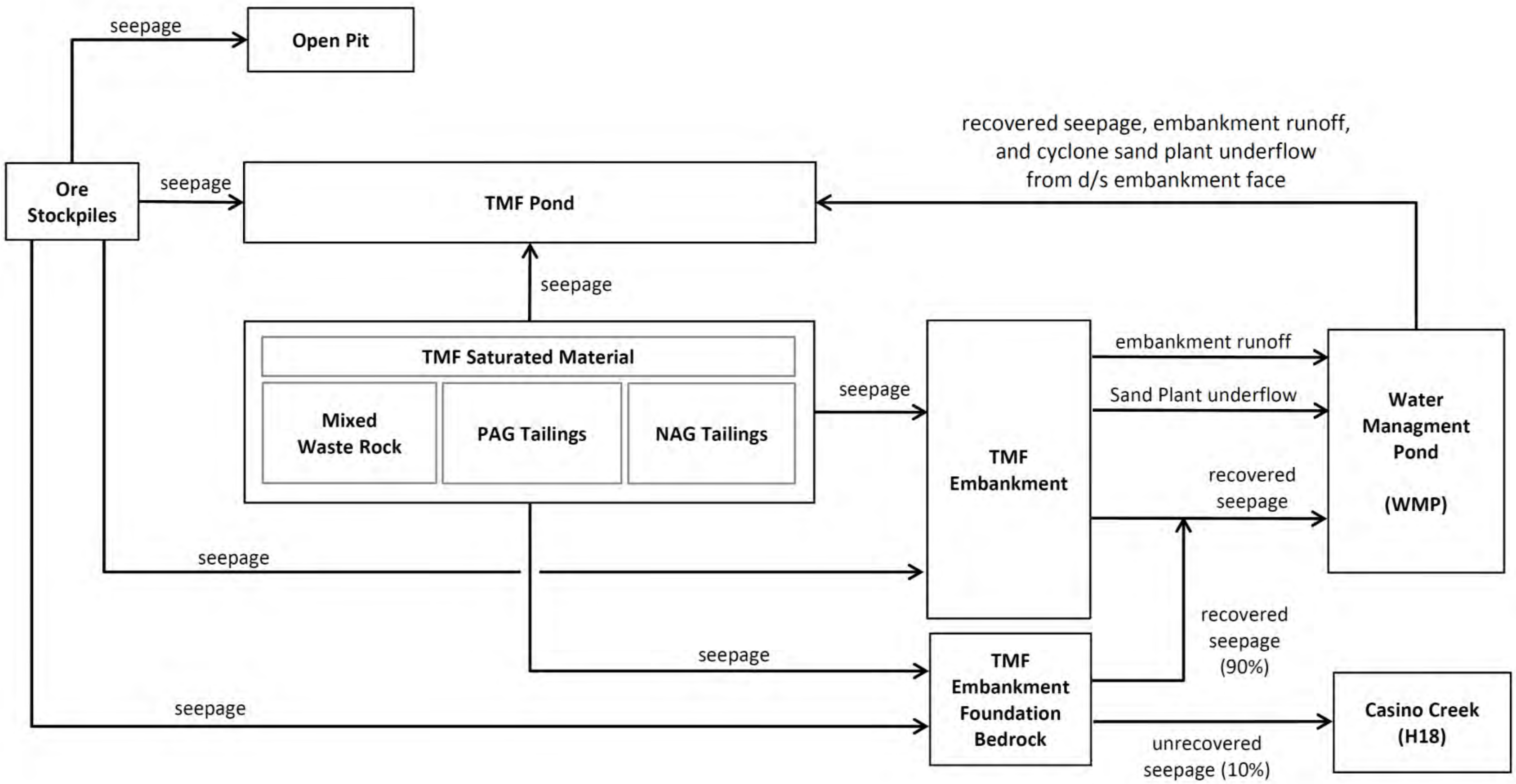


Figure 9-1. WMP Mass Loading Diagram (Operations and Wetland Construction)

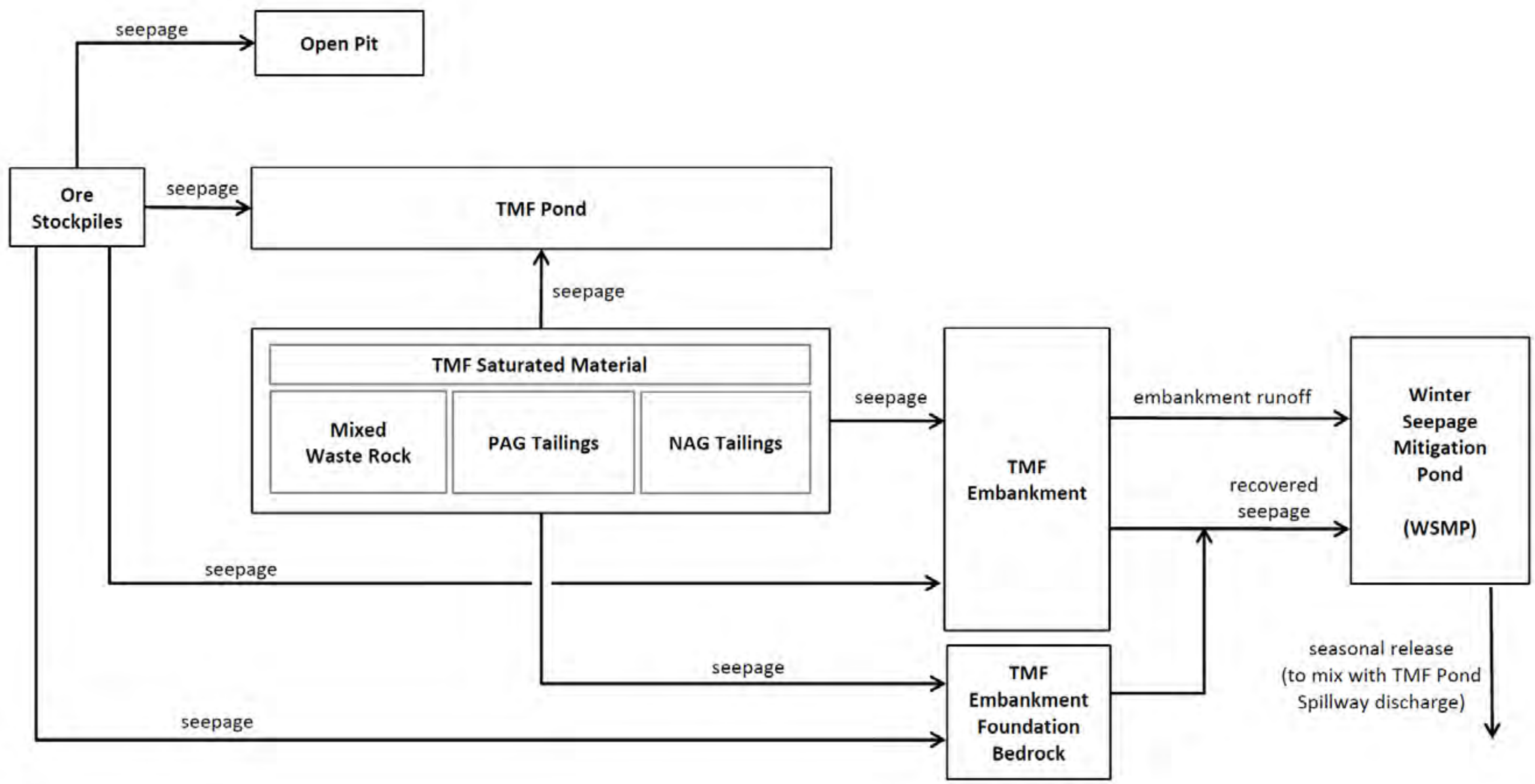


Figure 9-2. WSMP Mass Loading Diagram

9.2 Mass Load Balance and Water Quality Prediction

Water balance flows (KPL, 2013a) were combined with mine loading source terms (Lorax, 2013), and background water quality (from SEA) to predict mass loading rates of inflow and outflow of potential contaminants in the WMP and WSMP. This section provides a summary of the model results. Modelling methodology and results are provided in Appendix V of this report.

Average water quality in the WMP / WSMP while the pond water is being pumped to the TMF is presented Table 9-1 for representative years during Operations (Year 15) and Wetland Construction (Year 28). Average water quality in the WSMP from May to November (while the WSMP water is released into the TMF Spillway discharge) are presented in Table 9-2.

Table 9-1. WMP / WSMP Water Pumped to the TMF Pond

Water Quality Model Parameter		Water Quality (mg/L)	
		WMP (Operations)	WSMP (Wetland Construction)
Sulphate	(SO_4)	1,334	694
Cadmium	(Cd)	0.0007	0.0009
Copper	(Cu)	0.028	0.030
Iron	(Fe)	1.8	2.6
Molybdenum	(Mo)	0.31	0.18
Selenium	(Se)	0.0088	0.0054
Uranium	(U)	0.011	0.028
Average Annual Flow	(L/s)	214	62

Table 9-2 WSMP Water Released to Casino Creek

Water Quality Model Parameter		WSMP Water Quality (mg/L) (TMF Discharge and Pit Discharge Phases)
Sulphate	(SO_4)	861
Cadmium	(Cd)	0.0011
Copper	(Cu)	0.034
Iron	(Fe)	3.3
Molybdenum	(Mo)	0.24
Selenium	(Se)	0.0065
Uranium	(U)	0.039
Average Annual Flow	(L/s)	62

Individual contributions of each mass loading source are presented in Table 9-3 (Operations) and Table 9-4 (TMF Discharge and Pit Discharge), and Table 9-4 (Pit Discharge). Individual contributions of mass loading sources are provided in Appendix V for all modelled water quality parameters.

Table 9-3. Loading Source Contributions to WMP Pond (Operations)

Source of Loading	Fraction Contributing (%)						
	SO_4	Cd	Cu	Fe	Mo	Se	U
Background Runoff	0	0	0	0	0	0	0
Embankment Runoff	1	49	13	0	23	2	25
Stockpile Seepage	0	1	25	0	0	0	1
Tailings and Waste Rock Seepage	13	42	35	92	11	13	38
Sand Plant Slurry Underflow	86	8	28	7	66	85	36
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Year 15 was selected as the representative year during Operations.
2. Shaded cells are for sources that contribute >10% to the overall load.
3. Values are rounded to the nearest 1 and the total of individual values may not add to exactly 100.

Table 9-4. Loading Source Contributions to WSMP Pond (TMF Discharge and Pit Discharge Phases)

Source of Loading	Fraction Contributing (%)						
	SO_4	Cd	Cu	Fe	Mo	Se	U
Background Runoff	1	0	1	1	0	0	3
Embankment Runoff	4	20	9	0	29	13	46
Stockpile Seepage	0	0	0	0	0	0	0
Tailings and Waste Rock Seepage	96	80	90	99	71	87	51
Sand Plant Slurry Underflow	0	0	0	0	0	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Shaded cells are for sources that contribute >10% to the overall load.
2. Values are rounded to the nearest 1 and the total of individual values may not add to exactly 100.

10 Mine Sources of Loading to the Receiving Environment

Total loading from mine sources were calculated and used as input to the receiving environment water quality modeling (Section 11). Loading from mine sources into the receiving environment are expected to change throughout the Project life based on water management systems that are in place at a given time. The most notable milestone will be the transition from Wetland Construction to TMF Discharge, when the active water management systems are discontinued. At that time, pump-back of seepage into the TMF Pond will stop, and the TMF Pond will discharge into Casino Creek. After that time, seepage that is collected in the WSMP will be mixed with the TMF Spillway discharge during the open water season (warmer months).

Mine loading sources are described in the following sections for the active water management phases (Operations and Wetland Construction), and passive water management phases (TMF Discharge and Pit Discharge).

10.1 Operations and Wetland Construction Phases

During Operations and Wetland Construction, total loading into the receiving environment from mine sources were calculated as the sum of the loading in the unrecovered portion of the foundation seepage. The submerged tailings and waste rock would contribute loading to the seepage. Ore stockpile seepage would temporarily contribute to loading in the seepage.

KPL (2013a) predicted that the total water flow that will bypass the WMP system and enter Casino Creek will increase throughout Operations to a maximum of approximately 2.2 L/s. Bypass seepage is presented in Table 9-1. The average annual water quality of the bypassed seepage was calculated by SEA. Modelled seepage water quality in Year 15 of Operations is a reasonable representation of the average water quality in the bypass water during Operations. Average seepage flow rate in Year 15 (1.8 L/s) is shown on Figure 10-2 and average water quality in Year is presented in (Table 10-2). Water quality of the bypass seepage for additional water quality parameters are provided in Appendix V.

The KPL (2013a) water balance assumed that part way through Wetland Construction (Year 26), the WSMP will replace the WMP. Total inflow to the WSMP was pumped to the TMF Pond for the remainder of Wetland Construction in the modelling.

10.2 TMF Discharge and Pit Discharge Phases

During TMF Discharge and Pit Discharge, the WSMP will be released during the open water season and will be allowed to mix with the TMF spillway discharge prior to entering Casino Creek. SEA assessed the combined WSMP discharge and the TMF Pond for solubility controls using PHREEQC.

The combined mine discharge concentrations were assessed for solubility controls at each time step of the model simulation by coupling GoldSim and PHREEQC. During each timestep, GoldSim ran PHREEQC and the resulting concentrations returned from PHREEQC were used as the loading to Casino Creek at H18. Input assumptions are provided in Table 10-1. Geochemical modelling of the combined mine discharge removed only amorphous iron from solution.

Table 10-1 PHREEQC Assumptions for Combined Mine Discharge Water Quality

PHREEQC Input Assumptions	
Equilibrium Phases (minerals form solid phase - precipitate forms)	Fe(OH)3(a)
Database	wateq4f
pH	Charge balance (PHREEQC determines pH of solution and alkalinity)
PE	14 (oxidizing)
Oxygen	Atmospheric conditions
CO2	Atmospheric conditions

Mixing the seepage in the WSMP with the TMF discharge results in neutral mine water entering Casino Creek. The pH of the combined discharge, shown in Figure 10-1, generally ranges from pH 6 to pH 7.5. Metals that are soluble at lower pH (such as iron) precipitate out of solution upon mixing with the TMF Spillway water. The combined water quality (Table 10-2) and monthly rates of discharge (Figure 10-2) from the WSMP and TMF Pond are presented for representative years during TMF Discharge (Year 60) and Pit Discharge (Year 120). Model results for the full set of modelled water quality parameters are provided in Appendix VI.

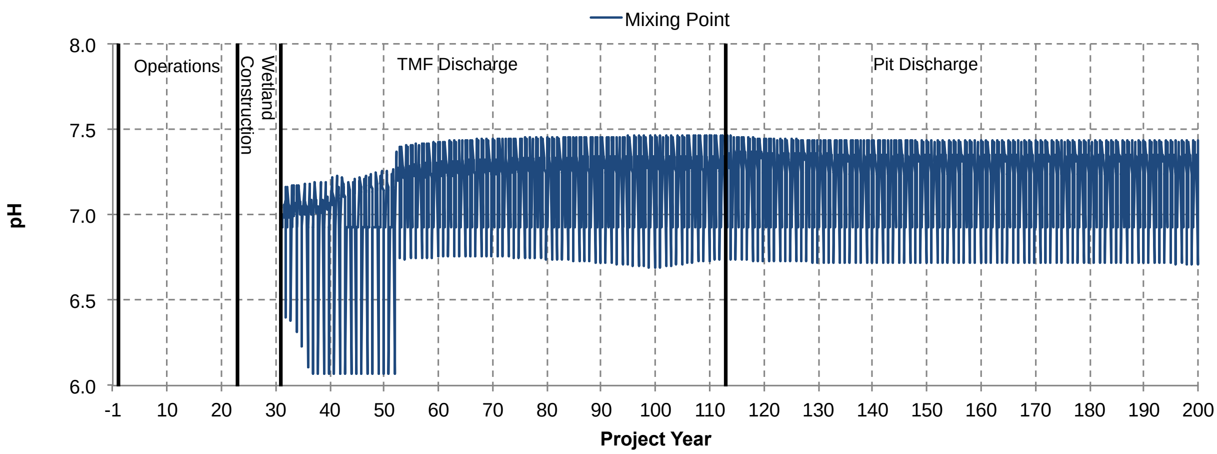


Figure 10-1. pH of the Combined Mine Discharge

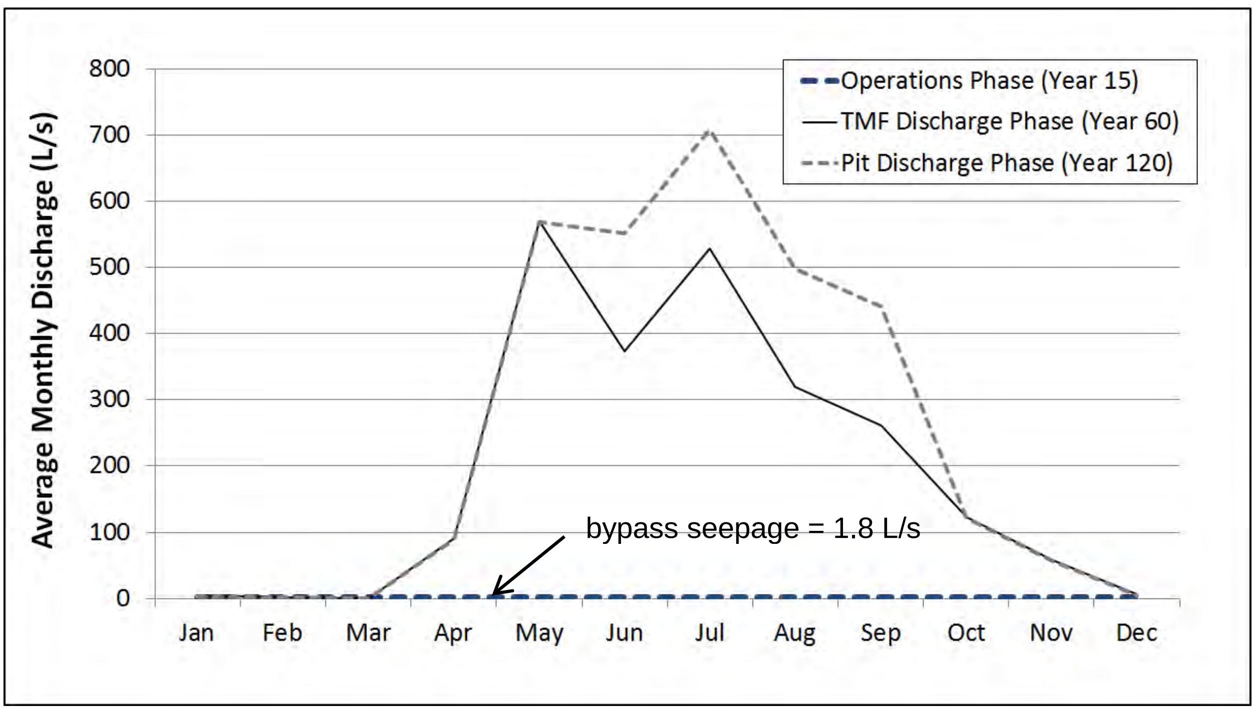


Figure 10-2. Monthly Flow of Mine Derived Water entering Casino Creek by Project Phase

Table 10-2. Water Quality of Mine Derived Water Entering Casino Creek

Water Quality Parameter		MMER (mg/L)	Mine Discharge Water Quality		
			Operations (Year 15)	TMF Discharge Phase (Year 60)	Pit Discharge Phase (Year 120)
Sulphate	(SO_4)	-	1,320	408	357
Cadmium	(Cd)	-	0.0014	0.00037	0.00033
Copper	(Cu)	0.3	0.052	0.011	0.0099
Iron	(Fe)	-	4.9	0.00019	0.00017
Molybdenum	(Mo)	-	0.27	0.11	0.10
Selenium	(Se)	-	0.0092	0.0045	0.0046
Uranium	(U)	-	0.032	0.020	0.019
Average Annual Flow	**L/s**		**1.8**	**195**	**254**

11 Receiving Environment Water Quality Model

Water quality was calculated for select locations downstream from the proposed mine. Selection of water quality prediction points, sources of loading, modelling methodology, and modelling results are presented in the following section.

11.1 Water Quality Prediction Points

All mine sources of loading are expected to report to Dip Creek watershed via Casino Creek. The following receiving environment water quality prediction points were selected:

- **Middle Casino Creek (H18)** – an existing stream flow monitoring station located immediately downstream from the confluence of Casino Creek and Brynelsen Creek. The spillway discharges location is planned for 250 m upstream of H18.

- **Lower Casino Creek (W4)** – an existing water quality and stream flow monitoring station located a short distance upstream from where Casino Creek joins Dip Creek.

- **Middle Dip Creek (W5)** – an existing water quality monitoring station, located a short distance downstream from the confluence of Casino Creek and Dip Creek.

11.2 Baseline Stream Flow

Average monthly baseline stream flow for the water quality prediction points were calculated by KPL (2013a) in the water balance (Table 11-1). The modelled stream flows were intended to represent average annual stream flows from the baseline hydrology assessment that was carried out by KPL (2013e).

Table 11-1. Baseline Monthly Stream Flow Estimates for Local Watercourses

Month	Middle Casino Creek (H18)	Lower Casino Creek (W4)	Upper Dip Creek (W9)	Middle Dip Creek (W5)
	Average Monthly Stream Flow (m^3/s)			
Jan	0.077	0.078	0.13	0.20
Feb	0.046	0.047	0.069	0.12
Mar	0.038	0.040	0.053	0.09
Apr	0.087	0.13	0.37	0.50
May	0.72	0.82	1.8	2.6
Jun	0.70	0.80	2.3	3.2
Jul	0.96	1.1	2.8	3.8
Aug	0.65	0.75	2.1	2.9
Sep	0.51	0.58	1.7	2.3
Oct	0.36	0.40	1.1	1.5
Nov	0.18	0.19	0.44	0.64
Dec	0.12	0.12	0.24	0.36
Mean Annual	**0.37**	**0.42**	**1.1**	**1.5**
Drainage Basin Area (km^2)	67	82	194	276
Mean Annual Runoff Depth (mm)	175	160	180	170

11.3 Baseline Water Quality

In the baseline water quality assessment by PECG (2013), baseline water quality was grouped into winter (November to April) and summer (May to October) seasons. For water quality modelling, SEA subdivided the summer water quality data into two sub-seasons: Spring (May and June), and Summer (July to October). SEA used the seasonal median water quality to represent baseline water quality for modelling. Baseline water quality data are presented for W18 (Table 11-2), W4 (Table 11-3), W9 (Table 11-4), and W5 (Table 11-5). CCME guidelines for the protection of aquatic life are presented beside the water quality data for reference.

Table 11-2. Baseline Water Quality at Brynelson Creek (W18)

Water Quality		CCME Guideline (mg/L)	W18 Median Water Quality (mg/L)			
			All Data	Winter	Spring	Summer
Sulphate	(SO_4)	218	23	38	20	20
Cadmium	(Cd)	0.000026	0.000013	0.000011	0.000015	0.000015
Copper	(Cu)	0.0020	0.0012	0.00056	0.0016	0.0016
Iron	(Fe)	0.30	0.053	0.010	0.11	0.11
Molybdenum	(Mo)	0.073	0.0012	0.0019	0.0011	0.0011
Selenium	(Se)	0.0010	0.000040	0.000040	0.000020	0.000020
Uranium	(U)	0.015	0.0034	0.0073	0.0026	0.0026

1. CCME guidelines for the protection of Aquatic Life are presented for reference. BC Water Quality guideline for SO_4 was used because CCME guidelines are not available. Guidelines for SO_4, Cd, Cu are hardness dependent. Values presented in this table were calculated using the median baseline hardness of Brynelson Creek at W18 (74 mg/L as $CaCO_3$).

Table 11-3. Baseline Water Quality at Casino Creek (W4)

Water Quality		CCME Guideline (mg/L)	W4 Median Water Quality (mg/L)			
			All Data	Winter	Spring	Summer
Sulphate	(SO_4)	309	41	60	20	41
Cadmium	(Cd)	0.000036	0.000027	0.000030	0.000046	0.000025
Copper	(Cu)	0.0026	0.0059	0.0019	0.014	0.0067
Iron	(Fe)	0.30	0.13	0.030	0.30	0.12
Molybdenum	(Mo)	0.073	0.0011	0.0013	0.00070	0.0011
Selenium	(Se)	0.0010	0.000070	0.000080	0.000065	0.000060
Uranium	(U)	0.015	0.0066	0.013	0.0036	0.0066

1. CCME guidelines for the protection of Aquatic Life are presented for reference. BC Water Quality guideline for SO_4 was used because CCME guidelines are not available. Guidelines for SO_4, Cd, Cu are hardness dependent. Values presented in this table were calculated using the median baseline hardness of Casino Creek at W4 (111 mg/L as $CaCO_3$).
2. Shaded cells exceed CCME guidelines.

Table 11-4. Baseline Water Quality at Dip Creek (W9)

Water Quality		CCME Guideline (mg/L)	W9 Median Water Quality (mg/L)			
			All Data	Winter	Spring	Summer
Sulphate	(SO_4)	309	15	22	3.5	13
Cadmium	(Cd)	0.000028	0.000012	0.0000080	0.000043	0.0000090
Copper	(Cu)	0.0020	0.00091	0.00068	0.0024	0.0012
Iron	(Fe)	0.30	0.084	0.043	0.90	0.12
Molybdenum	(Mo)	0.073	0.00059	0.00058	0.00042	0.00071
Selenium	(Se)	0.0010	0.000040	0.000020	0.000055	0.000030
Uranium	(U)	0.015	0.0053	0.0086	0.0035	0.0046

1. CCME guidelines for the protection of Aquatic Life are presented for reference. BC Water Quality guideline for SO_4 was used because CCME guidelines are not available. Guidelines for SO_4, Cd, Cu are hardness dependent. Values presented in this table were calculated using the median baseline hardness of Dip Creek at W9 (81 mg/L as $CaCO_3$).
2. Shaded cells exceed CCME guidelines.

Table 11-5. Baseline Water Quality at Dip Creek (W5)

Water Quality		CCME Guideline (mg/L)	W5 Median Water Quality (mg/L)			
			All Data	Winter	Spring	Summer
Sulphate	(SO_4)	309	24	34	8.1	23
Cadmium	(Cd)	0.000030	0.000017	0.000017	0.000054	0.000015
Copper	(Cu)	0.0022	0.0023	0.0011	0.0067	0.0023
Iron	(Fe)	0.30	0.089	0.052	0.72	0.078
Molybdenum	(Mo)	0.073	0.00081	0.00084	0.00049	0.00082
Selenium	(Se)	0.0010	0.000050	0.000055	0.000060	0.000050
Uranium	(U)	0.015	0.0056	0.0099	0.0030	0.0055

1. CCME guidelines for the protection of Aquatic Life are presented for reference. BC Water Quality guideline for SO_4 was used because CCME guidelines are not available. Guidelines for SO_4, Cd, Cu are hardness dependent. Values presented in this table were calculated using the median baseline hardness of Dip Creek at W9 (81 mg/L as $CaCO_3$).
2. Shaded cells exceed CCME guidelines.

11.4 Mass Loading Sources

Mass loading of contaminants from mine sources and naturally occurring sources were accounted for in the modelling and are described in the following section.

11.4.1 Mine Sources

Loading from the mine sources into the receiving environment are expected to change throughout the Project life based on water management systems that are in place at a given time. Calculation of loading from mine sources within the modelling timeframe is described in Section 10.

11.4.2 Background Loading

Naturally occurring loading present in the surface water from non-mining impacted areas was accounted for in the modelling. In this document, this source of mass loading is referred to as "background" loading.

At the proposed Casino mine site, the Upper Casino Creek drainage basin would be altered by mining from the development of the open pit and the construction of the TMF. W11 is located at the downstream-most location of the TMF. It was concluded by SEA that all area downstream from station W11 (except for the WMP and WSMP) would remain essentially unaltered from pre-mining conditions. As a result, all areas downstream from, (i.e. outside of the W11 drainage basin) would contribute background loading to the modelled water quality prediction points.

Background concentrations are for total metal concentrations, not dissolved.

11.4.3 Solubility Control in Casino Creek

SEA assessed the water quality predicted at H18 using PHREEQC at each time step of the model simulation by coupling GoldSim and PHREEQC. During each timestep, GoldSim ran PHREEQC and the resulting concentrations returned from PHREEQC were passed to Casino Creek at W4. Input assumptions are provided in Table 11-6. Geochemical modelling of Casino Creek at H18 precipitated amorphous iron during the Operations and Wetland Construction Phase when there is some seepage by-pass to H18. After mixing with non-contact stream waters, the iron concentrations are predicted to drop significantly.

Table 11-6 PHREEQC Assumptions for Combined Mine Discharge Water Quality

PHREEQC Input Assumptions	
Equilibrium Phases (minerals form solid phase - precipitate forms)	Fe(OH)3(a)
Database	wateq4f
pH	Charge balance (PHREEQC determines pH of solution and alkalinity)
PE	14 (oxidizing)
Oxygen	Atmospheric conditions
CO2	Atmospheric conditions

The pH of the combined discharge, shown in Figure 11-1 generally ranges from 6.7 to 7.4.

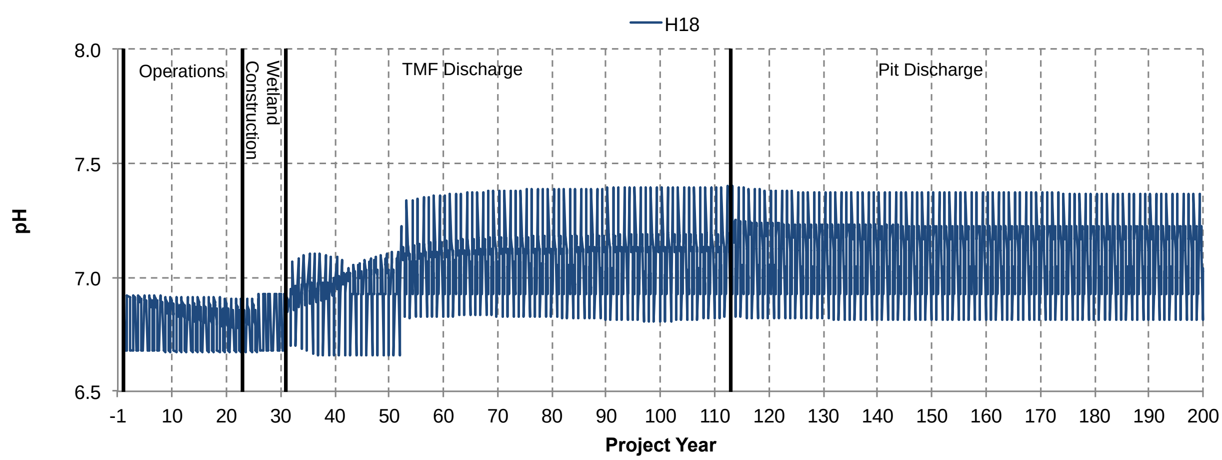


Figure 11-1 pH of the Casino Creek at H18

11.5 Mass Balance and Water Quality Modelling Equations

A mixing model was developed where the concentration of a given substance at each modelling point was calculated by adding the mass flow rate from each of the incoming loading sources, and dividing by the total volumetric flow rate at that modelling point.

The mass loading rate from each load source was calculated as the product of the concentration and the volumetric flow rate of water, as follows:

$$L = C * Q$$

Where:

L	is the mass loading rate for a given contaminant (mass of substance / time)
C	is the water quality concentration (mass of substance / volume of water); and
Q	is the flow rate of water in the modelled watercourse (volume of water / time)

Mass loading equations that were used to predict water quality in the receiving environment are presented in the following sub-sections for each modelling point.

11.5.1 Casino Creek (H18)

The total loading to H18 was calculated with the following relationship:

$$L_{H18} = L_{MINE} + L_{H18\ (BG)}$$

L_{H18}	total mass loading at H18
L_{MINE}	total mass load from mining sources
$L_{H18\ (BG)}$	background mass loading at H18

Calculation of mine sources of mass loading is described in Section 10. The background loading was calculated as the naturally occurring loading in the stream flow downstream from the TMF, and upstream from the H18 monitoring point. The equation for background loading is as follows:

$$L_{H18\ (BG)} = Q_{H18\ (BG)} * C_{H18\ (BG)}$$

$Q_{H18\ (BG)}$	background stream flow at H18
$C_{H18\ (BG)}$	background water quality (concentration) at H18

Background stream flow at H18 was calculated in the water balance model (KP 2013a). Background water quality was assumed to be equal to baseline water quality from Brynelsen Creek (W18) monitoring station because W18 makes up approximately 90% of the H18 background drainage basin.

11.5.2 Casino Creek (W4)

The total loading to W4 was calculated with the following relationship:

$$L_{W4} = L_{H18} + L_{W4\ (BG)}$$

L_{W4}	total mass loading at W4
$L_{W4\ (BG)}$	background mass loading at W4

The background loading was calculated as the naturally occurring loading in the stream flow downstream from H18, and upstream from the W4 monitoring point. The equation for background loading was calculated as:

$$L_{W4\ (BG)} = Q_{W4\ (BG)} * C_{W4\ (BG)}$$

$Q_{W4\ (BG)}$	background stream flow at W4
$C_{W4\ (BG)}$	background water quality W4

Background stream flow at H18 was calculated as the difference between baseline stream flows station W4 and H18. Background water quality at W4 was assumed to be equal to baseline water quality at W18 because W18 makes up a large portion of the W4 background drainage basin, once the TMF is constructed.

11.5.3 Dip Creek (W5)

Dip Creek (W5) is immediately downstream from the confluence between Casino Creek (at W4) and Dip Creek (at W9). Because the Dip Creek drainage basin at W9 will not be impacted by the casino Project, baseline loading at W9 be combined with the predicted loading at W4, to calculate total mass loading at W5. Water quality predictions for W5 were based on the following mass balance relationship:

$$L_{W5} = L_{W4} + L_{W9\ (BL)}$$
$$L_{W9\ (BL)} = Q_{W9\ (BL)} * C_{W9\ (BL)}$$

L_{W5}	predicted mass loading at W5
$L_{W9\ (BL)}$	baseline loading at W9
$Q_{W9\ (BL)}$	baseline stream flow at W9
$C_{W9\ (BL)}$	baseline water quality at W9

11.6 Water Quality Model Results

Water quality model results for all modelled water quality parameters are tabulated in Appendix VI of this document and are compared to CCME guidelines. CCME guidelines have not been defined as the target maximum water quality for the Casino Project; they have been compared to the water quality model results as a point of reference.

Casino Creek and Dip Creek model results are presented in Table 11-6 by Project phases for the seven parameters that were predicted to exceed guidelines at one time during the model simulation. Predicted water quality results are also presented as time-series water quality plots in the following sections.

Hardness based guidelines in the graphs were derived from median baseline hardness.

11.6.1 Casino Creek (H18 and W4)

Casino Creek model results are presented in Figure 11-2 to Figure 11-8 for the seven parameters that were predicted to exceed CCME at one time during the model simulation. Water quality at model node H18 and W4 are plotted on the same figures as they are very similar.

The predicted water quality was compared in Casino Creek to CCME for all parameters with the expectation of sulphate. There is no CCME guideline for sulphate and as a result the BCWQG was used. Baseline (pre-mining) concentrations were also included on the graphs.

The treatment wetlands have improved the water quality of a number of parameters from the TMF discharge. The release of seepage from the WSMP downstream of the Project results in some exceedances of CCME water quality guidelines in Casino Creek. The presentation of water quality results does not represent an impact assessment. PECG completed the impact assessment for the Casino Project. It should be noted that where natural baseline (background) water quality exceeds CCME, so will the values predicted in the model.

Table 11-7. Average Annual and Seasonal Water Quality Predictions in the Receiving Environment

Water Quality		CCME Guideline (mg/L)	Operations (Year 20)				TMF Discharge Phase (Year 60)				Pit Discharge Phase (Year 120)			
			Annual	Winter	Spring	Summer	Annual	Winter	Spring	Summer	Annual	Winter	Spring	Summer
Casino Creek (H18)														
Sulphate	(SO_4)	309	96	143	30	31	226	177	319	278	209	165	290	258
Cadmium	(Cd)	0.000036	0.000082	0.00012	0.000026	0.000027	0.00021	0.00015	0.00028	0.00029	0.00019	0.00015	0.00026	0.00025
Copper	(Cu)	0.0026	0.0043	0.0058	0.0022	0.0022	0.0065	0.0047	0.0093	0.0088	0.0060	0.0046	0.0085	0.0076
Iron	(Fe)	0.30	0.0003	0.0003	0.0002	0.0002	0.022	0.0068	0.041	0.045	0.019	0.0069	0.037	0.035
Molybdenum	(Mo)	0.073	0.015	0.024	0.0033	0.0035	0.056	0.041	0.077	0.079	0.053	0.038	0.073	0.074
Selenium	(Se)	0.0010	0.00052	0.00082	0.000098	0.00011	0.0022	0.0016	0.0033	0.0029	0.0024	0.0016	0.0035	0.0034
Uranium	(U)	0.015	0.0075	0.011	0.0030	0.0030	0.013	0.012	0.014	0.016	0.013	0.012	0.014	0.015
Casino Creek (W4)														
Sulphate	(SO_4)	309	85	127	27	28	200	158	281	243	187	148	260	233
Cadmium	(Cd)	0.000036	0.000070	0.00010	0.000022	0.000023	0.00018	0.00013	0.00025	0.00025	0.00017	0.00013	0.00023	0.00023
Copper	(Cu)	0.0026	0.0038	0.0050	0.0020	0.0021	0.0058	0.0041	0.0083	0.0078	0.0054	0.0041	0.0078	0.0070
Iron	(Fe)	0.30	0.02	0.04	0.01	0.02	0.026	0.0073	0.050	0.054	0.023	0.0074	0.045	0.043
Molybdenum	(Mo)	0.073	0.013	0.021	0.0027	0.0029	0.049	0.035	0.067	0.068	0.047	0.033	0.065	0.066
Selenium	(Se)	0.0010	0.00044	0.00070	0.000076	0.000083	0.0019	0.0014	0.0029	0.0025	0.0021	0.0014	0.0031	0.0030
Uranium	(U)	0.015	0.0071	0.010	0.0028	0.0029	0.012	0.011	0.013	0.014	0.012	0.011	0.013	0.014
Casino Creek (W5)														
Sulphate	(SO_4)	309	30	41	11	15	62	51	88	69	62	49	87	76
Cadmium	(Cd)	0.000030	0.000022	0.000026	0.000024	0.000011	0.000051	0.000034	0.000088	0.000067	0.000053	0.000034	0.000090	0.000071
Copper	(Cu)	0.0022	0.0015	0.0015	0.0018	0.0014	0.0021	0.0014	0.0036	0.0028	0.0021	0.0014	0.0036	0.0029
Iron	(Fe)	0.30	0.16	0.098	0.43	0.13	0.11	0.036	0.35	0.11	0.10	0.036	0.35	0.10
Molybdenum	(Mo)	0.073	0.0029	0.0043	0.00089	0.00100	0.012	0.0081	0.020	0.017	0.013	0.0076	0.021	0.019
Selenium	(Se)	0.0010	0.00010	0.00015	0.000047	0.000037	0.00049	0.00033	0.00087	0.00063	0.00058	0.00033	0.0010	0.00089
Uranium	(U)	0.015	0.0069	0.0089	0.0038	0.0043	0.0082	0.0092	0.0065	0.0068	0.0083	0.0092	0.0068	0.0073

1. Shaded cells show where modelled concentrations exceed the CCME Guidelines for the protection of freshwater aquatic life. Water quality limits have not been established and the CCME guidelines are provided as a point of reference only.
2. BC Water Quality guideline for sulphate was used because CCME guidelines are not available.
3. Water quality guidelines for SO4, Cd, Cu, Pb, and Ni are hardness dependent. Values presented in this table were calculated using the median baseline hardness of 111 mg/L as $CaCO_3$ (H18 and W4) and 90 mg/L as $CaCO_3$ (W5).

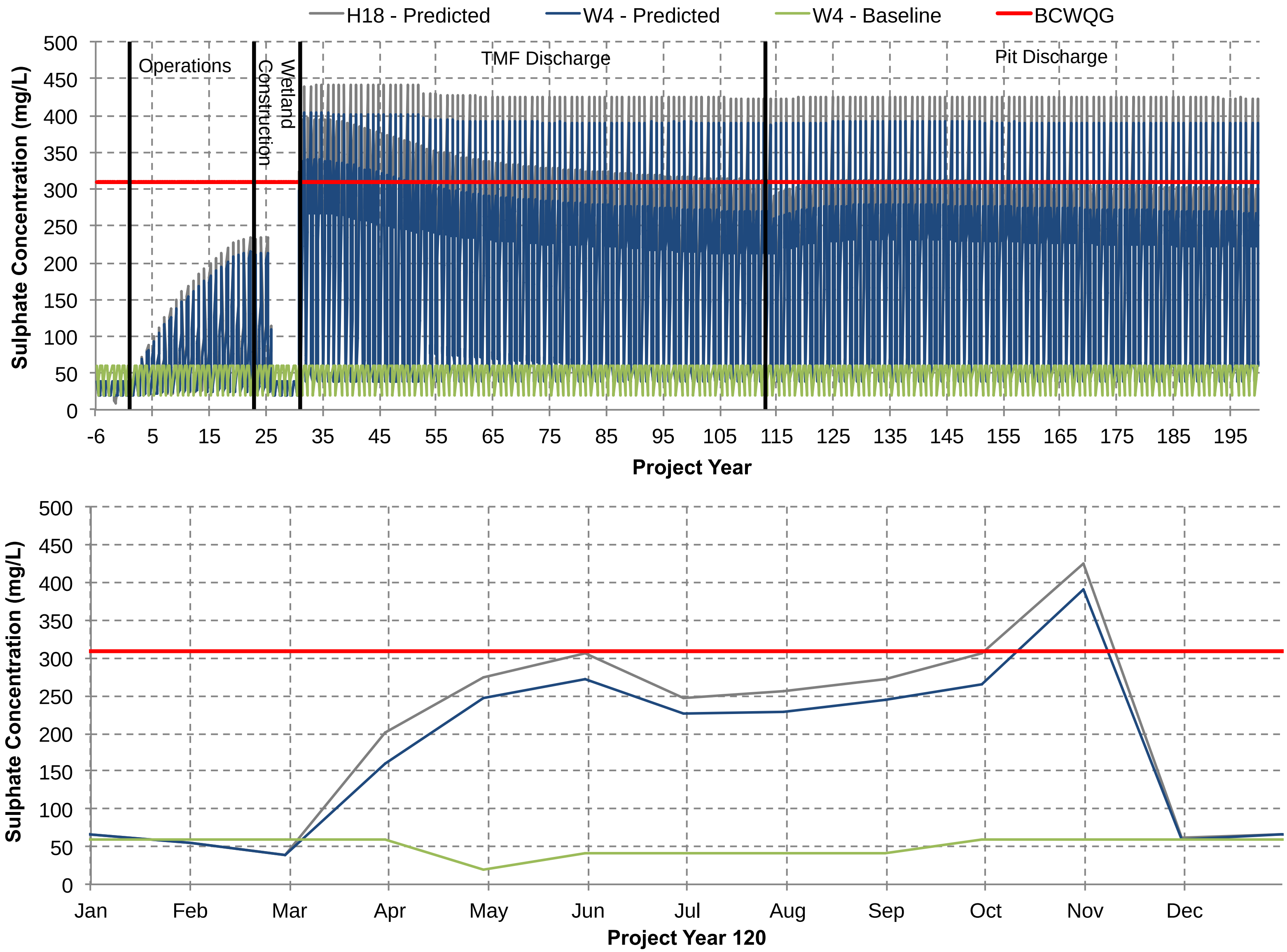


Figure 11-2. Modelled Sulphate Concentration at H18 and W4

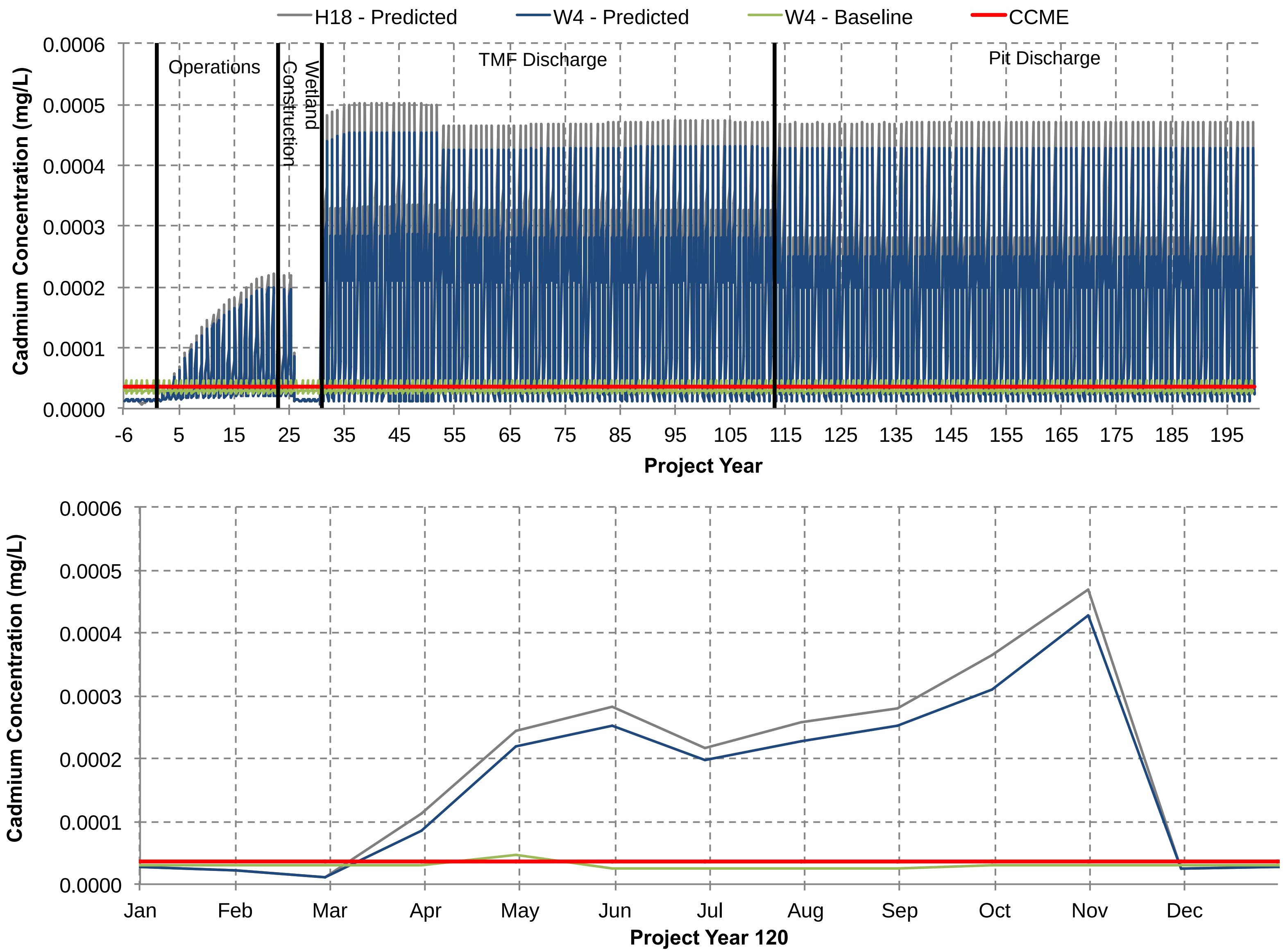


Figure 11-3. Modelled Cadmium Concentration at H18 and W4

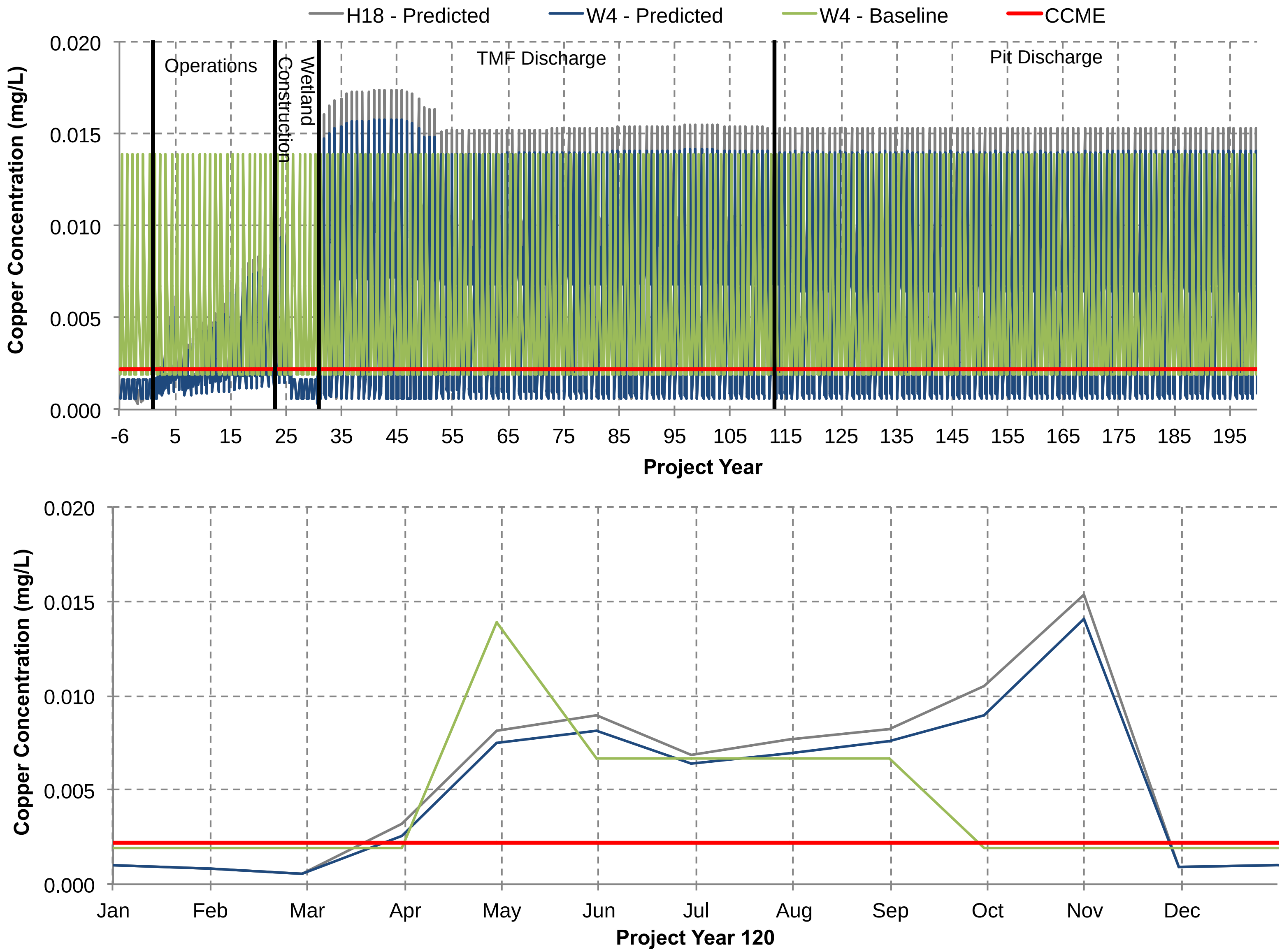


Figure 11-4. Modelled Copper Concentration at H18 and W4

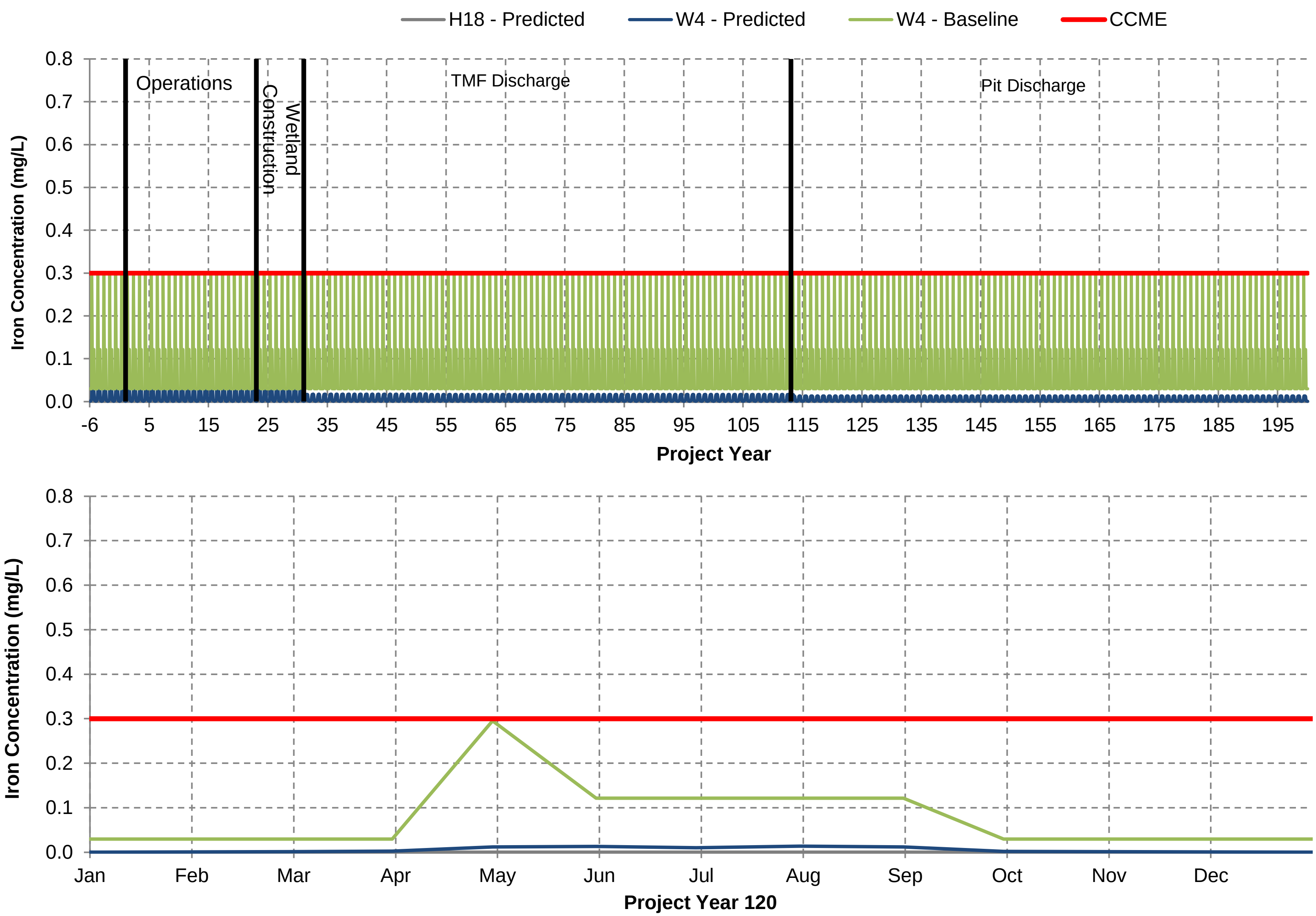
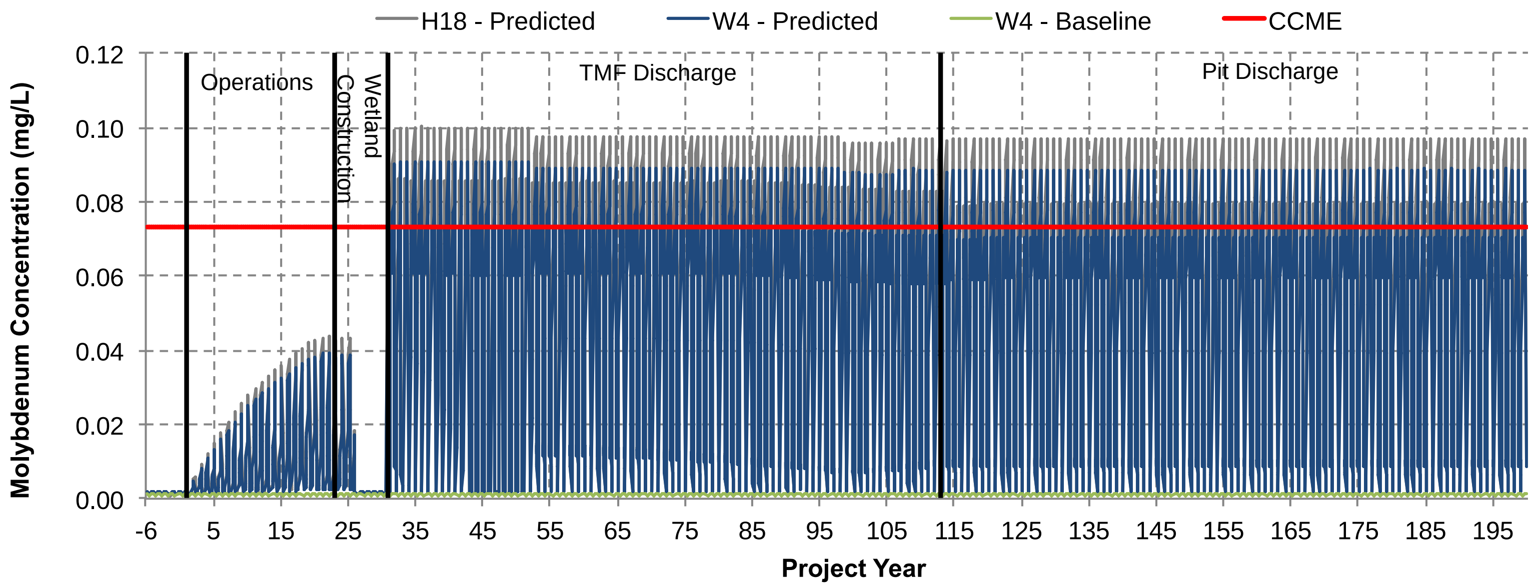


Figure 11-5. Modelled Iron Concentration at H18 and W4



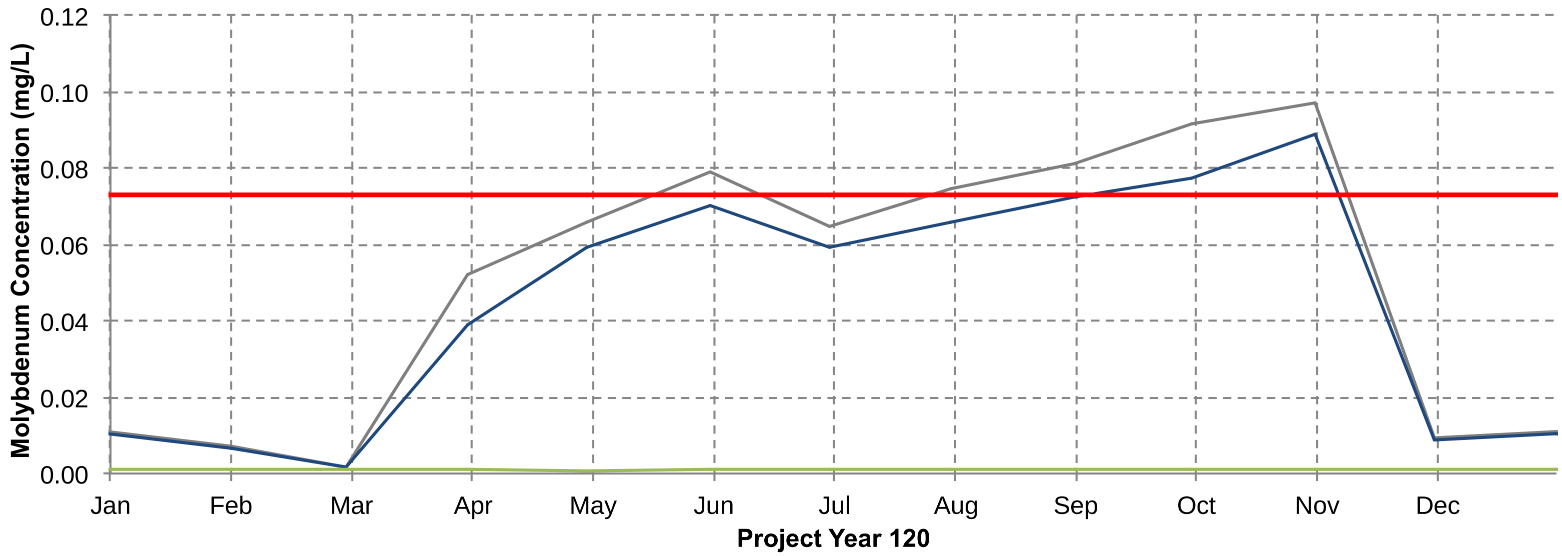


Figure 11-6. Modelled Molybdenum Concentration at H18 and W4

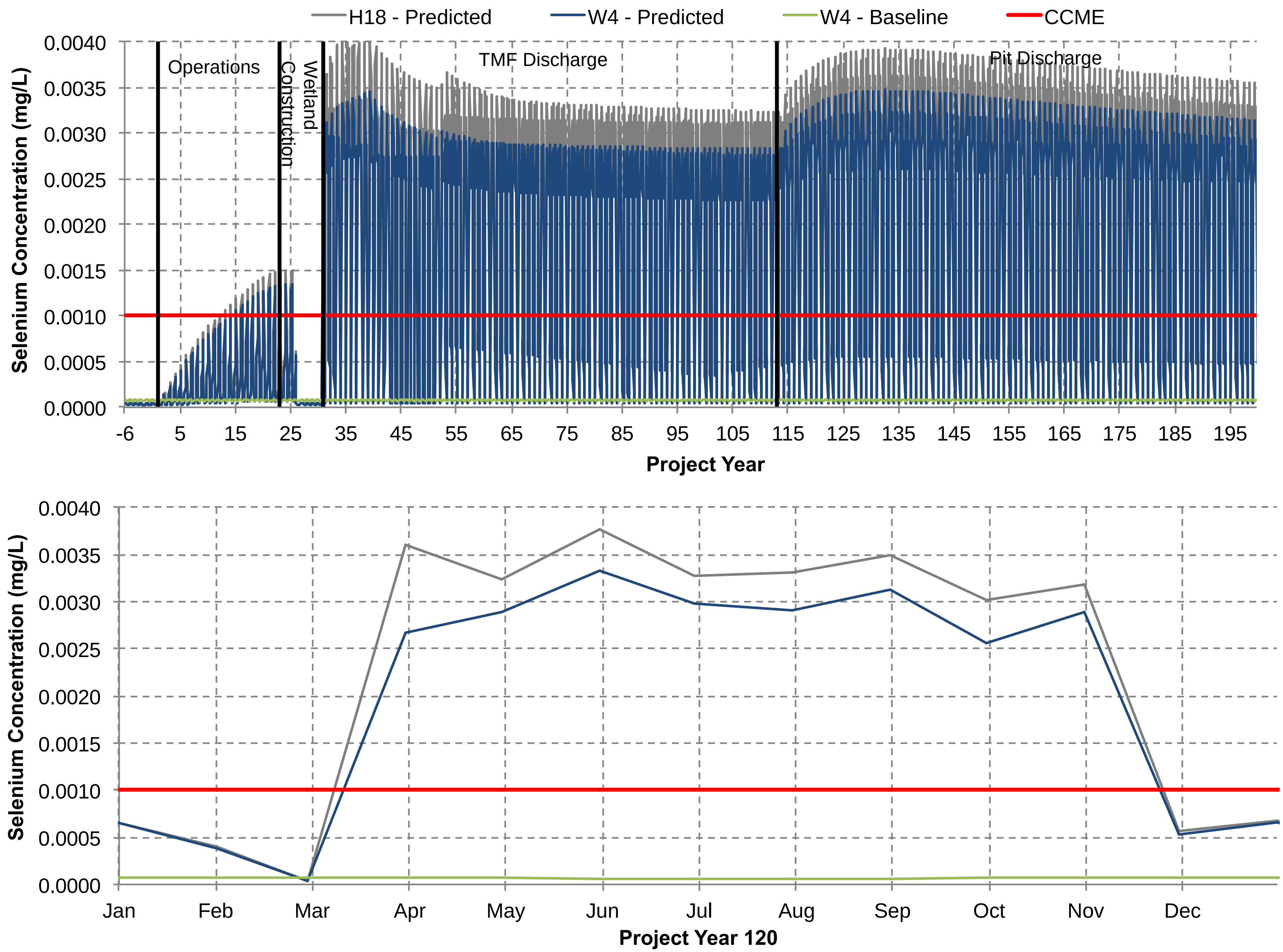


Figure 11-7. Modelled Selenium Concentration at H18 and W4

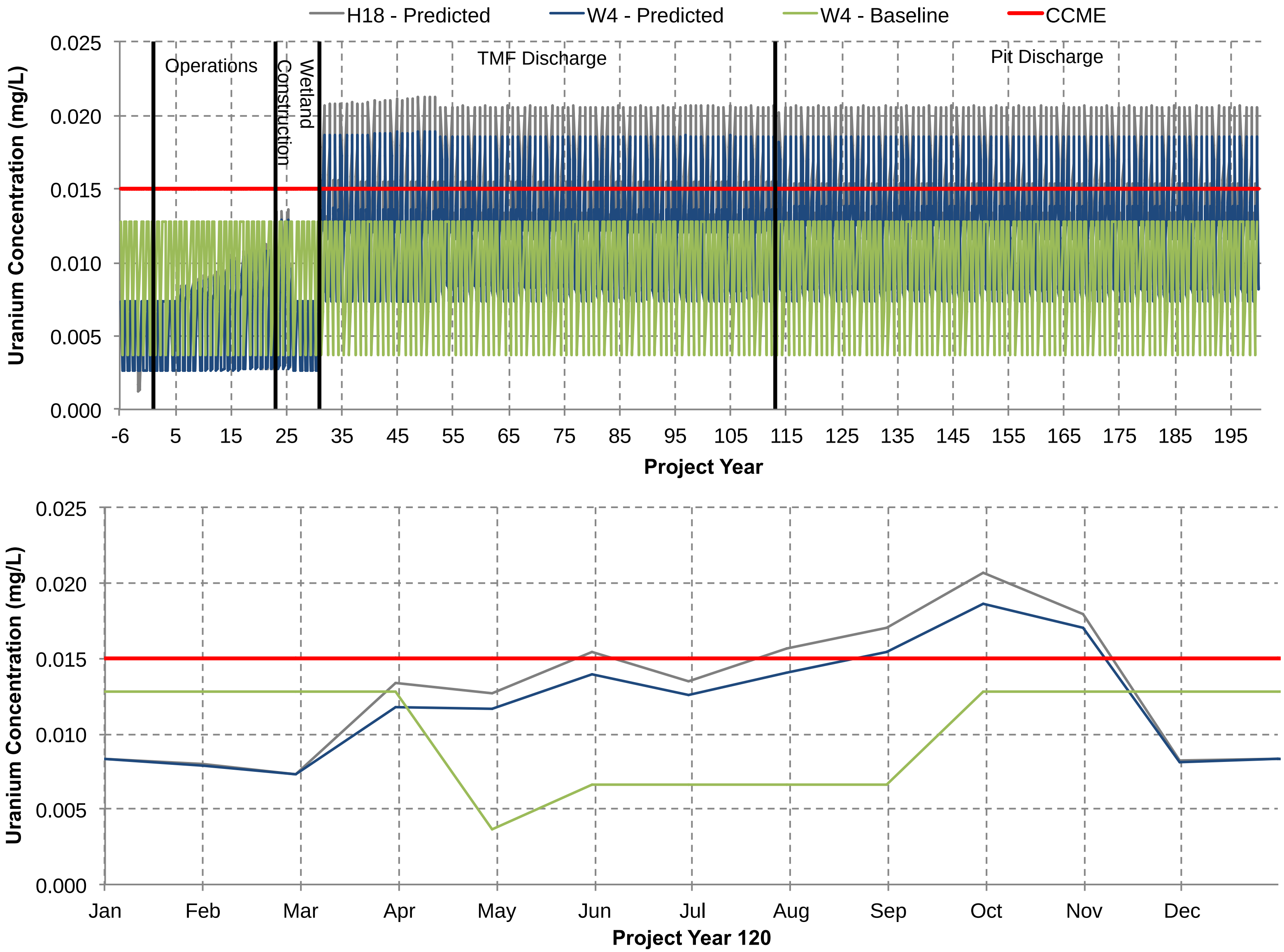


Figure 11-8. Modelled Uranium Concentration at H18 and W4

11.6.2 Dip Creek (W5)

Dip Creek model results are presented in Figure 11-8 to Figure 11-14 for the seven parameters that were predicted to exceed CCME at one time during the model simulation.

The predicted water quality was compared in Dip Creek to CCME for all parameters with the expectation of sulphate. There is no CCME guideline for sulphate and as a result the BCWQG was used. Baseline (pre-mining) concentrations were also included on the graphs.

In Dip Creek, there is sufficient dilution that the water quality guidelines are met with the exception of cadmium, copper and iron. For iron, the baseline water quality is higher than the predicted water quality. Cadmium and copper are discussed in more detail in the impact assessment.

The presentation of water quality results does not represent an impact assessment. PECG completed the impact assessment for the Casino Project.

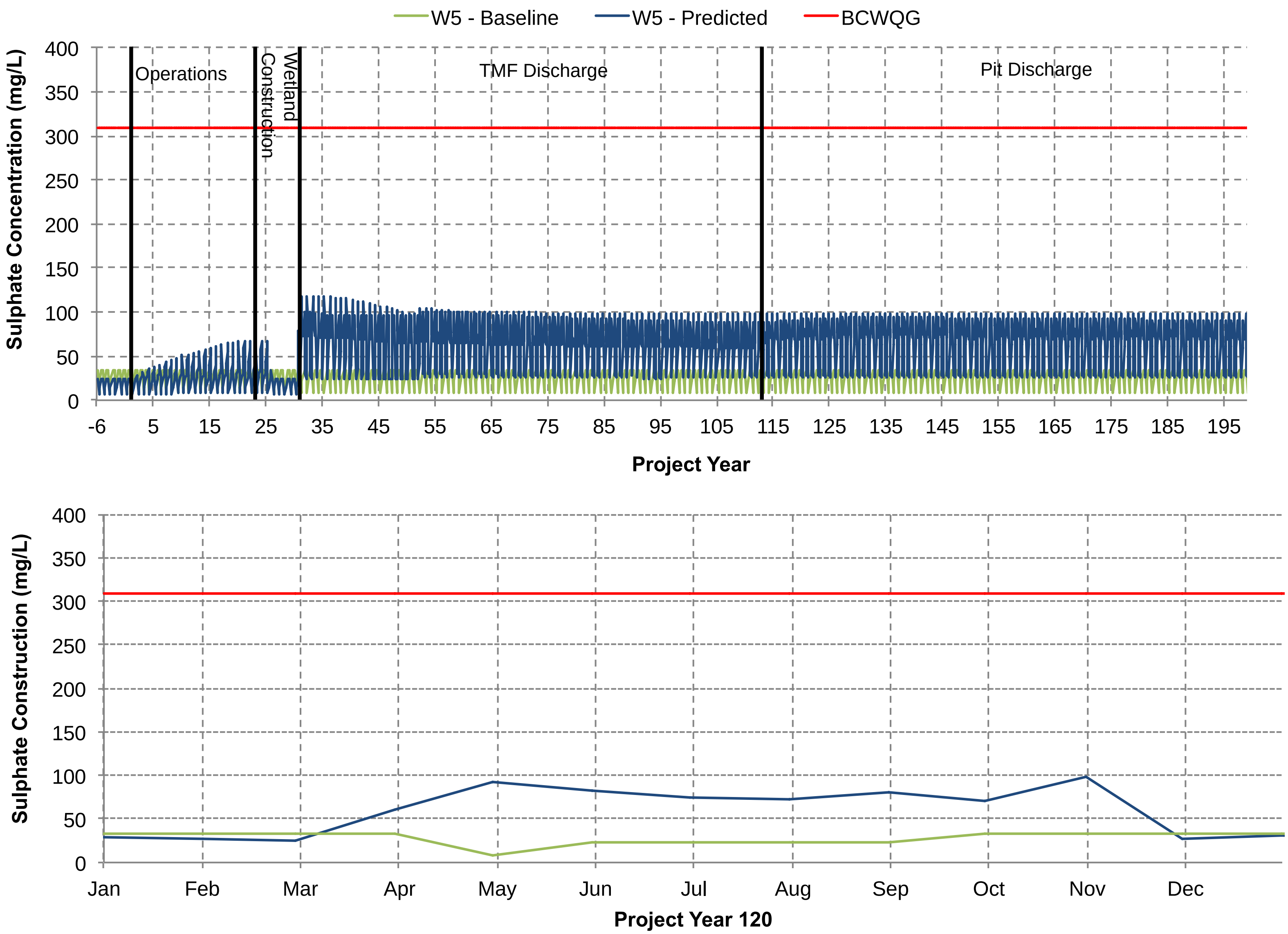


Figure 11-9. Modelled Sulphate Concentration at W5

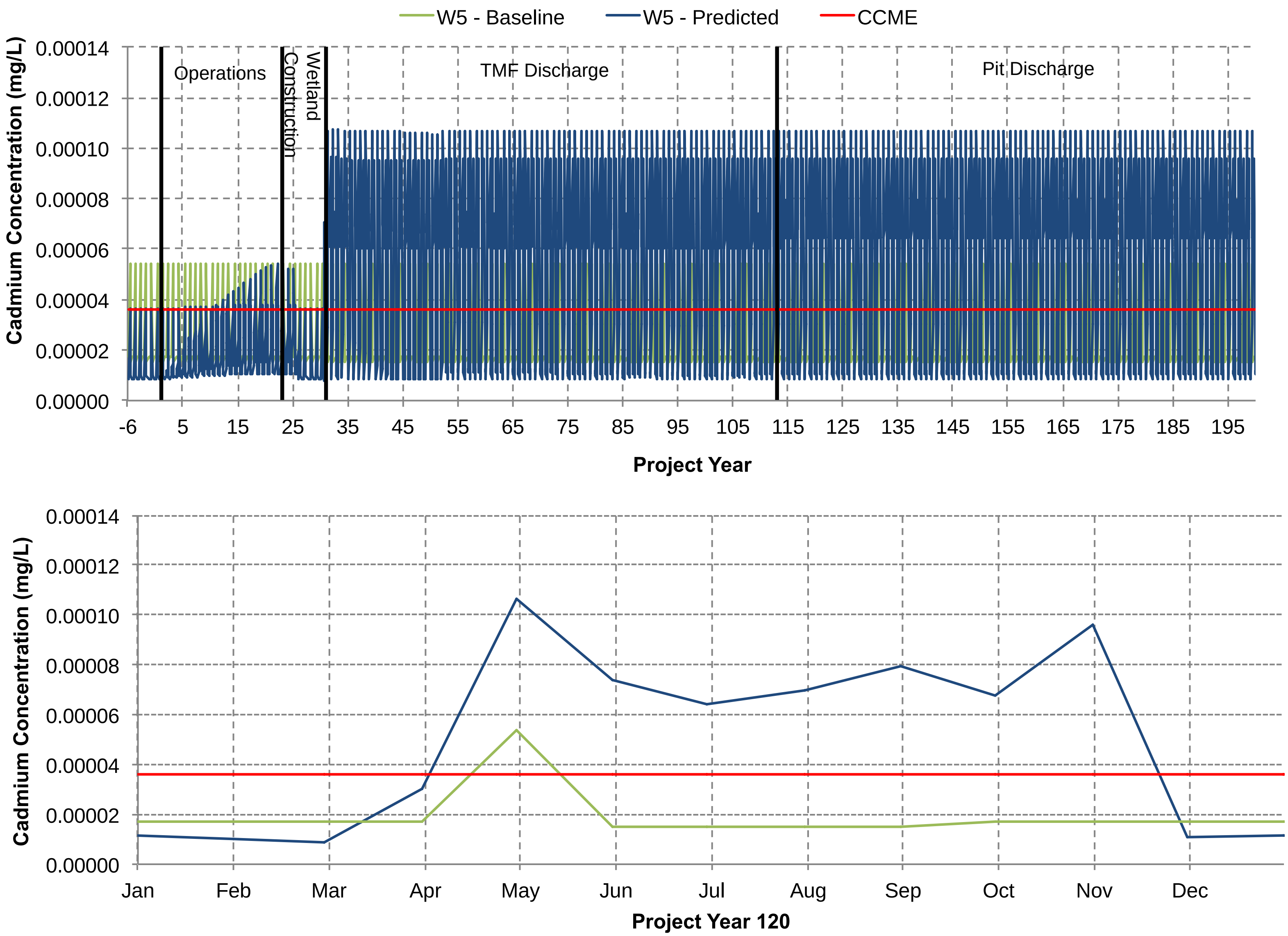


Figure 11-10. Modelled Cadmium Concentration at W5

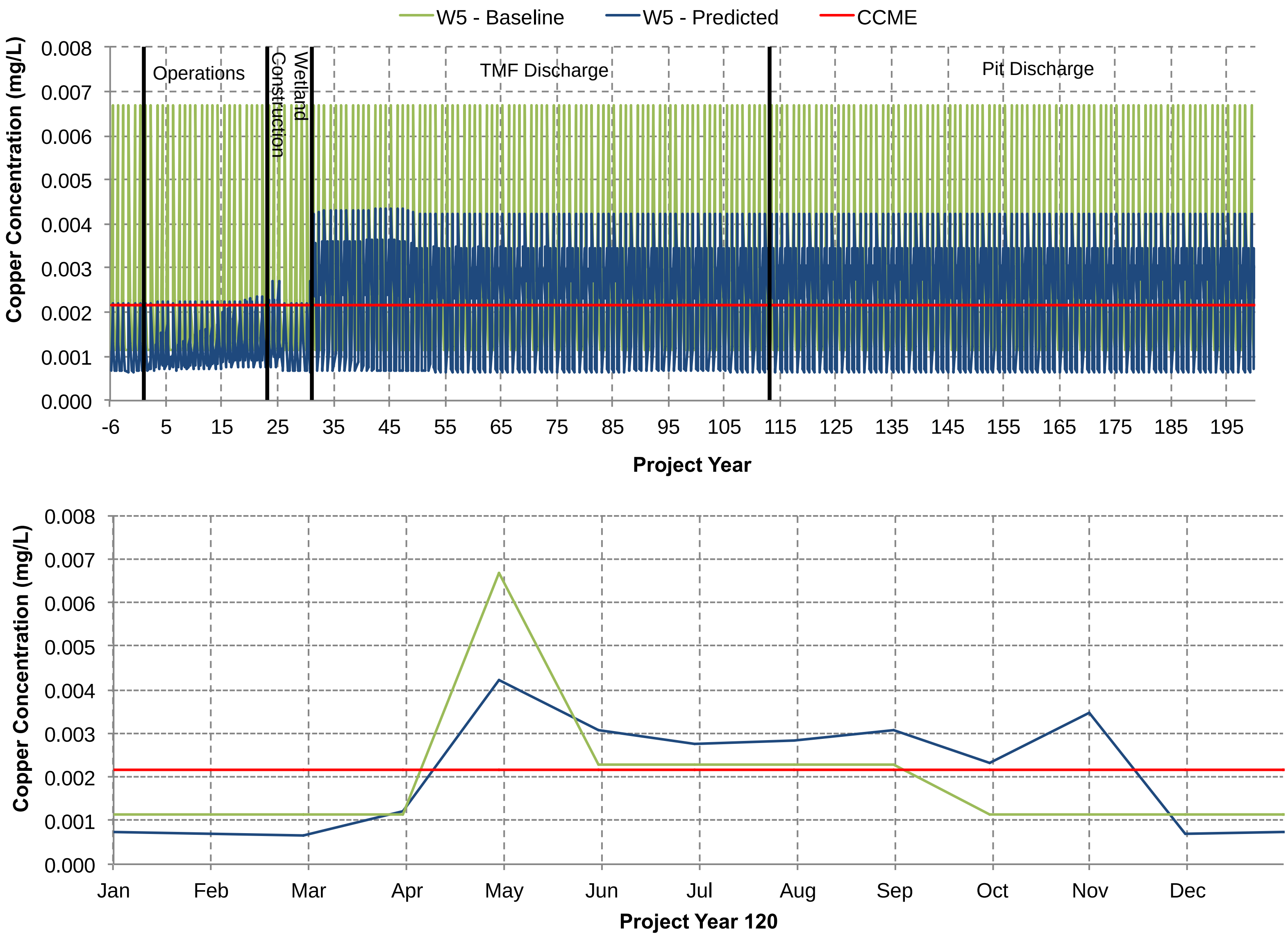


Figure 11-11. Modelled Copper Concentration at W5

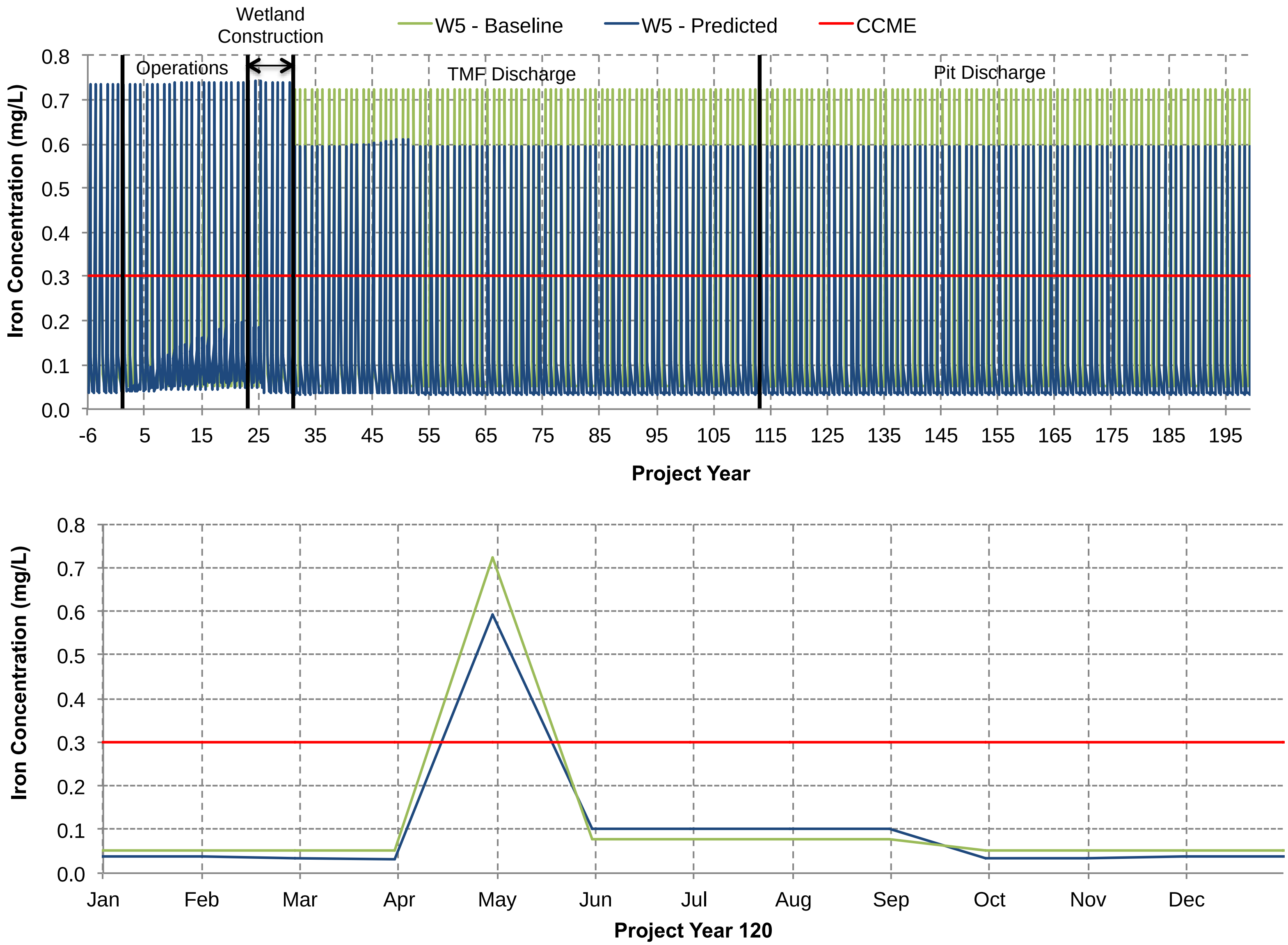
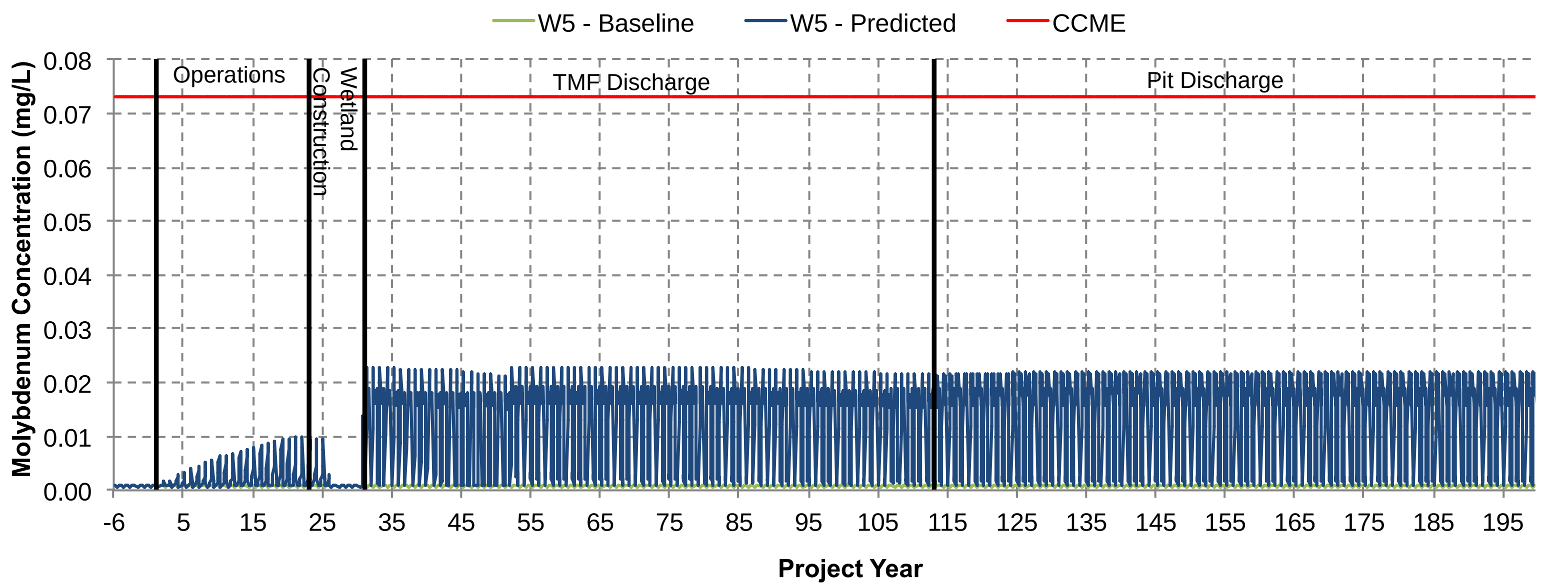


Figure 11-12. Modelled Iron concentration at W5



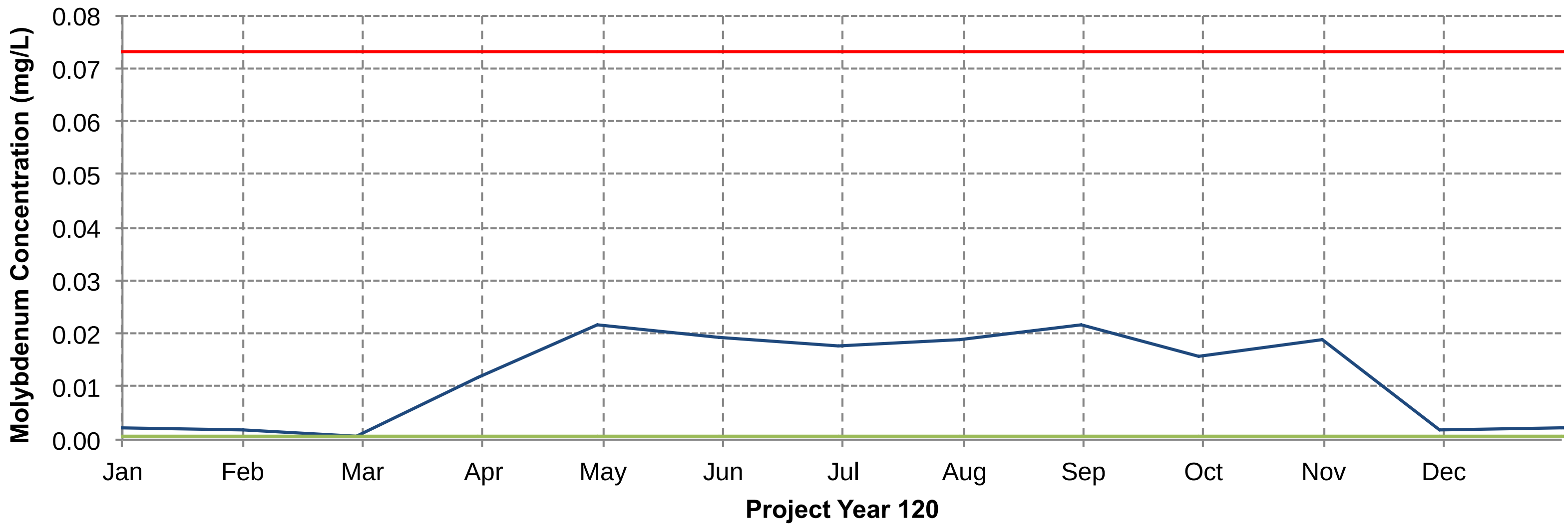


Figure 11-13. Modelled Molybdenum Concentration at W5

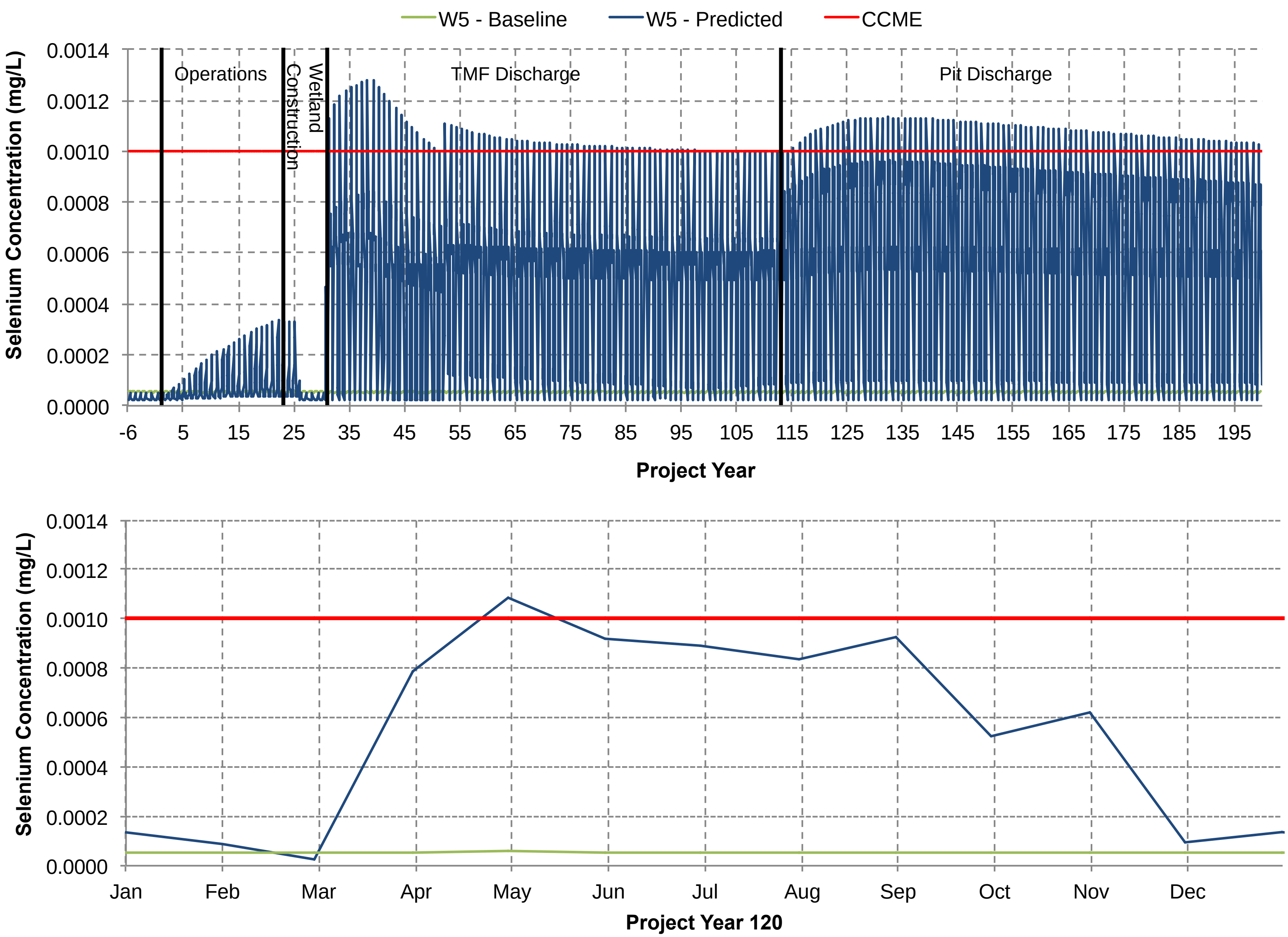


Figure 11-14. Modelled Selenium Concentration at W5

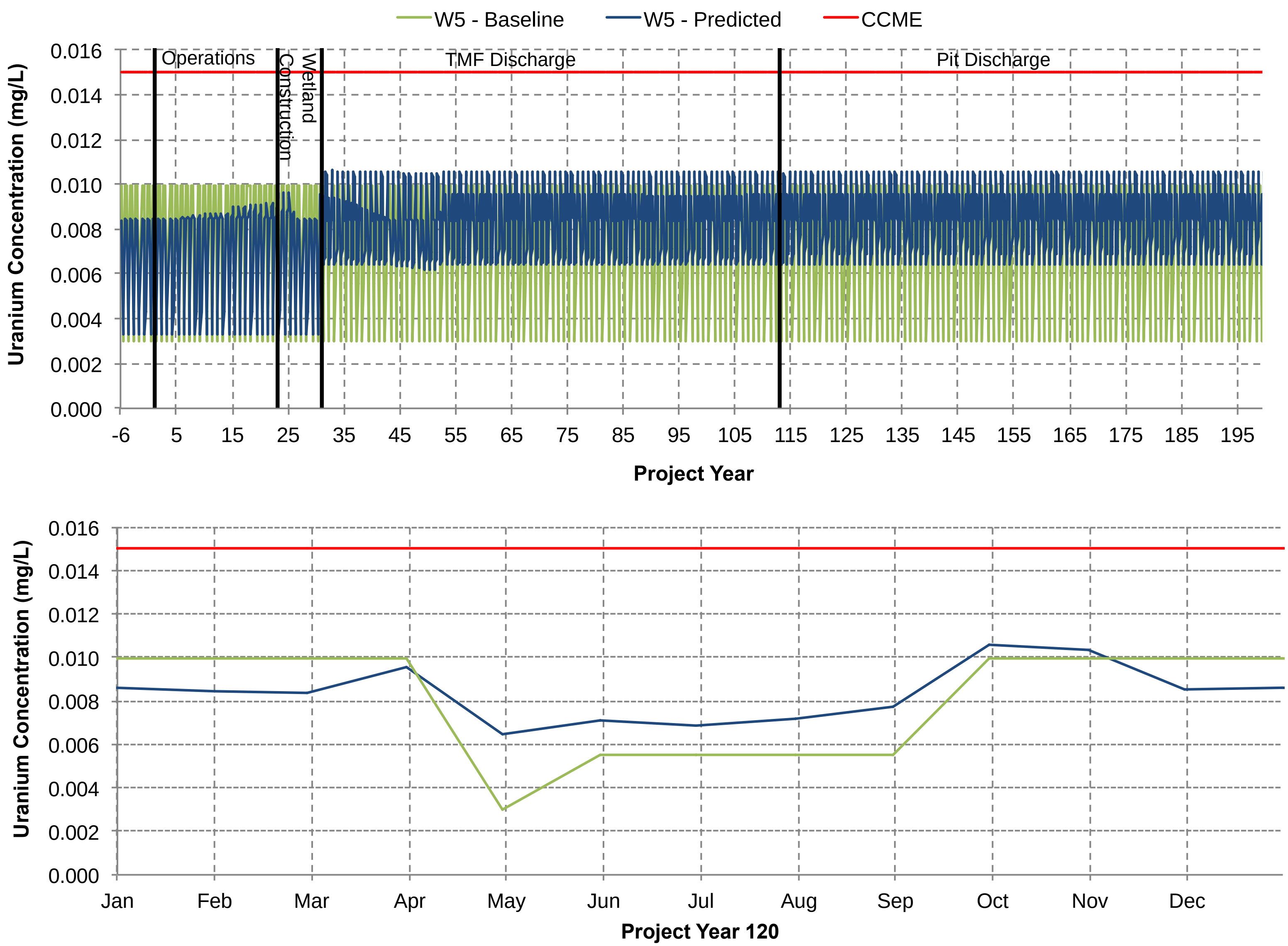


Figure 11-15. Modelled Uranium Concentration at W5

12 Summary and Discussion

A site-wide water quality model was developed for the proposed Casino Project. The model integrated the mine discharges and receiving environment flows. The water quality model was used as a planning tool to help select project water quality mitigations. This report documents the water quality resulting from the base case mine design developed for the YESAB submission.

The model was developed with a monthly time step and was run using monthly average flows. The water quality model was built within the GoldSim modelling platform, and was run for a simulation timeline of 200 years following the beginning of Operations. The GoldSim model included 29 water quality parameters.

Geochemical modelling has been integrated into the site-wide water quality model by use of dynamic links to PHREEQC. The model nodes with geochemical solubility controls include the following:

- Pit Lake
- TMF pond
- Seepage pond release mixed with TMF pond discharge
- Casino Creek at H18

These nodes are locations where mixing of water streams occurs and solubility controls affect the concentrations of some water quality parameters (such as aluminum, copper and iron).

12.1 Model Mitigations

The water quality model was used as a rationale for the selection of a number of Project mitigations. Initially, copper was used as the constituent of concern (COC) for the mitigation planning as copper exceeded water quality targets by orders of magnitude in the source terms. Once the Project met targets for copper, mitigations were considered for other COCs including cadmium, sulphate, selenium, molybdenum, uranium, cyanide and iron.

Key Project mitigation plans for seepage from the TMF and Ore Stockpiles are summarized.

- Source control for one of the six ore stockpiles was identified as essential Project mitigation. The groundwater seepage pathway from the southern-most ore pile was found to be problematic in Casino Creek. As a result, the base case model incorporated mitigation (pumping wells) to intercept most of that loading. The collected discharge will be directed to the TMF pond.

- Some of the waste rock generated in the first years of mine operations will be acidic supergene. This rock was moved from placement within the TMF to a temporary ore stockpile. If this waste rock were to be submerged and placed without neutral hypogene rock, the seepage is not acceptable for release to the environment. This mitigation plan allows for passive management of the source loadings as the rock is moved into the pit after Operations.

- The winter seepage mitigation pond (WSMP) will store winter seepage and release it during the open water season such that it can be mixed with the TMF Pond discharge water. This design feature removes iron at the point where the discharges mix. This mitigation is included in the Project to avoid discharging seepage in winter when there is no other flow available for mixing. This strategy avoids long-term pump back.

- Water collected in the WSMP will be pumped back into the TMF Pond until initial discharge of the TMF Pond.

Key Project mitigation plans for the Heap Leach Facility are summarized.

- In year 19 after the Heap operations are complete, surplus water will be pumped to the Open Pit. Because the Pit Lake will not discharge for approximately 90 years, cyanide degradation will remove this source.

- It was determined in the water quality model that a bioreactor for the Heap Leach Facility discharge is not required in the base case. However, this mitigation is included as a contingency.

Key Project mitigation plans for the Open Pit are summarized.

- The North TMF wetland was designed to passively treat the Pit Lake discharge. The water quality model of the Pit Lake showed that the discharge will be at acceptable concentrations and pH for successful treatment in the North TMF wetland.

- The runoff from the Canadian Creek catchment will be directed to the Pit Lake in perpetuity to increase the alkalinity entering the Pit Lake.

Key Project mitigation plans for the TMF are summarized.

- As a result of the upward migration of porewater through the submerged waste rock in the TMF and into the TMF Pond water, the South TMF wetland was identified as being a critical component of the Project.

- TMF pumping to the Pit Lake will lower the water level in the TMF and will create suitable working conditions for the construction of the TMF wetlands.

- The placement of the waste rock within the TMF has been the subject of numerous design changes and the resulting design is the optimal strategy as the waste rock is in the upper part of the TMF where there is minimal foundation seepage.

The wetland passive treatment system was designed by Clear Coast Consulting Inc. Passive treatment by the North and South wetlands was modelled as follows:

- The wetlands treat Cd, Cu, Mo, Hg, Ag, Zn to the CCME guideline.
- The wetland treat SO4 to be 85% of the inflow concentration (i.e. 15% removal)

12.2 Results of the Model

The water quality was evaluated in Casino Creek and Dip Creek. While the treatment wetlands have reduced the water quality of a number of parameters, the release of seepage from the WSMP downstream of the Project results in some exceedances of water quality guidelines in Casino Creek. This list includes cadmium, copper, selenium, sulphate, uranium, molybdenum, and iron. Baseline water quality used in the model is compared to the predicted water quality and the guideline.

In Dip Creek, there is sufficient dilution that the water quality guidelines are met with the exception of cadmium, copper and iron. For iron, the baseline water quality is higher than the predicted water quality. Cadmium and copper are discussed in more detail in the impact assessment.

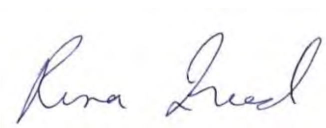
13 Closure

This document was prepared by SEA for the account of Casino Mining Corporation and the YESAB environmental assessment review. The material in it reflects SEA's judgement in light of the information available to SEA at the time of document preparation. Any use which a third party makes of this document or any reliance on decisions to be based on it is the responsibility of such third parties.

We trust this water quality assessment meets your requirements for the Casino Project YESAB application. If you have any questions, please contact the undersigned.

Yours truly,

Source Environmental Associates Inc.



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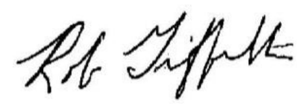
Senior Environmental Engineer



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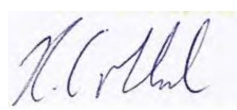
Environmental Engineer



Rob Marsland, M.Sc., P. Eng.
Senior Environmental Engineer

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Casino Project

Water Quality Predictions

Appendix I
Open Pit Water Quality Modelling

Prepared by:

Source
ENVIRONMENTAL ASSOCIATES INC.

December 2013

Table of Contents

List of Figures

List of Tables

List of Appendices

1 Introduction

The Casino Project (the Project) is a proposed mining project in the west-central Yukon. The deposit will be mined using open pit methods, with a nominal mill throughput of approximately 120,000 tonnes/day of ore over a 22 year operating life. Milling operations will produce molybdenum and copper concentrates through conventional flotation circuit milling and gold and silver bullion will be produced by cyanide heap leaching.

The open pit will be up to 600 m deep and up to 2400 m wide when finished. After mining, dewatering of the open pit will cease and a Pit Lake will form by groundwater recharge, overland runoff, and direct precipitation on the water surface. During mine decommissioning, any unused ore present in the stockpiles will be placed in the pit. Surplus water from the Tailings Management Facility (TMF) Pond and Heap Leach Facility (HLF) will be temporarily pumped to the Open Pit to help fill the Pit Lake faster.

A Pit Lake water balance was developed by Knight Piesold Ltd. (KPL, 2013a) and was used by Source Environmental Associates Inc. (SEA) as the basis for pit water quality predictions. The model was developed using GoldSim modelling software and was run with monthly time-steps, for average monthly environmental conditions, over a time-frame from beginning of Pit Lake formation, to 200 years after the beginning of Operations. A schematic showing the mass transport flow paths through the Pit Lake system is presented in Figure 1-1.

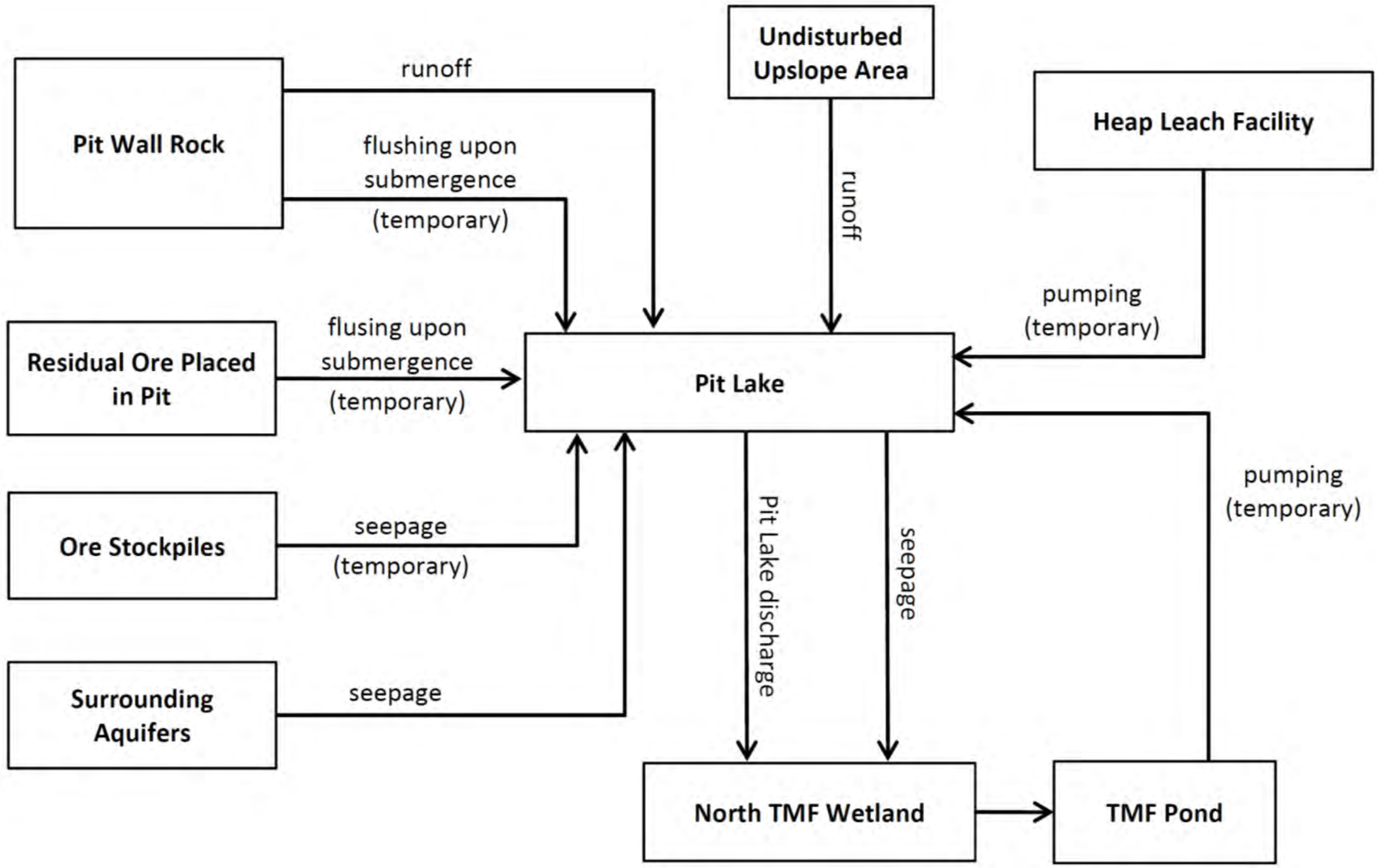

Figure 1-1 Mass Transport Flow Paths through the Post-Closure Pit Lake System

2 Casino Project Water Management Phases

The Casino Project life was sub-divided into five water management phases (Table 2-1) in this document. Project years are described in years relative to the beginning of milling operations. For example, Year -2 refers to the second year before Operations begins, and Year 2 refers to the second year of Operations. Relevant project activities related to water quality modeling are provided in Table 2-1.

Table 2-1. Water Management Phases

Water Management Phase	Project Year	Water Management Activities
Construction	-4 to -1	• overburden stripping • mining and stockpiling of ore
Operations	1 to 22	• Final year of Open Pit Mining, year 18 • Final year of milling, year 22 • Dewatering from Open Pit will be pumped to mill to be used as make up water until end of Year 18. • Beginning in Year 19, dewatering will be discontinued, and the Open Pit will be allowed to fill with water by groundwater recharge, overland runoff, and direct precipitation. Pit Lake will begin to form. • Beginning Year 19, Surplus HLF ore rinsing water will be pumped to the Pit Lake.
Wetland Construction	23 to 30	• Any unprocessed ore will be placed in the Open Pit. • Construction of the North TMF Wetland that will eventually be used for treatment of the discharge from the Pit Lake. • Year 24 to Year 28 – HLF drain down water pumped to Pit Lake • Year 23 to Year 27 – TMF Pond water will be pumped to Pit Lake
TMF Pond Discharge	31 to 112	• TMF Pond will discharge to Casino Creek via South TMF Wetland • No changes to Pit Lake water management
Pit Lake Discharge	>113	• Pit Lake will discharge to the North TMF Wetland treatment system. Treated effluent from the wetland will discharge to the TMF Pond.

3 Pit Lake Water Balance Model

The KPL (2013a) water balance model was developed to estimate the Pit Lake inflow and outflow rates, and the time required for the Pit Lake to fill and overflow. The following characteristics of the Open Pit were provided to SEA from KPL:

- maximum storage capacity of the pit = 280 Mm^3
- maximum water surface elevation of the Pit Lake = 1095 m
- total planar area of exposed pit walls (Pit Lake empty) = 3.14 km^2
- total planar area of exposed pit walls (Pit Lake full) = 1.16 km^2
- final planar area of the Pit Lake = 1.98 km^2

When the Pit Lake fills with water, the total water volume and surface area of water stored within the Pit Lake will vary. Pit Lake water surface elevation versus storage capacity and surface area (Figure 3-1) were provided to SEA by KPL with their Goldsim water balance model.

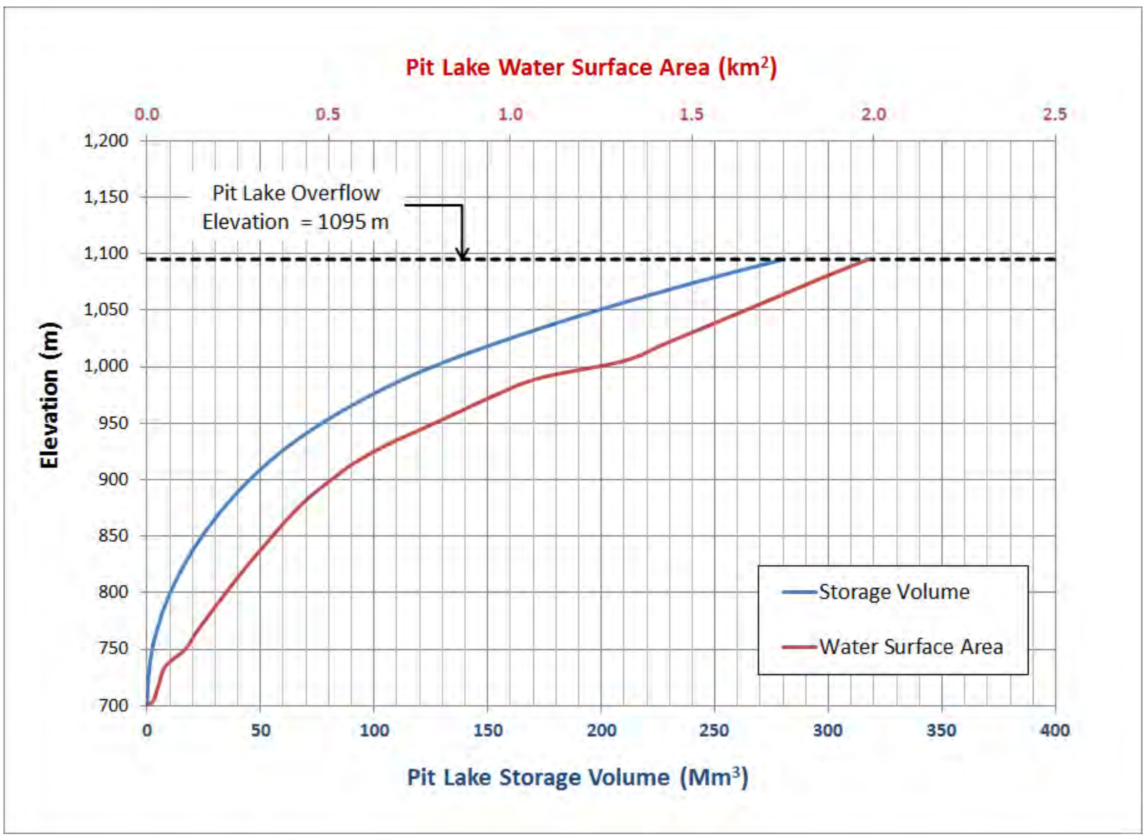

Figure 3-1 Pit Storage-Elevation and Area-Elevation Curves

The average annual surplus water from pit walls in the KPL (2013a) water balance was 370 mm. The KPL (2013a) water balance simulation showed that under average annual hydrologic conditions, the Pit Lake will fill to its maximum capacity by approximately Year 113. Average annual Pit Lake inflows and outflows are presented in Table 3-1 for representative years of the following conditions: shortly following mine Operations (Year 24), and long-term, following pit filling and discharge (Year 120). Some description of the water balance flows are provided in Section 4 as they are related to the development of the Pit Lake mass balance and water quality model.

Table 3-1 Pit Lake Water Balance Model Results

Water Balance Component	Average Annual Discharge (L/s)	
	Wetland Construction Phase (Year 24)	Pit Discharge Phase (Year 120)
Inflows		
Precipitation on Lake Surface	7	30
Groundwater Seepage	22	12
Ore Stockpile Seepage	<1	0
Pit Wall Runoff	32	14
Upslope Overland Runoff	33	33
Pumping from TMF Pond	336	0
Pumping from the HLF	33	0
Total Inflow	463	89
Outflows		
Evaporation	4	19
Groundwater Seepage	0	11
Discharge	0	59
Total Outflow	4	89
Net (Inflow - Outflow)	459	0

According to the *Conceptual Reclamation and Closure Plan* (BCL, 2013), the total annual Pit Lake overflow volume will be discharged to the TMF wetland at a controlled rate during the warmest months of the year (June through September, inclusive) for optimal operation of the TMF wetland treatment system. KPL (2013a) modelled the discharge as a constant flow of approximately 180 l/s over the four month period.

4 Pit Lake Water Quality Model

A mixing model was developed to predict water quality for 29 water quality parameters in the Pit Lake as it fills and eventually discharges to the North TMF Wetland treatment system. Water balance flows (from KPL) were combined with mine loading source terms (from Lorax, 2013) and background water quality (from SEA) to predict mass loading rates of inflow and outflow of potential contaminants in the Pit Lake water. This section provides a summary of the Pit Lake water quality modelling methodology.

Tables of model input and output values are provided for each modelled water quality paramaeter in Appendix I - A (model input) and Appendix I - B (model results).

4.1 Mass Load Inflows

4.1.1 Precipitation

The monthly inflow of precipitation into the Pit Lake was calculated as the top surface area of the Pit Lake, multiplied by the monthly depth of precipitation. The Pit Lake surface area varied from 0 km^2 (immediately following mine closure), to 1.98 km^2 (when the Pit Lake level was at its maximum elevation of 1095 m). As a result, the inflow of precipitation to the Pit Lake water surface varied during the period of time when the Pit Lake was filling. Average annual inflow to the final Pit Lake from the KPL (2013a) water balance model is provided in Table 3-1.

While precipitation was accounted for in the water balance, no load was associated with precipitation in the water quality model.

4.1.2 Background Runoff

Runoff from the upslope undisturbed area was calculated as the monthly surplus water multiplied by drainage area. Average annual surplus water was calculated by KP (2013a) to be 140 mm. The final pit will intercept runoff from approximately 6.8 km^2, and 0.6 km^2 of undisturbed areas within the Canadian Creek, and Casino Creek drainage basins, respectively (total area of 7.4 km^2).

The mass loading rate into the Pit Lake from overland runoff was calculated as the monthly rate of overland runoff inflow, multiplied by the monthly water quality concentrations of the overland runoff.

A total of 18 water quality samples were collected at the Upper Canadian Creek (W7) monitoring station between 2008 and 2012 (PECG, 2013). The median value of all water quality samples (Appendix I - A, Table I - A 1) were used to represent average annual overland runoff water quality draining to the Pit Lake from undisturbed areas surrounding the perimeter of the pit.

4.1.3 Background Groundwater

KPL (2013a) calculated the groundwater inflow into the pit from the surrounding upslope groundwater catchments to be 33 l/s at the end of operations and would decrease to 12 l/s once the pit reaches its maximum Pit Lake elevation (1095 m). In the KPL water balance model, groundwater inflow decreased linearly from 33 l/s to 12 l/s proportionally to water surface elevation in the pit as the Pit Lake water surface elevation varied from 700 m (Pit Lake empty) to 1095 m (Pit Lake full).

The load contributions to the Pit Lake from background groundwater were calculated as the monthly rate of groundwater inflow, multiplied by the estimated groundwater inflow water quality. The *2012 Baseline Hydrogeology Report (KPL, 2013c)* provides groundwater monitoring station information and water quality analysis results. Median water quality from each of the monitoring wells in the vicinity of the Open Pit (94-337, HG10-01, HG10-02, HG10-04, HG10-07) were combined by SEA to represent average annual water quality of the groundwater entering the Pit Lake. The representative background groundwater water quality that was used by SEA in the water quality modelling is provided in Appendix I - A (Table I - A 1).

4.1.4 Seepage from Ore Stockpiles

While the ore stockpiles are present during Operations, contact water (from rainfall and snowmelt) will drain from the rock as runoff or infiltration to groundwater. Runoff from the stockpiles will be captured by the TMF Pond. Hydrogeological modelling (KPL, 2013d) indicated that depending on the stockpile location, infiltrated contact water will flow towards either the TMF Pond or the Open Pit.

According to the KPL (2013a) water balance model, seepage from the Hypogene Low Grade Ore, Supergene Sulphide Low Grade Ore, and Marginal Grade Ore Stockpile would continue to flow into the Open Pit for a few years after the Pit Lake begins to form (i.e. after Year 19). Average annual seepage rates from the KP water balance are shown in Table 4-1.

Seepage concentrations into the Open Pit Lake were calculated by combining the seepage flow rates (Table 4-1) with mass loading rates, and mass of rock in the stockpiles. Calculation methodology of stockpile mass loading to the Open Pit is described in Appendix II (Ore Stockpile Water Quality Modelling).

Table 4-1. Ore Stockpile Seepage to the Open Pit

Year	Average Annual Seepage to Pit Lake (l/s)		
	Hypogene Low Grade Ore	Supergene Sulphide Low Grade Ore	Marginal Grade Ore Stockpile
19	0.2	1.3	0.6
20	0.2	1.3	0.6
21	0.2	1.3	0.6
22	0.2	1.2	0.6
23	0.1	0.8	0.6
24	0.1	0.4	0.6
25	0.0	0.1	0.4
26	0.0	0.0	0.1
> 26	0.0	0.0	0.0

4.1.5 Pit Wall Runoff

Pit wall runoff for a given time-step was calculated as the monthly surplus water multiplied by the planar area of un-submerged pit walls. The planar area of un-submerged pit wall decreased incrementally from the maximum value (immediately following closure) to the minimum value (at final Pit Lake level) in each monthly time-step as the Pit Lake surface elevation increased and submerged the wall rock.

Fracturing of open pit mine walls due to blasting exposes the wall rock to the process of weathering. The fractured rock can be expected to contribute mass loading into the Pit Lake following mine closure. Source terms were developed by Lorax (2013) for each of mineralization zones that are expected to be exposed on the Casino pit wall, including: Oxide Cap (CAP), Supergene (SUP), and Hypogene (HYP).

The estimated planar areas of each mineralization zone were provided by Lorax, (2013) and were subdivided into pit wall areas above and below the ultimate pit water surface elevation of 1095 m. The values used in the model are given in Table 4-2.

Table 4-2 Pit Wall Planar Area by Mineralization Zone

Mineralization Zone	Planar (Horizontal Projection) Area (m^2)		
	Below 1095 m Elevation	Above 1095 m Elevation	Total
Hypogene (HYP)	1,900,064	351,665	2,251,729
Supergene (SUP)	65,496	493,435	558,931
Oxide Cap (CAP)	0	320,340	320,340
Total	**1,965,560**	**1,165,440**	**3,131,000**

After Lorax (2013)

Lorax (2013) provided a derivation of geochemical source terms for the exposed Casino pit wall rock. The source terms were developed by scaling loading rates measured in laboratory-based kinetic tests (unsaturated columns and standard humidity cells) to field conditions. Average annual source term loading rates were provided based on a horizontal planar 1 m^2 unit area of exposed pit wall to allow for the terms to be applied in a dynamic water quality prediction model with time integrated wall exposures. Loading rates are presented in Appendix I - A (Table I - A 2).

Results of acid-base accounting (ABA) analyses by Lorax indicated that a large portion of the SUP and HYP zones are potentially acid generating (PAG). Therefore both acidic and neutral source terms were provided for the HYP and SUP mineralization zones in addition to the single CAP source term.

The rate at which the HYP and SUP pit wall rock acidifies will influence the Pit Lake chemistry. Weathering rates observed in neutral pH humidity cells were used by Lorax to estimate NP depletion rates and predict time until acidification. Lorax (2013) developed the following relationships to estimate the proportion of acidic and neutral pit wall for 200 years following initial exposure of the pit wall rock (t is in years):

$$\text{Fraction NP Depletion (HYP)} = 0.00258t + 0.08$$

$$\text{Fraction NP Depletion (SUP)} = -1.31\times10^{-9}\,t^4 + 6.24\times10^{-7}\,t^3 - 1.04\times10^{-4}\,t^2 + 0.00838t + 0.45$$

Figure 4-1 illustrates the component parts of acidic and neutral wall rock that were calculated using the equations (from Lorax) for the duration of the model simulation. Beyond the model simulation time frame, a portion of supergene and hypogene wall rock will remain neutral even after long-term exposure.

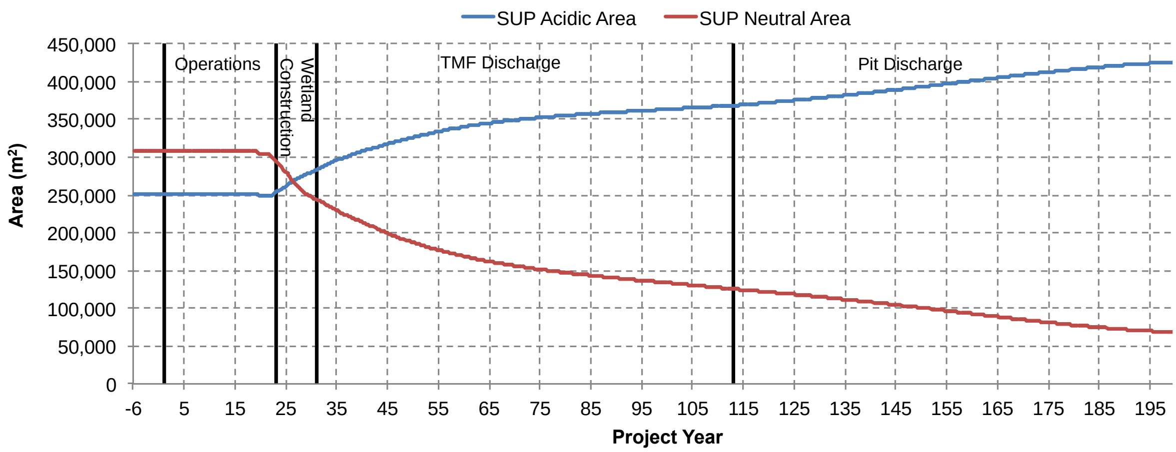

Figure 4-1 Areas of Supergene Acidic and Supergene Neutral wall rock in the Pit Wall with time

4.1.6 Pit Wall Rock Submergence

Pit wall runoff can be expected to travel along preferential flow paths through the fractures of the pit wall rock. As a result, a portion of the oxidation products that form on the walls would not be regularly flushed from those poorly drained portions of the wall rock surfaces. However, as the Pit Lake elevation rises and submerges the wall rock, those built-up oxidation products could be flushed into the Pit Lake. Lorax (2013) derived source terms to account for the build-up and flushing of oxidation products from the wall rock as follows:

$$L = m / (A * t)$$

Where:

L is the wall rock build-up source term (mg/m^2/year)
m is mass of oxidation products built up on the wall rock (mg);
A is the planar area of exposed wall rock (m^2); and
t is the length of time the wall rock is exposed to the atmosphere (years).

The wall rock build-up source term values by Lorax are presented in Appendix I-A (Table I-A2) of this document.

In a given time step of the model, the mass of built-up substance flushed from wall rock into the Pit Lake were calculated as the product between the wall rock flushing source term (in mg/m^2/year), planar area of wall rock submerged during that time step (m^2), and the duration (years) the wall rock was exposed to the atmosphere prior to submergence. The model conservatively assumes that all of the accumulated oxidation product could dissolve in to the pit lake during the timestep when the rock becomes flooded.

In order to assess the time of exposure at the time of wall rock submergence, the pit shell was sub-divided into elevation bands of equal exposure times (from the time they were mined) at the end of open pit mining. The higher elevations have a longer exposure time than the lower elevation bands that were mined out last. Table 4-3 shows a breakdown of the incremental exposure times that were assumed by SEA.

Table 4-3 Time of Exposure of Pit Wall Rock at the End of Mining

Elevation Band	Incremental Average Wall Rock Exposure Time (yr)
700 m – 800 m	1
800 m – 900 m	2
900 m – 1000 m	6
1000 m – 1050 m	11
1050 m – 1095 m	16
> 1095 m	20

The modelling approach used to estimate the geochemical effect of the mine walls on the Pit Lake water quality generally follows *The Minewall Approach*, developed as a formal standardized technique for the MEND program, which is documented by Morin and Hutt (2004). As the Pit Lake level rises, all wall rock below the water surface is submerged, and loading ceases for that submerged portion of the wall rock. The total planar area of un-submerged wall rock was calculated for each model time-step. From that, the relative proportions of acidic and neutral un-submerged wall rock were calculated, and their respective loading rates into the Pit Lake were applied.

The total exposure time for a submerged band of wall rock was calculated as the average wall rock exposure time prior to the start of pit filling (i.e., during mining) (Table 4-3), plus the number of years that elapsed after the Pit Lake filling began and until submergence of that section of wall rock.

4.1.7 Flushing from LGO Placed in Open Pit

It was assumed that following mining, 5% of the low grade ore and 100% of the Marginal Ore Stockpile would be backfilled into the pit. The Gold Ore and Supergene Oxide Ore were assumed to be processed completely. Table 4-4 shows the total ore masses, and estimated mass of each pile that was assumed by SEA to be placed in the Pit Lake after mining. In KPL's water balance, a specific gravity of 2.8 was assumed for ore for displacing volume in the pit water balance. The total consolidated volume of ore in the Pit Lake would account for a reduction in available water storage volume of 5.7 Mm^3.

When the ore is placed in the Open Pit, the built-up oxidation products from the rock surfaces could be flushed into the Pit Lake. Lorax (2013) estimated the loading from each ore type going to the Pit Lake (Appendix I - A, Table I - A 2 Loading Rates for Pit Wall Runoff, Flushing (from Submergence) of Pit Wall Rock and Flushing of Ore Stockpile Rock).

Table 4-4 Summary of Ore Stockpiles Placed in the Open Pit

Stockpile	Mass (tonnes)	
	Total Ore to Pile	Unused Ore Placed in Pit
Gold Ore	35,000,000	0
Supergene Oxide Ore	32,410,000	0
Supergene Oxide LGO	14,043,000	702,150
Supergene Sulphide LGO	39,351,000	1,967,550
Hypogene LGO	90,433,000	4,521,650
Marginal Ore	8,837,100	8,837,100
Total	**220,074,100**	**16,028,450**

4.1.8 Pumping from TMF

Water in the TMF pond will be pumped to the Open Pit from Year 23 to Year 27 at an average pumping rate of 336 L/s (total volume of 53 Mm^3) to lower the TMF Pond level and create suitable working conditions for the construction of the TMF wetlands and TMF closure spillway. Pumping to the Open Pit will also help fill the pit faster.

Mass transport from the TMF Pond was calculated as the concentration in the TMF Pond, multipled by the pumping rate over a given time-step. Water quality of the TMF Pond water was calculated by SEA in the water quality model. Development of the TMF Pond model is described in Appendix IV (TMF Pond Water Quality). Average TMF Pond water quality over the five year duration of pumping to the Open Pit is provided in Appendix I - A (Table I - A 1).

4.1.9 Pumping from the Heap Leach Facility

Closure of the facility will begin by rinsing (Year 19 to Year 23) and drain down (Year 24 to Year 28). Surplus water will be directed to the Pit Lake, after treatment with a cyanide destruction circuit and a bioreactor for selenium and mercury (Clear Coast Consulting, 2013). The bioreactor is the preferred treatment method for selenium and mercury. Alternate treatment methods may also be considered to remove selenium and mercury during the rinsing and drain down phase.

KPL estimated that the rinsing will take place from Year 19 to Year 23 with an average annual pumping rate of 1.6 L/s to the Pit Lake from the HLF. Drain down was estimated to take place from Year 24 to Year 28 at an average flow rate of 33 L/s. After drain down (Year 29 and beyond), pumping to the Pit Lake will stop, and drainage from the HLF will be directed down slope to the TMF Pond.

Mass transport from the HLF to the Pit Lake was calculated as the concentration in pumped surplus water, multiplied by the pumping rate over a given time-step. Water quality of the rinsing and drain down water was estimated by Lorax (2013) prior to treatment and is summarized in Appendix I - A (Table I - A 1). Following treatment in the bioreactor, the selenium and mercury levels are reduced to 0.02 mg/L and 0.00026 mg/L, respectively. This mitigation was designed to reduce selenium levels in the North TMF wetland (Clear Coast Consulting, 2013).

4.2 Mass Load Outflow

4.2.1 Evaporation

The monthly outflow from the Pit Lake due to evaporation was calculated as the top surface area of the Pit Lake for a given time-step, multiplied by the monthly depth of evaporation. Average annual lake evaporation was estimated by KPL (2013a) to be 302 mm.

While evaporation was accounted for in the water balance, no load was associated with evaporation in the water quality model.

4.2.2 Groundwater

KPL (2013a) estimated the net groundwater outflow from the pit to the surrounding down gradient catchments would be 0 l/s when the pit level reached the tailings pond elevation of approximately 990 m and would increase to 12 l/s by the time the pit reaches its maximum Pit Lake elevation (approximately 1095 m).

The rate of mass transport exiting the Pit Lake for a given time-step was calculated as the concentration in the Pit Lake, multipled by the groundwater outflow rate.

4.2.3 Pit Lake Discharge

After the pit fills to its maximum storage capacity, surplus Pit Lake water will be released into the TMF where it will initially flow through the North TMF Wetland treatment system prior to discharge to the main TMF Pond. On an annual basis, the total volume of overflow would equal the total Pit Lake inflow volume, minus evaporation and seepage losses. The pit discharge will be regulated such that flow will only occur during the open water season when the North TMF Wetland is the most biologically productive. KPL predicted that for average annual conditions, the Pit Lake would be released at a an average rate of 180 L/s over a four month period in the summer.

The rate of mass transport exiting the Pit Lake discharge for a given time-step was calculated as the concentration in the Pit Lake, multipled by the rate of release of Pit Lake water.

4.3 Calculation of Pit Lake Water Quality

Water quality in the Pit Lake was calculated as the cumulative mass of a given substance in the Pit Lake water, divided by the water volume stored in the Pit Lake over a given time step interval.

The Pit Lake mixing model output concentrations were assessed for solubility controls at each time step of the model simulation by coupling GoldSim and PHREEQC. PHREEQC is a geochemical modelling software developed by the United States Geological Survey. During each timestep, Goldsim ran PHREEQC and the resulting concentrations were returned from PHREEQC. The calculated water quality from PHREEQC at each time step became the input concentration to the North TMF wetland.

The assumptions used in the PHREEQC pit lake model are listed in Table 4-5. Calcite was used in PHREEQC to represent the neutralization potential associated with the submerged wall rock.

Because Pit Lake discharge water will come from the upper layer, the solubility controls on the Pit Lake were be assumed to have redox conditions of the oxygenated, upper layer.

Table 4-5 PHREEQC Assumptions used in the Pit Lake model

PHREEQC Input Assumptions	
Equilibrium Phases (minerals form solid phase - precipitate forms)	Fe(OH)3(a), Al(OH)3(a), Gypsum, Malachite, Alunite
Equilibrium Phases (no mineral formation)	Cd(OH)2(a), Cu(OH)2, Zn(OH)2-a, ZnCO3:H2O, Otavite (CdCO3), Smithsonite, Tenorite, Jarosite
Database	wateq4f
Acidity / Alkalinity Balance	Alkalinity was higher than acidity throughout the simulation.
pH	Charge balance (PHREEQC determines pH of solution and alkalinity)
PE	14 (oxidizing)
Oxygen	Atmospheric conditions
CO_2	$pCO_2 = -2$
Stratification	Full mixing throughout the water column was assumed, such that geochemical conditions would be the same throughout the pit.

5 Results and Discussion

5.1 Water Quality Predictions

Average annual water quality in the Pit Lake are provided for select parameters in Table 5-1 for intial discharge of the Pit Lake (Year 113) to the North TMF wetland, and long-term conditions (Year 200). Model output concentrations for all modelled water quality parameters are provided in Appendix I - B.

Table 5-1 Pit Lake Water Quality Model Results

Water Quality		Pit Lake Water Quality (mg/L)	
		Initial Pit Lake Discharge (Year 113)	Long-Term (Year 200)
Sulphate	(SO_4)	474	352
Cadmium	(Cd)	0.0039	0.0035
Copper	(Cu)	0.37	0.36
Iron	(Fe)	0.00014	0.00014
Molybdenum	(Mo)	0.18	0.099
Selenium	(Se)	0.0083	0.0052
Uranium	(U)	0.062	0.055

Time-series plots of Pit Lake water quality model output concentrations are provided for select parameters (Figure 5-1 to Figure 5-7) to illustrate water quality variations over the duration of the model simulation.

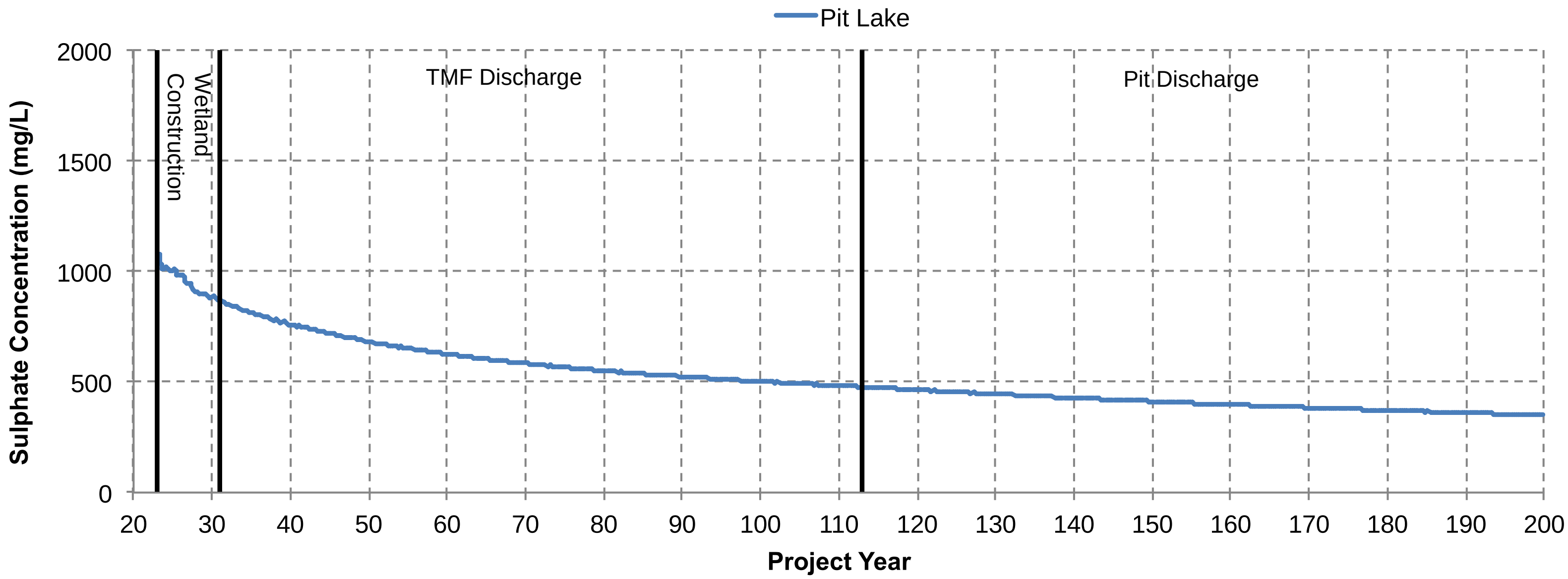

Figure 5-1. Modelled Sulphate Concentration in the Pit Lake

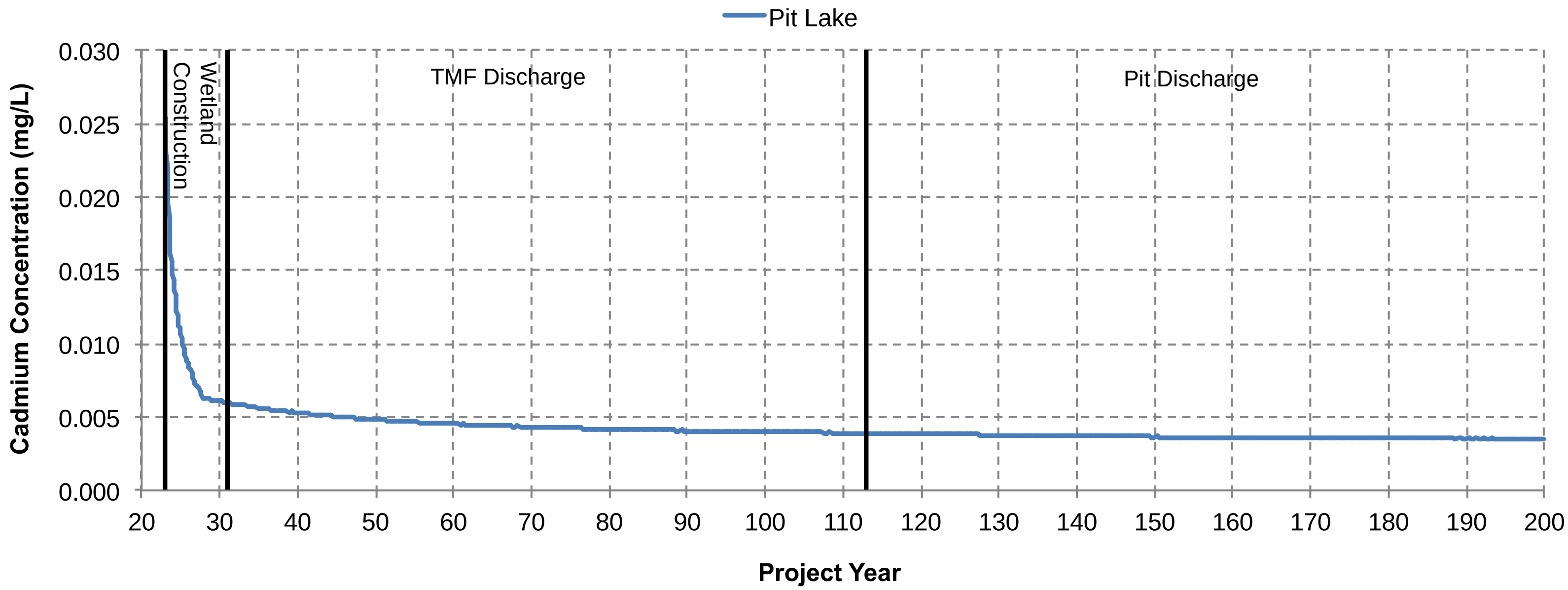

Figure 5-2. Modelled Cadmium Concentration in the Pit Lake

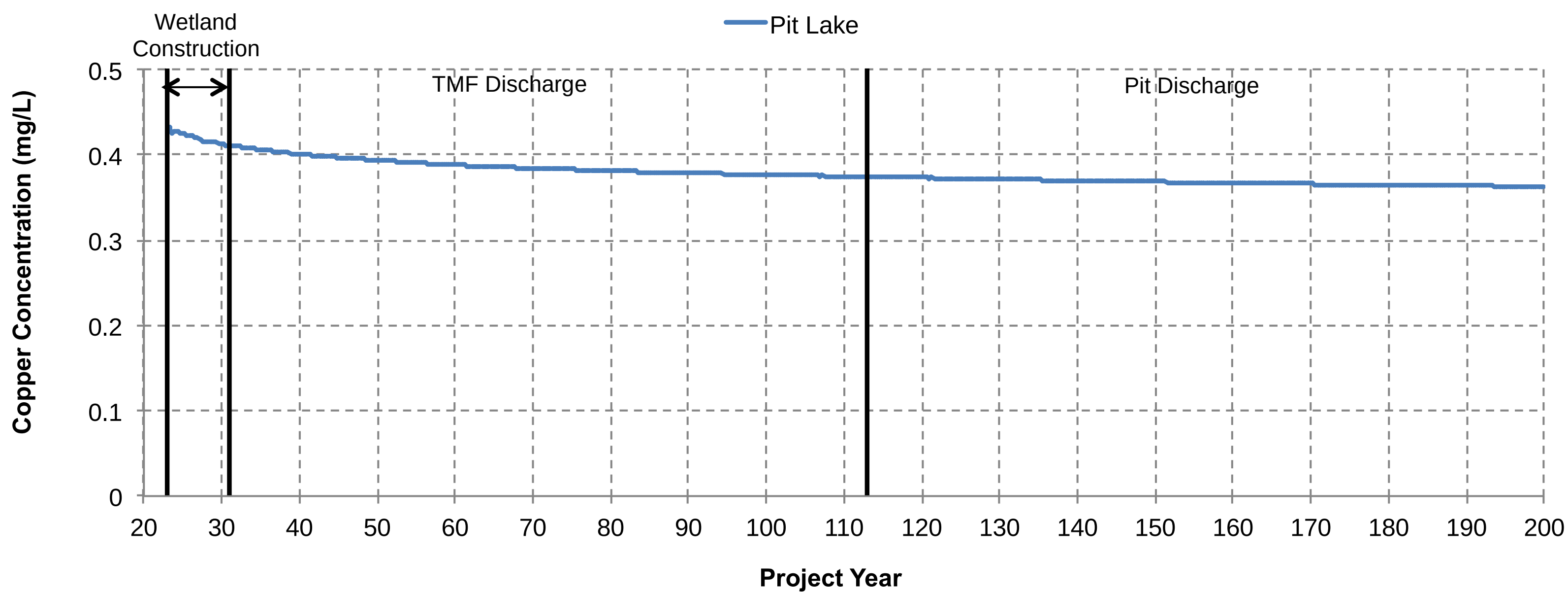

Figure 5-3. Modelled Copper Concentration in the Pit Lake

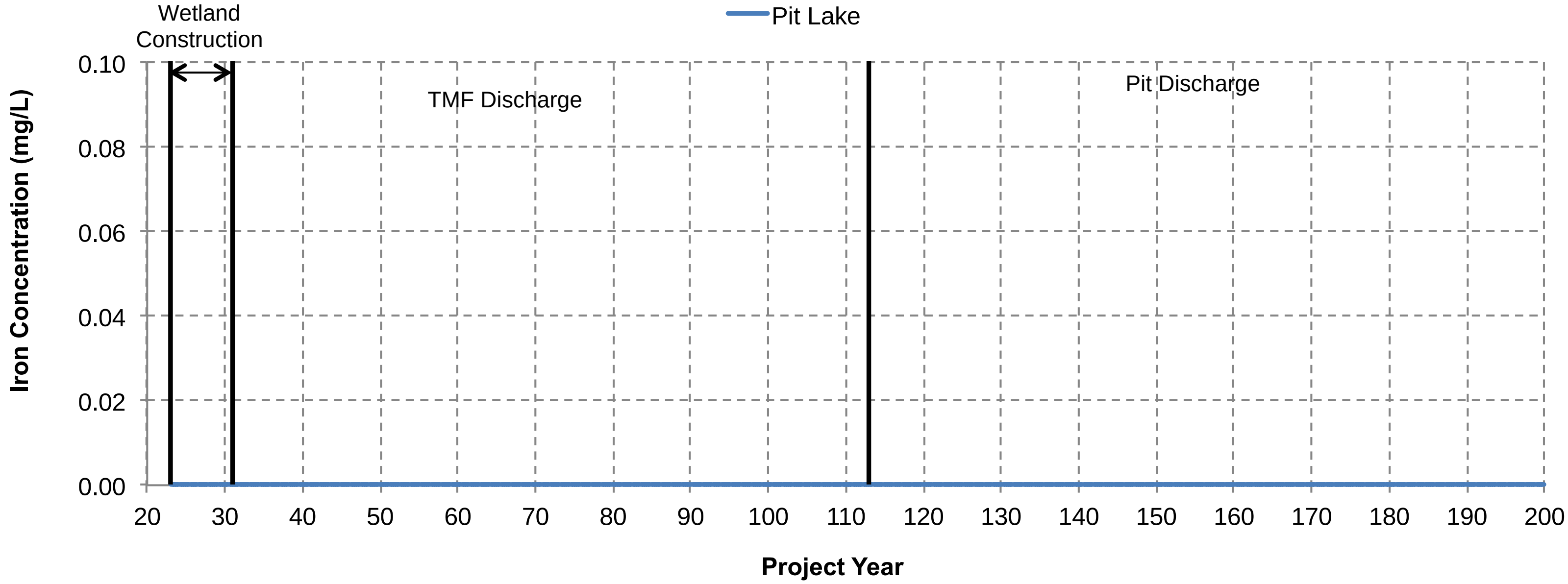

Figure 5-4. Modelled Iron Concentration in the Pit Lake

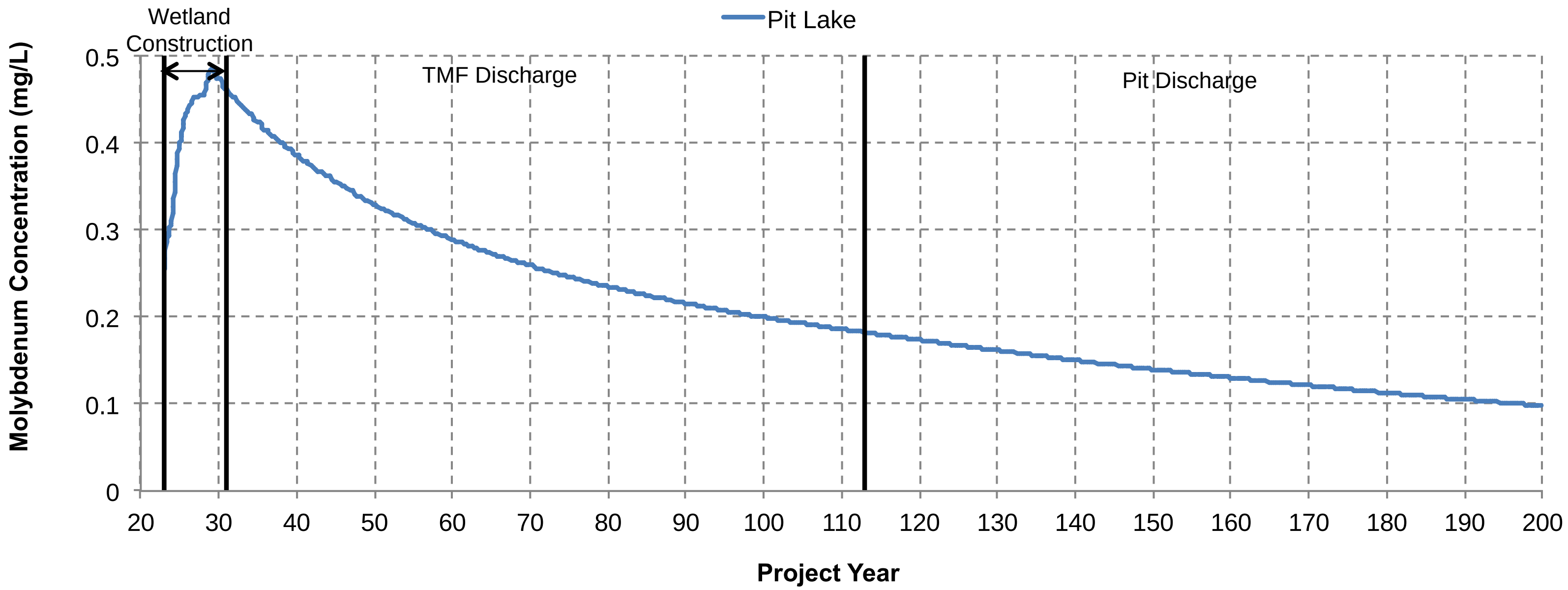

Figure 5-5. Modelled Molybdenum Concentration in the Pit Lake

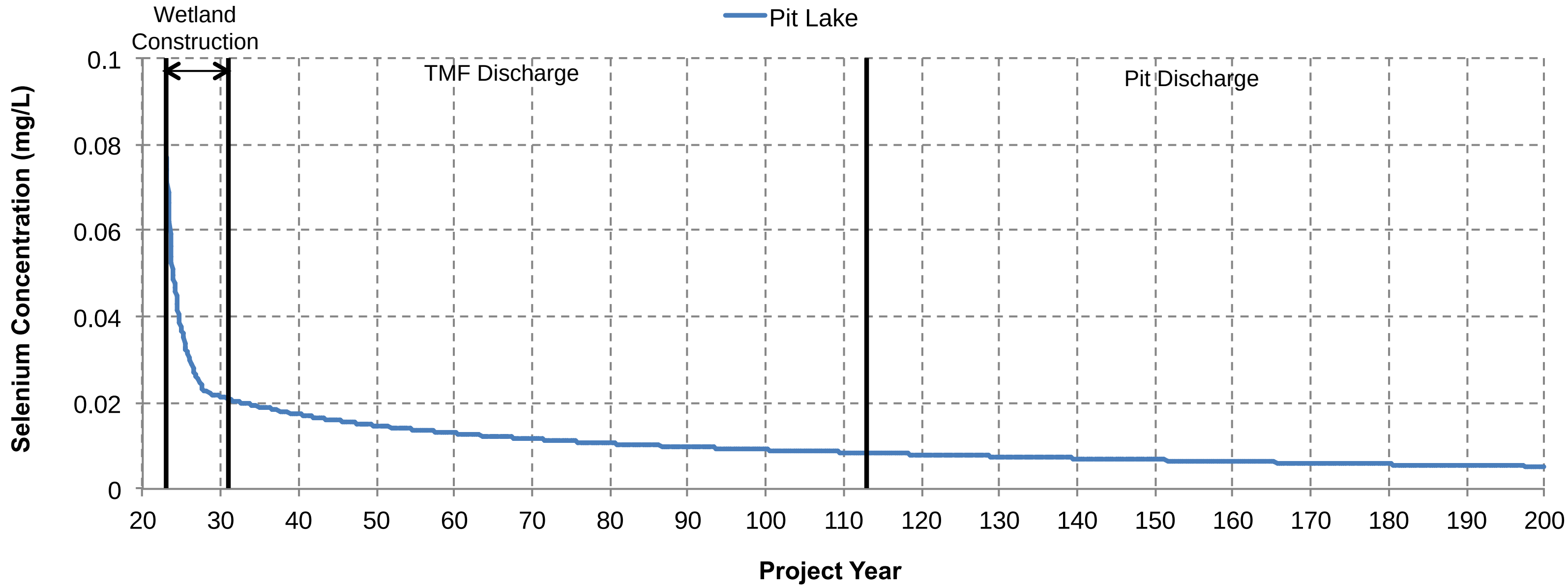

Figure 5-6. Modelled Selenium Concentration in the Pit Lake

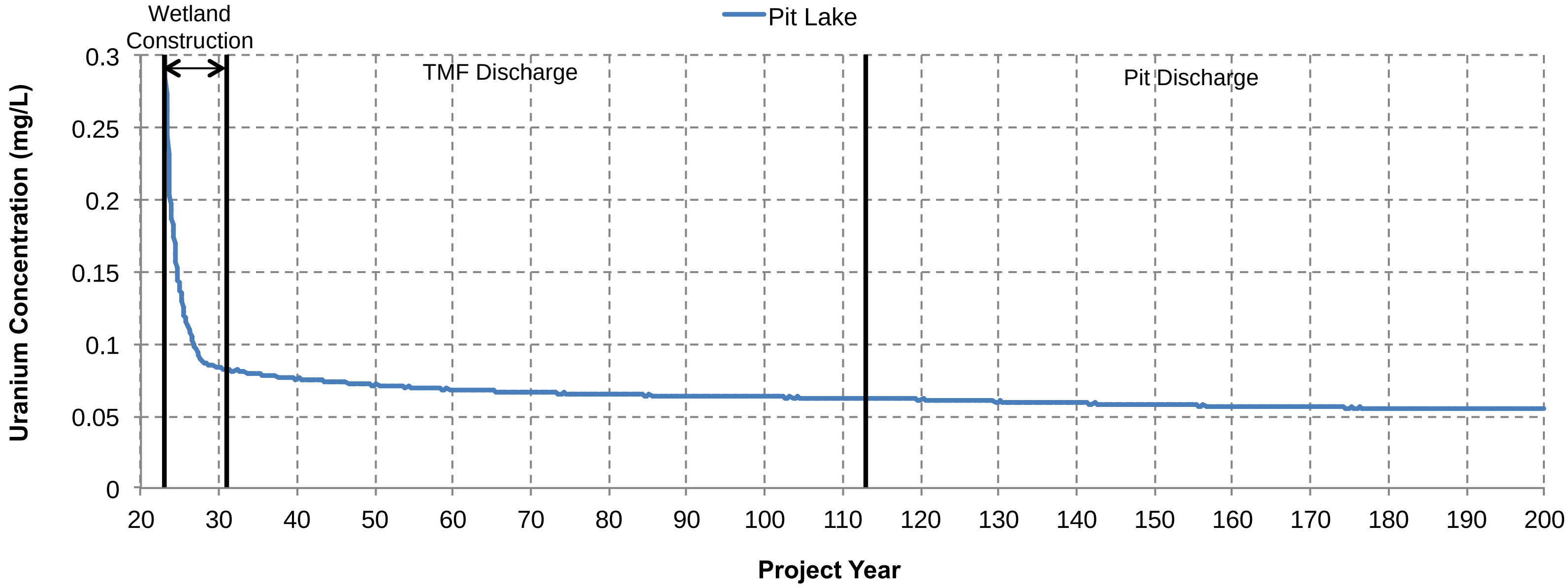

Figure 5-7. Modelled Uranium Concentration in the Pit Lake

5.2 Post Closure Pit Lake pH

The Pit Lake acidity loading and available alkalinity in the water indicated that over the duration of the model simulation, the available alkalinity exceeded the acidity. PHREEQC results (Figure 5-8) showed a near neutral pH over the duration of the simulation. There is excess NP in the hypogene wall rock.

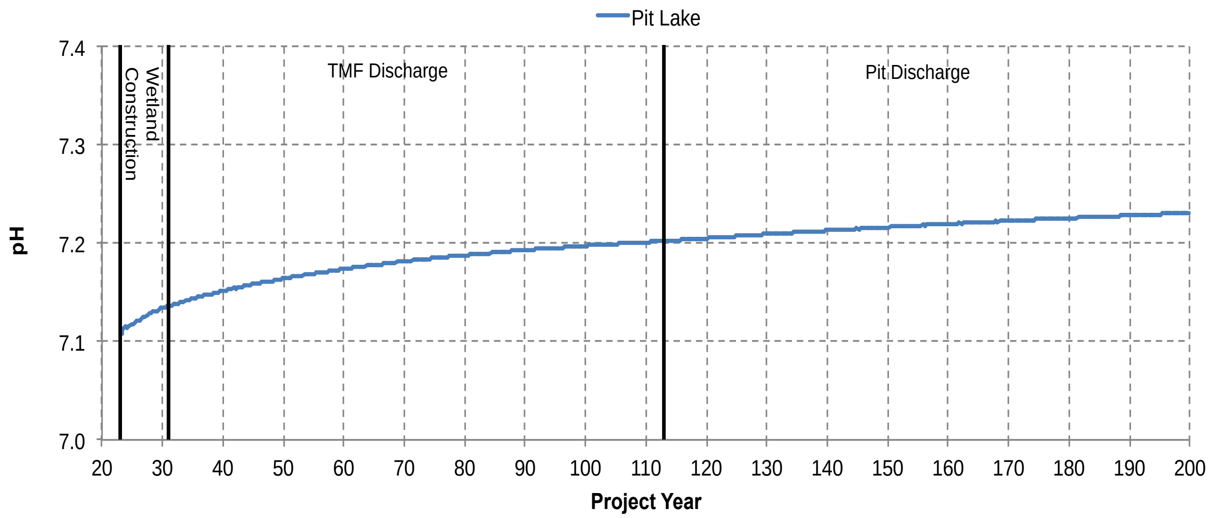

Figure 5-8 Simulated pH of the Pit Lake

5.3 Natural Degradation of Cyanide

HLF operations were assumed to be complete in Year 19. Surplus rinsing and drain down water will be pumped to the Open Pit after that time. Numerous gold mining operations located in Canada make use of the natural degradation processes for removal of cyanide from site water. Generally WAD-CN is removed rapidly – essentially all WAD-CN dissipates during a single open water season. The half-life of WAD-CD is very short – as little as a few hours, as the solution pH drops below pH 8. For the purposes of the model, it has been conservatively assumed the half-life is 0.05 years (18 days). Total cyanide was assumed to degrade slower, with a half-life of 0.5 years. Because the Pit Lake will not discharge for approximately 85 years after the final year of drain down pumping to Pit Lake (Year 28), cyanide degradation will remove this source prior to initial discharge of the Pit Lake.

5.4 Individual Contributions from Loading Sources

Individual contributions of each mass loading source are presented for select water quality parameters. Table 5-2 represents cumulative loading contributions at the time of initial discharge of the Pit Lake.

Table 5-3 represents the long-term (perpetual) contributions and was calculated from annual mass loading inflows at the end of the simulation (Year 200). Loading contributions for all water quality parameters are presented in Appendix II-B.

Table 5-2 Cumulative Fraction Contributing to Pit Lake Water Quality – Initial Pit Lake Discharge (Year 113)

Pit Lake Loading Source	Fraction Contributing (%)						
	SO_4	Cd	Cu	Fe	Mo	Se	U
Runoff	3	1	0	0	0	0	0
Groundwater	21	8	1	27	1	0	9
Ore Stockpile Seepage							
Hypogene	0	0	0	0	0	0	0
Supergene Sulphide	0	2	2	1	0	2	1
Marginal Ore	0	0	0	0	0	0	0
Pit Wall Runoff							
CAP	1	1	1	0	0	3	0
Hypogene (neutral)	9	1	0	0	17	5	7
Hypogene (acidic)	7	9	15	23	0	3	14
Supergene (neutral)	3	0	0	0	2	1	2
Supergene (acidic)	6	32	35	18	0	8	22
Pit Wall Flushing upon Submergence							
CAP	0	0	0	0	0	0	0
Hypogene (neutral)	3	0	0	0	6	2	2
Hypogene (acidic)	3	4	7	11	0	1	6
Supergene (neutral)	0	0	0	0	0	0	0
Supergene (acidic)	0	0	0	0	0	0	0
Ore Rock Flushing upon Submergence							
Supergene Oxide LGO	0	2	2	1	0	3	1
Supergene Sulphide LGO	1	5	5	2	0	5	3
Hypogene LGO	6	1	2	1	6	15	3
Marginal Ore	5	27	30	15	0	35	19
TMF Pond Pumping	21	3	0	0	16	12	11
HLF Draindown	8	4	1	2	51	5	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Note: Shaded cells are for sources that contribute >10% to the overall load.

Table 5-3 Annual Fraction Contributing to Pit Lake Water Quality – Long-Term Conditions (Year 200)

Pit Lake Loading Source	Fraction Contributing (%)						
	SO_4	Cd	Cu	Fe	Mo	Se	U
Runoff	8	2	0	0	1	1	0
Groundwater	40	10	1	28	15	1	13
Ore Stockpile Seepage	0	0	0	0	0	0	0
Pit Wall Runoff	0	0	0	0	0	0	0
CAP	3	1	2	0	1	18	0
Hypogene (neutral)	5	0	0	0	71	6	3
Hypogene (acidic)	24	20	31	41	1	18	33
Supergene (neutral)	2	0	0	0	11	3	1
Supergene (acidic)	18	66	66	30	0	53	50
Pit Wall Flushing	0	0	0	0	0	0	0
Ore Rock Flusing	0	0	0	0	0	0	0
TMF Pond Pumping	0	0	0	0	0	0	0
HLF Draindown	0	0	0	0	0	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Note: Shaded cells are for sources that contribute >10% to the overall load.

Closure activities carried out during the Wetland Construction Phase (pumping from the HLF and TMF, and disposal of residual stockpile ore rock) will influence Pit Lake water quality upon intial discharge, but those loading contributions will be temporary and will not affect the long-term water quality in the Pit Lake.

A portion of the pit wall (i.e. the “high wall”) that is above the elevation of the final Pit Lake will remain un-submerged. Runoff from the high wall will be a perpetual source of mass loading into the Pit Lake. The acidic portion (Supergene Acidic or Hypogene Acidic) of the Open Pit high wall rock is expected to be the largest contributor of mass load into the Pit Lake in the long-term.

6 References

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Appendix I - A

Water Quality Modelling Input Source Terms

Table I - A 1 Pit Lake Water Quality Model Inflow Concentrations (mg/L)

Water Quality Parameter		Overland Runoff (W7)	Background Groundwater	Ore Stockpile Seepage (max concentration)[1]			Pumped from TMF Pond [2]	Pumped from HLF
				Hypogene LGO	Supergene Sulphide LGO	Marginal Grade Ore		
Hardness (as $CaCO_3$)		44	691	1,919	1,106	645	929	1,697
Acidity (as $CaCO_3$)			22	0.27	1,046	866	0.37	0
Alkalinity (as $CaCO_3$)		7.1	123	68	0	0	9.0	70
Sulphate	(SO_4)	47	578	1,890	2,220	1,590	938	1,920
Chloride	(Cl)	0.25	0.91	37	16	3.0	25	638
Fluoride	(F)	0.065	0.63	2.4	25	6.3	1.6	2.1
Aluminum	(Al)	0.057	0.15	0.0023	121	98	0.96	0.069
Antimony	(Sb)	0.000065	0.00015	0.28	0.080	0.0027	0.0053	0.77
Arsenic	(As)	0.00024	0.0088	0.030	0.046	0.0087	0.0061	0.036
Barium	(Ba)	0.049	0.011	0.0056	0.0053	0.023	0.087	0.0064
Cadmium	(Cd)	0.00017	0.0019	0.0093	0.12	0.079	0.00091	0.0084
Calcium	(Ca)	13	218	609	302	211	359	666
Chromium	(Cr)	0.00015	0.00036	0.014	0.021	0.015	0.0024	0.0010
Cobalt	(Co)	0.000079	0.034	0.052	0.34	0.24	0.0039	5.7
Copper	(Cu)	0.0023	0.37	0.056	147	119	0.060	2.8
Iron	(Fe)	0.047	16	0.0099	125	107	0.14	9.5
Lead	(Pb)	0.000076	0.00051	0.0024	0.040	0.040	0.0018	0.0015
Magnesium	(Mg)	2.7	36	97	86	29	8.1	7.8
Manganese	(Mn)	0.0047	1.2	0.13	4.1	0.46	1.3	0.0036
Mercury	(Hg)	0.0000050	0.000015	0.00060	0.00040	0.00014	0.000015	0.000026
Molybdenum	(Mo)	0.00026	0.010	2.5	0.0090	0.0010	0.32	4.2
Nickel	(Ni)	0.00097	0.0050	0.071	2.0	2.0	0.0037	0.24
Potassium	(K)	0.53	2.7	51	24	3.4	21	246
Selenium	(Se)	0.000060	0.000076	0.30	0.20	0.20	0.011	0.02
Silver	(Ag)	0.0000025	0.0000095	0.00070	0.00085	0.00054	0.000049	0.053
Sodium	(Na)	4.0	11	8.2	7.9	1.2	29	432
Thallium	(Tl)	0.0000025	0.000027	0.00050	0.00094	0.00027	0.00036	0.0018
Uranium	(U)	0.000074	0.037	0.50	1.1	0.90	0.030	0.0018
Zinc	(Zn)	0.014	0.15	0.57	9.5	7.7	0.017	0.072

1 Concentration of stockpile seepage will vary depending on the mass of ore in the stockpile at the time of infiltration through the stockpile. Contact water quality is expected to be equal to or less than the concentrations shown (Lorax, 2013).

2 Average concentration over the duration of pumping from the TMF to the Pit (Year 23 to Year 27).

Table I - A 2 Loading Rates for Pit Wall Runoff, Flushing (from Submergence) of Pit Wall Rock and Flushing of Ore Stockpile Rock

Water Quality Parameter	Pit Wall Runoff ($mg/m^2/year$) [1]					Rate of Buildup of Substances on the Pit Walls ($mg/m^2/year$) [1]					Flushing of Ore When Placed in the Pit (mg/tonne)			
	Hypogene		Supergene		CAP	Hypogene		Supergene		CAP	Supergene Oxide LGO	Supergene Sulphide LGO	Hypogene LGO	Marginal Ore
	Neutral	Acidic	Neutral	Acidic		Neutral	Acidic	Neutral	Acidic					
Hardness	153,468	663,200	157,172	619,840	36,495	86,960	375,320	88,939	351,050	20,751	272,350	280,470	1,762,580	282,500
Acidity	127	480,000	265	130,000	3,310	72	272,000	150	73,500	1,870	255,000	262,000	96,300	366,000
Alkalinity	18,000	0	10,300	0	530	0	0	0	0	0	0	0	439,000	0
Sulphate (SO_4)	129,000	1,150,000	139,000	764,000	43,200	73,200	653,000	78,600	433,000	24,500	545,000	562,000	1,690,000	693,000
Chloride (Cl)	1,840	4,300	1,810	867	359	1,040	2,440	1,020	491	203	3,960	4,080	9,180	1,300
Fluoride (F)	717	1,200	1,710	910	117	406	677	971	515	66	6,080	6,260	4,510	2,730
Aluminum (Al)	1.3	63,700	1.9	14,300	503	0.75	36,100	1.1	8,110	285	29,700	30,500	14,800	43,000
Antimony (Sb)	4.4	1.6	2.4	0.79	0.35	2.5	0.91	1.4	0.45	0.20	31	32	68	1.2
Arsenic (As)	4.5	5.9	1.1	1.3	0.39	2.5	3.4	0.61	0.72	0.22	11	12	7.4	3.8
Barium (Ba)	75	20	162	3.3	43	43	11	92	1.9	24	202	208	190	10
Cadmium (Cd)	0.16	7.2	0.085	12	0.24	0.089	4.1	0.048	6.5	0.14	30	31	2.3	35
Calcium (Ca)	52,400	98,000	54,800	203,000	11,400	29,700	55,500	31,000	115,000	6,480	74,500	76,600	666,000	92,500
Chromium (Cr)	0.27	19	0.74	2.2	0.57	0.15	11	0.42	1.2	0.32	5.1	5.2	3.4	6.5
Cobalt (Co)	0.91	148	2.7	35	8.0	0.52	84	1.5	20	4.6	84	87	13	104
Copper (Cu)	13	16,600	45	17,400	653	7.2	9,390	25	9,830	370	36,200	37,200	5,810	52,100
Iron (Fe)	8.0	43,800	8.0	15,500	25	4.5	24,800	4.5	8,800	14	32,200	33,100	4,520	46,600
Lead (Pb)	0.34	1.1	0.33	0.47	0.22	0.19	0.63	0.19	0.27	0.12	17	10	0.59	18
Magnesium (Mg)	5,480	102,000	4,920	27,400	1,950	3,100	57,700	2,790	15,500	1,110	21,000	21,700	23,800	12,500
Manganese (Mn)	54	560	128	67	102	31	317	73	38	58	1,000	1,030	1,020	200
Mercury (Hg)	0.0080	0.043	0.013	0.040	0.0096	0.0045	0.024	0.0075	0.022	0.0055	0.099	0.10	0.16	0.059
Molybdenum (Mo)	85	1.2	31	0.12	0.47	48	0.65	18	0.067	0.27	3.8	2.3	612	0.35
Nickel (Ni)	1.4	83	2.0	13	2.6	0.78	47	1.1	7.1	1.5	842	506	18	876
Potassium (K)	3,730	27,700	4,420	16,100	4,520	2,110	15,700	2,500	9,100	2,560	5,960	6,140	12,600	1,460
Selenium (Se)	1.7	3.9	2.0	5.6	2.5	0.96	2.2	1.1	3.2	1.4	84	51	74	88
Silver (Ag)	0.0053	0.16	0.013	0.078	0.049	0.0030	0.090	0.0075	0.044	0.028	0.21	0.22	0.17	0.24
Sodium (Na)	351	6,900	430	5,710	1,450	199	3,910	244	3,240	821	1,030	1,990	2,020	520
Thallium (Tl)	0.10	0.18	0.100	0.079	0.087	0.057	0.10	0.057	0.045	0.049	0.23	0.24	0.12	0.12
Uranium (U)	32	179	24	131	0.80	18	102	13	74	0.45	271	279	121	393
Zinc (Zn)	17	1,390	30	1,120	24	9.4	788	17	634	13	2,340	2,410	140	3,360

1. Loading units are in terms of horizontal (planar) unit area.
2. After Lorax 2013

Appendix I - B

Water Quality Modelling Results

Table I - B 1 Pit Lake Water Quality Model Results (mg/L)

Water Quality Model Parameter	Pit Lake Water Quality	
	Initial Pit Lake Discharge (Year 113)	Long Term Post-Closure (Year 200)
Hardness (as $CaCO_3$)	461	335
Acidity (as $CaCO_3$)	69	68
Alkalinity (as $CaCO_3$)	185	194
Sulphate (SO_4)	474	352
Chloride (Cl)	17	9.5
Fluoride (F)	1.2	0.86
Aluminum (Al)	0.0088	0.0095
Antimony (Sb)	0.018	0.010
Arsenic (As)	0.0058	0.0044
Barium (Ba)	0.076	0.061
Cadmium (Cd)	0.0039	0.0035
Calcium (Ca)	241	199
Chromium (Cr)	0.0026	0.0024
Cobalt (Co)	0.13	0.078
Copper (Cu)	0.37	0.36
Iron (Fe)	0.00014	0.00014
Lead (Pb)	0.0014	0.00088
Magnesium (Mg)	14	13
Manganese (Mn)	0.54	0.42
Mercury (Hg)	0.000025	0.000022
Molybdenum (Mo)	0.18	0.099
Nickel (Ni)	0.046	0.029
Potassium (K)	7.4	3.0
Selenium (Se)	0.0083	0.0052
Silver (Ag)	0.0010	0.00054
Sodium (Na)	16	10
Thallium (Tl)	0.00017	0.00012
Uranium (U)	0.062	0.055
Zinc (Zn)	0.39	0.37

Table I - B 2 Cumulative Fraction Contributing to Pit Lake Water Quality for Initial Pit Lake Discharge (Year 113)

Pit Lake Loading Source	Hard-ness	Acid-ity	Alk	SO4	Cl	F	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Hg	Mo	Ni	K	Se	Ag	Na	Tl	U	Zn
Runoff	3	1	0	3	1	2	0	0	2	21	1	3	2	0	0	0	2	6	0	7	0	1	2	0	0	8	1	0	1
Groundwater	27	5	0	21	1	9	0	0	26	2	8	26	2	4	1	27	5	37	40	9	1	2	5	0	0	11	3	9	6
Ore Stockpile Seepage																													
Hypogene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Supergene Sulphide	0	1	0	0	0	1	1	0	1	0	2	0	1	0	2	1	2	0	1	1	0	3	0	2	0	0	0	1	1
Marginal Ore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pit Wall Runoff																													
CAP	1	1	0	1	0	1	1	0	1	6	1	1	2	1	1	0	2	1	2	4	0	1	4	3	0	1	6	0	1
Hypogene (neutral)	12	0	0	9	3	15	0	5	19	22	1	12	3	0	0	0	5	11	3	10	17	1	15	5	0	1	16	7	1
Hypogene (acidic)	2	34	0	7	1	6	38	0	5	1	9	1	37	5	15	23	4	8	6	9	0	8	1	3	1	0	6	14	17
Supergene (neutral)	3	0	0	3	1	9	0	3	6	12	0	3	2	0	0	0	1	3	2	4	2	0	4	1	0	0	4	2	0
Supergene (acidic)	3	21	0	6	1	9	19	0	3	0	32	3	9	3	35	18	3	3	1	17	0	3	1	8	1	0	6	22	30
Pit Wall Flushing upon Submergence																													
CAP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypogene (neutral)	3	0	0	3	1	5	0	2	6	8	0	4	1	0	0	0	2	4	1	3	6	0	5	2	0	0	2	2	0
Hypogene (acidic)	4	16	0	3	1	3	18	0	3	1	4	0	17	3	7	11	2	4	3	4	0	4	0	1	0	0	3	6	8
Supergene (neutral)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Supergene (acidic)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ore Rock Flushing upon Submergence																													
Supergene Oxide LGO	0	1	0	0	0	1	1	0	1	1	2	0	0	0	2	1	3	0	1	1	0	4	0	3	0	0	0	1	1
Supergene Sulphide LGO	0	3	0	1	0	4	3	1	1	2	5	0	1	0	5	2	5	1	1	3	0	7	0	5	0	0	1	3	4
Hypogene LGO	7	2	0	6	1	7	3	5	2	4	1	8	2	0	2	1	1	2	3	10	6	1	2	15	0	0	1	3	1
Marginal Ore	2	16	0	5	0	8	16	0	2	0	27	2	8	2	30	15	36	3	1	7	0	56	1	35	1	0	3	19	26
TMF Pond Pumping	25	0	100	21	17	15	0	7	11	19	3	27	9	3	0	0	26	16	36	8	16	1	6	12	1	22	24	11	1
HLF Draindown	8	0	0	8	74	4	0	74	12	0	4	9	1	79	1	2	2	1	0	2	51	9	54	5	95	55	24	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Shaded cells are for sources that contribute >10% to the overall load.

Table I - B 3 Annual Fraction Contributing to Pit Lake Water Quality – Long-Term Conditions (Year 200)

Pit Lake Loading Source	Hard	Acid.	Alk	SO4	Cl	F	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Hg	Mo	Ni	K	Se	Ag	Na	Tl	U	Zn
Runoff	10	1	12	8	11	6	0	3	4	**52**	2	10	3	0	0	0	9	10	1	12	1	4	13	1	3	45	2	0	2
Groundwater	**59**	5	**79**	**40**	14	20	0	3	**51**	4	10	**62**	3	21	1	28	23	**53**	**70**	13	15	7	**24**	1	4	**48**	8	13	7
Ore Stockpile Seepage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pit Wall Runoff																													
CAP	3	1	0	3	5	3	1	5	2	14	1	3	3	4	2	0	8	3	5	7	1	3	23	18	17	4	21	0	1
Hypogene (neutral)	7	0	7	5	12	9	0	30	11	12	0	8	1	0	0	0	6	5	1	4	**71**	1	21	6	1	1	12	3	0
Hypogene (acidic)	8	**60**	0	24	**37**	20	**67**	14	18	4	20	4	**72**	**50**	31	**41**	**27**	21	17	21	1	**65**	5	18	36	1	**27**	33	34
Supergene (neutral)	3	0	2	2	5	10	0	**31**	6	12	0	4	1	0	0	0	3	2	1	3	11	1	9	3	1	0	5	1	0
Supergene (acidic)	9	34	0	18	15	**32**	31	14	8	1	**66**	10	17	24	**66**	30	23	7	4	**39**	0	20	5	**53**	**37**	1	25	**50**	**56**
Pit Wall Flushing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ore Rock Flusing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TMF Pond Pumping	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HLF Draindown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Shaded cells are for sources that contribute >10% to the overall load.

Casino Project
Water Quality Predictions

Appendix II
Ore Stockpiles Water Quality Modelling

Prepared by:

Source Environmental Associates Inc.

December 2013

Table of Contents

List of Figures

List of Tables

List of Appendices

1 Introduction

During Operations of the Casino Project (the Project), six ore piles will be temporarily stockpiled on surface. The stockpiles include:

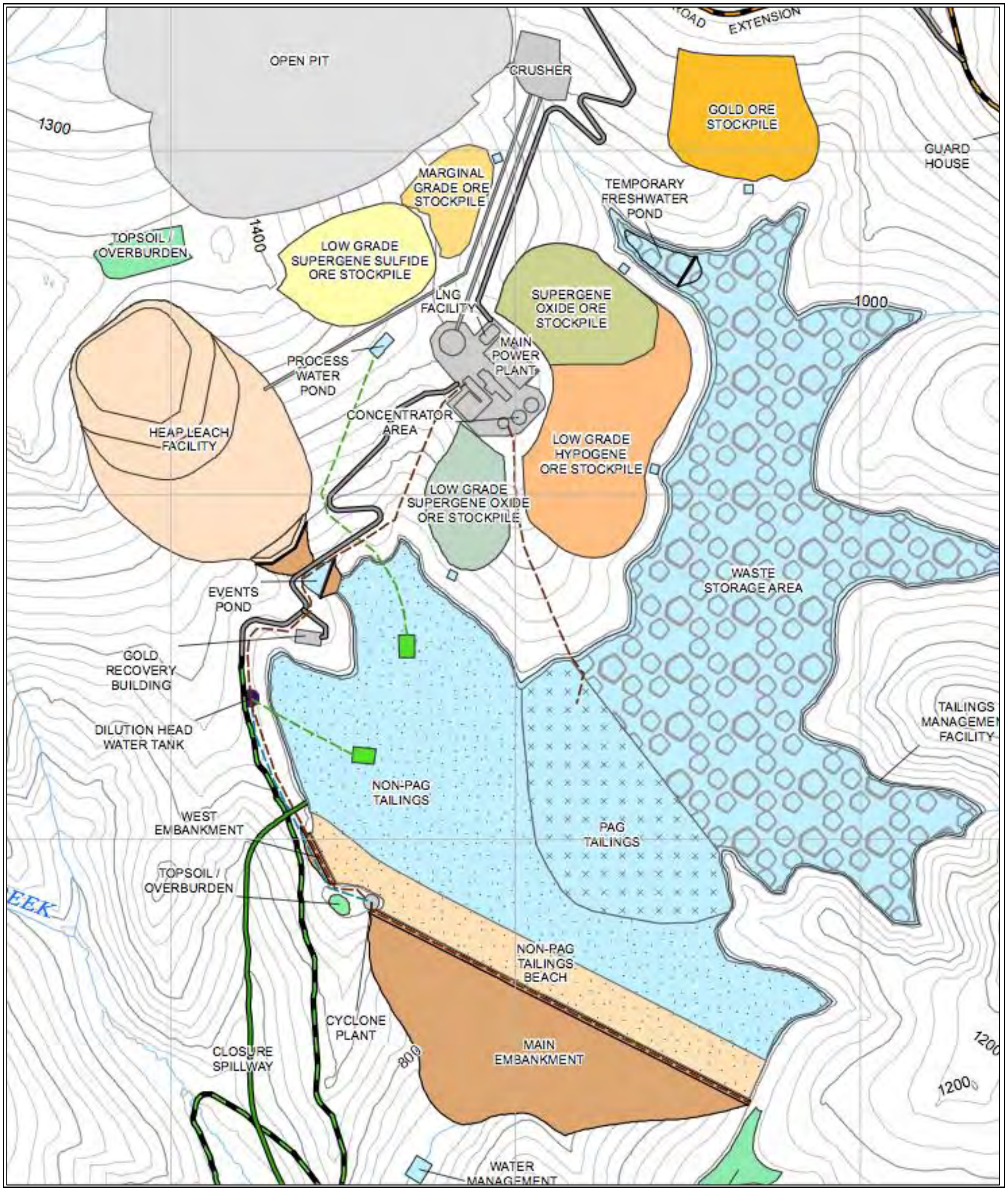
- Gold Ore;
- Supergene Oxide Ore;
- Low Grade Supergene Oxide;
- Low Grade Hypogene;
- Low Grade Supergene Sulphide; and,
- Marginal Ore (MGO)

The gold ore will be crushed then processed in the Heap Leach Facility (HLF), and the marginal ore will be backfilled to the Open Pit. The remaining 4 piles will be milled in the processing facility. Stockpile locations are shown on Figure 1-1. The schedule of ore stockpiling rock is provided in Appendix II-A (Table II - A 1).

While the ore stockpiles are present during Operations, contact water (from rainfall and snowmelt) will drain from the rock as runoff or infiltrate to groundwater. Runoff from the stockpiles will be captured by the TMF Pond. Prior to construction of the TMF, runoff water from the stockpiles will be conveyed to the temporary Freshwater Storage Pond (FWSP) in the northern upper reach of the final TMF footprint. The FWSP water will be used to supply makeup water to the HLF (KPL, 2013a). Hydrogeological modelling (KPL, 2013b) indicated that depending on the stockpile location, infiltrated contact water will flow to one or more of the following receptors: the TMF Pond; Open Pit; TMF Embankment; or TMF Foundation bedrock.

Because the stockpiles will be temporary structures, they will be temporary sources of loading. The transient effect of the stockpiles on the site-wide water quality was accounted for by Source Environmental Associates Inc. (SEA) in the water quality model.

This document summarizes the calculation methodology and results of mass loading from the stockpiles to the various receptors around the project site. Mass transport rates were calculated using flow rates from the KPL (2013c) water balance model, combined with geochemical source terms provided by Lorax (2013), and the stockpile schedule from KPL (2013d). Hydrogeological modelling results from KPL (2013b) were used to predict average travel times of groundwater from the stockpiles to their receptors.



Adapted from KPL, 2013a

Figure 1-1 Ore Stockpile General Arrangement at Maximum Footprint

2 Water Quality Model

A site-wide water quality model was developed by SEA. The model simulation was run with monthly time steps for a timeline beginning a few years prior to Construction, through to 200 years following the beginning of Operations.

Project years are described in this document relative to the beginning of milling Operations. For example, Year -2 refers to the second year before Operations begins, and Year 2 refers to the second year of Operations. Construction will span from Year -4 to Year -1, and Operations from Year 1 to Year 22. Modelling methodology and results are presented in the following sections.

2.1 Modelling Approach

The rate of mass transport from the ore (via contact water) was calculated for 29 water quality parameters using source terms from Lorax (2013) and water balance flows from KPL (2013c). Ore Pile source terms from Lorax include both a loading rate based on the amount of rock present in the stockpile (i.e. mass of constituents per mass of rock) and a maximum concentration limit based on solubility controls. In the GoldSim model, development of the total loadings in mass per time (i.e. Kg/month) for each ore pile was the first step in a multi-step process.

Once the total load for each constituent was determined for an ore pile, this total load was then partitioned by the annual quantity of flow to surface water and groundwater. Surface water runoff was directed to the TMF pond. Groundwater loadings were further partitioned into the following four pathways shown on Figure 2-1.

- Seepage to the TMF Pond
- Seepage to the Open Pit
- Seepage to the TMF Embankment
- Seepage to the TMF Foundation

Once the total load was partitioned to a groundwater pathway, a delay was applied in the water quality model to simulate the travel time for the loading from the stockpile to the receptor.

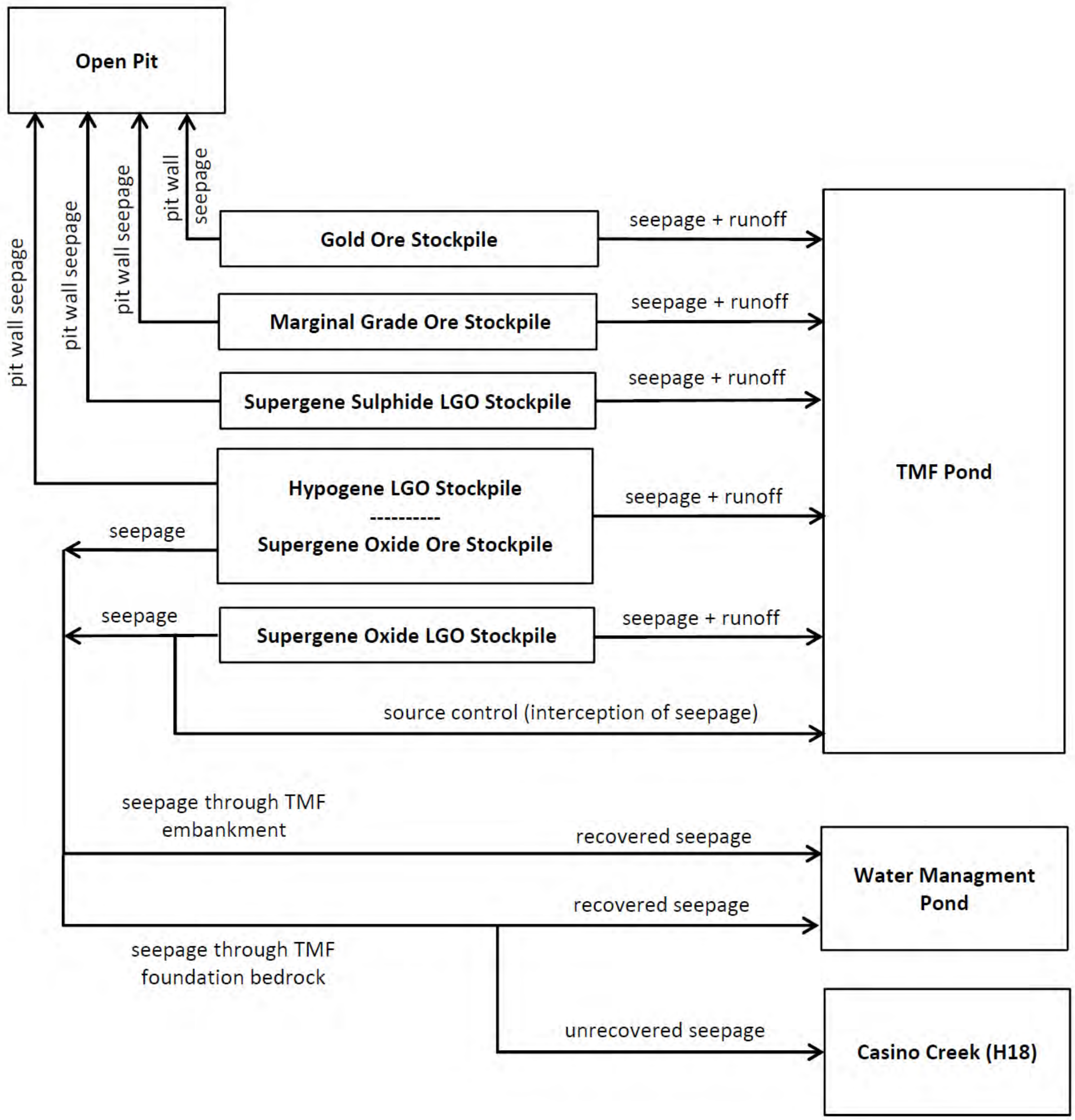


Figure 2-1 Mass Loading Pathways from the Ore Stockpiles

2.2 Mass Loading from Ore Piles

Mass loading rate source terms for the six ore stockpiles were developed by Lorax (2013) on an annual basis and are presented in Appendix II-A (Table II - A 2). SEA generated mass transport rates (in kg/month) in the contact water from each stockpile for 29 water quality parameters. The amount of rock stockpiled on surface directly affects the quantity and quality of the ore stockpile contact water. The ore deposition schedule is summarized in Appendix II-A (Table II - A 1).

The source term loading rates were multiplied by the total rock mass stored in the stockpiles to calculate total load from the ore piles during a given model time-step. The loading concentrations from the ore piles were compared to solubility controls for the suite of parameters. Lorax (2013) provided maximum allowable contact water concentrations (Appendix II-A, Table II - A 3) based on water availability and solubility constraints. The total mass load in the contact water was reduced if the resulting contact water concentration exceeded the maximum allowable concentration provided by Lorax (2013).

Lorax predicted the pH of the contact water to be pH 4.7 for the Gold Ore, pH 7.2 for the Low Grade Hypogene Ore, and pH 3.2 for the other stockpiles (Table II - A 4). Water quality modeling indicated that only the Low Grade Hypogene Ore stockpile is affected by solubility controls; the solubility controls apply to copper, iron and other parameters that are relatively insoluble at neutral pH). Time series plots of copper mass loading rates from the Low Grade Supergene Oxide Ore (Figure 2-2) and the Low Grade Hypogene stockpile (Figure 2-3) illustrate the calculated total mass loading from the stockpiles.

Once the mass loadings from each stockpile were determined, the next step in the model was to partition this total load into the flow pathways to receptors.

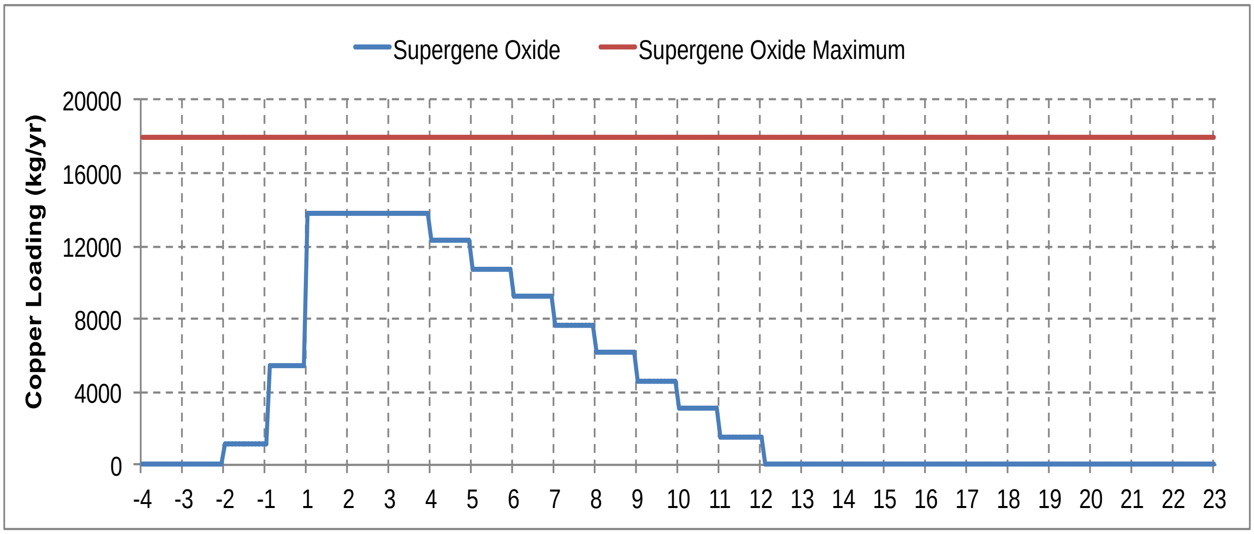


Figure 2-2 Copper Loadings and Maximum Solubility in the Supergene Oxide Low Grade Ore Stockpile Drainage

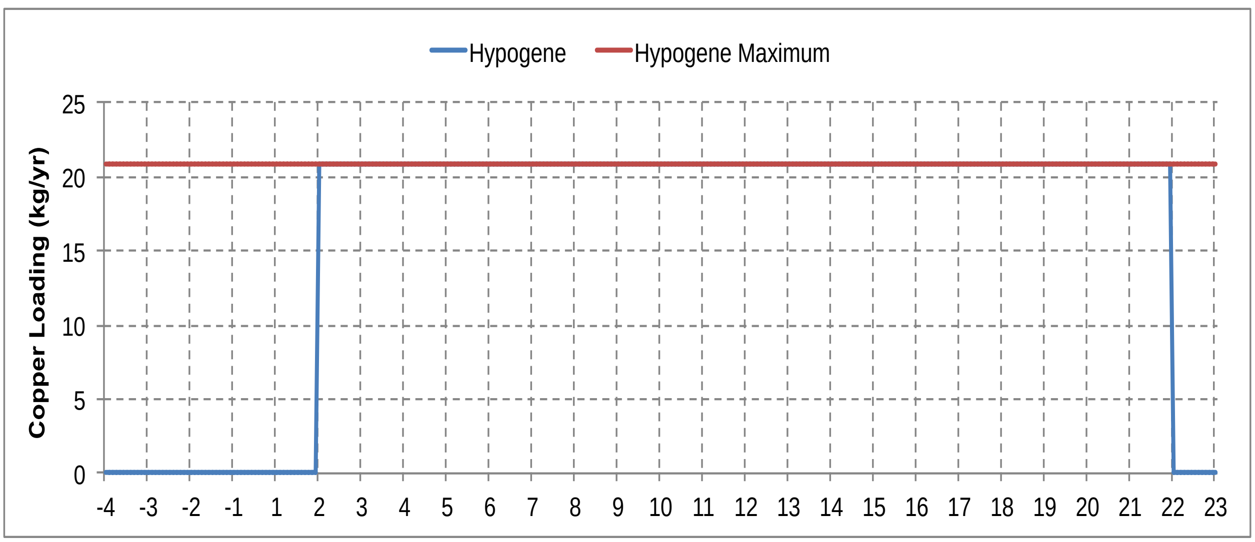


Figure 2-3 Copper Loadings and Maximum Solubility in the Hypogene Low Grade Ore Stockpile Drainage

2.3 Partition Loadings by Pathway

The ore contact water is expected to follow several possible pathways from the stockpiles. Surface water (runoff) from all stockpiles will report to the TMF Pond. The ratio of the annual surface water flow to the total contact water flow was used to partition the loading to surface water for each stockpile. The remainder of the loading was allocated as seepage between up to four groundwater pathways. Because the model was run with monthly timesteps and the loadings partitioning was done annually, the ratio used was based on the cumulative long-term average ratio. There is no surface water flow in the winter time but groundwater seepage continues year-round.

KPL (2013b) provided relative proportions of the total seepage by individual flow pathways for three snapshots in time: Year 4, Year 10, and Year 19. As results were fairly similar among the three snapshots, a constant value was used. Table 2-1 shows the assumption used in the SEA model. Year 19 was used to represent the flow (and load) partitioning for all years of the model simulation, with the following exceptions:

- Year 10 was used for the Supergene Ore as it does not exist at year 19 (it is replaced by the Hypogene pile) and
- Year 10 was used for the Low Grade Supergene Sulphide and Marginal Grade Ore as to be more conservative because by year 19 there is no seepage to the TMF pond.

Modelling results indicated that seepage from the Low Grade Supergene Oxide stockpile could have a noticeable (albeit temporary) effect on Casino Creek water quality. Interception of seepage (i.e. source control) was integrated into the project description to mitigate the potential impacts of the Low Grade Supergene Oxide seepage on water quality in Casino Creek. KPL (2013b) assumed that 90% of the seepage would be recovered and conveyed to the TMF Pond.

Table 2-1 Stockpile Seepage Partitioning by Receptor in the Water Quality Model

Stockpile Receptor	Fraction of Total Seepage Discharge (%)
Gold Ore Stockpile	
Open Pit	20%
TMF Pond	80%
Supergene Oxide	
Open Pit	4%
TMF Pond	95%
TMF Embankment Seepage	1%
TMF Foundation Seepage	0%
Low Grade Supergene Oxide Ore Stockpile	
TMF Pond	65%
TMF Embankment Seepage	25%
TMF Foundation Seepage	10%
Low Grade Hypogene Ore Stockpile	
Open Pit	3%
TMF Pond	95%
TMF Embankment Seepage	1%
TMF Foundation Seepage	1%
Low Grade Supergene Sulfide Ore Stockpile	
Open Pit	95%
TMF Pond	5%
Marginal Grade Ore Stockpile	
Open Pit	95%
TMF Pond	5%

Adapted from KPL (2013b)

2.4 Delay of Seepage along Pathway

To simulate groundwater flow velocities in the seepage, a time delay was applied to the seepage mass loading in the water quality model. The seepage was assumed to report to its receptor after a period of time equal to an estimated seepage travel time. Median, minimum, and maximum seepage travel times from the stockpiles to their receptors were approximated by KPL (2013b).

SEA calculated an average travel time in the GoldSim model using a triangular probability distribution to produce a base case value. Travel time calculation from the gold ore stockpile to the Open Pit is shown on Figure 2-4. The resulting mean time delay was calculated to be 3.8 years, based on minimum (1.3 years), maximum (7.3 years) and median (2.8 years) delays.

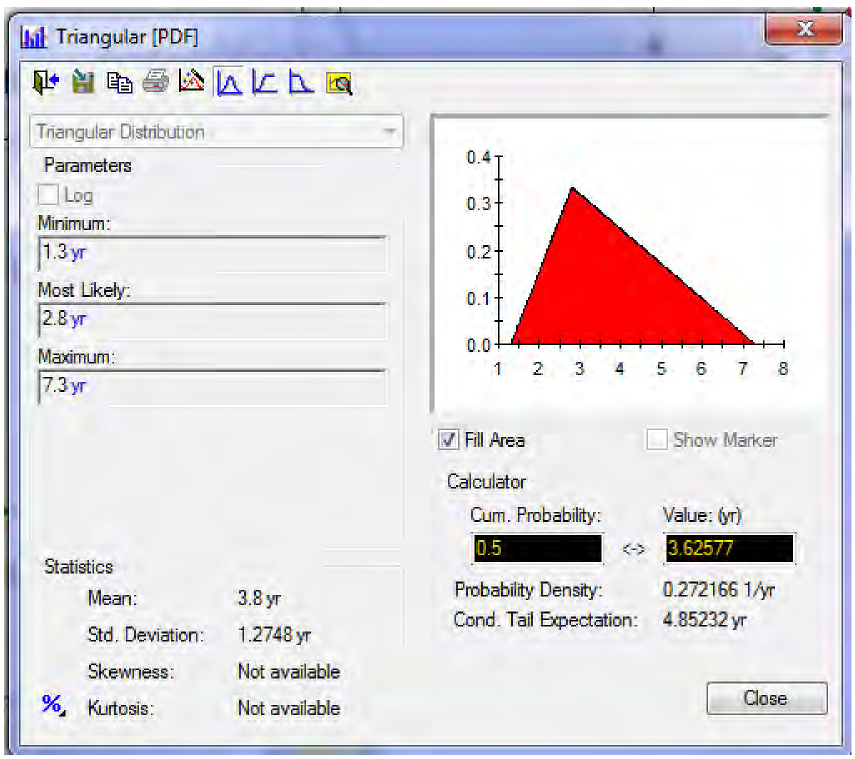


Figure 2-4 Gold Ore Stockpile Time Delay GoldSim Calculations

The calculated average values used in the model are presented in Table 2-2.

Table 2-2 Average Travel Time from Stockpile to Receptor

Stockpile Receptor	Average Travel Time to Discharge Location (Years)
Gold Ore Stockpile	
Open Pit	3.8
TMF Pond	1.8
Supergene Oxide	
Open Pit	2.7
TMF Pond	3.8
TMF Embankment Seepage	8.3
TMF Foundation Seepage	15.0
Low Grade Supergene Oxide Ore Stockpile	
TMF Pond	9.2
TMF Embankment Seepage	7.7
TMF Foundation Seepage	27.7
Low Grade Hypogene Ore Stockpile	
Open Pit	2.7
TMF Pond	3.8
TMF Embankment Seepage	8.3
TMF Foundation Seepage	15.0
Low Grade Supergene Sulfide Ore Stockpile	
Open Pit	3.4
TMF Pond	33.2
Marginal Grade Ore Stockpile	
Open Pit	3.4
TMF Pond	33.2

Adapted from KPL (2013b)

3 Summary and Results

The ore stockpile water quality modelling methodology respected the principal of mass conservation. The total loading from each ore pile was partitioned to the appropriate receptors in the fully-integrated water quality model.

Loadings from the ore stockpiles to the various receptors will vary over time. Generally, the rate of loading from the ore stockpiles will vary proportionally to the stockpile mass.

During Operations, the majority of the loads will be captured by runoff to the TMF Pond, or by groundwater intercepted by the TMF Pond or Open Pit. A lag time was applied to the stockpile seepage water to simulate the travel time that it will take for the stockpile contact water to reach the receptors as seepage. Application of the time delay resulted in some seepage reaching the TMF Pond, TMF Embankment and TMF Foundation after Operations.

Because the stockpiles will be temporary structures, they will be temporary sources of loading. All water quality effects to the receptors were predicted to cease by Year 55 of the model simulation.

The water quality model was used to evaluate where mitigation measures can be implemented to minimize the influence of stockpile loading on the receiving environment water quality. Interception of seepage (i.e. source control) from the Low Grade Supergene Oxide stockpile was incorporated into the input assumptions for partitioning of loads to the receptors, such that most of the load from this stockpile is directed to the TMF.

Calculated rates of mass transport at the stockpile loading receptors are presented (in kg/year) in Appendix, II-B for Years 5, 15, 25 and 35. The mass loading calculations showed that the Supergene Oxide and Low Grade Supergene Sulphide stockpiles will be largest sources of stockpile mass loading for most parameters. The Low Grade Supergene Oxide and the Marginal Ore stockpiles produce lower loading, and the Gold Ore stockpile loadings are lower still. The copper loadings from the Hypogene stockpile were calculated to be the lowest as they are limited by the maximum solubility of copper in the neutral pH drainage from this ore pile as predicted by Lorax (2013).

4 References

Knight Piesold, 2013a. Casino Copper-Gold Project – Water Management Plan. Ref. No. VA101-325/14-2. Rev 0. Prepared for Casino Mining Corporation. December 12, 2013.

Knight Piesold, 2013b. Casino Project – Numerical Groundwater Modelling. Ref. No. VA101-325/14-6. Rev 0. Prepared for Casino Mining Corporation. October 25, 2013.

Knight Piesold, 2013c. Casino Copper-Gold Project – YESAB Water Balance Model Report. Ref. No. VA101-325/14-10. Rev A. Prepared for Casino Mining Corporation. October 31, 2013.

Knight Piesold, 2013d. Casino Copper-Gold Project – Ore Stockpile Restructuring by Ore Type, KP reference number VA13-02301.

Lorax Environmental, 2013. Casino Geochemical Source Term Development. Project No. J862-5. Prepared for Casino Mining Corporation. December 4, 2013.

Appendix II - A

Model Inputs

Table II - A 1 Ore Stockpile Schedule

YEAR	Gold Ore		Supergene Oxide Ore		Low Grade Supergene Oxide Ore		Low Grade Hypogene Ore		Low Grade Supergene Sulphide Ore		Marginal Grade Ore
	Gold Ore to Stockpile (tonnes)	Gold Ore Stockpile to Crusher (tonnes)	To Stockpile (tonnes)	From Stockpile to Mill (tonnes)	To Stockpile (tonnes)	From Stockpile to Mill (tonnes)	To Stockpile (tonnes)	From Stockpile to Mill (tonnes)	To Stockpile (tonnes)	From Stockpile to Mill (tonnes)	Ore to Stockpile (tonnes)
-3	0	0	20,000	0	0	0	0	0	0		0
-2	5,072,000	0	2,806,000	0	0	0	0	0	0		0
-1	12,529,000	0	9,950,000	0	31,000	0	0	0	153,000		21,600
1	9,542,000	0	19,634,000	0	387,000	0	0	0	452,000		421,200
2	8,454,000	0	0	0	2,034,000	0	1,186,000	0	3,967,000		1,319,850
3	3,754,000	0	0	0	742,000	0	1,010,000	0	1,643,000		1,642,050
4	0	1,316,000	0	3,600,000	3,739,000	0	1,300,000	0	5,733,000		5,432,400
5	0	8,630,000	0	3,600,000	3,320,000	0	6,511,000	0	6,681,000		9,767,700
6	0	8,053,000	0	3,600,000	1,209,000	0	19,141,000	0	1,883,000		7,254,000
7	0	352,000	0	3,600,000	0	0	11,948,000	0	25,000		5,704,200
8	3,986,000	0	0	3,600,000	107,000	0	6,524,000	0	144,000		5,487,300
9	4,227,000	0	0	3,600,000	276,000	0	6,267,000	0	1,757,000		5,938,650
10	9,110,000	0	0	3,600,000	280,000	0	1,321,000	0	3,974,000		6,331,050
11	0	7,862,000	0	3,600,000	105,000	0	1,642,000	0	3,196,000		8,631,900
12	0	8,500,000	0	3,610,000	397,000	0	5,768,000	0	3,296,000		10,546,650
13	0	8,200,000	0	0	767,000	0	6,930,000	0	1,332,000		8,169,750
14	0	8,887,000	0	0	606,000	0	4,343,000	0	1,721,000		4,612,950
15	0	4,874,000	0	0	43,000	0	5,742,000	0	2,835,000		2,707,200
16	0	0	0	0	0	0	6,584,000	0	559,000		253,350
17	0	0	0	0	0	0	4,216,000	0	0		0
18	0	0	0	0	0	0	0	0	0		0
19	0	0	0	0	0	1,011,000	0	24,160,000	0	5,744,000	0
20	0	0	0	0	0	1,570,000	0	30,404,000	0	13,081,000	0
21	0	0	0	0	0	4,429,000	0	32,177,000	0	8,377,000	0
22	0	0	0	0	0	7,033,000	0	3,692,000	0	12,149,000	0
TOTALS	**56,674,000**	**56,674,000**	**32,410,000**	**32,410,000**	**14,043,000**	**14,043,000**	**90,433,000**	**90,433,000**	**39,351,000**	**39,351,000**	**84,241,800**

Provided by KPL (2013)

Table II - A 2 Mass Loading Rates of Ore Stockpiles

Water Quality Parameter		Stockpile Mass Loading Rates (mg/tonne/year)					
		Gold Ore	Supergene Oxide Ore	Low Grade Supergene Oxide Ore	Low Grade Hypogene Ore	Low Grade Supergene Sulphide Ore	Marginal Grade Ore
Hardness		3,427	4,360	3,951	29,374	4,062	4,092
Acidity		201	3,388	3,695	1,605	3,800	5,309
Alkalinity		0	0	0	7,320	0	0
Sulphate	(SO_4)	10,300	7,558	7,900	28,200	8,140	10,040
Chloride	(Cl)	363	68	57	153	59	19
Fluoride	(F)	17	101	88	75	91	40
Aluminum	(Al)	26	393	430	247	442	623
Antimony	(Sb)	0.15	0.55	0.44	1.1	0.46	0.017
Arsenic	(As)	0.098	0.19	0.16	0.12	0.17	0.055
Barium	(Ba)	11	3.6	2.9	3.2	3.0	0.15
Cadmium	(Cd)	0.053	0.43	0.44	0.038	0.45	0.50
Calcium	(Ca)	1,010	1,180	1,080	11,100	1,110	1,340
Chromium	(Cr)	0.16	0.070	0.073	0.056	0.076	0.094
Cobalt	(Co)	1.1	1.2	1.2	0.21	1.3	1.5
Copper	(Cu)	68	480	524	97	539	755
Iron	(Fe)	3.3	426	466	75	480	676
Lead	(Pb)	0.12	0.17	0.24	0.0099	0.15	0.25
Magnesium	(Mg)	220	344	305	396	314	181
Manganese	(Mn)	26	18	15	17	15	2.9
Mercury	(Hg)	0.0021	0.0016	0.0014	0.0026	0.0015	0.00086
Molybdenum	(Mo)	0.13	0.038	0.055	10	0.033	0.0051
Nickel	(Ni)	0.33	8.5	12	0.29	7.3	13
Potassium	(K)	814	103	86	210	89	21
Selenium	(Se)	0.37	0.85	1.2	1.2	0.73	1.3
Silver	(Ag)	0.013	0.0030	0.0030	0.0028	0.0031	0.0034
Sodium	(Na)	2,810	17	15	34	29	7.5
Thallium	(Tl)	0.019	0.0038	0.0033	0.0020	0.0034	0.0017
Uranium	(U)	0.093	3.6	3.9	2.0	4.1	5.7
Zinc	(Zn)	5.8	31	34	2.3	35	49

Provided by Lorax (2013)

Table II - A 3 Maximum Allowable Concentration of Ore Stockpile Contact Water

Water Quality Parameter		Maximum Allowable Concentration (mg/L)					
		Gold Ore	Supergene Oxide Ore	Low Grade Supergene Oxide Ore	Low Grade Hypogene Ore	Low Grade Supergene Sulphide Ore	Marginal Grade Ore
Hardness		878	1,029	662	1,919	1,106	645
Acidity		45	820	637	0.27	1,046	866
Alkalinity		10	0	0	68	0	0
Sulphate	(SO_4)	2,310	1,780	1,300	1,890	2,220	1,590
Chloride	(Cl)	81	16	9.3	37	16	3.0
Fluoride	(F)	3.7	24	14	2.4	25	6.3
Aluminum	(Al)	5.8	92	71	0.0023	121	98
Antimony	(Sb)	0.034	0.13	0.072	0.28	0.080	0.0027
Arsenic	(As)	0.022	0.045	0.027	0.030	0.046	0.0087
Barium	(Ba)	0.0043	0.0060	0.0067	0.0056	0.0053	0.023
Cadmium	(Cd)	0.012	0.10	0.072	0.0093	0.12	0.079
Calcium	(Ca)	259	279	181	609	302	211
Chromium	(Cr)	0.035	0.016	0.012	0.014	0.021	0.015
Cobalt	(Co)	0.25	0.28	0.20	0.052	0.34	0.24
Copper	(Cu)	15	113	87	0.056	147	119
Iron	(Fe)	0.30	100	77	0.0099	125	107
Lead	(Pb)	0.027	0.040	0.040	0.0024	0.040	0.040
Magnesium	(Mg)	56	81	51	97	86	29
Manganese	(Mn)	5.7	4.1	2.4	0.13	4.1	0.46
Mercury	(Hg)	0.00050	0.00038	0.00023	0.00060	0.00040	0.00014
Molybdenum	(Mo)	0.030	0.0090	0.0090	2.5	0.0090	0.0010
Nickel	(Ni)	0.074	2.0	2.0	0.071	2.0	2.0
Potassium	(K)	182	24	14	51	24	3.4
Selenium	(Se)	0.082	0.20	0.20	0.30	0.20	0.20
Silver	(Ag)	0.0028	0.00070	0.00050	0.00070	0.00085	0.00054
Sodium	(Na)	628	4.0	2.4	8.2	7.9	1.2
Thallium	(Tl)	0.0042	0.00090	0.00055	0.00050	0.00094	0.00027
Uranium	(U)	0.021	0.85	0.65	0.50	1.1	0.90
Zinc	(Zn)	1.3	7.3	5.6	0.57	9.5	7.7

Provided by Lorax (2013)

Table II - A 4 pH of Stockpile Contact Water

Water Quality Parameter	pH of Stockpile Contact Water					
	Gold Ore	Supergene Oxide Ore	Low Grade Supergene Oxide Ore	Low Grade Hypogene Ore	Low Grade Supergene Sulphide Ore	Marginal Grade Ore
pH	4.7	3.2	3.2	7.2	3.2	3.2

Provided by Lorax (2013)

Appendix II - B

Ore Stockpile Loading Results

Table II - B 1 Ore Stockpile Loadings to Receptors – Year 5

	Annual Loading (kg)																									
Parameter	Hardness	Acidity	SO4	Cl	F	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	K	Se	Si	Na	Sr	U	Zn
Source of Loading																											
Receptor																											
Gold Ore Stockpile																											
Groundwater to Open Pit	7084	413	21201	746	34	54	0.31	0.20	0.05	0.11	2088	0.3	2.3	139	3	0.3	455	52	0.3	0.7	1674	0.75	85	5777	21	0.2	12
Groundwater to TMF Pond	36026	1905	97765	3424	156	247	1.42	0.93	0.18	0.50	10617	1.5	10.5	639	13	1.2	2313	241	1.3	3.1	7703	3.47	329	26579	106	0.9	55
Runoff to TMF Pond	64991	3812	195338	6884	313	495	2.84	1.86	0.45	1.00	19154	3.0	21.1	1286	31	2.3	4172	484	2.5	6.3	15437	6.96	805	53290	192	1.8	110
Low Grade Supergene Oxide Ore Stockpile																											
Groundwater to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff to TMF Pond	41467	38261	81695	586	900	4450	4.50	1.68	0.57	4.52	11332	0.8	12.7	5429	4832	2.5	3204	147	0.6	125.7	881	12.57	668	5707	34	40.8	351
Groundwater to Embankment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to Foundation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Low Grade Hypogene Ore Stockpile																											
Groundwater to Open Pit	566	1	544	3	1	0	0.02	0	0.02	0	214	0	0	0	0	0	8	0	0.2	0	4	0.02	4	1	1	0	0
Groundwater to TMF Pond	3246	9	3117	17	8	0	0.12	0.01	0.19	0	1227	0	0	2	0	0	44	2	1.1	0	23	0.14	24	4	6	0.2	0
Runoff to TMF Pond	213544	65	205873	1154	495	1	8.52	0.93	1.35	0.29	78446	0.4	1.6	14	2	0.1	2986	31	76.9	2.2	1584	9.28	1433	254	422	15.2	18
Groundwater to Embankment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to Foundation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Low Grade Supergene Sulfide Ore Stockpile																											
Groundwater to Open Pit	360	337	722	5	8	39	0.04	0.01	0.02	0.04	98	0	0.1	48	43	0	28	1	0	0.7	8	0.07	22	3	0	0.4	3
Groundwater to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff to TMF Pond	51132	47829	102456	745	1142	5563	5.74	2.13	0.52	5.68	13971	1.0	15.9	6784	6042	1.9	3952	188	0.4	92.3	1120	9.23	755	362	42	51.0	439
Marginal Ore Stockpile																											
Groundwater to Open Pit	116	150	284	1	1	18	0	0	0	0.01	38	0	0	21	19	0	5	0	0	0.4	1	0.04	4	0	0	0.2	1
Groundwater to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff to TMF Pond	24929	33407	61453	115	242	3804	0.11	0.34	0.89	3.05	8158	0.6	9.2	4601	4136	1.5	1106	18	0	77.3	129	7.73	831	46	47	34.8	297
Supergene Oxide Ore Stockpile																											
Groundwater to Open Pit	1126	878	1960	18	26	102	0.14	0.05	0.01	0.11	306	0	0.3	124	110	0	88	4	0	2.2	26	0.22	9	4	1	0.9	8
Groundwater to TMF Pond	18300	14275	31844	285	426	1656	2.24	0.81	0.10	1.82	4972	0.3	5.0	2022	1795	0.7	1424	72	0.2	35.3	429	3.53	138	72	14	15.1	131
Runoff to TMF Pond	93411	72580	161910	1448	2164	8419	11.83	4.13	0.64	9.25	25279	1.5	25.3	10283	9126	3.6	7369	375	0.8	182.1	2207	18.21	914	364	73	76.9	666
Groundwater to Embankment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table II - B 2 Ore Stockpile Loadings to Receptors – Year 15

Parameter	Annual Loading (kg)																									
	Hardness	Acidity	SO4	Cl	F	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	K	Se	Si	Na	Sr	U	Zn
Source of Loading																											
Receptor																											
Gold Ore Stockpile																											
Groundwater to Open Pit	6905	405	20753	731	33	53	0.30	0.20	0.05	0.11	2035	0.3	2.2	137	3	0.2	443	51	0.3	0.7	1640	0.74	85	5662	20	0.2	12
Groundwater to TMF Pond	10153	595	30514	1075	49	77	0.44	0.29	0.18	0.16	2992	0.5	3.3	201	10	0.4	652	76	0.4	1.0	2412	1.09	329	8325	30	0.3	17
Runoff to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Low Grade Supergene Oxide Ore Stockpile																											
Groundwater to TMF Pond	149	137	293	2	3	16	0.02	0.01	0	0.02	41	0	0.0	19	17	0	11	1	0	0.5	3	0.05	2	20	0	0.1	1
Runoff to TMF Pond	56242	51895	110590	795	1221	6036	6.10	2.27	0.57	6.13	15370	1.0	17.1	7359	6551	3.4	4339	200	0.8	170.2	1191	17.01	668	7741	46	55.3	476
Groundwater to Embankment	58	53	114	1	1	6	0.01	0.00	0	0.01	16	0	0	8	7	0	4	0	0	0.2	1	0.02	1	8	0	0.1	0
Groundwater to Foundation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Low Grade Hypogene Ore Stockpile																											
Groundwater to Open Pit	8508	1	8358	120	10	0	0.89	0.10	0.02	0.03	2717	0.0	0.2	0	0	0.0	311	1	8.0	0.2	165	0.97	35	26	44	1.6	2
Groundwater to TMF Pond	233976	33	229860	2928	286	0	21.62	2.35	0.69	0.73	74704	1.1	4.1	7	1	0.2	7578	16	195.2	5.6	4019	23.54	959	645	1070	38.7	45
Runoff to TMF Pond	460870	65	452750	7974	564	1	58.79	6.41	1.35	2.00	147140	2.9	11.1	14	2	0.5	20639	31	530.3	15.2	10945	64.11	1888	1756	2901	105.3	121
Groundwater to Embankment	2836	0	2786	24	3	0	0.18	0.02	0.01	0.01	905	0	0	0	0	0	62	0	1.6	0	33	0.19	12	5	9	0.3	0
Groundwater to Foundation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Low Grade Supergene Sulfide Ore Stockpile																											
Groundwater to Open Pit	39896	37319	79942	581	891	4341	3.58	1.66	0.24	4.43	10901	0.7	12.4	5293	4714	1.4	3084	146	0.3	72.0	874	7.20	349	283	33	39.8	343
Groundwater to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff to TMF Pond	105708	98883	211814	1537	2358	11502	7.73	4.39	0.52	11.74	28885	2.0	32.8	14026	12084	3.8	8171	386	0.9	190.7	2301	19.07	755	749	87	105.4	908
Marginal Ore Stockpile																											
Groundwater to Open Pit	11820	15683	29095	55	115	1802	0.05	0.16	0.42	1.45	3869	0.3	4.4	2181	1958	0.7	524	8	0	36.7	61	3.67	394	22	22	16.5	141
Groundwater to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff to TMF Pond	6862	8902	16835	32	66	1045	0.03	0.09	0.24	0.84	2247	0.2	2.5	1266	1133	0.4	304	5	0	21.3	36	2.13	228	13	13	9.6	82
Supergene Oxide Ore Stockpile																											
Groundwater to Open Pit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to TMF Pond	1642	1276	2847	25	38	148	0.21	0.07	0.08	0.16	444	0	0.4	181	160	0.1	130	7	0	3.2	39	0.32	108	6	1	1.4	12
Runoff to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to Embankment	163	127	282	3	4	15	0.02	0.01	0	0.02	44	0	0	18	16	0	13	1	0	0.3	4	0.03	2	1	0	0.1	1

Table II - B 3 Ore Stockpile Loadings to Receptors – Year 25

	Annual Loading (kg)																									
Parameter	**Hardness**	**Acidity**	**SO4**	**Cl**	**F**	**Al**	**Sb**	**As**	**Ba**	**Cd**	**Ca**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Mo**	**Ni**	**K**	**Se**	**Si**	**Na**	**Sr**	**U**	**Zn**
Source of Loading																											
Receptor																											
Gold Ore Stockpile																											
Groundwater to Open Pit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Low Grade Supergene Oxide Ore Stockpile																											
Groundwater to TMF Pond	184	170	361	3	4	20	0.02	0.01	0	0.02	50	0	0.1	24	21	0	14	1	0	0.6	4	0.06	2	25	0	0.2	2
Runoff to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to Embankment	71	65	139	1	2	8	0.01	0	0	0.01	19	0	0	9	8	0	5	0	0	0.2	1	0.02	1	10	0	0.1	1
Groundwater to Foundation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Low Grade Hypogene Ore Stockpile																											
Groundwater to Open Pit	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to TMF Pond	25682	24	24655	134	66	0	0.99	0.11	0.49	0.03	9705	0	0.2	5	1	0	346	11	8.9	0.3	184	1.08	187	29	49	1.8	2
Runoff to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to Embankment	2836	0	2786	55	3	0	0.38	0.04	0.01	0.01	905	0	0.1	0	0	0	139	0	3.4	0.1	73	0.44	12	12	18	0.7	1
Groundwater to Foundation	2836	0	2786	34	3	0	0.25	0.03	0.01	0.01	905	0	0.0	0	0	0	88	0	2.3	0.1	46	0.27	12	7	12	0.4	1
Low Grade Supergene Sulfide Ore Stockpile																											
Groundwater to Open Pit	4387	4104	8791	64	98	477	0.49	0.18	0.07	0.49	1199	0.1	1.4	582	518	0.2	339	16	0.0	7.9	96	0.79	100	31	4	4.4	38
Groundwater to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marginal Ore Stockpile																											
Groundwater to Open Pit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Supergene Oxide Ore Stockpile																											
Groundwater to Open Pit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to Embankment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table II - B 4 Ore Stockpile Loadings to Receptors – Year 35

Parameter	Annual Loading (kg)																										
	Hard-ness	Acid-ity	SO4	Cl	F	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	K	Se	Si	Na	Sr	U	Zn
Source of Loading																											
Receptor																											
Gold Ore Stockpile																											
Groundwater to Open Pit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Low Grade Supergene Oxide Ore Stockpile																											
Groundwater to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to Embankment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to Foundation	23	21	46	0.3	0.5	2.5	0.003	0.001	0.0003	0.0025	6	0.0004	0.007	3.03	2.70	0.001	2	0.08	0.0003	0.07	0.5	0.007	0.3	3.19	0.02	0.02	0.2
Low Grade Hypogene Ore Stockpile																											
Groundwater to Open Pit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to Embankment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to Foundation	2641	0	2593	20.4	3.3	0.003	0.2	0.016	0.0083	0.0051	845	0.0074	0.028	0.08	0.01	0.001	53	0.19	1.36	0.04	27.9	0.164	10.9	4.48	7.44	0.27	0.3
Low Grade Supergene Sulfide Ore Stockpile																											
Groundwater to Open Pit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to TMF Pond	266	249	533	3.9	5.9	28.9	0.030	0.011	0.0124	0.0295	73	0.0049	0.082	35.26	31.40	0.010	21	0.97	0.0022	0.48	5.8	0.048	16.1	1.88	0.22	0.26	2.3
Runoff to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marginal Ore Stockpile																											
Groundwater to Open Pit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to TMF Pond	50	64	122	0.2	0.5	7.5	0.0002	0.001	0.0018	0.0061	16	0.0011	0.018	9.14	8.18	0.003	2	0.04	0.0001	0.15	0.3	0.015	1.6	0.09	0.09	0.07	0.6
Runoff to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Supergene Oxide Ore Stockpile																											
Groundwater to Open Pit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff to TMF Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater to Embankment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Casino Project
Water Quality Predictions

Appendix III
Heap Leach Facility Water Quality Modelling

Prepared by**:**

Source
ENVIRONMENTAL ASSOCIATES INC.

December 2013

Table III-1 HLF Surplus Water Quality

Water Quality Parameter		HLF Surplus Water Quality (mg/L)		
		Rinsing and Drain Down (Year 19 to 28)	10 Years Post Drain Down (Year 29 to 38)	Long Term (Year 39 and beyond)
Hardness		1,697	3,497	2,392
Alkalinity		70	47	47
Sulphate	(SO4)	1,920	2,100	424
Cyanide (Total)		11	0.20	
Cyanide (WAD)		5.0	0.030	
Chloride	(Cl)	638	240	38
Fluoride	(F)	2.1	3.0	1.3
Aluminum	(Al)	0.069	0.0070	0.0060
Antimony	(Sb)	0.77	0.77	0.47
Arsenic	(As)	0.036	0.036	0.036
Barium	(Ba)	0.0064	0.0077	0.0077
Cadmium	(Cd)	0.0084	0.0050	0.00028
Calcium	(Ca)	666	756	532
Chromium	(Cr)	0.0010	0.0010	0.0010
Cobalt	(Co)	5.7	2.6	0.49
Copper	(Cu)	2.8	0.016	0.0011
Iron	(Fe)	9.5	0.0040	0.0040
Lead	(Pb)	0.0015	0.00028	0.00028
Magnesium	(Mg)	7.8	392	259
Manganese	(Mn)	0.0036	0.0045	0.00031
Mercury	(Hg)	0.018	0.000020	0.000020
Molybdenum	(Mo)	4.2	4.2	0.94
Nickel	(Ni)	0.24	0.093	0.0073
Potassium	(K)	246	0	246
Selenium	(Se)	0.40	0.23	0.098
Silver	(Ag)	0.053	0.00078	0.00062
Sodium	(Na)	432	15	0.56
Thallium	(Tl)	0.0018	0.00011	0.00011
Uranium	(U)	0.0018	0.63	0.17
Zinc	(Zn)	0.072	0.39	0.22

Concentrations provided by Lorax (2013)

Casino Project

Water Quality Predictions

Appendix IV
TMF Pond Water Quality Modelling

Prepared by:

Source
ENVIRONMENTAL ASSOCIATES INC.

December 2013

Table of Contents

List of Figures

List of Tables

List of Appendices

1 Introduction

The Casino Project (the Project) is a proposed mining project in the west-central Yukon. The deposit will be mined using open pit methods, with a nominal mill throughput of approximately 120,000 tonnes/day of ore over a 22 year operating life. Milling operations will produce molybdenum and copper concentrates through conventional flotation circuit milling and gold and silver bullion will be produced by cyanide heap leaching.

The Tailings Management Facility (TMF) will be the primary water and waste management component of the Project. The TMF was designed by Knight Piesold Ltd (KPL) to store approximately 956 million tonnes of tailings and up to 649 million tonnes of waste rock and overburden (KPL, 2012). The TMF will be situated in the Casino Creek valley southeast of the Open Pit. Two embankments, the Main Embankment, and the West Saddle Embankment will be constructed across the Casino Creek valley to create the storage impoundment.

A site-wide water balance model was developed by KPL (2013a). Source Environmental Associates Inc. (SEA) combined the water balance flows with mine loading source terms (Lorax, 2013), and background water quality (from PEGC, 2013) to predict water quality in the TMF Pond.

2 Casino Project Water Management Phases

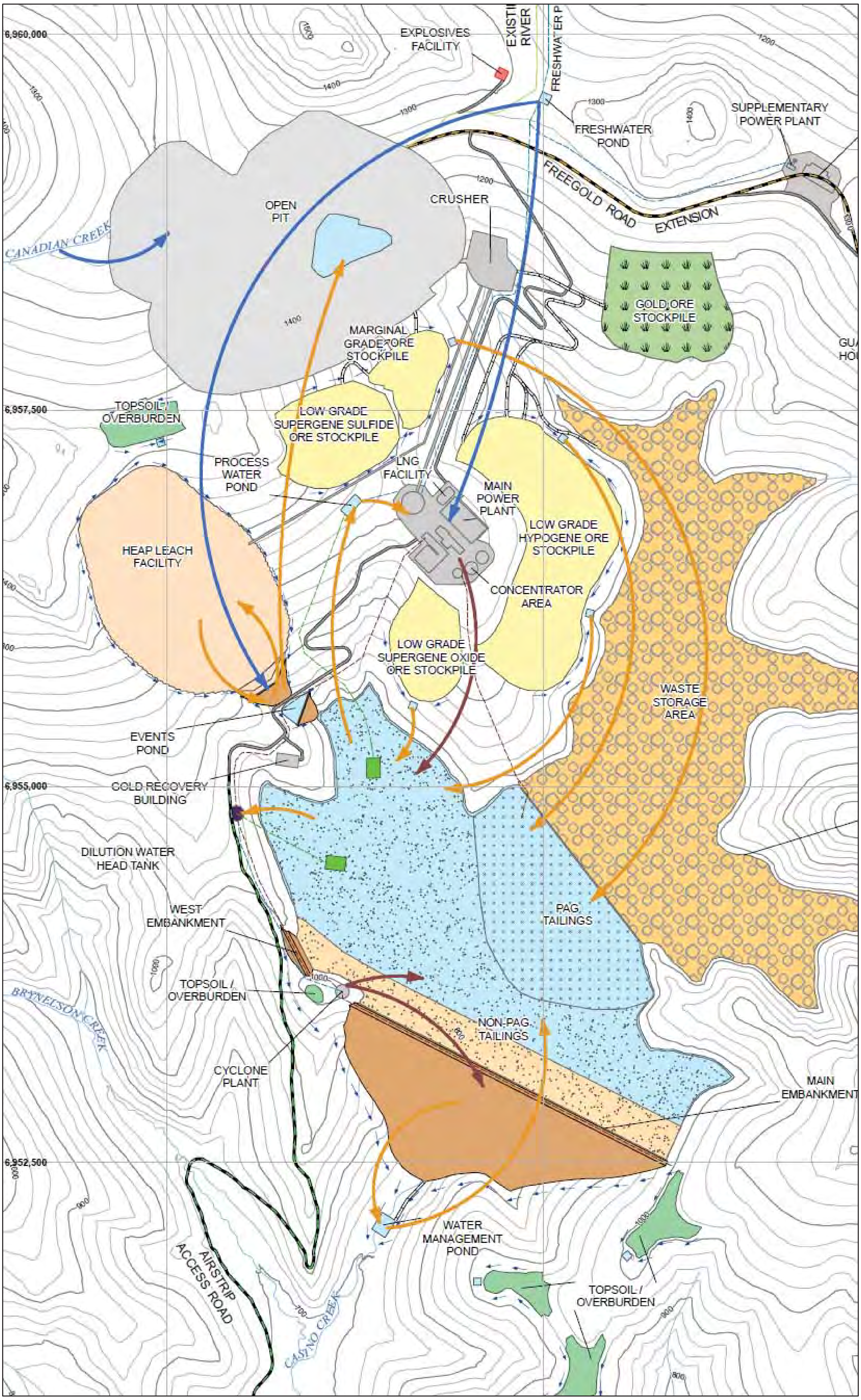
The Casino Project life was sub-divided into five water management phases in this document. Project years are described in years relative to the beginning of milling operations. For example, Year -2 refers to the second year before Operations begins, and Year 2 refers to the second year of Operations.

Water management phases and relevant project activities related to water quality modeling are provided in Table 2-1. Layout of the Project site is illustrated in Figure 2-1 for Operations. Development of the TMF during Operations is provided in Figure 2-2. Long-term site conditions following mine closure are shown on Figure 2-3.

Table 2-1 Water Management Phases

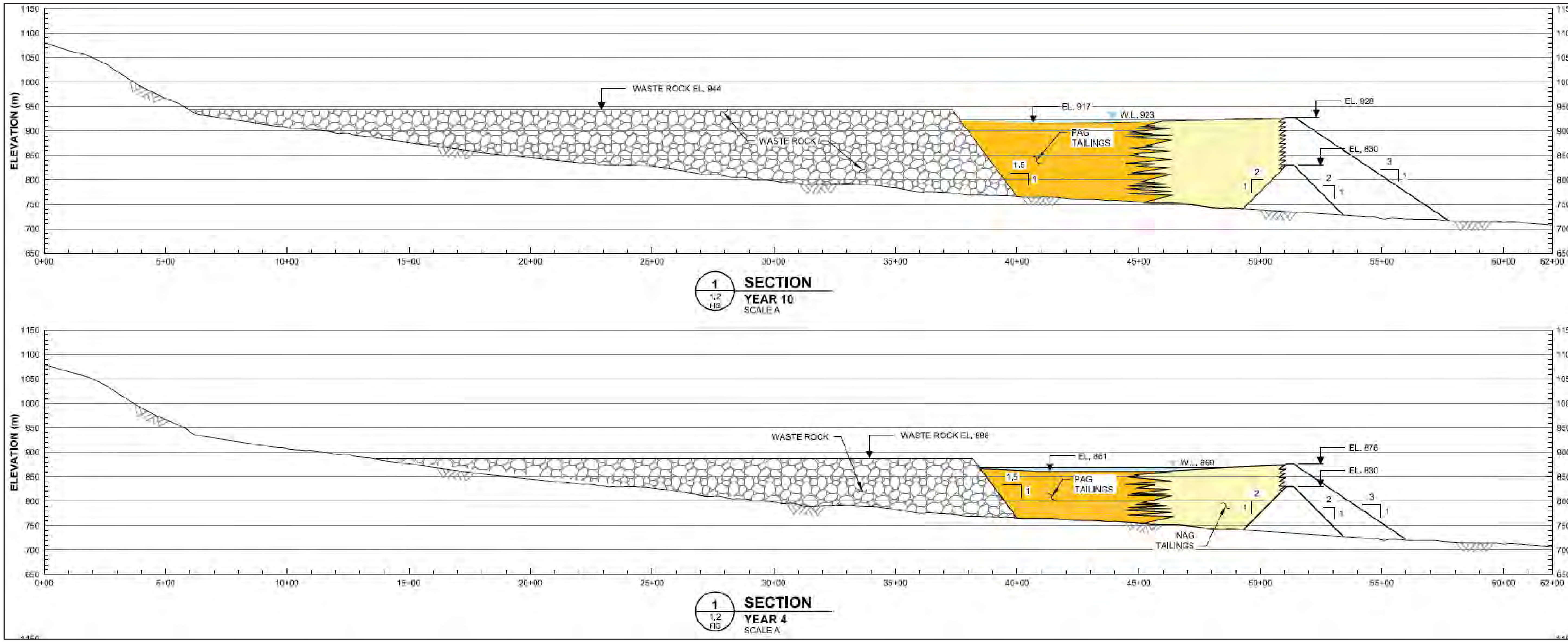
Water Management Phase	Project Year	Water Management Activities
Construction	-4 to -1	• TMF starter embankment construction (using suitable earth and rockfill from borrow sources). • Construction of TMF Water Management Pond (WMP) downstream from the embankments to recover seepage and embankment runoff. • Open Pit construction will begin and ore will be stockpiled within the drainage basin of the TMF. • Construction of the Fresh Water Supply Pond (FWSP) at the north end of the TMF to be used as an interim source of fresh water. • Construction of the freshwater supply pipeline to draw fresh water from the Yukon River during Operations.
Operations	1 to 22	• Mill will start-up in Year 1 and will continue to end of Year 22. • Tailings will be sent to the TMF via slurry. Approximately 80% of the total tailings produced will be non-acid generating (NAG) material, and 20% will be potentially acid generating (PAG). • Waste Rock placed at the north end of TMF. • Some of the NAG tailings will be processed in the Cyclone Sand Plant to produce embankment construction material. • Runoff from the ore stockpiles and mill site will be directed into the TMF Pond. • Water recovered in WMP will be pumped to TMF Pond. • TMF Pond water will be reclaimed to the mill. • Makeup water will be supplied to the mill from the Yukon River via the freshwater supply pipeline. • No interaction between Heap Leach Facility (HLF) water management system and TMF water management system throughout Operations.
Wetland Construction	23 to 30	• Year 23 to Year 28 – TMF Pond water will be pumped to Pit Lake. • North TMF Wetland and South TMF Wetland will be constructed while the water level in the TMF Pond is low.

Water Management Phase	Project Year	Water Management Activities
		• Any unprocessed low or marginal grade ore will be placed in the Pit Lake. • Winter Seepage Mitigation Pond (WSMP) will be constructed to replace the WMP (downstream from embankment). Seepage collected in the WMP / WSMP will be pumped back to TMF Pond until end of the Wetland Construction Phase. • After pumping to Pit Lake, the TMF Pond will be allowed to fill by natural recharge. • The tailings beach, stockpile areas, HLF, mill site, and other disturbed surfaces will be covered and re-vegetated. • Year 29 (and beyond) – drainage from reclaimed HLF will be directed into the TMF Pond.
TMF Discharge	31 to 112	• TMF Pond will discharge to Casino Creek • Seepage recovered downstream from the TMF embankments will be stored in the Winter Seepage Mitigation Pond (WSMP) through the low-flow months of the year (winter), and released during those months when the TMF Pond water discharges via the Closure Spillway, such that the seepage water quality will be less influential on the water quality in Casino Creek. • South TMF Wetland will treat TMF Pond water prior to discharge over the TMF Spillway and into Casino Creek.
Pit Discharge	>113	• Pit Lake will discharge to the North TMF Wetland treatment system. Treated effluent from the wetland will discharge to the TMF Pond. • WSMP will continue to operate as before.



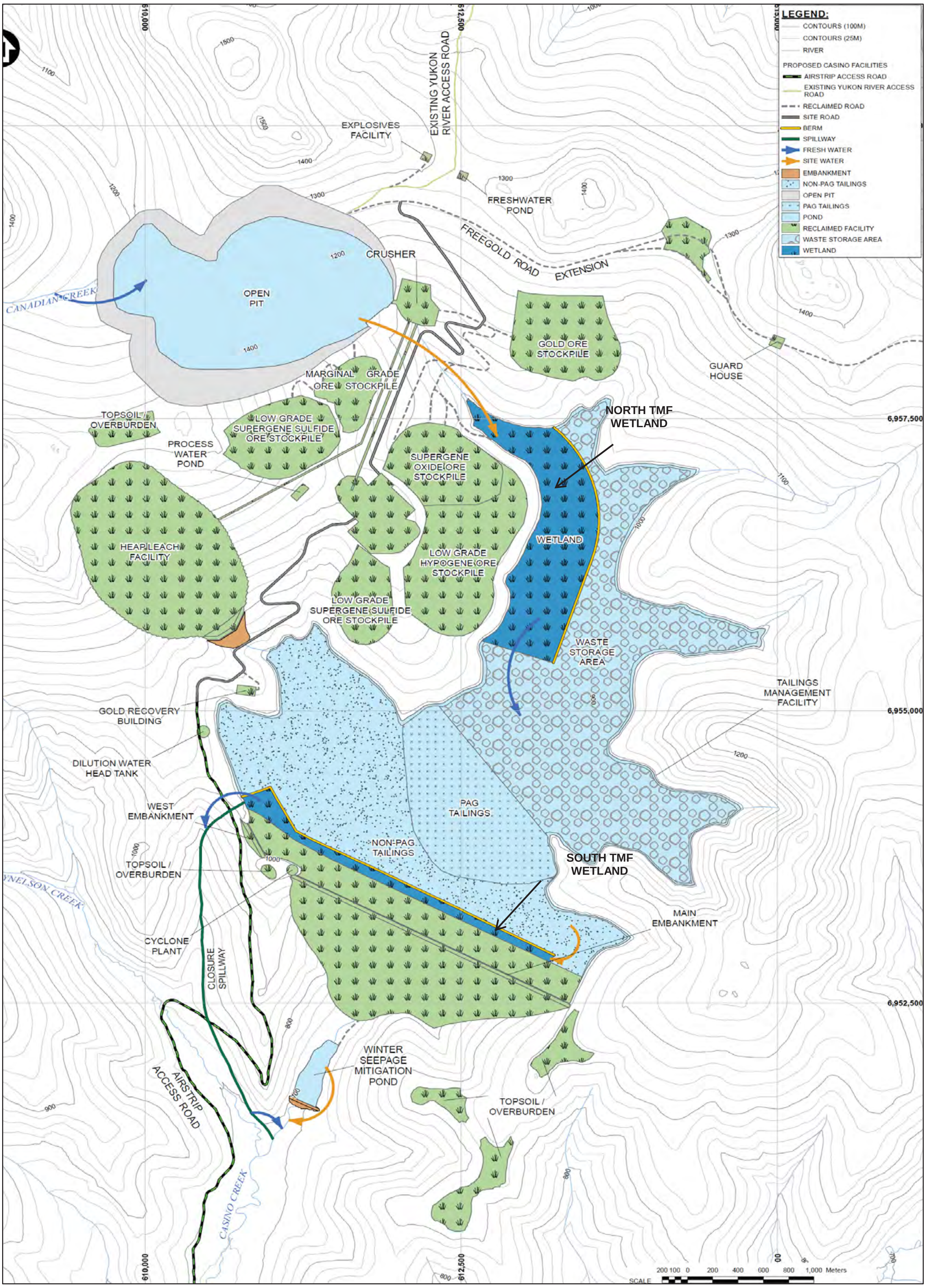
Source: Casino YESAB Water Balance Report (KPL, 2013a)

Figure 2-1 Casino Project Overview (Operations, Year 19)



Source: Revised Waste Deposition Strategy to Improve Water Quality (KPL, 2013b)

Figure 2-2 TMF Waste Deposition Strategy – Typical Sections (Years 4 and 10)



Source: Casino YESAB Water Balance Report (KPL, 2013a)

Figure 2-3 Casino Project Overview (Pit Discharge Phase)

3 Model Overview

A site-wide water balance model was developed by KPL (2013a). SEA combined the water balance flows with mine loading source terms (Lorax, 2013), and background water quality to predict water quality in the TMF Pond for 29 water quality parameters. The model was developed using GoldSim modelling software and was run with monthly time-steps. The model simulation was run for a time period beginning a few years prior to the Construction Phase, and continued for 200 years following the beginning of the Operations Phase. Average monthly environmental conditions were assumed.

Schematics are provided to illustrate the mass transport pathways associated with the TMF Pond during Operations (Figure 3-1) and long term conditions following mine closure (i.e. Pit Discharge Phase) in Figure 3-2. Tables of model input and output values are provided for each modelled water quality paramaeter in Appendix IV - A (model input) and Appendix IV - B (model results).

Table 3-1 Project Timeline

Project Year	Project Activity
-4	start of construction
-3	Start of mining the Open Pit
1	start of milling (start of Operations Phase)
18	final year of Open Pit Mining
19	Open Pit dewatering stops, Pit Lake begins to form
19	end of waste rock placement in TMF and begin covering waste rock with tailings layer
22	final year of milling (end of Operations Phase)
23	start of pumping TMF Pond to Open Pit (start Wetland Construction Phase)
24	end of HLF rinsing and start of HLF drain down (pump to Open Pit)
26	transition from the WMP to the WSMP
27	end of pumping TMF to Open Pit
28	start of TMF filling by natural recharge
29	HLF drainage directed to TMF Pond
31	Initial discharge of TMF Pond and WSMP to Casino Creek
113	Initial discharge of Pit Lake to TMF (into North TMF Wetland)

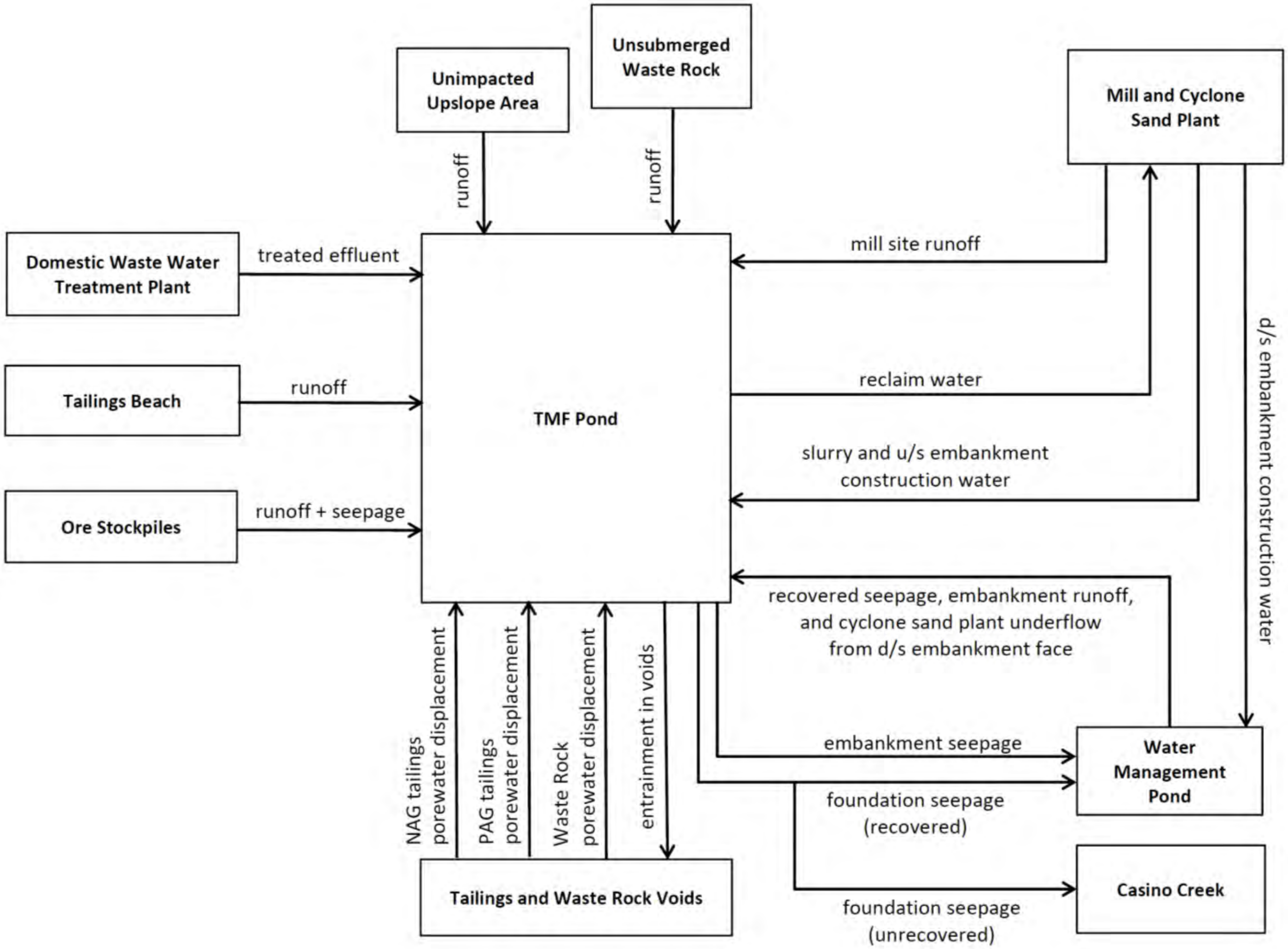


Figure 3-1 Mass Transport Flow Paths through the TMF Pond (Operations)

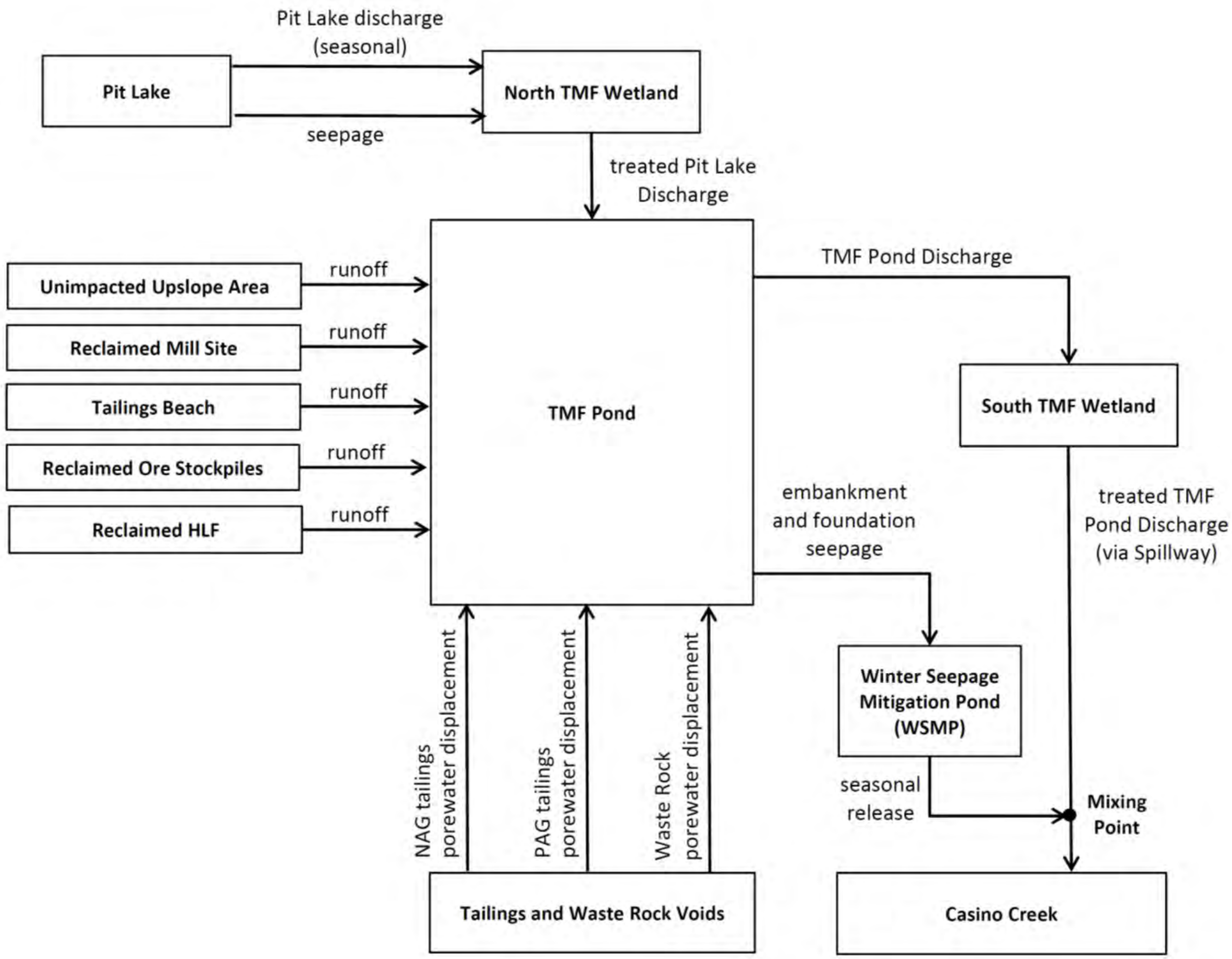


Figure 3-2 Mass Transport Flow Paths through the TMF Pond (Pit Discharge Phase)

4 Water Balance Model

The KPL (2013a) water balance model was developed to estimate the TMF Pond inflow and outflow rates for water quality modelling, water management and waste deposition planning. A summary of water balance assumptions and results are provided in the following section.

The TMF Pond will not discharge to the receiving environment during Operations or the Wetland Construction Phase. During the Wetland Construction Phase, the TMF Pond will be pumped to the Pit Lake for five years (Year 23 to Year 27), then will be allowed to fill by natural recharge. The TMF Discharge Phase will begin when the TMF Pond fills to its maximum storage capacity and then discharges to Casino Creek via the engineered Closure Spillway. The water balance simulation showed that under average annual hydrologic conditions, the TMF Discharge Phase will begin in Year 31.

The water balance predictions showed that the Open Pit will discharge in Year 113. Additional information related to the Pit Lake water balance and water quality model is provided in Appendix I (Open Pit Water Quality Modelling).

Inflow and outflow of water to the TMF Pond from the KPL water balance model are summarized in Table IV - A 1 to illustrate the average annual conditions over the duration of the water quality model. Year 60 and Year 120 were selected by SEA as representative years for the TMF Discharge Phase and the Pit Discharge Phase, respectively.

5 Water Quality Model

This section provides a description of the modelling methodology that was used for the prediction of mass transport of substances through the TMF Pond water column and the resulting water quality. Relevant water balance components are discussed where applicable to the water quality modelling calculations. Tables of model input for each modelled water quality parameter are provided in Appendix IV - A.

5.1 TMF Pond Inflows

5.1.1 Precipitation on TMF Pond Surface

The monthly inflow of water to the TMF Pond by precipitation was calculated as the top surface area of the TMF Pond for a given time-step, multiplied by the monthly depth of precipitation. Consequently, calculated inflows from precipitation increased throughout Operations as pond surface area increased, and reached steady state once the TMF Pond remained constant in Phase II.

While precipitation was accounted for in the water balance, no load was associated with precipitation in the water quality model.

5.1.2 Overland Runoff from Unimpacted Areas

Areas not disturbed by mining activities will contribute a load (i.e. background load) to the TMF Pond via overland runoff. The mass loading rate into the TMF Pond from overland runoff was calculated as the monthly rate of runoff, multiplied by the average annual water quality concentrations of the overland runoff.

Water quality monitoring data was available for Casino Creek (monitoring stations W12, W8, W11) within the drainage basin of the TMF Pond (Figure 5-1). However, the water quality at those sites has been impacted by drainage from Proctor Gulch, where groundwater comes into contact with the Casino ore body (PECG, 2013). During Operations the ore body will be mined out and overland runoff will no longer be impacted by the presence of the ore body. Therefore, the Casino Creek water quality stations do not provide an appropriate representation of background runoff after the open pit excavation is complete.

Meloy Creek (W13) water quality data was selected by SEA to represent background water quality to the TMF Pond because it was the nearest watercourse to the TMF Pond that is not impacted by the presence of the Casino ore body. The median water from 12 water quality samples collected between 2008 and 2012 at W13 were used to represent average annual overland runoff water quality. Median water quality at W13 is presented in Appendix IV - A (Table IV - A 2).

Meloy Creek (W13) water quality data may be somewhat impacted by the presence of a historical adit. The adit, from lead/zinc/silver exploration between 1965 and 1980 was partially sealed by CMC in 2008. What remains today is a pipe that discharges at surface in upper Meloy Creek watershed. This water (site W43) was included in the 2008-2012 baseline studies (PEGC, 2013). Discharge occurs only during the spring and summer months and is frozen from October to April. At the point of discharge, it travels down the watershed for roughly two kilometres before joining Meloy Creek. Because the flow rate from the adit is relatively low compared to total stream flow at Meloy Creek, the loading from the adit appears to be almost negligible in W13 for most parameters. The influence of the loading from the adit discharge on background water quality is not considered by SEA to be an overly conservative assumption for most parameters. However, cadmium (Cd) in the W13 data appeared to be relatively high and may result in a slight over prediction of long-term Cd levels in the TMF Pond.

Runoff from the mill site (approximately 0.3 km^2) during operations will be affected by the land disturbance created by the construction of the mill. However, the potential load from the disturbed area is considered by SEA to be negligible compared to major sources of loading to the TMF Pond during Operations (e.g., waste rock, tailings slurry, ore stockpiles, etc.). Therefore, drainage from the mill site was assumed by SEA to have background runoff water quality (from W13) for modelling.

5.1.3 Surplus Fresh Water Supply Pond Discharge

The Fresh Water Supply Pond (FWSP) will be constructed along Casino Creek and used during Construction and early Operations. During that time, upper Casino Creek will feed the pond and surplus FWSP water will discharge to the TMF Pond. Average annual discharge from the FWSP to the TMF Pond is presented in Table IV - A 1.

Proctor Gulch will still be in place during Construction (i.e. it will not have been mined out by the Open Pit by that time) and will therefore still contribute mass loading to Casino Creek. Water quality data from Casino Creek at W8 (median of 13 samples collected between 2008 and 2012) were selected to represent FWSP discharge in the modelling and is presented in Appendix IV - A (Table IV - A 2).

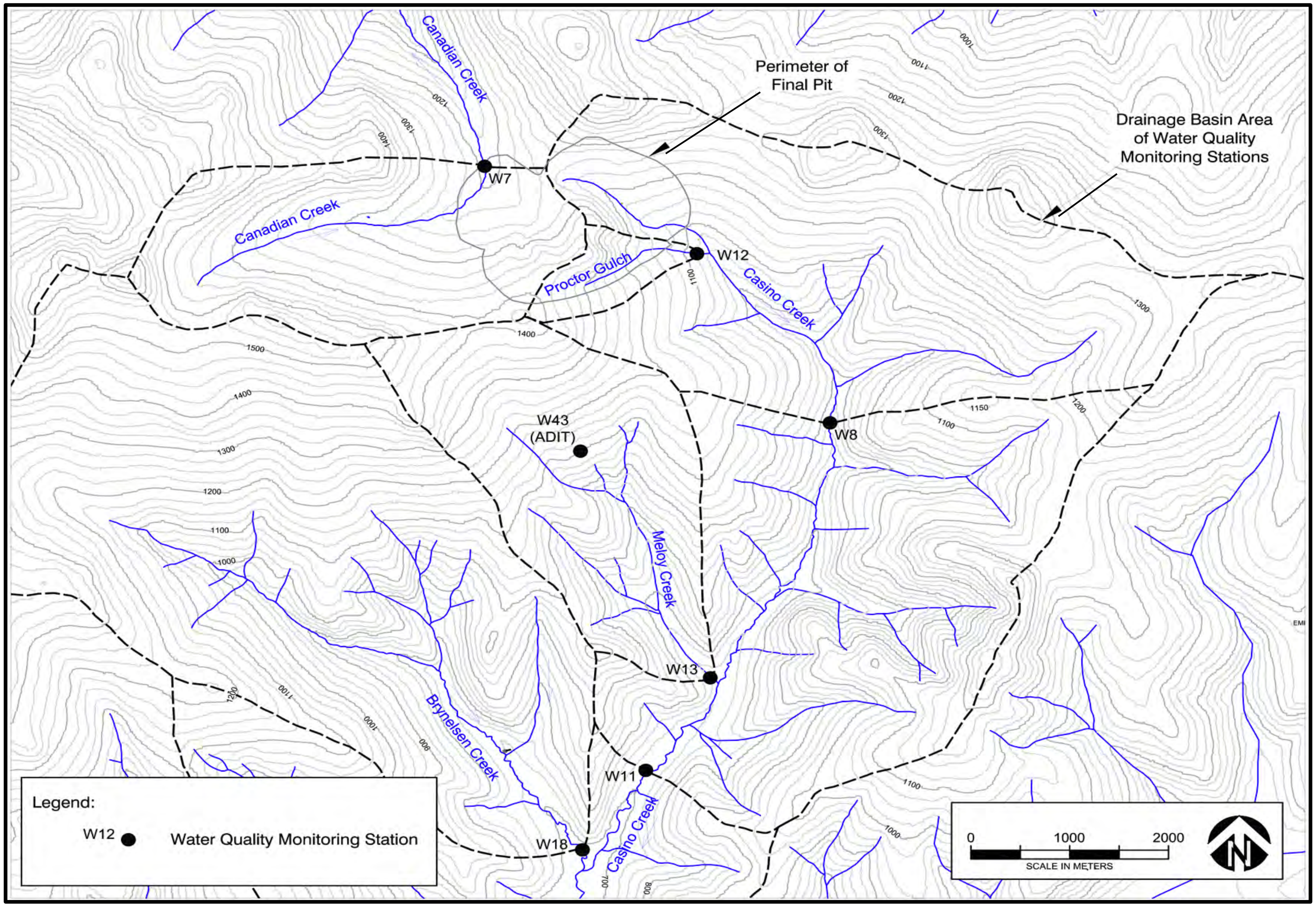


Figure 5-1 Water Quality Monitoring Stations in the Vicinity of the TMF

5.1.4 Treated Domestic Wastewater

Treated domestic wastewater from the water treatment plant will discharge to the TMF Pond during Operations. Mass loading was calculated as the flow rate multiplied by the water quality of the effluent. The average effluent discharge rate was 1.3 L/s in the KPL (2013a) water balance.

Prior to its use for domestic purposes, the water supply will be suitable for human consumption and will not contain significant levels of heavy metals. SEA assumed the treated wastewater quality to be equal to the background runoff water quality. The impact of this simplifying assumption on water quality model results is considered by SEA to be negligible.

5.1.5 Ore Stockpile Runoff and Seepage

While the ore stockpiles are present during Operations, contact water (from rainfall and snowmelt) will drain from the rock as runoff or infiltration to groundwater. Runoff from the stockpiles will be captured by the TMF Pond.

Hydrogeological modelling (KPL, 2013c) indicated that depending on the stockpile location, infiltrated contact water will flow to one or more of the following receptors: the TMF Pond, Open Pit, TMF Embankment (towards the WMP) or TMF Foundation bedrock (towards Casino Creek). SEA estimated an average travel time from a range of travel times provided by KPL (2013c) and assumed that the mass load associated with the stockpile seepage will report to the TMF Pond after a lag-time equal to the seepage travel time (Table 5-1). Methodology of the travel time estimate is provided in Appendix II (Ore Stockpile Water Quality Modelling.

Table 5-1 Seepage Travel Time from Stockpiles to TMF Pond

Stockpile	Seepage Travel time to TMF Pond (years)
Gold Ore	1.8
Marginal Grade Ore	33.2
Supergene Oxide Ore	3.8
Low Grade Supergene Oxide Ore	9.2
Low Grade Supergene Sulphide Ore	33.2
Low Grade Hypogene Ore	3.8

Seepage and runoff concentrations into the TMF Pond were calculated by combining the seepage flow rates with mass loading rates, and mass of rock in the stockpiles. Calculation methodology of stockpile mass loading is described in Appendix II (Ore Stockpile Water Quality Modelling).

During the Wetland Construction Phase, any residual stockpile rock will be placed in the pit, and the stockpile areas will be reclaimed (covered with overburden and re-vegetated). Loading from the reclaimed stockpile areas during the Wetland Construction Phase and beyond were calculated by multiplying the monthly overland runoff by background overland runoff water quality.

5.1.6 Drainage from Unsubmerged Waste Rock

Waste rock will be placed at the north end of the TMF. When the waste rock is placed during Operations, the top surface will be maintained above the normal operating pond level of the supernatant pond to provide a dry, stable placement surface for machine access and waste rock deposition.

Drainage water from the unsubmerged portion of waste rock will carry a mass load into the TMF Pond. Total drainage from the waste rock area to the TMF Pond will increase proportionally with the footprint area throughout operations, with the ultimate waste rock footprint area achieved in Year 17. After that time, waste rock drainage will decrease as the waste rock is covered with tailings, beginning in Year 19. The waste rock and tailings will be submerged after Operations and waste rock runoff will no longer be a source of mass load to the TMF Pond.

Lorax (2013) provided loading rates to calculate mass loading from the unsubmerged waste rock during a given time step. The mass load was calculated by multiplying the mass of unsubmerged waste rock (tonnes) from the KPL water balance, by the loading rates. Total mass load and volume of runoff water were combined at each time step to calculate contact water concentration.

Lorax provided maximum allowable concentrations for the waste rock drainage water to take into consideration water availability and solubility constraints. If the calculated waste rock runoff water quality exceeded the maximum allowable concentrations, waste rock drainage water quality was set equal to the maximum allowable concentrations for that time step.

Loading rates and maximum allowable concentrations are provided in Appendix IV - A (Table IV - A 3).

5.1.7 Tailings Beach Runoff

The footprint area of the tailings beach will increase from 0 km^2 to 0.7 km^2 during Operations. After that time, the tailings beach area will remain constant at 0.7 km^2. Average annual tailings beach runoff (from the KPL water balance) is provided in Table IV - A 1.

Runoff from the tailings beach will contribute a mass load to the TMF Pond in Operations and will continue into Post-Closure. Mass loading into the TMF Pond was calculated as the runoff flow rate multiplied by the tailings beach runoff water quality.

Lorax (2013) developed two sets of runoff concentrations for the tailings beach. The first was intended to be used for Operations and the second for Post-Closure conditions (Wetland Construction Phase and beyond). Concentrations in the runoff are expected to be lowest after Operations because by then, the tailings slurry (process) water will have been flushed out and the tailings beach will also be covered and vegetated. Runoff water quality values are presented in Appendix IV - A (Table IV - A 2).

5.1.8 Surplus Heap Leach Facility Discharge

The Heap Leach Facility (HLF) will process oxide gold ore by leaching it with an aqueous cyanide solution. The HLF will be situated upslope from the TMF, but will operate independently from the TMF during Operations. That is, there will be no interaction of water or waste between the TMF Pond and the HLF throughout Operations.

During rinsing (Year 19 to Year 23) and draindown (Year 24 to Year 28) of the HLF, surplus water will be directed to the Pit Lake. Following drain down, the final slopes of the HLF will be graded, covered, and re-vegetated. The water quality model assumes that 20% of surplus water (i.e. 20% of net precipitation) infiltrates and becomes seepage at the toe of the HLF while the remaining 80% of surplus water is non-contact runoff. Both the toe seepage and the surface runoff from the HLF will be directed downslope to the TMF Pond. The average annual flow from the HLF to the TMF Pond was estimated by KPL (2013a) to be 13 L/s. This flow combines the non-contact runoff and the HLF toe seepage.

Lorax (2013) provided a source term for three time periods; 1) rinsing and draindown, 2) 10 years following draindown and 3) longterm. The first set of source terms was applied during the drain down period and this loading was allocated to the pit lake (as described in Appendix I). The second set was applied for ten years following drain down (Year 29 to Year 38) while the water quality stabilizes to long-term conditions. Long-term water quality was applied for Year 39 and beyond.

Mass loading from the HLF to the TMF Pond was accounted for in the water quality modelling by multiplying the estimated HLF toe seepage flow rate by the estimated water quality. HLF drainage water quality values are presented in Appendix IV - A (Table IV - A 2).

5.1.9 Tailings Slurry Water

NAG and PAG tailings will be transported from the Mill to the TMF as slurry. A portion of the NAG tailings slurry will be conveyed to the Cyclone Sand Plant. Overflow from the sand plant will be discharged to the TMF Pond. The water content that drains from the upstream side of the embankment construction sand (i.e. Sand Plant underflow slurry water) will also report to the TMF Pond. The sand plant will also draw water from the TMF Pond as supplemental feed water. The sand plant process will not introduce additional mass load or water to the TMF Pond system. Average annual inflow rates of slurry water inflow (Table IV - A 1) represent the net rate of slurry water inflow to the TMF Pond (i.e. tailings slurry + sand plant overflow + upstream embankment construction water, minus sand plant feed water).

The water component of the tailings slurry will be process water from the Mill. Slurry water quality was estimated by Lorax (2013). Loading into the TMF Pond was calculated as the concentration in the slurry water multiplied by the total slurry water inflow rate.

TMF Pond water will be reclaimed to the Mill for re-use. Certain water quality parameters are expected to accumulate within the process water over time as the TMF Pond water is recirculated through the mill. Loading rates were provided by Lorax (2013) for those parameters (Sb, As, Mo, Se and U) as g/tonne (i.e., gram of loading per tonne of ore processed). In the water quality model, an incremental mass of those accumulating substances was added to the slurry water quality at each time step based on the mine production schedule (approximately 120,000 tonne/day) from the KPL (2013a) water balance. Slurry water source terms are provided in Appendix IV - A (Table IV - A 2).

5.1.10 Tailings and Waste Rock Porewater Displacement

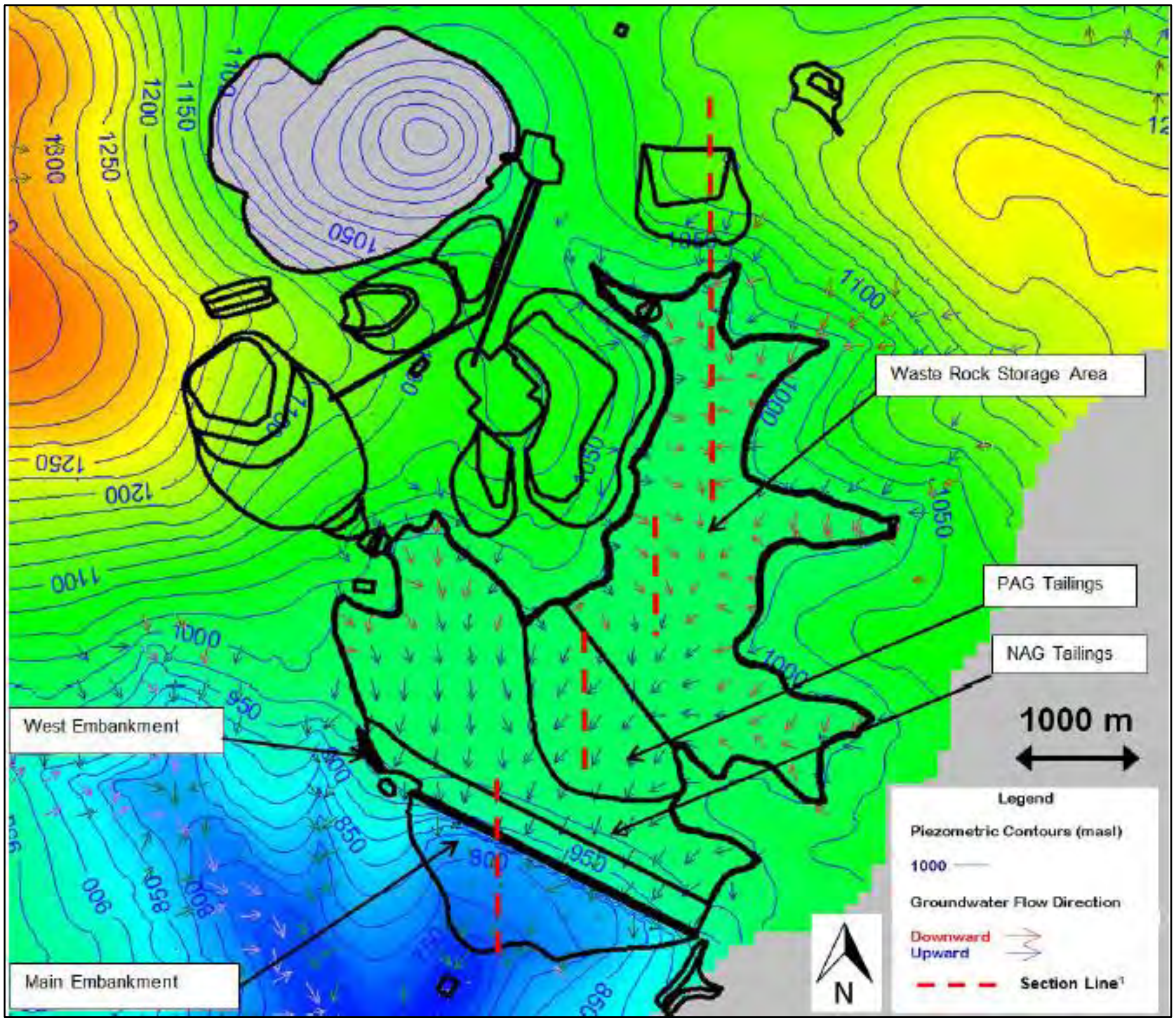
KPL (2013c) predicted that there will be upward groundwater flow from a portion of the saturated PAG tailings into the TMF Pond. The majority of the waste rock is also expected to have upward groundwater flow (Figure 5-2).

Inflow to the TMF Pond from tailings pore water will be highest during Operations due to tailings consolidation, and will gradually reduce following Operations as the tailings consolidation process slows. When tailings consolidation stops, the on-going tailings and waste rock pore water displacement will be the result of groundwater flow through the tailings and waste rock voids. Average annual flow from the tailings and waste rock into the TMF Pond are summarized in Table IV - A 1.

The KPL water balance provided the total flow rate of tailings pore water displacement which was the sum of groundwater flow and tailings consolidation flow from the combined NAG and PAG tailings. SEA subdivided the total flow into NAG and PAG components. KPL (2013c, Table 5.1) provided estimates of groundwater seepage from the tailings to the TMF Pond for various snapshots in time. The relative proportions of NAG and PAG seepage were adopted by SEA and used to sub-divide the total seepage flow rates. Relative proportions of PAG and NAG seepage are presented in Table 5-2.

Table 5-2 Components of Total Tailings Porewater to the TMF Pond

Year	Fraction of Total Tailings Pore Water Flow from Tailings to TMF Pond (%)	
	PAG	NAG
4	11	89
10	12	88
19	5	95
22	4	96
>22	4	96



Source: KPL (2013c)

Figure 5-2 Numerical Hydrogeological Model of TMF, Hydraulic Gradients

Lorax (2013) estimated the porewater quality of the Waste Rock, NAG Tailings and PAG Tailings (provided in Appendix IV - A, Table IV - A 4). Mass loading into the TMF Pond was calculated in the water quality model by multiplying the water quality by the flow rate for the given time steps. Water quality for years not provided by Lorax were assumed by SEA to be equal to the nearest later year (i.e., years 0-3 were equal to year 4, years 5-9 were equal to year 10, etc.). During operations, it would be reasonable to assume the tailings consolidation portion of the porewater would be similar to tailings slurry water, or pond water (for subaqueously deposited tailings (e.g., PAG tailings) however, once mill operations cease, all tailings pore water would be expected to be of the characteristics assigned by Lorax and included in the water quality model. This simplifying assumption does not have an effect on long term TMF pond water quality – i.e., once the TMF commences discharge.

Following Operations, the North TMF Wetland will be constructed over the waste rock. A portion of the total upward flow of pore water from the waste rock will enter the North TMF Wetland. Some mass load will be removed in the North TMF Wetland prior to entering the TMF Pond via the wetland discharge. The total mass load associated with the upward flow through waste rock was conservatively assumed to enter the TMF Pond rather than part of it entering the North TMF Wetland for treatment.

A layer of tailings (approximately 3 m thick) will be placed over waste rock in the last few years of Operations and will act as a growth medium for the wetland and an attenuation barrier for metals transport from waste rock. The attenuation associated with this tailings layer was not accounted for in the development of the source terms or in the water quality model input assumptions.

5.1.11 Water Management Pond / Winter Seepage Mitigation Pond

A seepage recovery system will be in place to collect TMF embankment seepage and foundation seepage. The system will also collect runoff from the downstream (south) faces of the TMF embankments, and water that drains from the embankment sands during embankment construction (i.e., Sand Plant underflow slurry water).

The Water Management Pond (WMP) will be in place during Operations, and the Winter Seepage Mitigation Pond (WSMP) will replace it during the Wetland Construction Phase (Year 26 in the model). In the model, inflow to the WMP/WSMP during Operations and Wetland Construction Phases is pumped to the TMF Pond.

A description of the water balance and water quality model for the WMP/WSMP is provided in Appendix V (Seepage Pond Water Quality Modelling). Loading from the WMP into the TMF Pond was calculated as pumped flow rate, multiplied by the water quality in the WMP/WSMP. Average annual water quality values of the WMP / WSMP are presented in Appendix IV - A (Table IV - A 2) for a representative year during Operations (Year 15) for the WMP and during the Wetland Construction Phase (Year 28) for the WSMP.

5.1.12 Treated Pit Lake Discharge (North TMF Wetland Discharge)

The KPL (2013a) water balance simulation showed that under average annual hydrologic conditions, the Pit Lake will fill to its maximum capacity and discharge to the TMF by Year 113. Before entering the TMF Pond, the Pit Lake discharge will be directed to the North TMF Wetland, an engineered wetland located at the northern edge of the TMF (on Figure 2-3). After the pit lake discharge flows through the wetland system, the treated Pit Lake discharge will enter the TMF Pond.

According to the *Conceptual Reclamation and Closure Plan* (BCL, 2013), the total annual Pit Lake overflow volume will be discharged to the TMF wetland at a controlled rate during the warmest months of the year (June through September, inclusive) for optimal operation of the TMF wetland treatment system. KPL (2013a) modelled the discharge as a constant flow of approximately 180 l/s over the four month period. The TMF Wetland was assumed by KPL to have a pond area of 1 km^2. Inflow of water to the wetland system will composed of direct precipitation, background runoff, Pit Lake discharge, and seepage (up to 12 L/s) from the Pit Lake. Outflow will include evaporation and discharge via the outlet into the TMF Pond. Average annual discharge from the wetland system is provided in Table IV - A 1.

Clear Coast Consultants (2013) recommended using CCME limits as the maximum expected water quality concentrations in effluent, and 15% removal for sulphate (Table 5-3) from the North TMF Wetland. The wetland may achieve better results, however, the maximum upper limit was used in the water qualty model.

Water qualily was calculated as the balance of inflows and outflows of water and loadings to the North TMF Wetland. If the calculated water quality in the wetland effluent exceeded the maximum effluent concentrations (Table 5-3) then water quality in the effluent was set equal to the maximum allowable concentrations.

Average annual inflow water quality from the North TMF Wetland to the TMF Pond is provided in Appendix IV - A (Table IV - A 2) for intial discharge of the Pit Lake (Year 113), and long-term conditions (Year 200).

Table 5-3 Maximum Effluent Water Quality from the North TMF Wetland

Water Quality Parameter		Maximum Effluent Water Quality (mg/L)
Sulphate	(SO_4)	15% reduction
Cadmium	(Cd)	0.00012
Copper	(Cu)	0.0040
Molybdenum	(Mo)	0.073
Mercury	(Hg)	0.000026
Selenium	(Se)	-
Silver	(Ag)	0.00010
Uranium	(U)	0.015
Zinc	(Zn)	0.030

5.2 TMF Pond Outflows

The rate of mass exiting the TMF Pond for a given pond outflow rate was calculated as the concentration in the TMF Pond, multipled by the outflow rate of water over a given time-step. TMF Pond outflows are summarized in the following section.

5.2.1 Evaporation

The monthly outflow of water from the TMF Pond due to evaporation was calculated for a given time step as the pond area, multiplied by the monthly depth of evaporation. Calculated losses to evaporation increased throughout Operations as pond surface area increased. Average annual evaporation (Table IV - A 1) reached steady state in the TMF Discharge Phase.

While evaporation was accounted for in the water balance, no outflow of mass load was associated with evaporation in the water quality model.

5.2.2 Tailings and Waste Rock Void Entrainment

When tailings and waste rock are deposited in the TMF, the pond water will become entrained in the voids of the deposited solids. Losses to voids will only take place during Operations, because waste rock and tailings will be saturated following Operations. The average annual rate of entrainment is provided in Table IV - A 1.

5.2.3 Mill Reclaim

Water will be reclaimed to the mill for processing during Operations. Average annual reclaim rate from the KP (2013a) water balance model is presented in Table IV - A 1.

5.2.4 Pumping to Open Pit

Water from the TMF pond will be pumped to the Open Pit from Year 23 to Year 28 during the Wetland Construction Phase to provide suitable working conditions for wetland construction and to help fill the pit faster. The mass load pumped from the TMF Pond was accounted for in the Pit Lake water quality model (Appendix I, Open Pit Water Quality Modelling).

5.2.5 Foundation and Embankment Seepage

KPL (2013c) predicted that toward the south end of the TMF, vertical hydraulic gradients within the tailings will be primarily downward (Figure 5-2). That is, water from the TMF supernatant pond will infiltrate the tailings and flow downward into the foundation material and/or the TMF Embankment. Flow rates will increase throughout operations as the height of the embankment increases, and will stabilize following completion of the embankments. Average annual flow from the TMF Pond to the foundation and embankment are summarized in Table IV - A 1.

5.2.6 Spillway Discharge

In the TMF Discharge Phase, and beyond, surplus TMF Pond water will discharge through the South TMF Wetland and over the TMF spillway and into Casino Creek. The South TMF Wetland is an engineered wetland for the removal of some contaminants. The wetland layout was designed by BCL (2013) and is illustrated on Figure 2-3. South TMF Wetland water quality will be discussed in Section 5.4.

5.3 Calculation of TMF Pond Water Quality

Water quality in the TMF Pond was calculated as the cumulative mass of a given substance in the pond water, divided by the free water volume stored in the pond over a given time step interval.

The TMF Pond mixing model output concentrations were assessed for solubility controls at each time step of the model simulation by coupling GoldSim and PHREEQC. PHREEQC is a geochemical modelling software developed by the United States Geological Survey. During each timestep, Goldsim ran PHREEQC and the resulting concentrations returned from PHREEQC were linked to the South TMF wetland. Input assumptions are provided in Table 5-4.

Table 5-4 PHREEQC Assumptions for TMF Pond Water Quality Modelling

PHREEQC Input Assumptions	
Equilibrium Phases (minerals form solid phase - precipitate forms)	Fe(OH)3(a)
Database	wateq4f
pH	Charge balance (PHREEQC determines pH of solution and alkalinity)
PE	10 (oxidizing)
Oxygen	Atmospheric conditions
CO2	Atmospheric conditions

5.4 South TMF Wetland Discharge Water Quality

In the TMF Discharge Phase (and beyond), TMF Pond water will be released over the TMF spillway and into Casino Creek. Prior to discharge over the spillway, the TMF Pond water will travel through the South TMF Wetland, an engineered wetland for the removal of certain contaminants. The wetland layout was designed by BCL (2013) and is illustrated on Figure 2-3.

Clear Coast Consultants (2013) provided maximum water quality concentrations for the South TMF Wetland effluent (Table 5-5), and this treatment was included in the water quality model. 15% removal efficiency was incorporated into the wetland for sulphate. If no treatment was specified, the modelled TMP Pond water quality for that parameter was assumed to report to Casino Creek via the spillway.

Table 5-5 Maximum Effluent Water Quality from the South TMF Wetland

Water Quality Parameter		Maximum Effluent Water Quality (mg/L)
Sulphate	(SO_4)	15% reduction
Cadmium	(Cd)	0.00014
Copper	(Cu)	0.0040
Molybdenum	(Mo)	0.073
Mercury	(Hg)	0.000026
Selenium	(Se)	-
Silver	(Ag)	0.00010
Uranium	(U)	0.015
Zinc	(Zn)	0.030

6 Results and Discussion

6.1 Water Quality Predictions

Average annual TMF Pond water quality for select parameters are provided in Table 6-1 for a typical year during Operations (Year 15), initial discharge of the TMF to Casino Creek (Year 31), and long-term, discharge (Year 120) for select water quality parameters. Water quality model results are also provided for the TMF Spillway discharge to illustrate the modelled effects of the treatment wetland on TMF Pond water quality prior to discharge to Casino Creek. Tables of water quality model results are provided for all modelled parameters in Appendix IV - B (Table IV - B 1). Time series plots for select parameters are provided in Figure 6-1 to Figure 6-7.

Table 6-1 TMF Pond Water Quality Model Results

Water Quality Parameter		TMF Pond Water Quality (mg/L)		
		Operations (Year 15)	Initial TMF Pond Discharge (Year 31)	Long-Term (Year 120)
Sulphate	(SO_4)	1,269	492	296
Cadmium	(Cd)	0.00067	0.00055	0.00018
Copper	(Cu)	0.33	0.073	0.086
Iron	(Fe)	0.0017	0.00034	0.00015
Molybdenum	(Mo)	0.34	0.13	0.067
Selenium	(Se)	0.017	0.0050	0.0046
Uranium	(U)	0.020	0.037	0.046
Water Quality Parameter		**TMF Spillway Water Quality (mg/L)**		
		Operations (Year 15)	**Initial TMF Pond Discharge (Year 31)**	**Long-Term (Year 120)**
Sulphate	(SO_4)	-	399	250
Cadmium	(Cd)	-	0.00014	0.00014
Copper	(Cu)	-	0.0040	0.0040
Iron	(Fe)	-	0.00033	0.00015
Molybdenum	(Mo)	-	0.073	0.066
Selenium	(Se)	-	0.0047	0.0046
Uranium	(U)	-	0.015	0.015

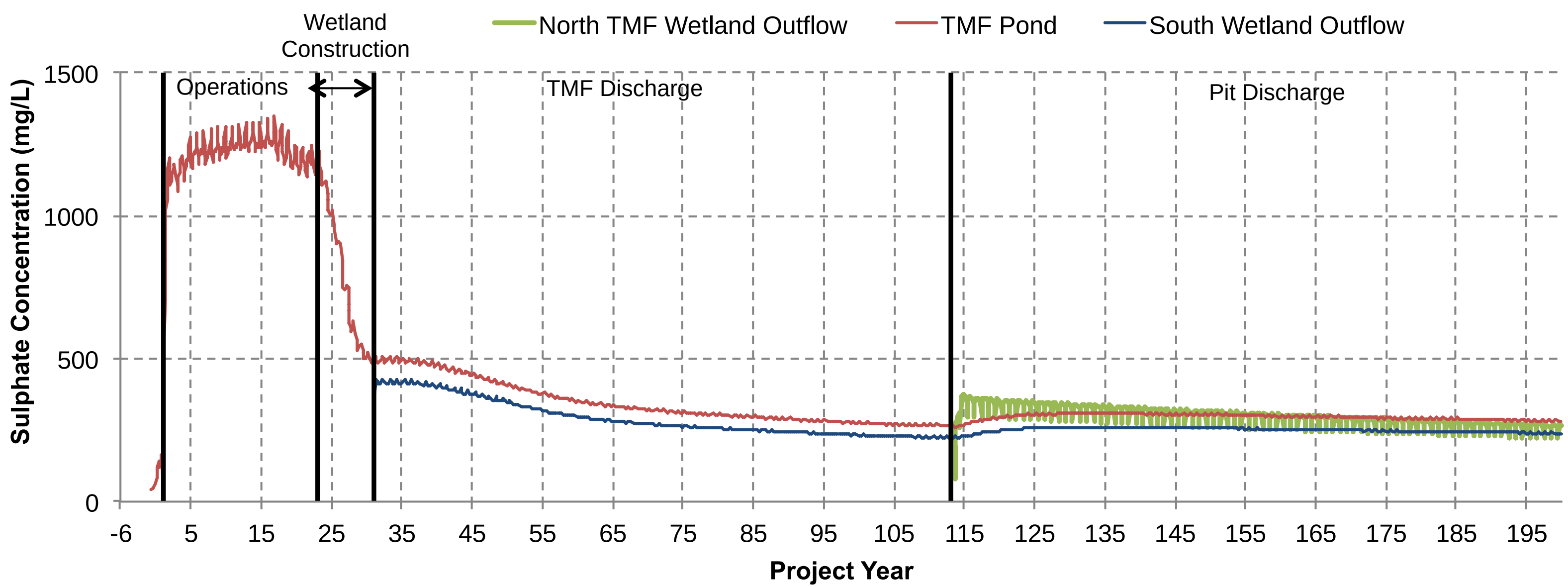


Figure 6-1 Modelled Sulphate Water Quality in the TMF Pond and Wetlands

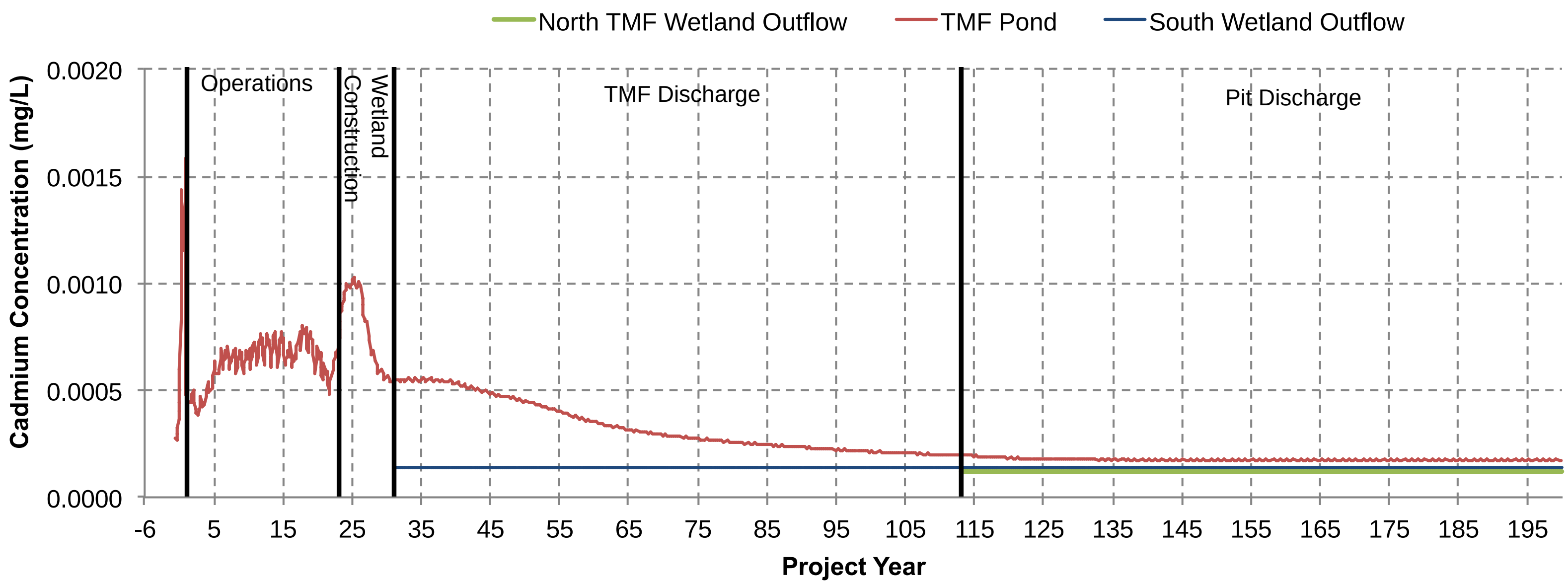


Figure 6-2 Modelled Cadmium Water Quality in the TMF Pond and Wetlands

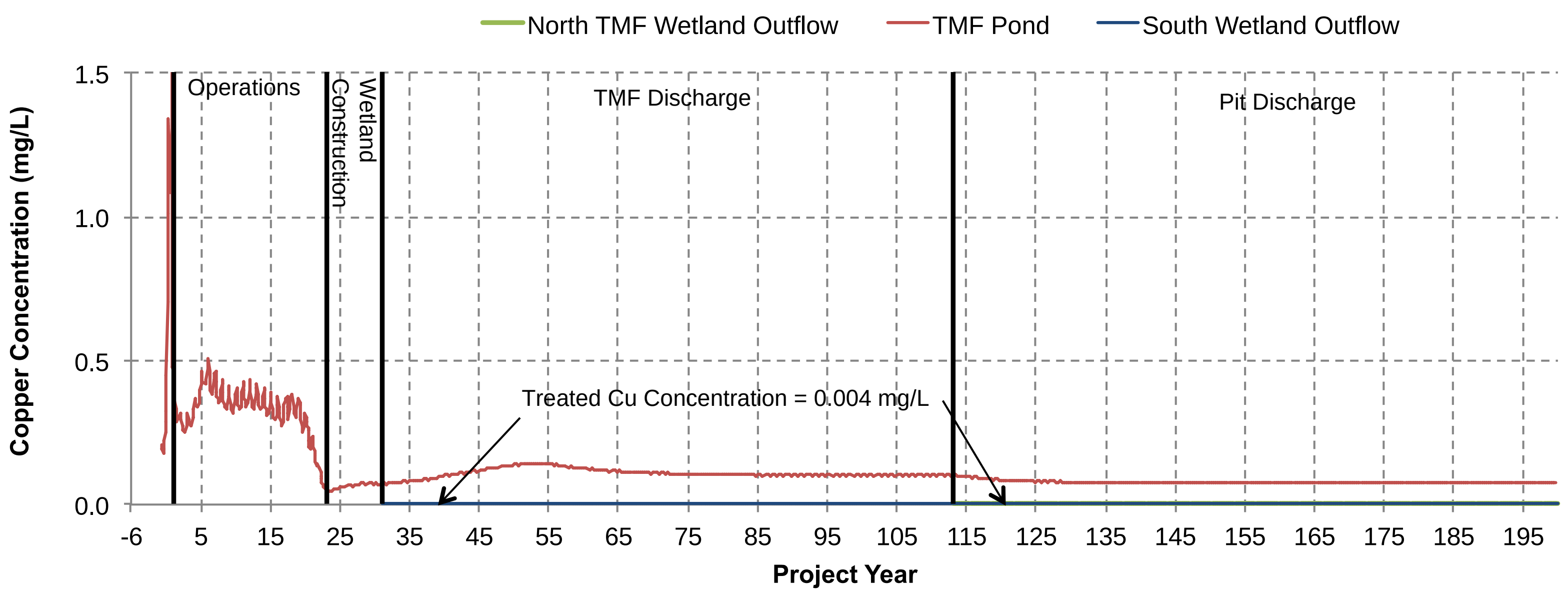


Figure 6-3 Modelled Copper Water Quality in the TMF Pond and Wetlands

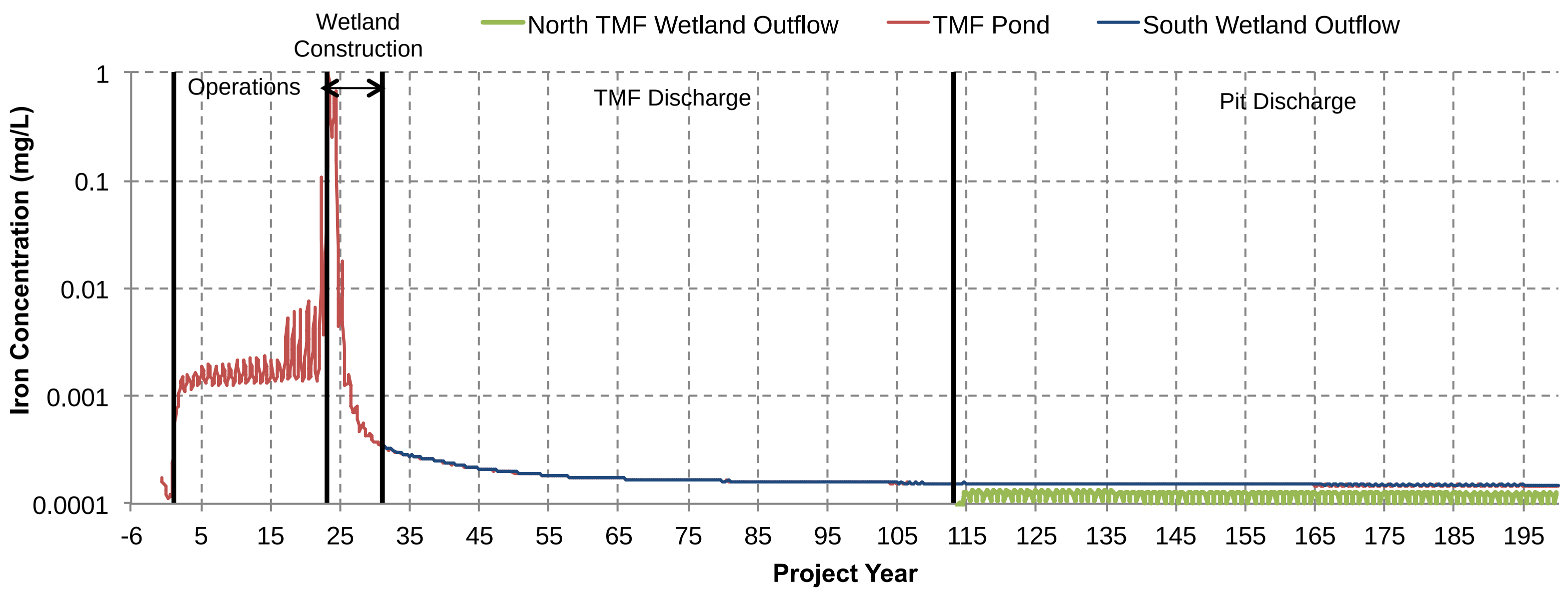


Figure 6-4 Modelled Iron Water Quality in the TMF Pond and Wetlands

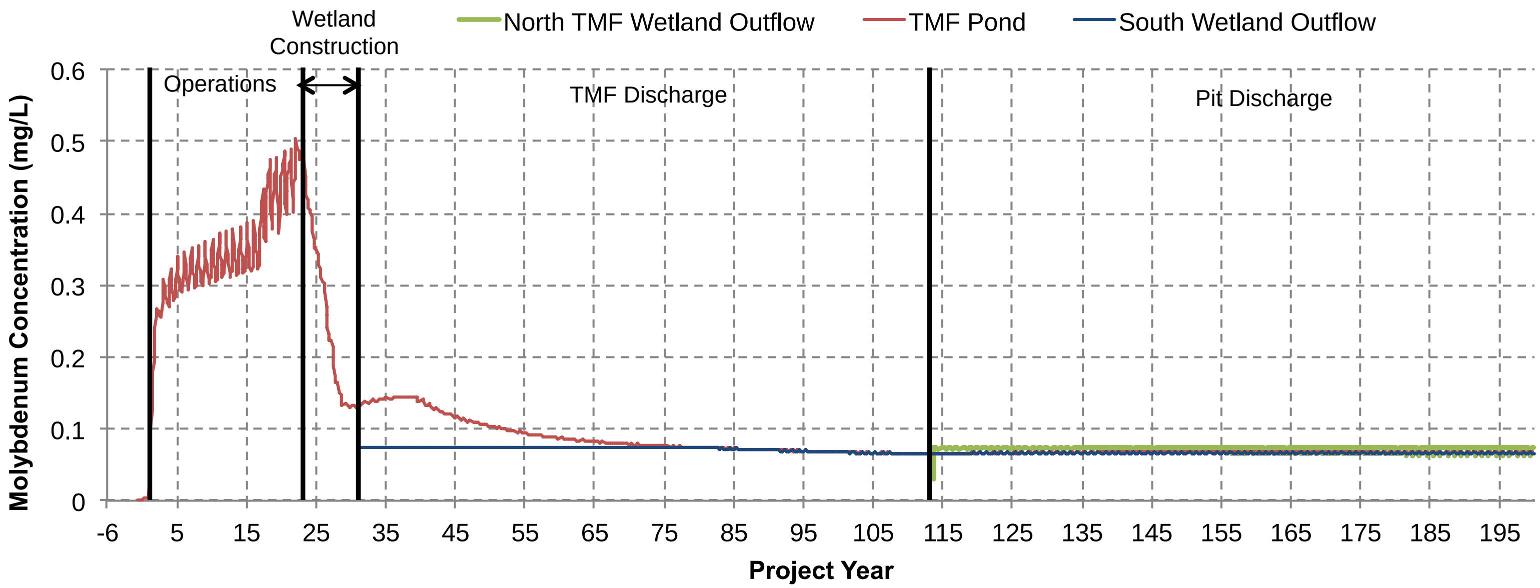


Figure 6-5 Modelled Molybdenum Water Quality in the TMF Pond and Wetlands

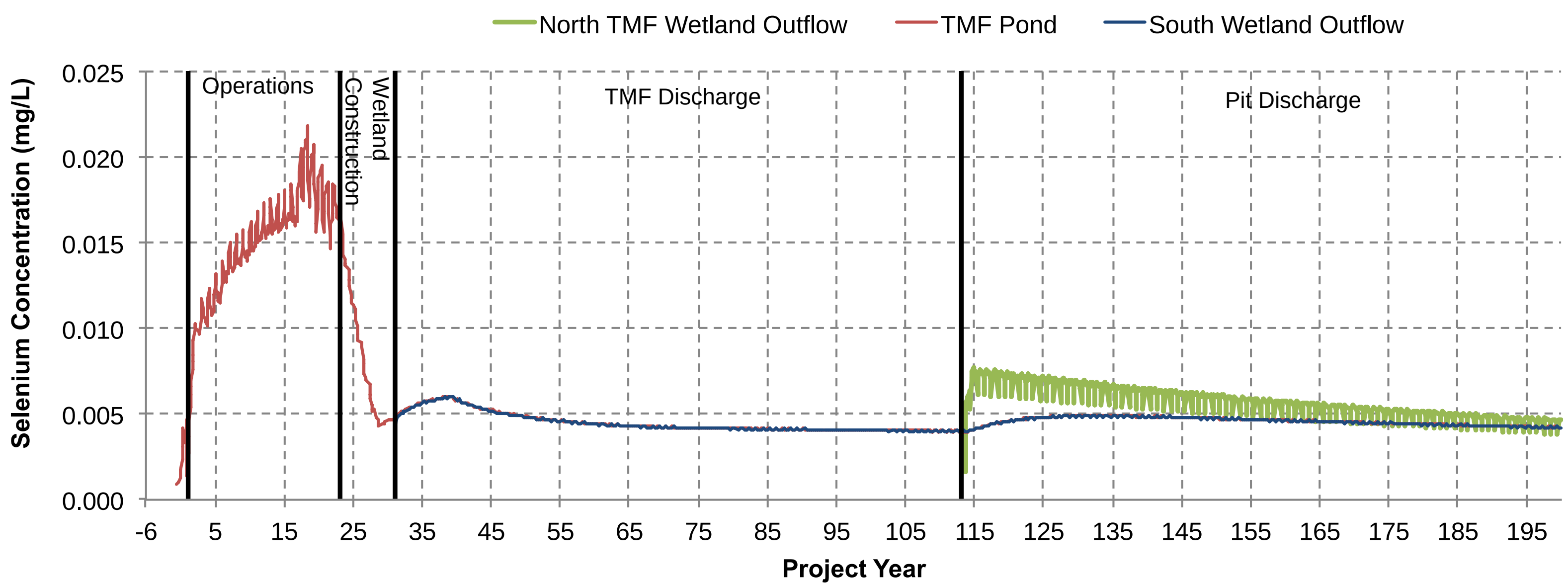


Figure 6-6 Modelled Selenium Water Quality in the TMF Pond and Wetlands

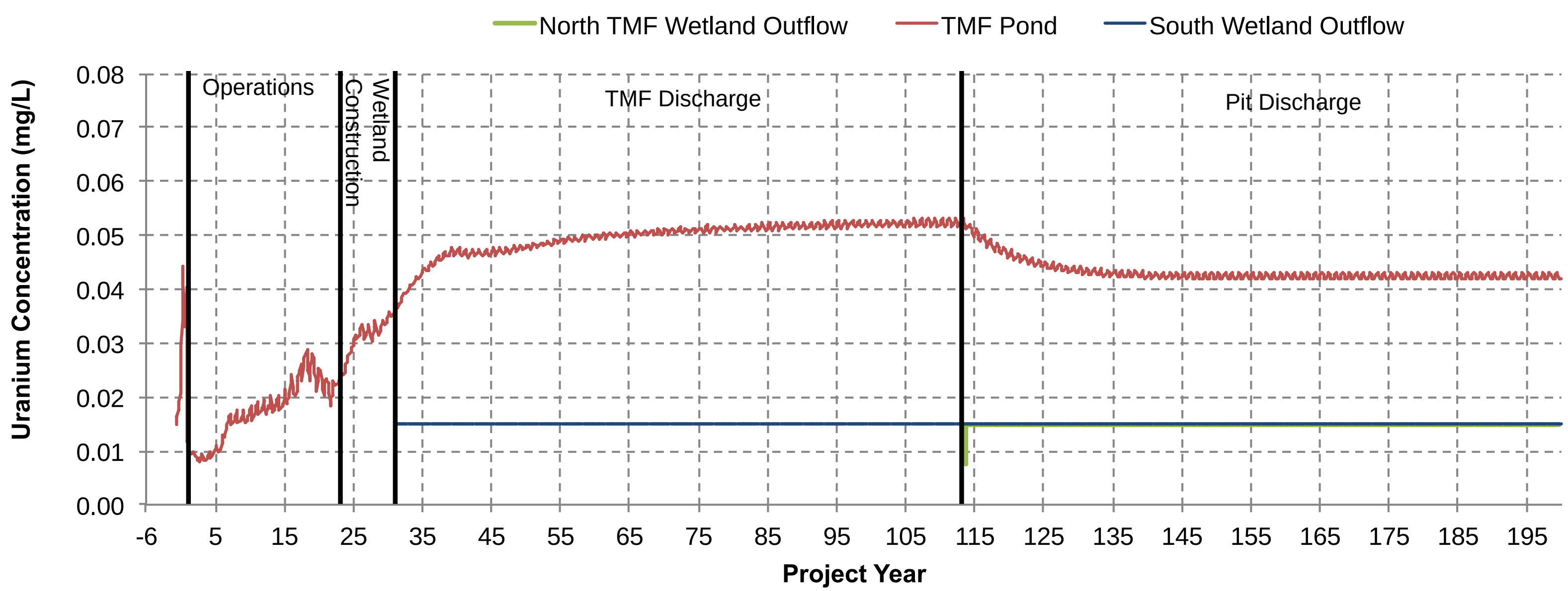


Figure 6-7 Modelled Uranium Water Quality in the TMF Pond and Wetlands

Figure 6-8 shows an example of the accumulation of selenium in the process water quality to illustrate the influence of the process water on the TMF Pond water quality. The blue line is the process water quality and the red line is the TMF Pond water quality. Because the TMF pond experiences seasonal dilution, the reclaim water concentration also varies, and thus so will the process water.

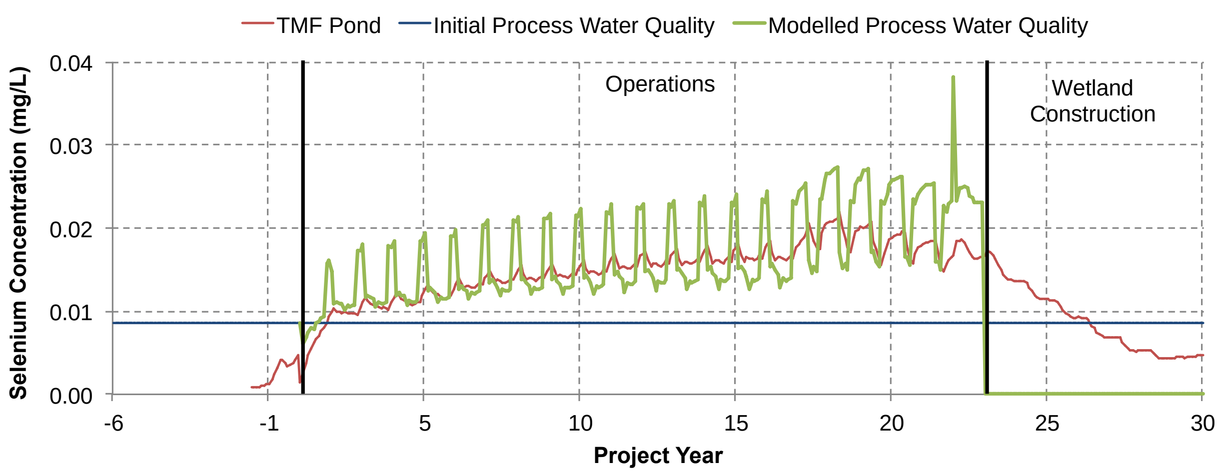


Figure 6-8 Example of Process Water Quality and TMF Pond Quality for Selenium

6.2 TMF Pond pH

PHREEQC is able to determine the pH of the TMF Pond from the mixed concentration of constituents using “charge balance”. The TMF Pond pH was calculated to be pH 6.7 at initial TMF Pond discharge (Year 31) and stabilized at pH 7.4 during the Pit Discharge Phase (Figure 6-9).

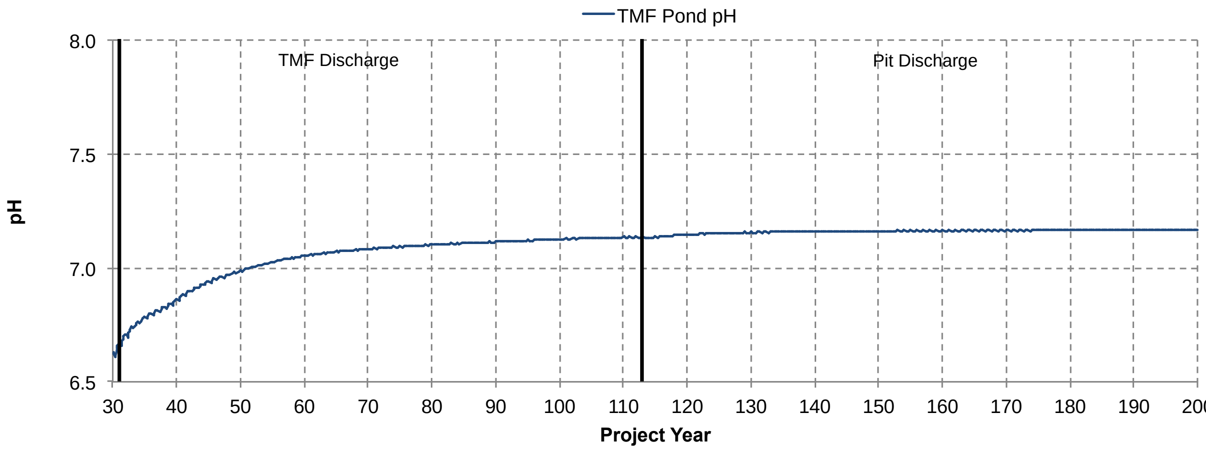


Figure 6-9 Simulated pH of the TMF Pond

6.3 Individual Contributions of Mass Loading Sources to the TMF

Individual contributions of each mass loading source are presented in Table 6-2. Loading Source Contributions to the TMF Pond (Operations) (typical year during Operations) and Table 6-3Table 6-3 (typical year following discharge form TMF and prior to Pit Lake discharge), and Table 6-4 (typical year followoing discharge of the Pit Lake). Individual contributions of mass loading sources are provided in Appendix IV for all modelled water quality parameters.

In general, during TMF Discharge, upward fluxes of porewater from the tailings and waste rock are the dominant loads to the TMF Pond. Once the Pit Discharge Phase begins (via the North TMF Wetland), this source is a large proportion of the overall load to the TMF Pond for some water quality paramters.

As the waste rock is expected to have copper concentrations that impact the TMF long-term, the South TMF wetland was added as an integral part of the Project.

Table 6-2. Loading Source Contributions to the TMF Pond (Operations)

Source of Loading	Fraction Contributing (%)						
	SO_4	Cd	Cu	Fe	Mo	Se	U
Background Runoff	0	1	0	0	0	0	3
Stockpile (runoff + seepage)	1	41	93	18	2	8	18
Waste Rock Runoff	0	9	0	0	0	11	8
Tailings Beach Runoff	0	1	0	0	1	0	0
HLF Drainage	0	0	0	0	0	0	0
Tailings Slurry	72	4	1	3	75	66	47
PAG Tailings Pore Water	1	1	0	3	1	1	2
NAG Tailings Pore Water	14	34	1	66	12	7	4
Waste Rock Pore Water	1	1	2	5	1	1	14
WMP Pump Back	9	6	0	5	8	5	3
North TMF Wetland Discharge	0	0	0	0	0	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Year 15 was selected as the representative year during Operations.
2. Shaded cells are for sources that contribute >10% to the overall load.
3. Values are rounded to the nearest 1 and the total of individual values may not add to exactly 100.

Table 6-3. Loading Source Contributions to the TMF Pond (TMF Discharge Phase)

Source of Loading	Fraction Contributing (%)						
	SO_4	Cd	Cu	Fe	Mo	Se	U
Background Runoff	6	22	1	3	0	1	16
Stockpile (runoff + seepage)	0	0	0	0	0	0	0
Waste Rock Runoff	0	0	0	0	0	0	0
Tailings Beach Runoff	1	1	0	0	4	1	2
HLF Drainage	3	4	0	0	20	37	7
Tailings Slurry	0	0	0	0	0	0	0
PAG Tailings Pore Water	1	1	0	1	1	1	0
NAG Tailings Pore Water	29	41	2	32	26	14	1
Waste Rock Pore Water	56	27	97	63	41	38	72
WMP Pump Back	0	0	0	0	0	0	0
North TMF Wetland Discharge	4	4	0	0	8	8	2
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Year 60 was selected as the representative year during the TMF Discharge Phase.
2. Shaded cells are for sources that contribute >10% to the overall load.
3. Values are rounded to the nearest 1 and the total of individual values may not add to exactly 100.

Table 6-4. Loading Source Contributions to the TMF Pond (Pit Discharge Phase)

Source of Loading	Fraction Contributing (%)						
	SO_4	Cd	Cu	Fe	Mo	Se	U
Background Runoff	5	25	1	5	0	0	14
Stockpile (runoff + seepage)	0	0	0	0	0	0	0
Waste Rock Runoff	0	0	0	0	0	0	0
Tailings Beach Runoff	1	1	0	0	4	1	1
HLF Drainage	2	4	0	0	16	23	6
Tailings Slurry	0	0	0	0	0	0	0
PAG Tailings Pore Water	0	0	0	0	0	0	0
NAG Tailings Pore Water	6	12	0	11	6	2	0
Waste Rock Pore Water	44	31	97	84	34	24	65
WMP Pump Back	0	0	0	0	0	0	0
North TMF Wetland Discharge	42	25	2	0	40	50	13
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Year 120 was selected as the representative year during the Pit Discharge Phase.
2. Shaded cells are for sources that contribute >10% to the overall load.
3. Values are rounded to the nearest 1 and the total of individual values may not add to exactly 100.

7 References

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Appendix IV - A

Water Quality Modelling Input Data

Table IV - A 1 Average Annual Inflow and Outflow of Water for the TMF Pond

Water Management Phase	Project Year	Average Annual Inflow (L/s)								Tailings Porewater						Average Annual Outflow (L/s)							
		Precipit-ation	Back-ground Runoff (1,2)	FWSP	Stockpile Runoff (2)	Waste Rock Runoff	Tailings Beach	HLF Runoff	Tailings Slurry (3)	NAG (4)	PAG (4)	Waste Rock Porewater (4)	WMP	North TMF Wetland Discharge	Total Inflow	Evapor-ation	Reclaim to Mill	Tailings and WR Voids	Pump to Open Pit	Embank-ment Seepage	Founda-tion Seepage	Spillway Discharge	Total
Construction	-3	0	94	0	0	0.6	0	0	0	0	0	0	0	0	95	0	0	0	0	0	0	0	0
	-2	0	93	2	0	1.8	0	0	0	0	0	0	0.2	0	97	0	0	0	0	0	0	0	0
	-1	1	89	20	1.2	3.6	0	0	0	0	0	3	0.4	0	118	1	0	87	0	0	0	0	88
Operations	1	5	105	17	7.0	5.9	1.1	0	322	181	14	8	145	0	811	4.1	611	603	0	0.6	0	0	1,219
	2	9	102	0	8.8	8.1	1.3	0	1,006	210	16	14	164	0	1,539	7.2	697	834	0	1.9	0	0	1,540
	3	12	100	0	11	10	1.6	0	1,000	240	18	19	171	0	1,582	9.4	771	799	0	3.4	0.4	0	1,583
	4	13	98	0	12	12	1.8	0	981	269	21	22	185	0	1,614	10	833	764	0	4.8	1.2	0	1,614
	5	15	96	0	13	14	1.8	0	970	286	22	23	190	0	1,631	12	827	785	0	5.3	2.5	0	1,632
	6	16	95	0	13	17	1.9	0	974	292	22	23	187	0	1,641	13	822	799	0	5.8	3.7	0	1,643
	7	17	93	0	14	20	2.0	0	973	297	23	23	190	0	1,651	13	829	800	0	6.2	5.0	0	1,653
	8	19	92	0	15	21	2.0	0	977	302	23	24	198	0	1,674	15	836	811	0	6.6	6.2	0	1,674
	9	21	90	0	15	23	2.1	0	988	308	24	24	201	0	1,697	16	839	829	0	7.1	7.5	0	1,699
	10	22	89	0	15	25	2.2	0	960	311	26	25	199	0	1,674	17	834	809	0	7.6	8.7	0	1,676
	11	22	89	0	14	28	2.3	0	955	316	26	24	202	0	1,680	18	832	815	0	8.3	9.7	0	1,683
	12	23	88	0	13	30	2.3	0	977	321	27	24	210	0	1,716	18	841	837	0	8.9	11	0	1,716
	13	24	88	0	13	32	2.4	0	990	326	27	24	211	0	1,738	19	848	852	0	9.6	12	0	1,740
	14	26	87	0	12	33	2.5	0	977	331	27	24	214	0	1,735	20	853	842	0	10	13	0	1,738
	15	27	86	0	12	35	2.6	0	963	336	28	24	214	0	1,729	21	846	840	0	11	14	0	1,732
	16	29	85	0	12	36	2.6	0	960	341	28	24	214	0	1,733	23	842	843	0	12	15	0	1,734
	17	32	85	0	12	37	2.7	0	1,065	346	29	24	118	0	1,752	25	752	946	0	12	16	0	1,753
	18	37	85	0	12	37	2.8	0	1,075	351	29	24	115	0	1,768	29	742	969	0	13	17	0	1,769
	19	48	86	0	11	32	2.9	0	1,092	373	13	23	117	0	1,797	38	907	821	0	14	18	0	1,798
	20	68	86	0	6.7	19	2.9	0	1,095	378	13	23	99	0	1,791	53	899	805	0	14	18	0	1,790
	21	87	87	0	2.2	6.7	3.0	0	1,098	383	13	22	99	0	1,801	69	891	808	0	15	19	0	1,802
	22	99	87	0	0	0	3.0	0	588	387	14	21	46	0	1,244	77	523	401	0	15	20	0	1,036
Wetland Construction	23	88	80	0	0	0	3.0	0	0	257	9.1	21	45	0	503	68	0	0	336	14	20	0	438
	24	87	80	0	0	0	3.0	0	0	94	3.3	21	45	6.4	340	68	0	0	335	14	20	0	437
	25	87	80	0	0	0	3.0	0	0	82	2.9	21	45	10	331	68	0	0	336	14	20	0	438
	26	87	80	0	0	0	3.0	0	0	70	2.5	21	62	10	336	68	0	0	336	14	20	0	438
	27	86	81	0	0	0	3.0	0	0	58	2.0	21	62	10	323	67	0	0	336	14	20	0	437
	28	86	81	0	0	0	3.0	0	0	50	1.8	21	62	10	316	67	0	0	0	14	20	0	101
	29	87	80	0	0	0	3.0	6	0	49	1.7	21	62	10	321	68	0	0	0	14	20	0	102
	30	87	80	0	0	0	3.0	6	0	47	1.7	21	62	10	320	68	0	0	0	14	20	3	105
TMF Discharge	60	88	80	0	0	0	3.0	13	0	11	0.4	21	0	14	231	68	0	0	0	14	20	129	231
Pit Discharge	120	88	80	0	0	0	3.0	13	0	2.9	0.1	22	0	81	290	68	0	0	0	14	20	187	290

1. Includes domestic wastewater treatment plant effluent (average rate = 1.3 L/s during Operations) and mill site runoff
2. Following Operations, runoff from the reclaimed stockpile areas was accounted for as "Background Runoff" in the water balance.
3. Includes sand plant overflow, embankment construction water from the upstream face, minus the sand plant make-up water.
4. Porewater displacement from NAG Tailings, PAG Tailings, and Waste Rock includes tailings consolidation seepage (tailings only) and seepage from ore stockpiles.
5. Year 60 and Year 120 were selected as representative years to illustrate water balance results for TMF Discharge and Pit Discharge conditions, respectively.

Table IV - A 2 Source Terms for Inflows to the TMF Pond

Water Quality Model Parameter	Background Runoff (W13) [1] (mg/L)	FWSP Inflow (W8) [1] (mg/L)	Tailings Beach Runoff		HLF Drainage		Pumped Back Seepage [2]		Tailings Slurry Water [3]		North TMF Wetland	
			Operations (mg/L)	> Year 23 (mg/L)	Year 29 - Year 38 (mg/L)	> Year 39 (mg/L)	WMP (Operations) (mg/L)	WSMP (Year 28) (mg/L)	Water Quality (mg/L)	Accumulation (g/tonne)	Year 113 (mg/L)	Year 200 (mg/L)
Hardness (as $CaCO_3$)	125	107	110	179	3,497	2,392	1,267	983	1,248		406	295
Acidity (as $CaCO_3$)	1.1	2.1	0.24	0.028	0	0	0.072	0.27	0		61	60
Alkalinity (as $CaCO_3$)	105	38	68	75	47	47	64	69	63		163	171
Sulphate (SO_4)	28	73	101	150	2,100	424	1,334	951	1,320		355	264
Chloride (Cl)	0.25	0.25	0.054	7.8	240	38	36	33	36		15	8.4
Fluoride (F)	0.060	0.10	0.56	4.1	3.0	1.3	2.2	1.8	2.2		1.0	0.76
Aluminum (Al)	0.074	0.53	0.038	0.00019	0.0070	0.0060	3.2	0.012	4.8		0.0077	0.0084
Antimony (Sb)	0.00023	0.000090	0.044	0.029	0.77	0.47	0.0040	0.018	0.0025	0.0020	0.016	0.0089
Arsenic (As)	0.0014	0.00030	0.054	0.029	0.036	0.036	0.0054	0.0059	0.0041	0.0033	0.0051	0.0039
Barium (Ba)	0.090	0.052	0.029	0.023	0.0077	0.0077	0.075	0.090	0.058		0.067	0.054
Cadmium (Cd)	0.000087	0.00025	0.0048	0.00019	0.0050	0.00028	0.00069	0.0012	0.000043		0.00012	0.00012
Calcium (Ca)	34	31	40	60	756	532	501	376	497		212	175
Chromium (Cr)	0.00015	0.00010	0.043	0.0082	0.0010	0.0010	0.0033	0.0026	0.0025		0.0023	0.0021
Cobalt (Co)	0.000074	0.0023	0.0056	0.0016	2.6	0.49	0.0026	0.0055	0.00075		0.11	0.069
Copper (Cu)	0.0011	0.058	0.038	0.0099	0.016	0.0011	0.028	0.039	0.0050		0.0040	0.0040
Iron (Fe)	0.071	0.87	0.0050	0.0051	0.0040	0.0040	1.8	3.6	0.060		0.00013	0.00012
Lead (Pb)	0.0036	0.00029	0.0073	0.00020	0.00028	0.00028	0.0013	0.00090	0.0013		0.0012	0.00078
Magnesium (Mg)	9.7	7.0	2.3	7.4	392	259	3.4	11	1.3		12	11
Manganese (Mn)	0.040	0.068	0.0060	0.0065	0.0045	0.00031	0.73	1.6	0.0015		0.47	0.37
Mercury (Hg)	0.0000050	0.0000050	0.00043	0.000074	0.000020	0.000020	0.000012	0.000022	0.0000050		0.000022	0.000019
Molybdenum (Mo)	0.00053	0.00023	2.8	0.18	4.2	0.94	0.31	0.24	0.24	0.20	0.073	0.072
Nickel (Ni)	0.00036	0.00092	0.018	0.0041	0.093	0.0073	0.0039	0.0041	0.0025		0.041	0.026
Potassium (K)	1.1	0.88	66	54	0	246	64	3.1	86		6.5	2.7
Selenium (Se)	0.000047	0.000060	0.0022	0.0022	0.23	0.098	0.0088	0.0072	0.0085	0.0070	0.0073	0.0046
Silver (Ag)	0.000016	0.0000025	0.00047	0.00012	0.00078	0.00062	0.000062	0.000050	0.000050		0.00010	0.00010
Sodium (Na)	3.9	3.5	4.3	2.4	15	0.56	37	29	35		14	8.9
Thallium (Tl)	0.0000030	0.0000070	0.00020	0.000068	0.00011	0.00011	0.00052	0.00037	0.00050		0.00015	0.00010
Uranium (U)	0.012	0.0019	0.017	0.042	0.63	0.17	0.011	0.035	0.0031	0.0025	0.015	0.015
Zinc (Zn)	0.0061	0.018	0.14	0.015	0.39	0.22	0.014	0.018	0.0061		0.030	0.030

1. Median water quality from water quality data collected at W13 and W8.
2. Average water quality in pumped back water from Year 15 was selected as representative of WMP (Operations) and Year 28 for the WSMP.
3. Represents the water quality of the slurry water. For parameters where a "mass accumulation" source term was provided, the "water quality" value represents the initial water quality in the slurry water at the beginning of the model simulation.

Table IV - A 3 **Source Terms for Inflows to the TMF Pond - Loading Rates and Maximum Concentrations for Unsubmerged Waste Rock in the TMF during Operations**

Water Quality Parameter	Mass Loading Rate (mg/tonne/year)				Maximum Concentration (mg/L)		
	Year -3 to Year 4	Year 5 to Year 14	Year 15 to Year 20		Year -3 to Year 4	Year 5 to Year 14	Year 15 to Year 20
Hardness (as $CaCO_3$)	1,985	4,861	3,697		201	794	611
Acidity (as $CaCO_3$)	137	35	1.3		14.6	6.7	0.20
Alkalinity (as $CaCO_3$)	0	0	58		0	0	68
Sulphate (SO_4)	5,700	5,900	5,300		590	980	840
Chloride (Cl)	230	140	260		23	23	42
Fluoride (F)	17	16	19		1.8	2.6	3.1
Aluminum (Al)	19	4.1	0.020		1.9	0.69	0.0023
Antimony (Sb)	0.13	0.21	0.18		0.014	0.035	0.029
Arsenic (As)	0.080	0.18	0.24		0.0083	0.030	0.038
Barium (Ba)	0.076	0.042	0.040		0.0079	0.0069	0.0069
Cadmium (Cd)	0.027	0.12	0.060		0.0028	0.020	0.0089
Calcium (Ca)	630	1,600	1,200		64	260	200
Chromium (Cr)	0.12	0.20	0.29		0.012	0.034	0.046
Cobalt (Co)	0.53	0.68	0.55		0.054	0.11	0.087
Copper (Cu)	31	9.5	0.29		3.2	1.6	0.046
Iron (Fe)	3.2	0.69	0.060		0.33	0.11	0.0094
Lead (Pb)	0.051	0.033	0.020		0.0052	0.0054	0.0038
Magnesium (Mg)	100	210	170		10	35	27
Manganese (Mn)	12	5.3	0.56		1.2	0.87	0.089
Mercury (Hg)	0.0020	0.0036	0		0.00020	0.00059	0.00076
Molybdenum (Mo)	0.60	0.47	0.64		0.062	0.078	0.10
Nickel (Ni)	0.16	0.30	0.34		0.016	0.049	0.055
Potassium (K)	420	270	210		43	44	34
Selenium (Se)	0.78	1.8	1.9		0.080	0.30	0.30
Silver (Ag)	0.0071	0.0073	0.010		0.00073	0.0012	0.0013
Sodium (Na)	1,700	580	46		170	96	7.3
Thallium (Tl)	0.016	0.0084	0.010		0.0016	0.0014	0.00081
Uranium (U)	0.17	1.8	1.6		0.017	0.30	0.25
Zinc (Zn)	3.0	13	7.2		0.31	2.1	1.1

Table IV - A 4 **Source Terms for Inflows to the TMF Pond - Seepage from Saturated Tailings and Waste Rock**

Water Quality Parameter	Flux from Submerged Waste Rock to TMF Pond (mg/L)					Flux from PAG Tailings to TMF Pond (mg/L)					Flux from NAG Tailings to TMF Pond (mg/L)				
	Year 4	Year 9	Year 19	Year 22	> Year 22	Year 4	Year 9	Year 19	Year 22	> Year 22	Year 4	Year 9	Year 19	Year 22	> Year 22
Hardness (as $CaCO_3$)	1,268	1,398	1,480	1,480	1,480	1,278	1,289	1,293	1,299	1,297	1,257	1,256	1,258	1,259	1,262
Acidity (as $CaCO_3$)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alkalinity (as $CaCO_3$)	0	0	329	329	329	75	75	75	75	75	58	58	58	58	58
Sulphate (SO_4)	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320
Chloride (Cl)	36	36	36	36	36	35	38	38	38	38	36	36	36	36	36
Fluoride (F)	2.2	2.2	2.2	2.2	2.2	2.1	2.2	2.2	2.2	2.2	2.1	2.1	2.1	2.1	2.1
Aluminum (Al)	4.8	1.4	0.0020	0.0020	0.0020	0.0086	0.0086	0.0086	0.0086	0.0086	0.0058	0.0058	0.0058	0.0058	0.0058
Antimony (Sb)	0.0046	0.0040	0.0025	0.0025	0.0025	0.0029	0.0029	0.0029	0.0029	0.0029	0.0025	0.0025	0.0026	0.0025	0.0026
Arsenic (As)	0.0041	0.0041	0.0063	0.0063	0.0063	0.0044	0.0044	0.0043	0.0044	0.0044	0.0043	0.0043	0.0043	0.0043	0.0043
Barium (Ba)	0.21	0.15	0.067	0.067	0.067	0.077	0.074	0.074	0.074	0.074	0.11	0.11	0.11	0.11	0.11
Cadmium (Cd)	0.00044	0.00085	0.00056	0.00056	0.00056	0.00077	0.00077	0.00077	0.00077	0.00077	0.0016	0.0016	0.0016	0.0016	0.0016
Calcium (Ca)	498	498	498	498	498	498	498	498	498	498	498	498	498	498	498
Chromium (Cr)	0.0026	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Cobalt (Co)	0.015	0.038	0.042	0.042	0.042	0.0021	0.0051	0.0061	0.0071	0.0067	0.0016	0.0016	0.0019	0.0020	0.0023
Copper (Cu)	2.5	1.0	0.76	0.75	0.75	0.0088	0.018	0.018	0.018	0.018	0.017	0.020	0.024	0.024	0.024
Iron (Fe)	0.58	0.87	6.9	6.8	6.8	3.5	3.5	3.5	3.5	3.5	6.7	6.7	6.7	6.7	6.7
Lead (Pb)	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
Magnesium (Mg)	5.5	37	57	57	57	8.0	11	12	13	13	2.9	2.7	3.3	3.3	4.1
Manganese (Mn)	0.46	1.3	2.9	2.9	2.9	1.4	1.4	1.4	1.4	1.4	2.7	2.7	2.7	2.7	2.7
Mercury (Hg)	0.000024	0.000029	0.000042	0.000042	0.000042	0.000040	0.000039	0.000039	0.000039	0.000039	0.000010	0.0000085	0.000010	0.000010	0.000013
Molybdenum (Mo)	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.29	0.29	0.29	0.29	0.29
Nickel (Ni)	0.0047	0.013	0.017	0.017	0.017	0.0027	0.0038	0.0041	0.0045	0.0044	0.0025	0.0026	0.0027	0.0027	0.0028
Selenium (Se)	0.0085	0.013	0.012	0.012	0.012	0.0085	0.0088	0.0089	0.0090	0.0090	0.0085	0.0085	0.0086	0.0086	0.0086
Silver (Ag)	0.000072	0.000056	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050
Sodium (Na)	36	57	66	66	66	37	41	41	41	41	38	38	38	38	39
Thallium (Tl)	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050
Uranium (U)	0.011	0.16	0.28	0.28	0.28	0.014	0.028	0.034	0.042	0.039	0.0040	0.0039	0.0059	0.0063	0.0089
Zinc (Zn)	0.054	0.073	0.067	0.067	0.067	0.021	0.025	0.026	0.027	0.026	0.011	0.011	0.012	0.012	0.013

Appendix IV - B

Water Quality Modelling Results

Table IV - B 1 TMF Pond Water Quality Model Results

Water Quality Model Parameter	TMF Pond Water Quality (mg/L)			TMF Spillway Water Quality (mg/L)		
	Operations (Year 15)	Initial TMF Pond Discharge (Year 31)	Long-Term (Year 120)	Operations (Year 15)	Initial TMF Pond Discharge (Year 31)	Long-Term (Year 120)
Hardness (as $CaCO_3$)	1,203	546	398	-	521	397
Acidity (as $CaCO_3$)	2.2	0.53	15	-	0.51	15
Alkalinity (as $CaCO_3$)	11	55	158	-	52	158
Sulphate (SO_4)	1,269	492	296	-	399	250
Chloride (Cl)	35	15	9.1	-	14	9.1
Fluoride (F)	2.2	0.87	0.65	-	0.83	0.64
Aluminum (Al)	3.7	0.089	0.050	-	0.086	0.050
Antimony (Sb)	0.0059	0.0072	0.011	-	0.0069	0.011
Arsenic (As)	0.0064	0.0033	0.0038	-	0.0031	0.0038
Barium (Ba)	0.067	0.076	0.083	-	0.073	0.083
Cadmium (Cd)	0.00067	0.00055	0.00018	-	0.00014	0.00014
Calcium (Ca)	476	197	145	-	188	144
Chromium (Cr)	0.0029	0.0012	0.0011	-	0.0011	0.0011
Cobalt (Co)	0.0029	0.019	0.039	-	0.018	0.038
Copper (Cu)	0.33	0.073	0.086	-	0.0040	0.0040
Iron (Fe)	0.0017	0.00034	0.00015	-	0.00033	0.00015
Lead (Pb)	0.0015	0.0021	0.0027	-	0.0020	0.0027
Magnesium (Mg)	3.4	13	19	-	12	19
Manganese (Mn)	0.46	0.93	0.50	-	0.89	0.50
Mercury (Hg)	0.000011	0.000011	0.000015	-	0.000011	0.000015
Molybdenum (Mo)	0.34	0.13	0.067	-	0.073	0.066

Water Quality Model Parameter		TMF Pond Water Quality (mg/L)			TMF Spillway Water Quality (mg/L)		
		Operations (Year 15)	Initial TMF Pond Discharge (Year 31)	Long-Term (Year 120)	Operations (Year 15)	Initial TMF Pond Discharge (Year 31)	Long-Term (Year 120)
Nickel	(Ni)	0.0084	0.0032	0.012	-	0.0030	0.012
Potassium	(K)	68	2.7	6.4	-	2.7	6.4
Selenium	(Se)	0.017	0.0050	0.0046	-	0.0047	0.0046
Silver	(Ag)	0.000064	0.000033	0.000054	-	0.000031	0.000054
Sodium	(Na)	35	18	14	-	17	14
Thallium	(Tl)	0.00049	0.00018	0.00010	-	0.00017	0.00010
Uranium	(U)	0.020	0.037	0.046	-	0.015	0.015
Zinc	(Zn)	0.038	0.015	0.023	-	0.014	0.023

Table IV - B 2 Fraction Contributing to TMF Pond Water Quality – Operations (Year 15)

Source of Loading	Hard-ness	Acid-ity	Alk	SO_4	Cl	F	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Hg	Mo	Ni	K	Se	Ag	Na	Tl	U	Zn
Background Runoff	0	2	7	0	0	0	0	0	1	6	1	0	0	0	0	0	11	13	0	2	0	0	0	0	1	1	0	3	1
Stockpile (runoff + seepage)	1	96	0	1	0	3	6	16	3	0	41	1	3	29	93	18	7	13	2	24	2	62	0	8	6	0	1	18	56
Waste Rock Runoff	0	0	0	0	1	1	0	3	4	0	9	0	10	19	0	0	1	5	0	0	0	4	0	11	15	0	2	8	19
Tailings Beach Runoff	0	0	0	0	0	0	0	1	1	0	1	0	2	0	0	0	1	0	0	4	1	0	0	0	1	0	0	0	0
HLF Drainage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tailings Slurry	72	0	65	72	72	71	84	62	72	60	4	73	60	18	1	3	58	26	0	32	75	21	88	66	54	71	71	47	11
PAG Tailings Pore Water	1	0	1	1	1	1	0	1	1	1	1	1	1	2	0	3	1	4	4	4	1	1	0	1	1	1	1	2	1
NAG Tailings Pore Water	15	0	12	14	15	14	0	6	9	23	34	15	12	9	1	66	12	13	82	13	12	4	0	7	11	15	14	4	4
Waste Rock Pore Water	1	0	5	1	1	1	0	0	1	1	1	1	1	14	2	5	1	17	6	4	1	2	0	1	1	2	1	14	2
WMP Pump Back	9	0	9	9	9	9	9	7	8	9	6	9	11	5	0	5	7	6	6	9	8	4	11	5	9	9	9	3	3
North TMF Wetland Discharge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Year 15 was selected as a representative year during Operations.
2. Shaded cells are for sources that contribute >10% to the overall load.
3. Values are rounded to the nearest 1 and the total of individual values may not add to exactly 100.

Table IV - B 3 Fraction Contributing to TMF Pond Water Quality – TMF Discharge Phase (Year 60)

Source of Loading	Hard-ness	Acid-ity	Alk	SO_4	Cl	F	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Hg	Mo	Ni	K	Se	Ag	Na	Tl	U	Zn
Background Runoff	20	31	54	6	2	7	90	2	27	71	22	16	12	0	1	3	82	34	5	28	0	5	12	1	26	18	2	16	20
Stockpile (runoff + seepage)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste Rock Runoff	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tailings Beach Runoff	1	0	1	1	2	12	0	6	16	0	1	1	18	0	0	0	0	1	0	11	4	2	17	1	5	0	1	2	1
HLF Drainage	11	3	6	3	7	4	8	79	19	7	4	7	3	41	0	0	8	24	0	5	20	3	65	37	25	2	2	7	19
Tailings Slurry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PAG Tailings Pore Water	1	0	0	1	1	1	0	0	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0	1	0	1	1	0	0
NAG Tailings Pore Water	20	0	3	29	27	23	1	2	8	9	41	24	20	1	2	32	3	1	30	5	26	4	0	14	8	17	30	1	4
Waste Rock Pore Water	45	0	32	56	53	47	0	3	24	10	27	46	38	29	97	63	5	38	61	44	41	47	0	38	15	58	58	72	42
WMP Pump Back	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North TMF Wetland Discharge	4	66	3	4	9	6	0	8	5	3	4	5	8	28	0	0	2	2	3	6	8	39	6	8	20	4	6	2	13
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Year 60 was selected as a representative year during the TMF Discharge Phase
2. Shaded cells are for sources that contribute >10% to the overall load.
3. Values are rounded to the nearest 1 and the total of individual values may not add to exactly 100.

Table IV - B 4 Fraction Contributing to TMF Pond Water Quality – Pit Discharge Phase (Year 120)

Source of Loading	Hard-ness	Acid-ity	Alk	SO_4	Cl	F	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Hg	Mo	Ni	K	Se	Ag	Na	Tl	U	Zn
Background Runoff	16	2	35	5	1	4	85	1	17	56	25	11	6	0	1	5	71	27	4	16	0	1	8	0	14	14	1	14	13
Stockpile (runoff + seepage)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste Rock Runoff	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tailings Beach Runoff	1	0	1	1	1	8	0	3	10	0	1	1	9	0	0	0	0	1	0	6	4	0	12	1	3	0	1	1	1
HLF Drainage	8	0	4	2	5	2	8	47	12	5	4	5	1	12	0	0	7	19	0	3	16	1	46	23	13	1	1	6	12
Tailings Slurry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PAG Tailings Pore Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NAG Tailings Pore Water	4	0	0	6	5	4	0	0	1	2	12	4	3	0	0	11	1	0	7	1	6	0	0	2	1	4	6	0	1
Waste Rock Pore Water	36	0	21	44	35	31	0	2	15	8	31	31	19	8	97	84	5	30	55	26	34	10	0	24	8	46	44	65	27
WMP Pump Back	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North TMF Wetland Discharge	35	97	39	42	53	50	6	47	44	29	25	48	63	80	2	0	16	24	33	48	40	87	34	50	61	35	47	13	46
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Year 120 was selected as a representative year during the Pit Discharge Phase
2. Shaded cells are for sources that contribute >10% to the overall load.
3. Values are rounded to the nearest 1 and the total of individual values may not add to exactly 100.

Casino Project
Water Quality Predictions

Appendix V
Seepage Water Management Pond
Water Quality Modelling

Prepared by:

Source Environmental Associates Inc.

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Table of Contents

List of Figures

List of Tables

List of Appendices

1 Introduction

The Casino Project (the Project) is a proposed mining project in the west-central Yukon. The deposit will be mined using open pit methods, with a nominal mill throughput of approximately 120,000 tonnes/day of ore over a 22 year operating life. Milling operations will produce molybdenum and copper concentrates through conventional flotation circuit milling and gold and silver bullion will be produced by cyanide heap leaching.

Seepage water and runoff from the TMF embankment and foundation will be collected by an underdrain system and a surface ditch system that discharge into a Water Management Pond (WMP) located downstream of the TMF main embankment (KPL, 2012). Additionally, the WMP will collect hydrocyclone underflow from the tailings sand used to construct the TMF Embankment. All water collected in the WMP will be pumped back to the TMF Pond during Operations.

Following Operations, the Winter Seepage Mitigation Pond (WSMP) will be constructed to replace the WMP. Seepage recovered downstream from the TMF embankments will be stored in the WSMP through the low flow months of the year (winter), and released during months when Casino Creek flows are higher (spring, summer, and fall) when the seepage water can mix with the TMF Spillway discharge prior to entering Casino Creek.

A site-wide water balance model was developed by KPL (2013a) to be used for water quality modelling, water management and waste deposition planning. Source Environmental Associates Inc. (SEA) combined the water balance flows with mine loading source terms (Lorax, 2013), and background water quality (PECG, 2013) to predict water quality in the WMP / WSMP.

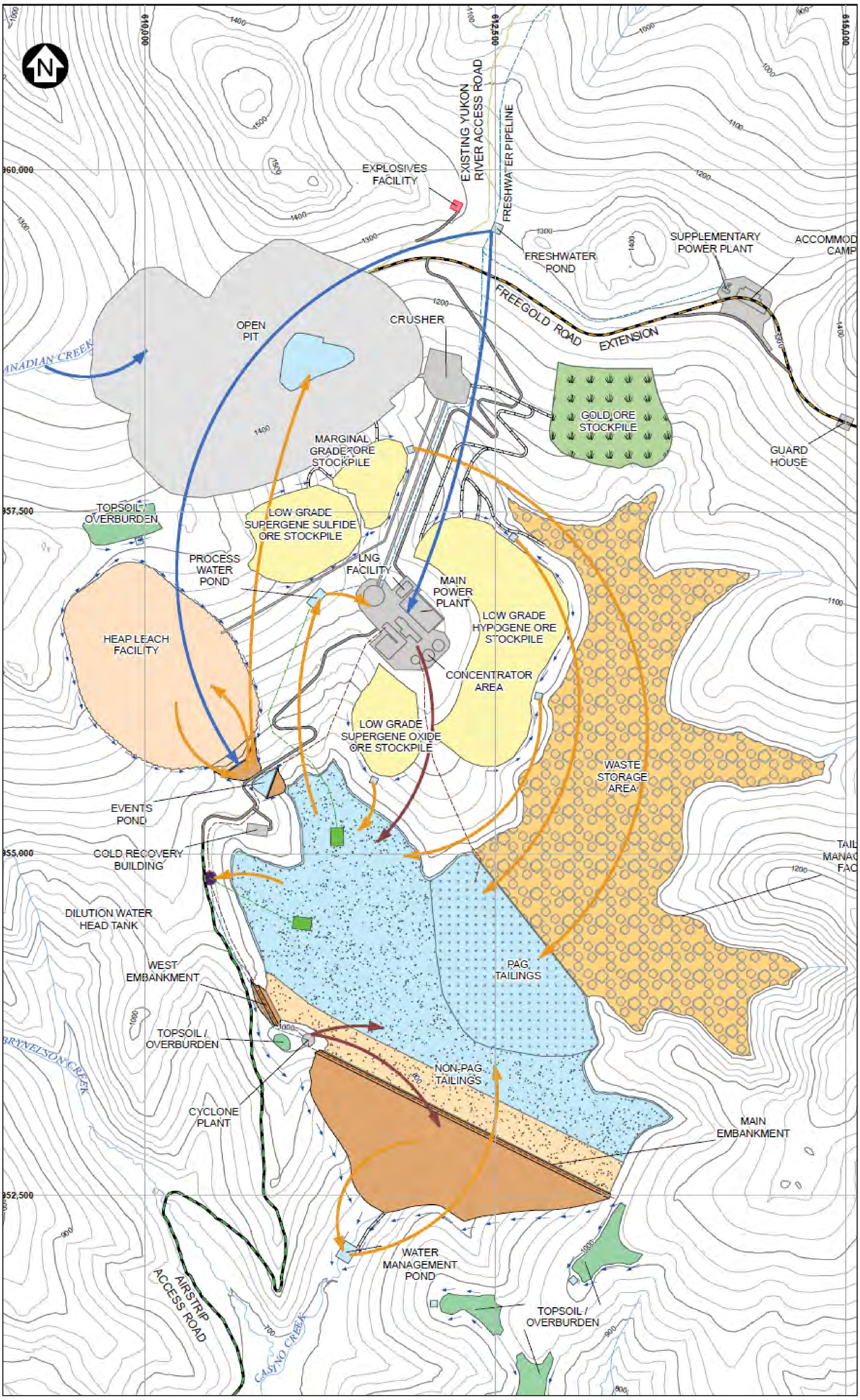
2 Casino Project Water Management Phases

The Casino Project life was sub-divided into five water management phases in this document. Project years are described in years relative to the beginning of milling operations. For example, Year -2 refers to the second year before Operations begins, and Year 2 refers to the second year of Operations.

Relevant project activities related to water quality modeling are provided in Table 2-1. Layout of the Project site is illustrated in Figure 2-1 for Operations. Long-term conditions following mine closure are shown on Figure 2-2.

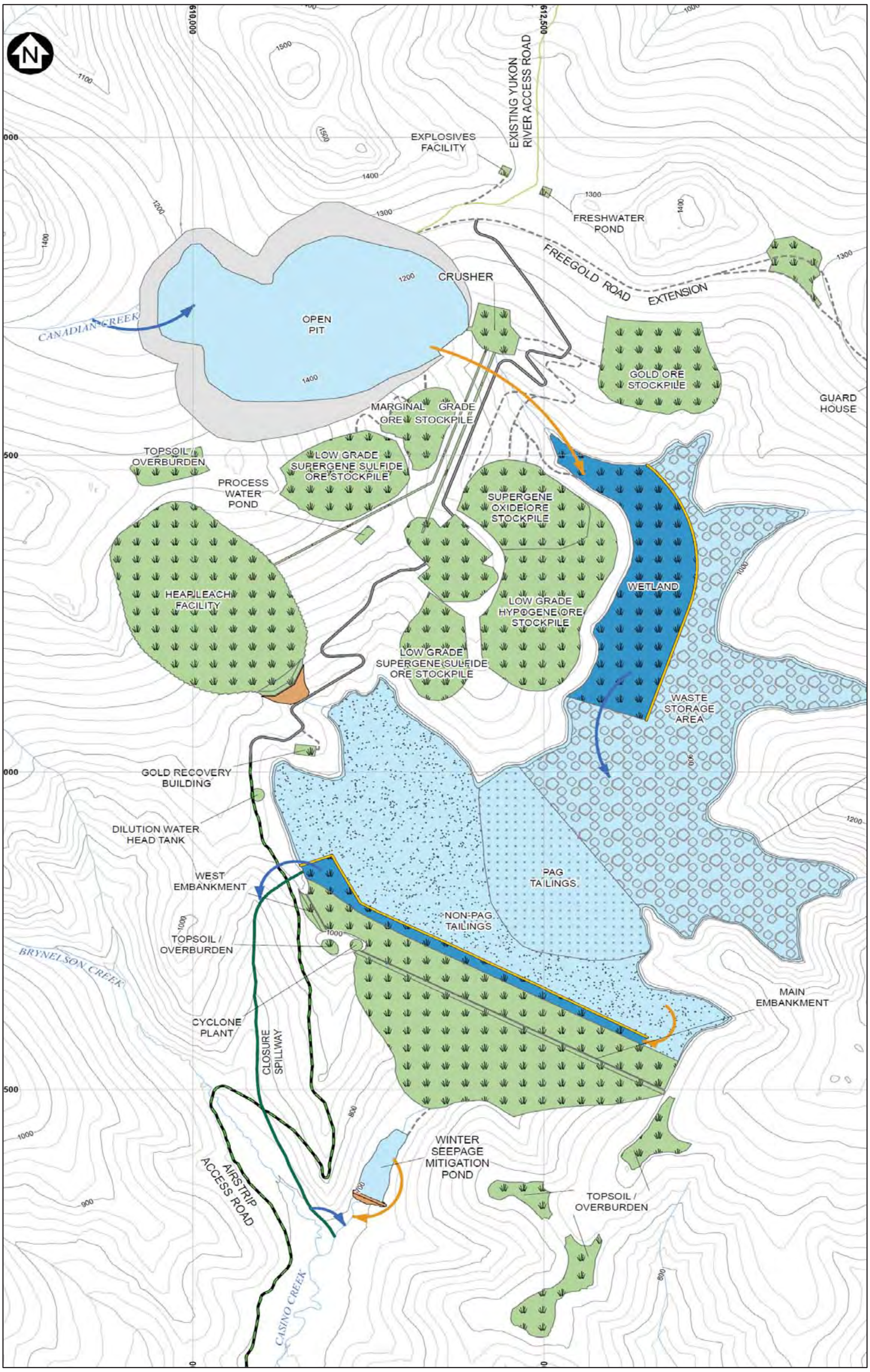
Table 2-1 Water Management Phases

Water Management Phase	Project Year	Project Activities Relevant to WMP and WSMP
Construction	-4 to -1	• Construction of the TMF and associated mining infrastructure. • WMP constructed downstream of the TMF to control sediment and detain runoff from disturbed areas. • Water collected in WMP pumped to TMF Pond.
Operations	1 to 22	• Mining and processing of ore. • Water from TMF embankment and foundation seepage, and surface runoff, and embankment construction water collected in the WMP and pumped back to the TMF Pond.
Wetland Construction	23 to 30	• Cessation of milling. • The Winter Seepage Mitigation Pond (WSMP) constructed downstream from the water management pond part-way through the Closure I Phase. • Pump back from the WMP / WSMP to the TMF Pond. • Re-vegetation of the TMF Embankment
TMF Discharge	31 to 112	• Storage of recovered seepage downstream from the TMF embankments in the WSMP through the low flow months of the year (winter) and release to Casino Creek during the open water season.
Pit Discharge	113 and beyond	



Source: Casino YESAB Water Balance Report (KPL, 2013a)

Figure 2-1 Casino Project Overview (Operations – Year 19)



Source: Casino YESAB Water Balance Report (KPL, 2013a)

Figure 2-2 Casino Project Overview (Pit Discharge Phase)

3 Model Overview

A site-wide water balance model was developed by KPL (2013a). SEA combined the water balance flows with mine loading source terms (from Lorax, 2013), and background water quality to predict water quality in the WMP / WSMP for 29 water quality paramters. The model was developed using GoldSim modelling software and was run with monthly time-steps. The model simulation was run for a time period beginning a few years prior to the Construction Phase, and continued for 200 years following the beginning of the Operations Phase. Average monthly environmental conditions were assumed.

Schematics are provided to illustrate the mass transport pathways associated with the WMP (Figure 3-1) and for the WSMP (Figure 3-2). Tables of model input and output values are provided for each modelled water quality paramaeter in Appendix V - A (model input) and Appendix V - B (model results).

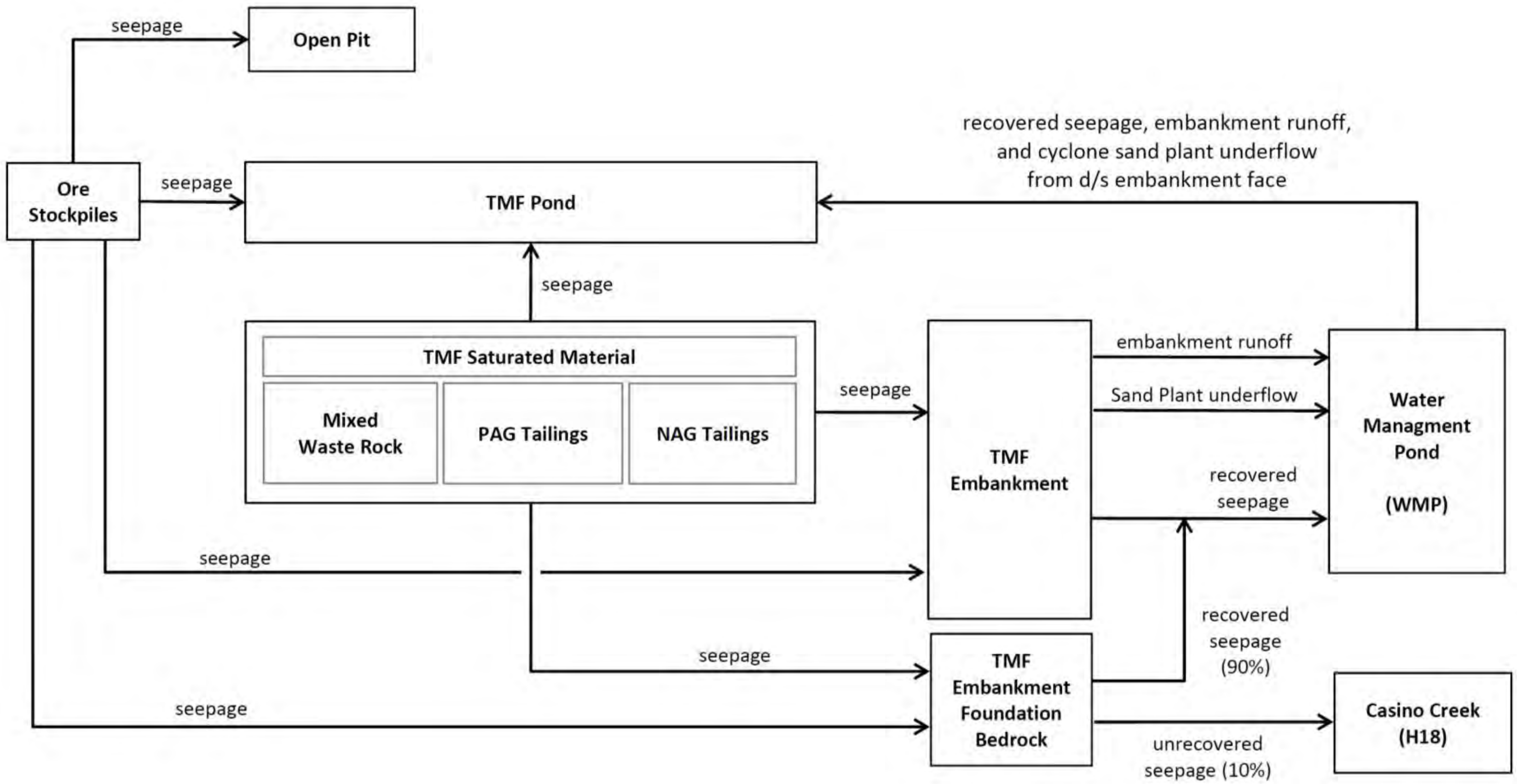


Figure 3-1 Mass Transport Flow Paths Associated with the WMP

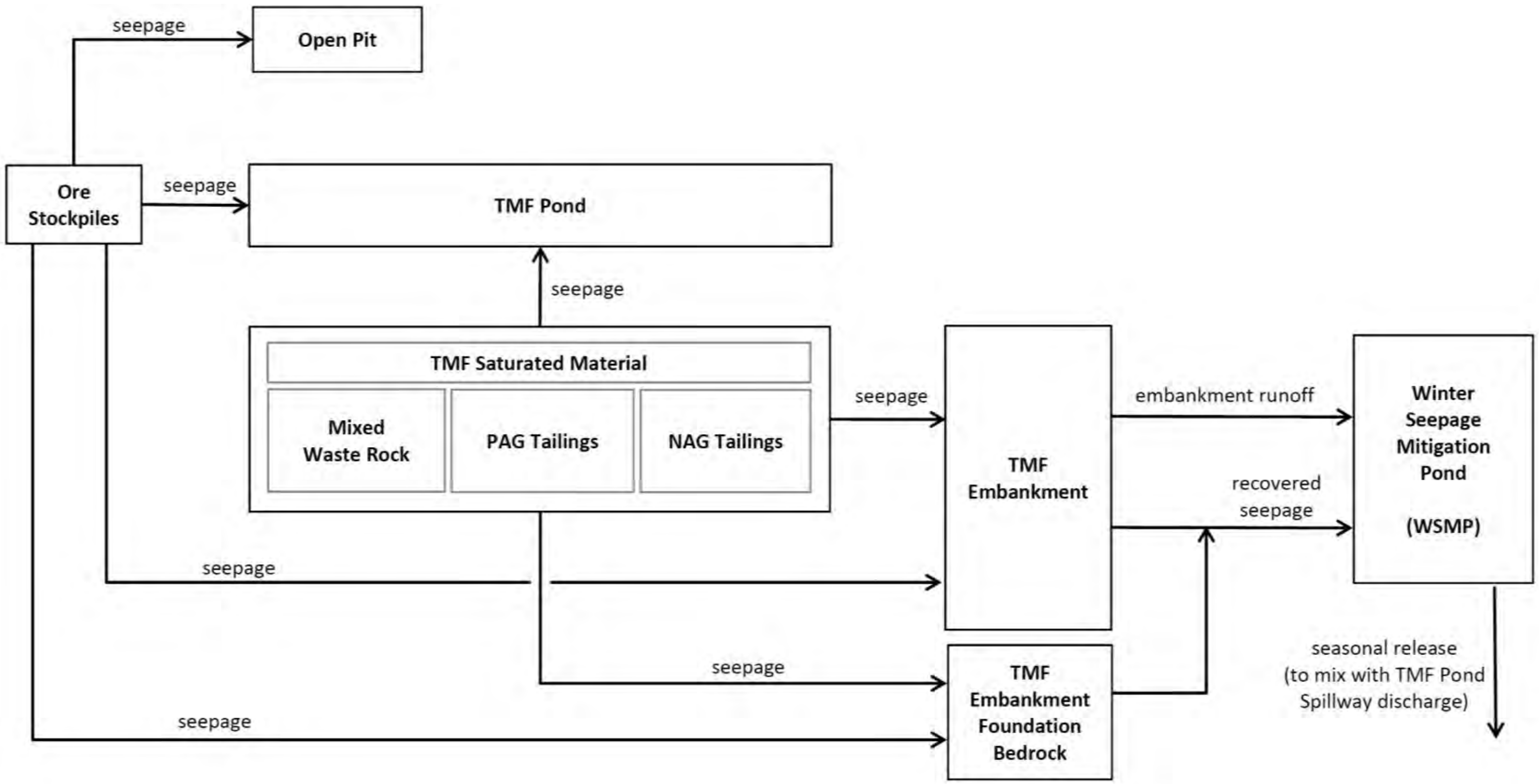


Figure 3-2 Mass Transport Flow Paths Associated with the WSMP

4 Water Balance Model

WMP / WSMP inflow and outflow rates from the KPL water balance were summarized by SEA in Table 4-1 to illustrate the average annual conditions over the duration of the water quality model. Year 60 and Year 120 were selected by SEA as representative years for the TMF Discharge Phase and the Pit Discharge Phase, respectively.

KPL (2013a) assumed that while the WMP is in place (during Operations and until Year 25 in the Wetland Construction Phase), 10% of the total TMF foundation seepage will be unrecovered by the WMP system in a given model time-step, and will report to Casino Creek. The flow rate of unrecovered TMF foundation seepage is provided in Table 4-1.

Following Operations, the WSMP will be constructed to replace the WMP. The KPL water balance model simulated the WSMP coming online (and replacing the WMP) in Year 26. After that time, the WSMP collects 100% of the total TMF seepage.

In the TMF Discharge Phase (and beyond), seepage recovered downstream from the TMF embankments will be stored in the WSMP through the low flow months of the year (winter), and seepage will be released with the TMF Spillway discharge.

KPL (2013a) estimated that for average annual conditions, the WSMP would release water at a constant rate of 130 L/s from May to August (inclusive) and flows would be gradually reduced to approximately 50 L/s by November. The WSMP will collect seepage from December to April. Pond water quality was multiplied by the monthly discharge rate to calculate mass loading into Casino Creek during a given time-step.

Foundation and embankment seepage are expected to increase with the size of the TMF embankment. Seepage rates through the embankment and foundation were predicted by KPL (2013b) using numerical groundwater modelling, and were accounted for by KPL in their water balance model (2013a).

Table 4-1 WMP Water Balance Results

	Water Management Phase	Project Year	Average Annual Inflow (L/s)						Outflow (L/s)		Unrecovered Foundation Seepage to Casino Creek (L/s)
			Overland Runoff	Embank-ment Runoff	Embank-ment Seepage	Founda-tion Seepage	Sand Plant Underflow	Total	Pump-back to TMF Pond	Seasonal Release	
WMP	Operations	1	0.4	1.7	0.7	0.7	142	146	146	0	0.1
		2	0.4	2.7	2.3	2.1	157	165	165	0	0.2
		3	0.4	3.6	3.8	3.5	160	172	172	0	0.4
		4	0.4	4.3	4.9	4.9	170	185	185	0	0.5
		5	0.4	4.8	5.3	6.2	174	191	191	0	0.7
		6	0.3	5.2	5.8	7.4	169	188	188	0	0.8
		7	0.3	5.7	6.2	8.7	170	191	191	0	1.0
		8	0.3	6.1	6.6	9.9	175	198	198	0	1.1
		9	0.3	6.6	7.1	11.2	177	202	202	0	1.2
		10	0.3	7.0	7.6	12.3	172	199	199	0	1.4
		11	0.3	7.4	8.3	13.1	174	203	203	0	1.5
		12	0.3	7.8	8.9	14.0	179	210	210	0	1.6
		13	0.3	8.1	9.6	14.8	179	212	212	0	1.6
		14	0.3	8.5	10.3	15.7	180	215	215	0	1.7
		15	0.3	8.9	10.9	16.5	178	215	215	0	1.8
		16	0.3	9.3	11.6	17.4	175	214	214	0	1.9
		17	0.3	9.6	12.3	18.2	77	117	117	0	2.0
		18	0.3	10.0	12.9	19.1	72	114	114	0	2.1
		19	0.3	10.3	13.6	19.7	72	116	116	0	2.2
		20	0.3	10.4	14.3	20.1	54	99	99	0	2.2
		21	0.2	10.6	15.0	20.4	53	99	99	0	2.3
		22	0.2	10.7	14.8	20.2	0	46	46	0	2.2
	Closure I	23	0.2	10.7	14.0	19.8	0	45	45	0	2.2
		24	0.2	10.7	14.0	19.8	0	45	45	0	2.2
		25	0.2	10.7	14.0	19.8	0	45	45	0	2.2
WSMP		26	15.7	10.7	14.0	22	0	62	62	0	0
		27	15.7	10.7	14.0	22	0	62	62	0	0
		28	15.7	10.7	14.0	22	0	62	62	0	0
		29	15.7	10.7	14.0	22	0	62	62	0	0
		30	15.7	10.7	14.0	22	0	62	62	0	0
	Closure II	60	15.7	10.7	14.0	22	0	62	0	62	0
	Closure III	120	15.7	10.7	14.0	22	0	62	0	62	0

5 Water Quality Model

This section provides a description of the modelling methodology that was used for the prediction of mass transport of substances to the WMP / WSMP and the resulting water quality. Relevant water balance components are discussed where applicable to the water quality modelling calculations.

5.1 WMP/WSMP Inflows

Inflows to the WMP and WSMP include: overland runoff; TMF embankment runoff; TMF embankment and foundation seepage collected by the seepage collection system; Cyclone Sand Plant underflow water; and, groundwater impacted by ore stockpile seepage.

5.1.1 Background Overland Runoff

Runoff from the undisturbed upslope area (i.e. background runoff) of the WMP / WSMP will be collected in the ponds. Mean annual runoff into the ponds are presented in Table 4-1. Median annual water quality from baseline sampling station at Brynelson Creek (W18) was used to calculate the mass loading to the WMP / WSMP. Input water quality values are provided in Appendix V - A (Table V - A 1).

5.1.2 TMF Embankment Runoff

NAG tailings will be used for the production of cyclone sand for construction of the TMF Embankments (KPL, 2012). According to KPL (2013a), the final drainage area of the embankments will be 1.2 km^2. Runoff from the downstream face of the embankments will be intercepted by collection ditches and directed to the WMP / WSMP. Average annual runoff from the embankment is provided in Table 4-1.

The mass loading rate of the embankment runoff into the WMP / WSMP was calculated as the monthly flow rate, multiplied by the runoff concentration. The embankment face will be re-vegetated upon mine closure. As a result, metal and sulphate leaching rates are expected to be lower following Operations as the re-vegetation will reduce contact of water with the embankment sand. Lorax (2013) provided runoff concentrations for Operations and Post-Closure (Appendix V-A, Table V - A 1).

5.1.3 TMF Embankment and Foundation Seepage

The foundation and embankment seepage are expected to increase with the size of the TMF facility and embankment footprint. Average annual seepage rates are provided in Table 4-1.

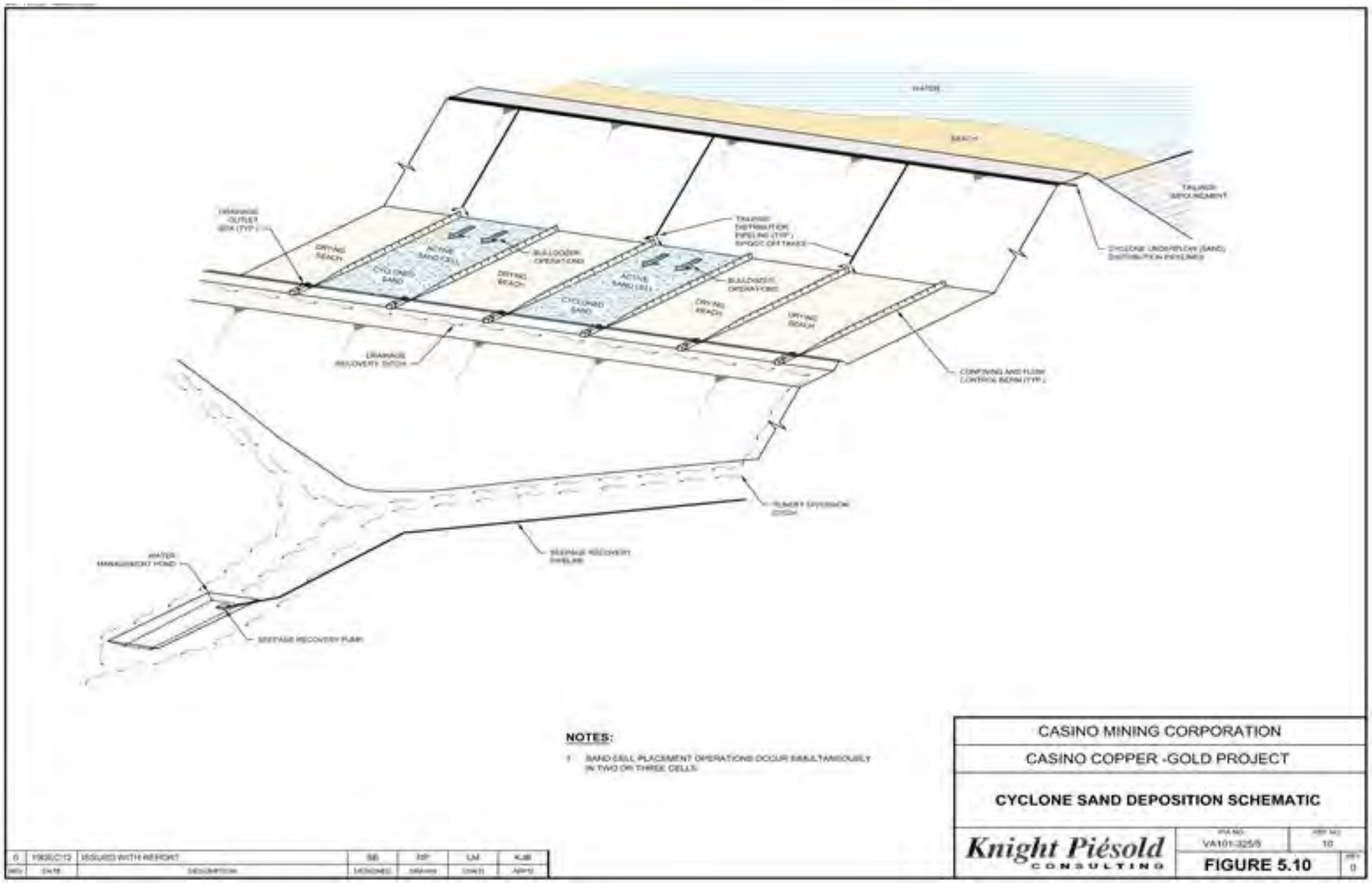
According to Lorax (2013), the seepage water quality will be affected by the quantity and source terms of the waste rock and tailings deposited in the TMF. As a result, Lorax provided source terms for the following stages of TMF Development: Year 4, 9, 19, 22, and >22 (Appendix V - A V-A, Table V - A 1). Mass loading into the WMP / WSMP were calculated by multiplying the seepage water quality by the seepage flow rate over a given time step. Seepage concentrations for years not explicitly provided by Lorax were assumed to be equal to the nearest later year (i.e., Years 0-4 were equal to Year 4, Years 5-9 were equal to Year 9, etc.).

TMF seepage was assumed to travel instantaneously from the source to receptor (i.e. through the embankment and through the foundation).

5.1.4 Cyclone Sand Plant Underflow (Embankment Construction Water)

During Operations, cyclone sand will be produced from bulk NAG tailings and discharged to the embankment for construction. Water expelled from the sand will be collected in the WMP (Figure 5-1).

Mill process (tailings slurry) water was used to represent the water quality of the embankment construction water. Loading into the WMP Pond was calculated as the concentration in the slurry water multiplied by the total slurry water inflow rate. Tailings slurry water quality changes over time for certain parameters, as discussed in Appendix IV – TMF Pond Water Quality Modelling.



Source: KPL (2012)

Figure 5-1 Cyclone Sand Deposition Schematic

5.1.5 Ore Stockpile Seepage

While the ore stockpiles are present during Operations, contact water (from rainfall and snowmelt) will drain from the rock as runoff or infiltration to groundwater. Runoff from the stockpiles will be captured by the TMF Pond.

Hydrogeological modelling (KPL, 2013b) indicated that depending on the stockpile location, infiltrated contact water will flow to one or more of the following receptors: the TMF Pond; Open Pit; TMF Embankment (towards the WMP); or TMF Foundation bedrock (towards the WMP and Casino Creek). SEA estimated an average travel time from a range of seepage travel times provided by KPL (2013b) and assumed that the mass load associated with the stockpile seepage will report to the WMP after a lag-time equal to the seepage travel time (Table 5-1).

Table 5-1 Seepage Travel Time from Stockpiles to WMP / WSMP

Stockpile	Seepage Travel time to WMP / WSMP via TMF Embankment [1] (years)	Seepage Travel time to WMP / WSMP via TMF Foundation [1] (years)
Gold Ore	(note 2)	(note 2)
Marginal Grade Ore	(note 2)	(note 2)
Supergene Oxide Ore	8.3	(note 2)
Low Grade Supergene Oxide Ore[3]	7.7	28
Low Grade Supergene Sulphide Ore	(note 2)	(note 2)
Low Grade Hypogene Ore	8.3	15

1. Average estimated travel time from KPL (2013b) hydrogeological modelling assessment.
2. Not expected to report to the TMF Embankment or Foundation
3. Seepage control is planned for this pile that is 90% efficient.

Seepage and runoff concentrations into the groundwater were calculated by combining the seepage flow rates with mass loading rates. Calculation methodology of stockpile mass loading is described in Appendix II (Ore Stockpile Water Quality Modelling).

5.2 WMP / WSMP Outflow

5.2.1 WMP / WSMP Pump Back to the TMF Pond

KPL (2013a) assumed that 100% of water collected in the WMP / WSMP will be pumped back to the TMF during Operations and Wetland Construction. Average annual outflow is presented Table 4-1. Water quality in the WMP was multiplied by the monthly pumping rate to calculate mass loading from the WMP to the TMF Pond.

5.2.2 WSMP Seasonal Release

KPL (2013a) estimated that during TMF Discharge and Pit Discharge (average annual conditions), the WSMP will release water at a constant rate of 130 L/s from May to August (inclusive) and flows would be gradually reduced to approximately 50 L/s by November. After that time, the WSMP will collect seepage from December to April. WSMP water quality was multiplied by the monthly discharge rate to calculate mass loading into Casino Creek during a given time-step.

5.3 Calculation of Water Quality in the WMP / WSMP

Water quality in the WMP was calculated as the cumulative mass of a given substance in the pond water, divided by the water volume stored in a pond over a given time step interval.

6 Results and Discussion

6.1 Water Pumped to the TMF Pond (Operations and Wetland Construction)

KPL (2013a) predicted that during Operations (Year 1 to Year 22), the average pump-back rate to the TMF Pond would be approximately 168 L/s (Table 2-1). During the Wetland Construction Phase, after the WSMP has been put in place (Year 26 to Year 30 in the model), the average rate of pump-back to the TMF Pond will be approximately 62 L/s. Pumped back water quality is presented for a typical year during Operations (Year 15) and Wetland Construction (Year 28). These results are provided for select parameters in Table 6-1 and for the full set of modelled parameters in Appendix V - B (Table V - B 1Water Pumped to the TMF Pond from the WMP / WSMP).

Table 6-1 Water Pumped to the TMF Pond from the WMP / WSMP

Water Quality Model Parameter		Water Quality (mg/L)	
		WMP [1] (Operations)	WSMP [2] (Wetland Construction)
Sulphate	(SO_4)	1,334	694
Cadmium	(Cd)	0.0007	0.0009
Copper	(Cu)	0.028	0.030
Iron	(Fe)	1.8	2.6
Molybdenum	(Mo)	0.31	0.18
Selenium	(Se)	0.0088	0.0054
Uranium	(U)	0.011	0.028
Average Annual Flow	**(L/s)**	**215**	**62**

1. Average annual water quality and flow for a representative year in Operation (Year 15).
2. Average annual water quality and flow for a representative year Wetland Construction (Year 28).

6.2 Water Released to the Receiving Environment

KPL (2013a) predicted that during Operations, up to 2.2 L/s (annual average) of seepage will bypass the WMP (Table 2-1) and will enter Casino Creek. The unrecovered seepage water quality will be influenced by the saturated TMF tailings and waste rock, and (temporarily) ore stockpile seepage. Unrecovered seepage water quality is presented for a representative year during Operations (Year 15) for select parameters in Table 6-3 and for the full set of modelled parameters in Appendix V - B (Table V - B 2).

Table 6-2 Unrecovered Seepage Water Quality

Water Quality Model Parameter		Water Quality (mg/L)	
		WMP Bypass [1] (Operations to Year 25)	WSMP (Year 26 to Year 30)
Sulphate	(SO_4)	1,320	-
Cadmium	(Cd)	0.0014	-
Copper	(Cu)	0.052	-
Iron	(Fe)	4.9	-
Molybdenum	(Mo)	0.27	-
Selenium	(Se)	0.0092	-
Uranium	(U)	0.032	-
Average Annual Flow	**(L/s)**	**1.8**	**no bypass flow**

1. Average annual water quality and flow for a representative year in Operation (Year 15).

The average annual discharge from the WSMP was predicted by KPL (2013a) to be 62 L/s during TMF Discharge and Pit Discharge Phases (Table 4-1) and will be released at a controlled flow rate of up to 130 L/s during the warmest months of the year when flow rates in Casino Creek are at their highest. WSMP discharge water quality are provided for a typical year during TMF Discharge and Pit Discharge in Table 6-3 for select parameters, and in Appendix V - B (Table V - B 3) for the full set of modelled parameters. Time series plots of WSMP water qualty are provided on Figure 6-1 to Figure 6-7 for select parameters.

Winter hold-back in the WSMP was modelled with a cell pathway in GoldSim so that mass conservation was achieved. PHREEQC modelling of the WSMP was conducted and the results indicated that no precipitation would occur in the WSMP over the winter because the pH is low (about pH 3.5). The low pH is a result of iron oxidation from the reducing conditions in groundwater compared to the oxidizing conditions in the WSMP. As a result, the mixing of the TMF pond water (relatively alkaline) with the WSMP release in summer was, in effect, used as a mitigation measure. Iron will be removed by precipitation after mixing with the TMF pond water because the pH of the resulting mixture will be neutral.

Table 6-3 Water Quality of Recovered Seepage Released to the Receiving Environment

Water Quality Model Parameter		WSMP Water Quality (mg/L)
		TMF Discharge and Pit Discharge Phases[1]
Sulphate	(SO_4)	861
Cadmium	(Cd)	0.0011
Copper	(Cu)	0.034
Iron	(Fe)	3.3
Molybdenum	(Mo)	0.24
Selenium	(Se)	0.0065
Uranium	(U)	0.039
Average Annual Flow	(L/s)	62

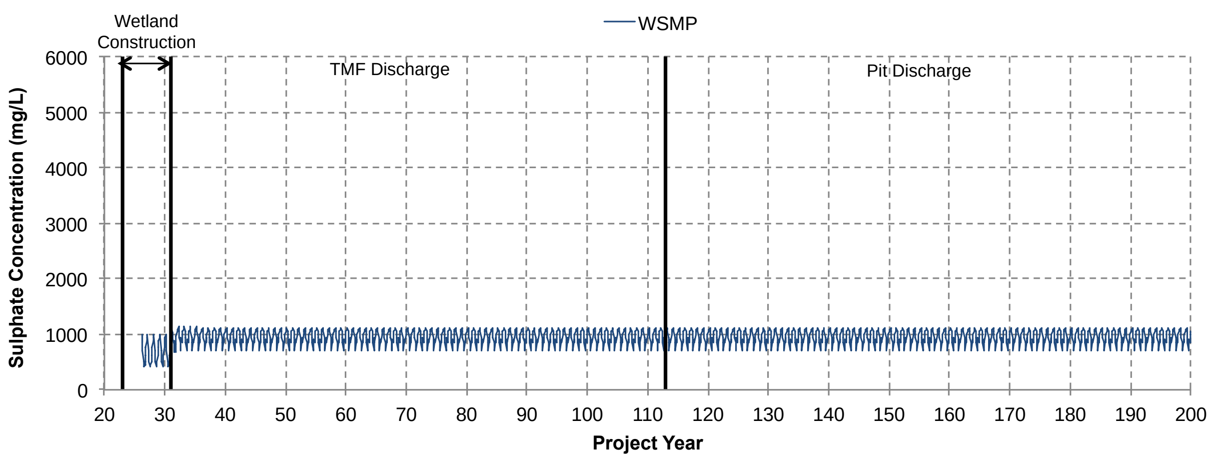


Figure 6-1 Modelled Sulphate Water Quality in the WSMP

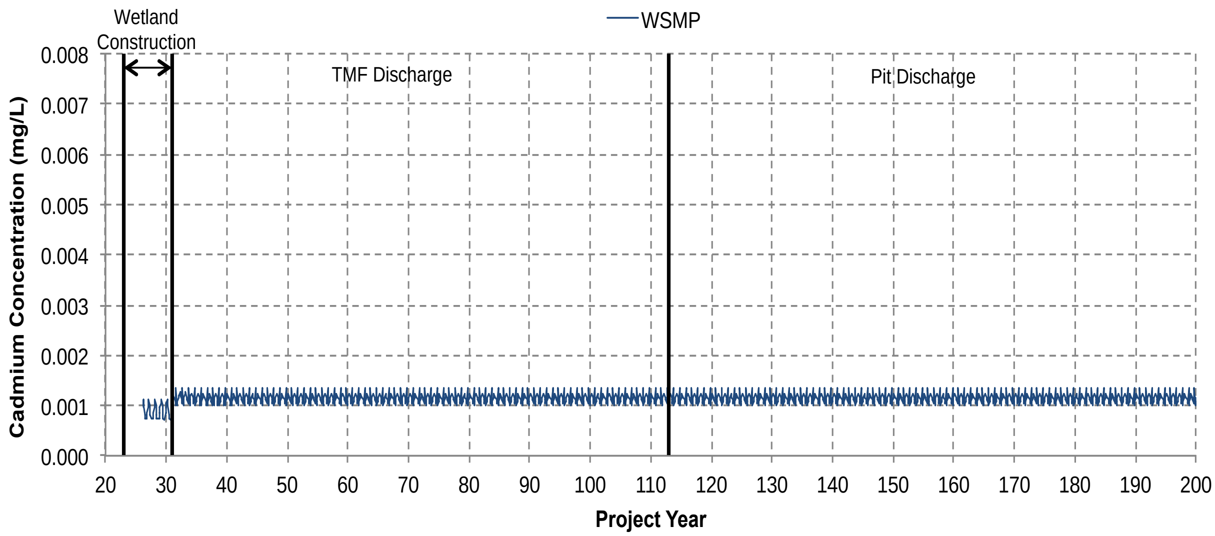


Figure 6-2 Modelled Cadmium Water Quality in the WSMP

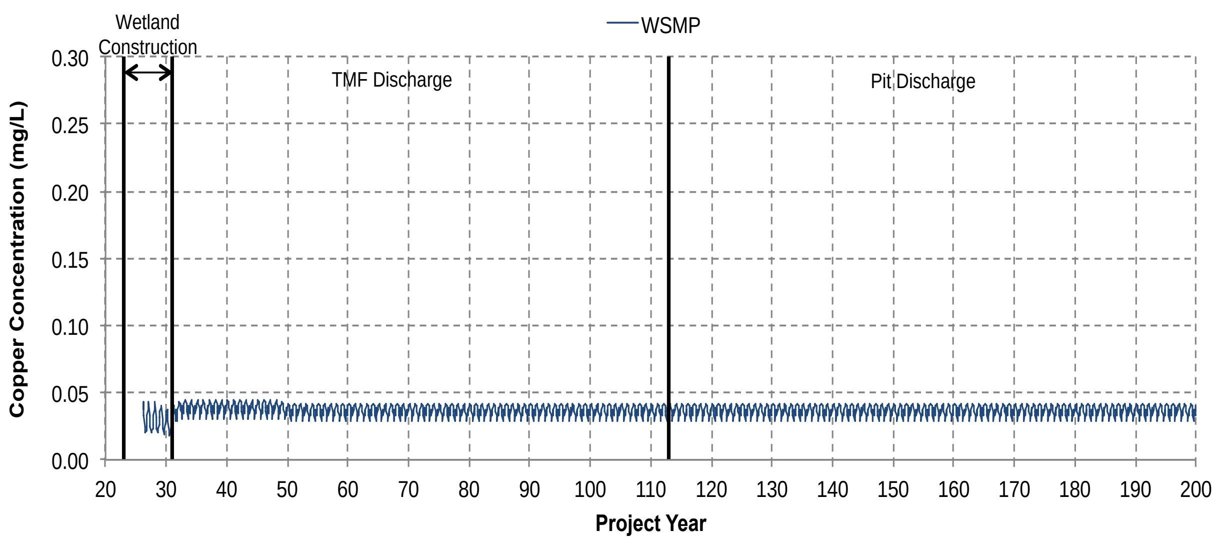


Figure 6-3 Modelled Copper Water Quality in the WSMP

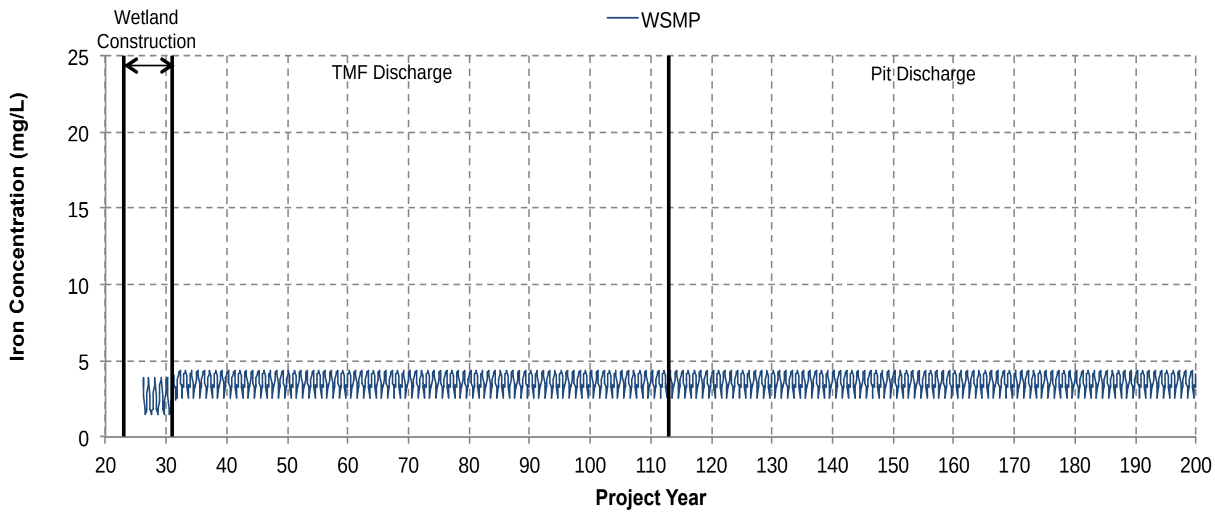


Figure 6-4 Modelled Iron Water Quality in the WSMP

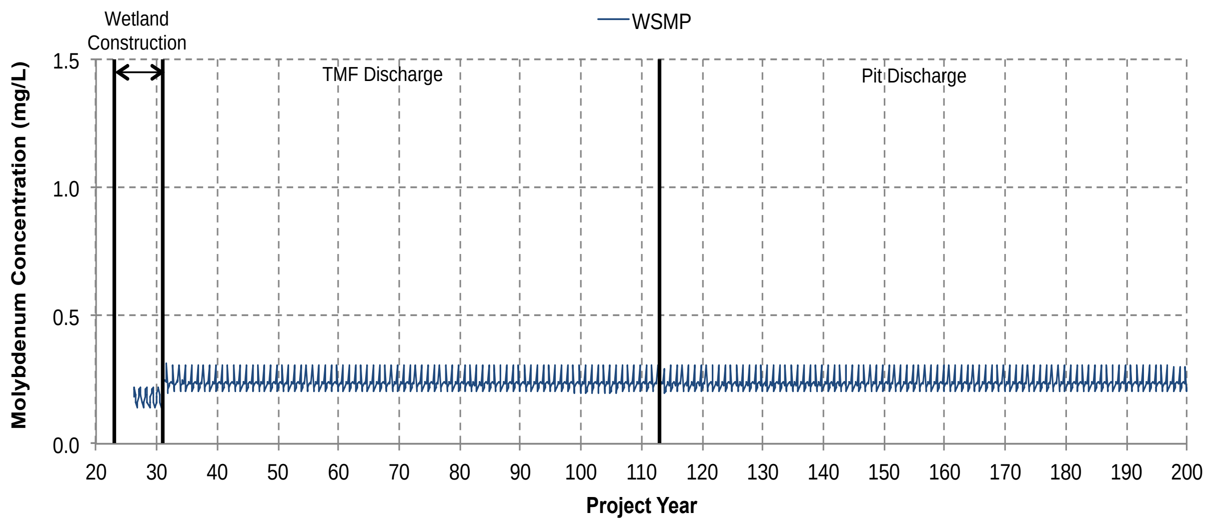


Figure 6-5 Modelled Molybdenum Water Quality in the WSMP

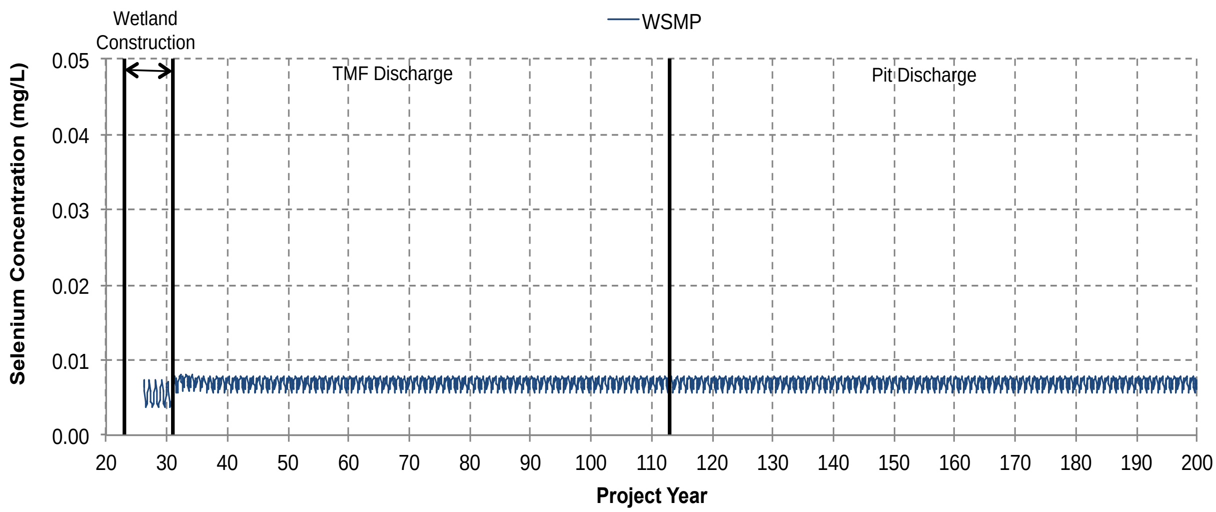


Figure 6-6 Modelled Selenium Water Quality in the WSMP

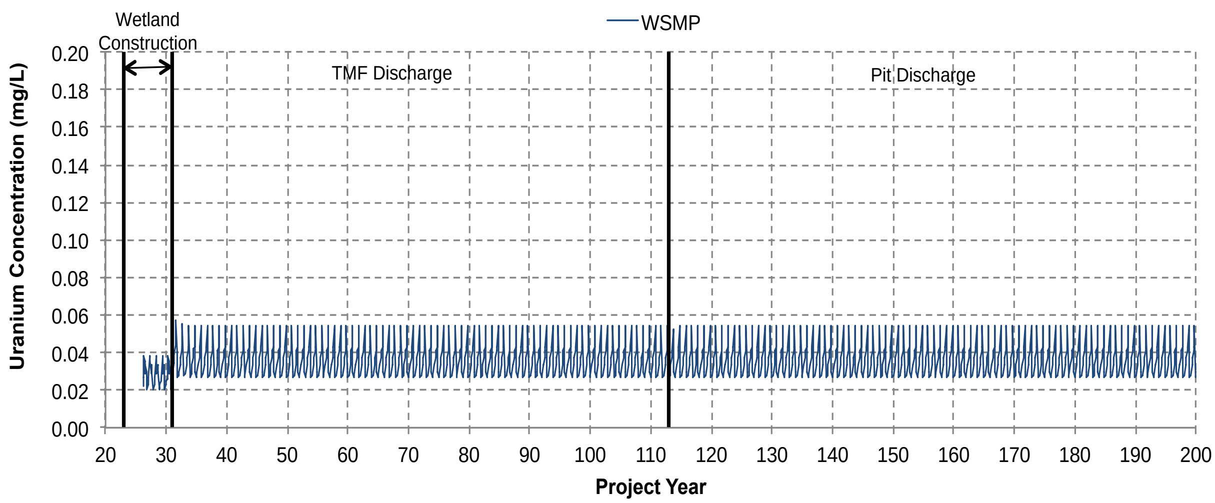


Figure 6-7 Modelled Uranium Water Quality in the WSMP

6.3 Individual Contributions of Mass Loading Sources

Individual contributions of mass loading sources are presented in Appendix V - B. During operations (Table V - B 4 Fraction Contributing to WMP Water Quality – Operations Phase (Year 15), the majority of the loadings to the WMP come from seepage or the sand plant underflow. During TMF Discharge and Pit Discharge (Table V - B 5), foundation and embankment seepage are the highest contributors to mass loading to the WSMP.

Table 6-4 Loading Contributions to the WMP (Operations)

Source of Loading	Fraction Contributing (%)						
	SO_4	Cd	Cu	Fe	Mo	Se	U
Background Runoff	0	0	0	0	0	0	0
Embankment Runoff	1	49	13	0	23	2	25
Stockpile Seepage	0	1	25	0	0	0	1
Tailings and Waste Rock Seepage	13	42	35	92	11	13	38
Sand Plant Slurry Underflow	86	8	28	7	66	85	36
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Year 15 was selected as the representative year during Operations.
2. Shaded cells are for sources that contribute >10% to the overall load.
3. Values are rounded to the nearest whole number and the total of individual values may not add to exactly 100.

Table 6-5 Loading Contributions to the WSMP (TMF Discharge / Pit Discharge Phases)

Source of Loading	Fraction Contributing (%)						
	SO_4	Cd	Cu	Fe	Mo	Se	U
Background Runoff	1	0	1	1	0	0	3
Embankment Runoff	4	20	9	0	29	13	46
Stockpile Seepage	0	0	0	0	0	0	0
Tailings and Waste Rock Seepage	96	80	90	99	71	87	51
Sand Plant Slurry Underflow	0	0	0	0	0	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Results represent TMF Discharge and Pit Discharge Phases.
2. Shaded cells are for sources that contribute >10% to the overall load.
3. Values are rounded to the nearest whole number and the total of individual values may not add to exactly 100.

7 References

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Lorax Environmental, 2013. Casino Geochemical Source Term Development. Project No. J862-5. Prepared for Casino Mining Corporation. December 4, 2013.

Appendix V - A

Water Quality Modelling Input Data

Table V - A 1 Source Terms for Inflows to the WMP / WSMP

Water Quality Model Parameter	Background Runoff (W18)	Embankment Runoff		Foundation Seepage (mg/L)					Embankment Seepage (mg/L)					Sand Plant Underflow	
		Operations	Post-Closure	Year 4	Year 9	Year 19	Year 22	> Year 22	Year 4	Year 9	Year 19	Year 22	> Year 22	Water Quality	Accumu-lation
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(g/tonne)
Hardness	74	333	571	1,262	1,277	1,283	1,289	1,297	1,257	1,256	1,258	1,259	1,262	1,248	
Acidity	1.2	0.053	0.051											0	
Alkalinity	63	95	124	45	56	54	53	51	64	64	64	64	64	63	
Sulphate (SO_4)	23	463	170	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	
Chloride (Cl)	0.25	8.2	69	36	36	36	36	36	36	36	36	36	36	36	
Fluoride (F)	0.040	0.55	2.5	2.2	2.1	2.2	2.2	2.2	2.1	2.1	2.1	2.1	2.1	2.2	
Aluminum (Al)	0.036	0.0040	0.0040	0.0020	0.0037	0.0033	0.0032	0.0028	0.0057	0.0057	0.0057	0.0057	0.0058	4.8	
Antimony (Sb)	0.00014	0.045	0.15	0.0031	0.0028	0.0028	0.0027	0.0028	0.0025	0.0025	0.0026	0.0025	0.0026	0.0025	0.0020
Arsenic (As)	0.00039	0.041	0.026	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0041	0.0033
Barium (Ba)	0.044	0.010	0.031	0.13	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.058	
Cadmium (Cd)	0.000013	0.0054	0.0012	0.0012	0.0014	0.0014	0.0014	0.0014	0.0016	0.0016	0.0016	0.0016	0.0016	0.000043	
Calcium (Ca)	20	120	193	498	498	498	498	498	498	498	498	498	498	497	
Chromium (Cr)	0.00015	0.026	0.0080	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	
Cobalt (Co)	0.000054	0.0089	0.0043	0.0048	0.0064	0.0077	0.0086	0.010	0.0016	0.0016	0.0019	0.0020	0.0023	0.00075	
Copper (Cu)	0.0012	0.048	0.016	0.12	0.044	0.052	0.054	0.065	0.017	0.020	0.027	0.027	0.027	0.0050	
Iron (Fe)	0.053	0.0052	0.0052	4.3	5.0	4.9	4.9	4.7	5.9	5.9	6.0	6.0	6.0	0.060	
Lead (Pb)	0.000061	0.000055	0.000092	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	
Magnesium (Mg)	5.8	8.1	22	4.2	7.8	9.4	11	13	2.9	2.7	3.3	3.3	4.1	1.3	
Manganese (Mn)	0.0037	0.0087	0.0073	1.8	2.2	2.1	2.2	2.1	2.4	2.4	2.4	2.4	2.5	0.0015	
Mercury (Hg)	0.0000050	0.00012	0.000080	0.000018	0.000015	0.000017	0.000017	0.000020	0.000010	0.0000085	0.000010	0.000010	0.000013	0.0000050	
Molybdenum (Mo)	0.0012	1.7	0.39	0.27	0.28	0.27	0.27	0.27	0.29	0.29	0.29	0.29	0.29	0.24	0.20
Nickel (Ni)	0.00030	0.027	0.0088	0.0031	0.0039	0.0043	0.0047	0.0052	0.0025	0.0026	0.0027	0.0027	0.0028	0.0025	
Potassium (K)	1.0	184	26											86	
Selenium (Se)	0.000040	0.0033	0.0046	0.0085	0.0090	0.0092	0.0094	0.0096	0.0085	0.0085	0.0086	0.0086	0.0086	0.0085	0.0070
Silver (Ag)	0.0000025	0.00036	0.00013	0.000056	0.000051	0.000051	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	
Sodium (Na)	3.3	9.1	1.1	37	40	40	40	41	38	38	38	38	38	35	
Thallium (Tl)	0.0000030	0.00052	0.00019	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	
Uranium (U)	0.0034	0.046	0.100	0.0071	0.026	0.032	0.040	0.048	0.0040	0.0039	0.0059	0.0063	0.0089	0.0031	0.0025
Zinc (Zn)	0.0014	0.11	0.024	0.023	0.020	0.023	0.023	0.026	0.011	0.011	0.012	0.012	0.013	0.0061	

Appendix V - B

Water Quality Modelling Results

Table V - B 1 Water Pumped to the TMF Pond from the WMP / WSMP

Water Quality Model Parameter		Water Quality (mg/L)	
		WMP [1] (Operations)	WSMP [2] (Wetland Construction)
Hardness		1,267	728
Acidity		0.072	0.23
Alkalinity		64	53
Sulphate	(SO_4)	1,334	694
Chloride	(Cl)	36	26
Fluoride	(F)	2.2	1.4
Aluminum	(Al)	3.2	0.012
Antimony	(Sb)	0.0040	0.017
Arsenic	(As)	0.0054	0.0049
Barium	(Ba)	0.075	0.066
Cadmium	(Cd)	0.00069	0.0009
Calcium	(Ca)	501	277
Chromium	(Cr)	0.0033	0.0021
Cobalt	(Co)	0.0026	0.0041
Copper	(Cu)	0.028	0.030
Iron	(Fe)	1.8	2.6
Lead	(Pb)	0.0013	0.00065
Magnesium	(Mg)	3.4	8
Manganese	(Mn)	0.73	1.1
Mercury	(Hg)	0.000012	0.000018
Molybdenum	(Mo)	0.31	0.18
Nickel	(Ni)	0.0039	0.0032
Potassium	(K)	64	3.0
Selenium	(Se)	0.0088	0.0054
Silver	(Ag)	0.000062	0.000040
Sodium	(Na)	37	21
Thallium	(Tl)	0.00052	0.00027
Uranium	(U)	0.011	0.028
Zinc	(Zn)	0.014	0.014
Average Annual Flow	**(L/s)**	**215**	**62**

1. Average annual water quality and flow for a representative year in Operation (Year 15).
2. Average annual water quality and flow for a representative year Wetland Construction (Year 28).

Table V - B 2 Unrecovered Seepage Water Quality

Water Quality Model Parameter		Water Quality (mg/L)	
		WMP Bypass [1] (Operations to Year 25)	WSMP [2] (Year 26 to Year 30)
Hardness		1,283	-
Acidity		0	-
Alkalinity		54	-
Sulphate	(SO_4)	1,320	-
Chloride	(Cl)	36	-
Fluoride	(F)	2.1	-
Aluminum	(Al)	0.0033	-
Antimony	(Sb)	0.0028	-
Arsenic	(As)	0.0043	-
Barium	(Ba)	0.11	-
Cadmium	(Cd)	0.0014	-
Calcium	(Ca)	498	-
Chromium	(Cr)	0.0025	-
Cobalt	(Co)	0.0077	-
Copper	(Cu)	0.052	-
Iron	(Fe)	4.9	-
Lead	(Pb)	0.0013	-
Magnesium	(Mg)	9.4	-
Manganese	(Mn)	2.1	-
Mercury	(Hg)	0.000017	-
Molybdenum	(Mo)	0.27	-
Nickel	(Ni)	0.0043	-
Potassium	(K)	0	-
Selenium	(Se)	0.0092	-
Silver	(Ag)	0.000051	-
Sodium	(Na)	40	-
Thallium	(Tl)	0.00050	-
Uranium	(U)	0.032	-
Zinc	(Zn)	0.023	-
Average Annual Flow	**(L/s)**	**1.8**	**no flow**

1. Average annual water quality and flow for a representative year (Year 15) in Operations.
2. After Year 26 (once WSMP comes online)

Table V - B 3 Water Quality of Recovered Seepage Released to the Receiving Environment

Water Quality Model Parameter		WSMP Water Quality (mg/L)
		TMF Discharge and Pit Discharge Phases
Hardness		925
Acidity		0.34
Alkalinity		74
Sulphate	(SO_4)	861
Chloride	(Cl)	35
Fluoride	(F)	1.8
Aluminum	(Al)	0.015
Antimony	(Sb)	0.029
Arsenic	(As)	0.0074
Barium	(Ba)	0.085
Cadmium	(Cd)	0.0011
Calcium	(Ca)	351
Chromium	(Cr)	0.0030
Cobalt	(Co)	0.0052
Copper	(Cu)	0.034
Iron	(Fe)	3.3
Lead	(Pb)	0.00081
Magnesium	(Mg)	11
Manganese	(Mn)	1.4
Mercury	(Hg)	0.000026
Molybdenum	(Mo)	0.24
Nickel	(Ni)	0.0043
Potassium	(K)	5.0
Selenium	(Se)	0.0065
Silver	(Ag)	0.000055
Sodium	(Na)	26
Thallium	(Tl)	0.00035
Uranium	(U)	0.039
Zinc	(Zn)	0.018
Average Annual Flow	**(L/s)**	**62**

Table V - B 4 Fraction Contributing to WMP Water Quality – Operations Phase (Year 15)

Parameter	Hard-ness	Acid-ity	Alk	SO4	Cl	F	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Hg	Mo	Ni	K	Se	Ag	Na	Tl	U	Zn
Background Runoff	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Embankment Runoff	1	7	6	1	1	1	0	42	29	1	49	1	30	21	13	0	0	14	0	45	23	29	9	2	23	1	4	25	36
Stockpile Seepage	0	87	0	0	0	0	0	1	0	0	1	0	0	1	25	0	0	0	0	1	0	2	0	0	0	0	0	1	2
Tailings and Waste Rock Seepage	13	0	11	13	13	12	0	8	9	22	42	13	9	40	35	92	13	38	99	16	11	12	0	13	10	14	12	38	19
Sand Plant Slurry Underflow	86	0	83	86	86	87	100	49	61	78	8	86	61	38	28	7	87	47	0	39	66	56	91	85	67	85	84	36	43
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table V - B 5 Fraction Contributing to WSMP Water Quality – TMF Discharge and Pit Discharge Phases

Parameter	Hard-ness	Acid-ity	Alk	SO4	Cl	F	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Hg	Mo	Ni	K	Se	Ag	Na	Tl	U	Zn
Background Runoff	2	97	23	1	0	1	79	0	1	15	0	2	1	0	1	1	2	15	0	5	0	2	6	0	1	4	0	3	2
Embankment Runoff	11	3	31	4	36	26	5	94	63	7	20	10	48	15	9	0	2	35	0	55	29	37	94	13	42	1	10	46	25
Stockpile Seepage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tailings and Waste Rock Seepage	86	0	47	96	64	74	16	6	36	79	80	88	51	85	90	99	96	50	100	39	71	61	0	87	56	96	90	51	73
Sand Plant Slurry Underflow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1. Shaded cells are for sources that contribute >10% to the overall load.

Casino Project
Water Quality Predictions

Appendix VI
Receiving Environment Water Quality Modelling

Prepared by:

Source
ENVIRONMENTAL ASSOCIATES INC.

December 2013

Table VI-1 Baseline Water Quality in Brynelsen Creek (W18)

Water Quality Model Parameter		CCME Guideline (mg/L)	W18 Median Water Quality (mg/L)			
			All Data	Winter	Spring	Summer
Hardness			74	116	63	63
Acidity			1.2	0.73	1.5	1.5
Alkalinity			63	88	51	51
Sulphate	(SO_4)	218	23	38	20	20
Chloride	(Cl)	640	0.25	0.25	0.25	0.25
Fluoride	(F)	0.12	0.040	0.050	0.040	0.040
Aluminum	(Al)	0.10	0.036	0.0079	0.066	0.066
Antimony	(Sb)		0.00014	0.00015	0.00014	0.00014
Arsenic	(As)	0.0050	0.00039	0.00036	0.00043	0.00043
Barium	(Ba)		0.044	0.058	0.040	0.040
Cadmium	(Cd)	0.000026	0.000013	0.000011	0.000015	0.000015
Calcium	(Ca)		20	31	17	17
Chromium	(Cr)	0.0089	0.00015	0.000050	0.00020	0.00020
Cobalt	(Co)		0.000054	0.000015	0.000065	0.000065
Copper	(Cu)	0.0020	0.0012	0.00056	0.0016	0.0016
Iron	(Fe)	0.30	0.053	0.010	0.11	0.11
Lead	(Pb)	0.0022	0.000061	0.000016	0.000073	0.000073
Magnesium	(Mg)		5.8	9.7	4.9	4.9
Manganese	(Mn)		0.0037	0.0036	0.0037	0.0037
Mercury	(Hg)	0.000026	0.0000050	0.0000050	0.0000050	0.0000050
Molybdenum	(Mo)	0.073	0.0012	0.0019	0.0011	0.0011
Nickel	(Ni)	0.08	0.00030	0.00015	0.00039	0.00039
Potassium	(K)		1.0	1.4	0.95	0.95
Selenium	(Se)	0.0010	0.000040	0.000040	0.000020	0.000020
Silver	(Ag)	0.00010	0.0000025	0.0000025	0.0000025	0.0000025
Sodium	(Na)		3.3	4.8	2.7	2.7
Thallium	(Tl)	0.00080	0.0000030	0.0000010	0.0000040	0.0000040
Uranium	(U)	0.015	0.0034	0.0073	0.0026	0.0026
Zinc	(Zn)	0.030	0.0014	0.0011	0.0015	0.0015

1. CCME Guidelines for protection of aquatic life are shown for reference. The BC Water Quality Guideline for sulphate was used because CCME guidelines are not available.
2. Water quality guidelines for SO4, Cd, Cu, Pb, and Ni are hardness dependent. Values presented in this table were calculated using the median baseline hardness of Brynelsen Creek at W18 (74 mg/L as $CaCO_3$).

Table VI-2 Baseline Water Quality in Casino Creek (W4)

Water Quality Model Parameter		CCME Guideline (mg/L)	W4 Median Water Quality (mg/L)			
			All Data	Winter	Spring	Summer
Hardness			111	162	64	111
Acidity			1.4	1.4	1.9	0.95
Alkalinity			79	110	44	79
Sulphate	(SO_4)	309	41	60	20	41
Chloride	(Cl)	640	0.25	0.25	1.1	0.25
Fluoride	(F)	0.12	0.070	0.070	0.060	0.070
Aluminum	(Al)	0.10	0.081	0.019	0.24	0.067
Antimony	(Sb)		0.00013	0.00013	0.00013	0.00014
Arsenic	(As)	0.0050	0.00043	0.00038	0.00063	0.00042
Barium	(Ba)		0.059	0.078	0.051	0.055
Cadmium	(Cd)	0.000036	0.000027	0.000030	0.000046	0.000025
Calcium	(Ca)		29	42	17	29
Chromium	(Cr)	0.0089	0.00010	0.000050	0.00040	0.00020
Cobalt	(Co)		0.000079	0.000031	0.00021	0.000083
Copper	(Cu)	0.0026	0.0059	0.0019	0.014	0.0067
Iron	(Fe)	0.30	0.13	0.030	0.30	0.12
Lead	(Pb)	0.0036	0.00018	0.00010	0.00021	0.00021
Magnesium	(Mg)		9.0	14	5.2	9.0
Manganese	(Mn)		0.011	0.011	0.023	0.0095
Mercury	(Hg)	0.000026	0.0000050	0.0000050	0.0000050	0.0000050
Molybdenum	(Mo)	0.073	0.0011	0.0013	0.00070	0.0011
Nickel	(Ni)	0.10	0.00037	0.00019	0.00072	0.00036
Potassium	(K)		1.0	1.3	0.87	0.97
Selenium	(Se)	0.0010	0.000070	0.000080	0.000065	0.000060
Silver	(Ag)	0.00010	0.0000025	0.0000025	0.0000068	0.0000025
Sodium	(Na)		4.1	5.8	2.4	4.1
Thallium	(Tl)	0.00080	0.0000020	0.0000010	0.0000045	0.0000015
Uranium	(U)	0.015	0.0066	0.013	0.0036	0.0066
Zinc	(Zn)	0.030	0.0018	0.0014	0.0035	0.0021

1. Shaded cells exceed the CCME guideline for protection of aquatic life.
2. BC Water Quality guideline for sulphate was used because CCME guidelines are not available.
3. Water quality guidelines for SO4, Cd, Cu, Pb, and Ni are hardness dependent. Values presented in this table were calculated using the median baseline hardness of Casino Creek at W4 (111 mg/L as $CaCO_3$).

Table VI-3 Baseline Water Quality in Dip Creek (W9)

Water Quality Model Parameter		CCME Guideline (mg/L)	W9 Median Water Quality (mg/L)			
			All Data	Winter	Spring	Summer
Hardness			81	120	54	73
Acidity			2.4	3.2	3.4	0.88
Alkalinity			74	110	46	66
Sulphate	(SO_4)	309	15	22	3.5	13
Chloride	(Cl)	640	0.25	0.25	1.0	0.25
Fluoride	(F)	0.12	0.050	0.050	0.050	0.050
Aluminum	(Al)	0.10	0.024	0.0071	0.10	0.032
Antimony	(Sb)		0.000080	0.000060	0.000080	0.000080
Arsenic	(As)	0.0050	0.00031	0.00020	0.00080	0.00032
Barium	(Ba)		0.053	0.076	0.049	0.047
Cadmium	(Cd)	0.000028	0.000012	0.0000080	0.000043	0.0000090
Calcium	(Ca)		21	31	14	19
Chromium	(Cr)	0.0089	0.00010	0.000050	0.00068	0.00020
Cobalt	(Co)		0.000071	0.000042	0.00050	0.000081
Copper	(Cu)	0.0020	0.00091	0.00068	0.0024	0.0012
Iron	(Fe)	0.30	0.084	0.043	0.90	0.12
Lead	(Pb)	0.0024	0.000084	0.000023	0.00066	0.000089
Magnesium	(Mg)		7.0	10	4.8	6.3
Manganese	(Mn)		0.022	0.025	0.068	0.015
Mercury	(Hg)	0.000026	0.0000050	0.0000050	0.0000050	0.0000050
Molybdenum	(Mo)	0.073	0.00059	0.00058	0.00042	0.00071
Nickel	(Ni)	0.08	0.00034	0.00027	0.0011	0.00046
Potassium	(K)		0.71	0.93	0.64	0.64
Selenium	(Se)	0.0010	0.000040	0.000020	0.000055	0.000030
Silver	(Ag)	0.00010	0.0000025	0.0000025	0.0000048	0.0000025
Sodium	(Na)		3.6	5.0	2.4	3.3
Thallium	(Tl)	0.00080	0.0000010	0.0000010	0.0000069	0.0000015
Uranium	(U)	0.015	0.0053	0.0086	0.0035	0.0046
Zinc	(Zn)	0.030	0.00070	0.00050	0.0034	0.00070

1. Shaded cells exceed the CCME guideline for protection of aquatic life.
2. BC Water Quality guideline for sulphate was used because CCME guidelines are not available.
3. Water quality guidelines for SO4, Cd, Cu, Pb, and Ni are hardness dependent. Values presented in this table were calculated using the median baseline hardness of Dip Creek at W9 (81 mg/L as $CaCO_3$).

Table VI-4 Baseline Water Quality in Dip Creek (W5)

Water Quality Model Parameter		CCME Guideline (mg/L)	W5 Median Water Quality (mg/L)			
			All Data	Winter	Spring	Summer
Hardness			90	135	56	88
Acidity			3.0	1.8	3.1	0.25
Alkalinity			75	105	41	74
Sulphate	(SO_4)	309	24	34	8.1	23
Chloride	(Cl)	640	0.43	0.25	1.0	0.25
Fluoride	(F)	0.12	0.060	0.060	0.055	0.060
Aluminum	(Al)	0.10	0.037	0.021	0.47	0.033
Antimony	(Sb)		0.00010	0.000080	0.000090	0.00010
Arsenic	(As)	0.0050	0.00036	0.00031	0.00077	0.00035
Barium	(Ba)		0.053	0.074	0.047	0.052
Cadmium	(Cd)	0.000030	0.000017	0.000017	0.000054	0.000015
Calcium	(Ca)		24	35	15	23
Chromium	(Cr)	0.0089	0.00015	0.000050	0.00060	0.00020
Cobalt	(Co)		0.000093	0.000052	0.00041	0.000093
Copper	(Cu)	0.0022	0.0023	0.0011	0.0067	0.0023
Iron	(Fe)	0.30	0.089	0.052	0.72	0.078
Lead	(Pb)	0.0028	0.00012	0.000072	0.0015	0.000094
Magnesium	(Mg)		7.5	11	4.6	7.5
Manganese	(Mn)		0.025	0.030	0.041	0.015
Mercury	(Hg)	0.000026	0.0000050	0.0000050	0.0000050	0.0000050
Molybdenum	(Mo)	0.073	0.00081	0.00084	0.00049	0.00082
Nickel	(Ni)	0.09	0.00032	0.00024	0.0011	0.00033
Potassium	(K)		0.77	1.1	0.71	0.74
Selenium	(Se)	0.0010	0.000050	0.000055	0.000060	0.000050
Silver	(Ag)	0.00010	0.0000025	0.0000025	0.000010	0.0000025
Sodium	(Na)		3.7	5.1	2.3	3.7
Thallium	(Tl)	0.00080	0.0000020	0.0000010	0.0000070	0.0000020
Uranium	(U)	0.015	0.0056	0.0099	0.0030	0.0055
Zinc	(Zn)	0.030	0.0012	0.00095	0.0042	0.0010

1. Shaded cells exceed the CCME guideline for protection of aquatic life.
2. BC Water Quality guideline for sulphate was used because CCME guidelines are not available.
3. Water quality guidelines for SO4, Cd, Cu, Pb, and Ni are hardness dependent. Values presented in this table were calculated using the median baseline hardness of Dip Creek at W5 (90 mg/L as $CaCO_3$).

Table VI-5 Water Quality of Mine Derived Water Entering Casino Creek

Water Quality Model Parameter		MMER (mg/L)	Mine Discharge Water Quality (mg/L)		
			Operations (Year 15)	TMF Discharge Phase (Year 60)	Pit Discharge Phase (Year 120)
Harndess			1,283	540	479
Acidity			0	1.4	11
Alkalinity			54	138.0603	158.2136
Sulphate	(SO4)		1,320	408	357
Chloride	(Cl)		36	15	14
Fluoride	(F)		2.1	0.89	0.82
Aluminum	(Al)		0.0033	0.057	0.039
Antimony	(Sb)		0.0028	0.013	0.013
Arsenic	(As)	0.5	0.0043	0.0041	0.0042
Barium	(Ba)		0.11	0.083	0.081
Cadmium	(Cd)		0.0014	0.00037	0.00033
Calcium	(Ca)		498	190	176
Chromium	(Cr)		0.0025	0.0013	0.0014
Cobalt	(Co)		0.0077	0.013	0.028
Copper	(Cu)	0.3	0.052	0.011	0.0099
Iron	(Fe)		4.9	0.00019	0.00017
Lead	(Pb)	0.2	0.0013	0.0021	0.0021
Magnesium	(Mg)		9.4	16	17
Manganese	(Mn)		2.1	0.79	0.64
Mercury	(Hg)		0.000017	0.000015	0.000016
Molybdenum	(Mo)		0.27	0.11	0.10
Nickel	(Ni)	0.5	0.0043	0.0040	0.0093
Potassium	(K)		0	5	6
Selenium	(Se)		0.0092	0.0045	0.0046
Silver	(Ag)		0.000051	0.000041	0.000049
Sodium	(Na)		40	17	16
Thallium	(Tl)		0.00050	0.00017	0.00014
Uranium	(U)		0.032	0.020	0.019
Zinc	(Zn)	0.5	0.023	0.019	0.020
Average Annual Flow	L/s		1.8	195	254

Table VI-6 Water Quality Predictions for Casino Creek (H18)

Water Quality Model Parameter	CCME Guideline (mg/L)	Operations (Year 20)				TMF Discharge Phase (Year 60)				Pit Discharge Phase (Year 120)			
		Annual	Winter	Spring	Summer	Annual	Winter	Spring	Summer	Annual	Winter	Spring	Summer
TSS		1.1	0.46	2.0	2.0	1.8	1.3	2.6	2.4	1.9	1.3	2.8	2.6
Acidity		1.0	0.67	1.5	1.5	1.1	0.90	1.3	1.3	2.0	1.5	2.7	2.5
Alkalinity		71	85	50	50	102	104	100	99	105	104	106	104
Sulphate (SO_4)	309	96	143	30	31	232	182	328	285	203	159	287	252
Chloride (Cl)	640	2.1	3.2	0.55	0.58	8.2	5.9	11	12	7.3	5.1	9.8	11
Aluminum (Al)	0.10	0.032	0.0074	0.065	0.065	0.043	0.028	0.067	0.065	0.033	0.019	0.052	0.053
Antimony (Sb)		0.00028	0.00036	0.00016	0.00016	0.0068	0.0046	0.0075	0.011	0.0069	0.0046	0.0078	0.012
Arsenic (As)	0.0050	0.00059	0.00068	0.00046	0.00046	0.0023	0.0017	0.0028	0.0033	0.0022	0.0016	0.0028	0.0033
Barium (Ba)		0.053	0.062	0.040	0.040	0.067	0.068	0.070	0.064	0.066	0.067	0.069	0.064
Cadmium (Cd)	0.000036	0.000082	0.00012	0.000026	0.000027	0.00021	0.00015	0.00028	0.00029	0.00020	0.00015	0.00028	0.00029
Calcium (Ca)		49	69	21	22	112	92	150	134	101	82	134	122
Chromium (Cr)	0.0089	0.00024	0.00025	0.00022	0.00022	0.00075	0.00052	0.00099	0.0011	0.00071	0.00049	0.00094	0.0011
Cobalt (Co)		0.00055	0.00084	0.00015	0.00016	0.0062	0.0047	0.0093	0.0078	0.0070	0.0050	0.011	0.0090
Copper (Cu)	0.0026	0.0043	0.0058	0.0022	0.0022	0.0065	0.0047	0.0093	0.0088	0.0064	0.0046	0.0093	0.0088
Iron (Fe)	0.30	0.00026	0.0003	0.0002	0.0002	0.022	0.0068	0.041	0.045	0.022	0.0070	0.041	0.046
Lead (Pb)	0.0036	0.00010	0.00012	0.000083	0.000084	0.00098	0.00074	0.0015	0.0012	0.00098	0.00070	0.0015	0.0013
Magnesium (Mg)		7.8	9.9	4.9	4.9	12	12	12	11	12	12	13	12
Manganese (Mn)		0.11	0.18	0.021	0.023	0.42	0.31	0.63	0.53	0.34	0.25	0.52	0.44
Mercury (Hg)	0.000026	0.0000058	0.0000062	0.0000051	0.0000051	0.000010	0.0000085	0.000011	0.000013	0.000010	0.0000085	0.000012	0.000013
Molybdenum (Mo)	0.073	0.015	0.024	0.0033	0.0035	0.056	0.041	0.077	0.079	0.054	0.038	0.074	0.076
Nickel (Ni)	0.10	0.00050	0.00056	0.00043	0.00043	0.0020	0.0015	0.0029	0.0027	0.0024	0.0017	0.0035	0.0032
Potassium (K)		1.1	1.3	0.94	0.94	2.9	2.5	3.2	3.7	3.2	2.7	3.7	4.1
Selenium (Se)	0.0010	0.00052	0.00082	0.000098	0.00011	0.0023	0.0017	0.0034	0.0030	0.0021	0.0015	0.0031	0.0028
Silver (Ag)	0.00010	0.0000050	0.0000064	0.0000029	0.0000029	0.000021	0.000016	0.000029	0.000029	0.000022	0.000016	0.000030	0.000030
Sodium (Na)		5.8	7.7	3.1	3.1	11	9.5	14	12	9.9	8.7	13	11
Thallium (Tl)	0.00080	0.000028	0.000042	0.0000081	0.0000086	0.000089	0.000065	0.00013	0.00012	0.000076	0.000054	0.00011	0.00010
Uranium (U)	0.015	0.0075	0.011	0.0030	0.0030	0.013	0.012	0.014	0.016	0.013	0.012	0.014	0.016
Zinc (Zn)	0.030	0.0025	0.0031	0.0017	0.0017	0.0098	0.0074	0.014	0.012	0.0092	0.0067	0.013	0.012

1. Shaded cells are modelled concentrations that exceed the CCME Guidelines for the protection of freshwater aquatic life. Water quality limits have not been established and the CCME guidelines are provided as a point of reference only.
2. BC Water Quality guideline for sulphate was used because CCME guidelines are not available.
3. Water quality guidelines for SO4, Cd, Cu, Pb, and Ni are hardness dependent. Values presented in this table were calculated using the median baseline hardness of Casino Creek at W4 (111 mg/L as $CaCO_3$).

Table VI-7 Water Quality Predictions for Casino Creek (W4)

Water Quality Model Parameter	CCME Guideline (mg/L)	Operations (Year 20)				TMF Discharge Phase (Year 60)				Pit Discharge Phase (Year 120)			
		Annual	Winter	Spring	Summer	Annual	Winter	Spring	Summer	Annual	Winter	Spring	Summer
TSS		1.1	0.47	2.0	2.0	1.7	1.2	2.5	2.4	1.8	1.2	2.7	2.5
Acidity		1.0	0.67	1.5	1.5	1.1	0.87	1.3	1.3	1.8	1.4	2.6	2.3
Alkalinity		71	85	50	50	97	101	93	93	100	101	99	97
Sulphate (SO_4)	309	85	127	27	28	205	162	289	249	180	142	253	221
Chloride (Cl)	640	1.8	2.8	0.46	0.49	7.1	5.1	10	10	6.3	4.4	8.5	9
Aluminum (Al)	0.10	0.032	0.0075	0.065	0.065	0.042	0.024	0.067	0.065	0.032	0.017	0.054	0.054
Antimony (Sb)		0.00025	0.00033	0.00015	0.00015	0.006	0.0039	0.007	0.010	0.006	0.0039	0.007	0.010
Arsenic (As)	0.0050	0.00055	0.00063	0.00045	0.00045	0.0020	0.0015	0.0025	0.0029	0.0020	0.0014	0.0025	0.0029
Barium (Ba)		0.053	0.061	0.040	0.040	0.065	0.066	0.066	0.061	0.064	0.065	0.065	0.061
Cadmium (Cd)	0.000036	0.000070	0.00010	0.000022	0.000023	0.00018	0.00013	0.00025	0.00025	0.00018	0.00013	0.00025	0.00025
Calcium (Ca)		45	63	20	21	100	83	133	119	90	75	119	108
Chromium (Cr)	0.0089	0.00022	0.00022	0.00021	0.00022	0.00067	0.00046	0.00089	0.0010	0.00063	0.00042	0.00085	0.00097
Cobalt (Co)		0.00047	0.00071	0.00012	0.00013	0.005	0.0039	0.008	0.007	0.006	0.0041	0.009	0.008
Copper (Cu)	0.0026	0.0038	0.0050	0.0020	0.0021	0.0058	0.0041	0.0083	0.0078	0.0057	0.0041	0.0083	0.0078
Iron (Fe)	0.30	0.02	0.04	0.01	0.02	0.026	0.0073	0.050	0.054	0.026	0.0075	0.050	0.054
Lead (Pb)	0.0036	0.00009	0.00010	0.00008	0.00008	0.00084	0.00062	0.0013	0.0011	0.00084	0.00058	0.0013	0.0011
Magnesium (Mg)		7.8	10	4.9	4.9	11	12	11	10	11	12	12	11
Manganese (Mn)		0.095	0.15	0.016	0.018	0.36	0.26	0.55	0.46	0.30	0.21	0.46	0.38
Mercury (Hg)	0.000026	0.0000056	0.0000060	0.0000051	0.0000051	0.0000094	0.0000080	0.000010	0.000012	0.000009	0.0000080	0.000011	0.000012
Molybdenum (Mo)	0.073	0.013	0.021	0.0027	0.0029	0.049	0.035	0.067	0.068	0.046	0.033	0.065	0.066
Nickel (Ni)	0.10	0.00046	0.00049	0.00042	0.00042	0.0018	0.0013	0.0025	0.0024	0.0021	0.0014	0.0031	0.0029
Potassium (K)		1.1	1.3	0.94	0.94	2.7	2.3	2.9	3.3	2.9	2.5	3.4	3.7
Selenium (Se)	0.0010	0.00044	0.00070	0.000076	0.000083	0.0020	0.00145	0.0029	0.0026	0.0018	0.00126	0.0027	0.0024
Silver (Ag)	0.00010	0.0000046	0.0000058	0.0000028	0.0000028	0.000019	0.000014	0.000025	0.000025	0.000019	0.000014	0.000026	0.000026
Sodium (Na)		5.5	7.2	3.0	3.0	10	8.8	12	11	9.1	8.1	11	9.8
Thallium (Tl)	0.00080	0.000024	0.000036	0.0000069	0.0000073	0.000077	0.000056	0.00012	0.00010	0.000066	0.000047	0.00010	0.000090
Uranium (U)	0.015	0.0071	0.010	0.0028	0.0029	0.012	0.011	0.013	0.014	0.012	0.011	0.013	0.014
Zinc (Zn)	0.030	0.0023	0.0028	0.0016	0.0016	0.009	0.0064	0.012	0.011	0.008	0.0058	0.012	0.011

1. Shaded cells are modelled concentrations that exceed the CCME Guidelines for the protection of freshwater aquatic life. Water quality limits have not been established and the CCME guidelines are provided as a point of reference only.
2. BC Water Quality guideline for sulphate was used because CCME guidelines are not available.
3. Water quality guidelines for SO4, Cd, Cu, Pb, and Ni are hardness dependent. Values presented in this table were calculated using the median baseline hardness of Casino Creek at W4 (111 mg/L as $CaCO_3$).

Table VI-8 Water Quality Predictions for Dip Creek (W5)

Water Quality Model Parameter	CCME Guideline (mg/L)	Operations (Year 20)				TMF Discharge Phase (Year 60)				Pit Discharge Phase (Year 120)			
		Annual	Winter	Spring	Summer	Annual	Winter	Spring	Summer	Annual	Winter	Spring	Summer
TSS		5.6	0.49	26	3.7	4.9	0.66	22	3.6	4.9	0.66	22	3.6
Acidity		2.2	2.8	2.0	0.96	2.1	2.7	1.8	0.99	2.3	2.9	2.2	1.2
Alkalinity		87	106	55	64	93	109	68	73	93	109	70	74
Sulphate (SO_4)	309	30	41	11	15	63	52	90	70	57	47	80	63
Chloride (Cl)	640	0.59	0.72	0.58	0.28	2.0	1.3	3.2	2.6	1.7	1.1	2.9	2.4
Aluminum (Al)	0.10	0.024	0.0072	0.065	0.037	0.027	0.011	0.065	0.040	0.025	0.0093	0.061	0.038
Antimony (Sb)		0.00010	0.00011	0.000091	0.000090	0.0014	0.00090	0.0019	0.0024	0.0015	0.00088	0.0020	0.0025
Arsenic (As)	0.0050	0.00033	0.00028	0.00053	0.00034	0.00070	0.00048	0.0011	0.00093	0.00069	0.00047	0.0011	0.00093
Barium (Ba)		0.062	0.074	0.047	0.046	0.065	0.074	0.053	0.051	0.065	0.074	0.053	0.050
Cadmium (Cd)	0.000030	0.000022	0.000026	0.000024	0.000011	0.000051	0.000034	0.000088	0.000067	0.000051	0.000033	0.000088	0.000067
Calcium (Ca)		29	37	17	19	44	42	50	43	41	40	46	40
Chromium (Cr)	0.0089	0.00016	0.000082	0.00039	0.00020	0.00027	0.00014	0.00055	0.00039	0.00026	0.00013	0.00053	0.00038
Cobalt (Co)		0.00016	0.00017	0.00025	0.000087	0.0014	0.00094	0.0026	0.0017	0.0016	0.00098	0.0030	0.0020
Copper (Cu)	0.0022	0.0015	0.0015	0.0018	0.0014	0.0021	0.0014	0.0036	0.0028	0.0021	0.0014	0.0036	0.0028
Iron (Fe)	0.30	0.16	0.098	0.43	0.13	0.11	0.036	0.35	0.11	0.11	0.036	0.35	0.11
Lead (Pb)	0.0028	0.000096	0.000038	0.00031	0.000088	0.00028	0.00016	0.00063	0.00033	0.00028	0.00015	0.00065	0.00034
Magnesium (Mg)		8.5	10	5.5	6.1	9.3	11	7.2	7.3	9.3	11	7.4	7.4
Manganese (Mn)		0.038	0.049	0.036	0.015	0.11	0.078	0.19	0.12	0.091	0.066	0.16	0.10
Mercury (Hg)	0.000026	0.0000051	0.0000052	0.0000050	0.0000050	0.0000060	0.0000057	0.0000066	0.0000066	0.0000061	0.0000056	0.0000066	0.0000067
Molybdenum (Mo)	0.073	0.0029	0.0043	0.00089	0.00100	0.012	0.0081	0.020	0.017	0.012	0.0075	0.019	0.016
Nickel (Ni)	0.088	0.00041	0.00031	0.00070	0.00045	0.00074	0.00050	0.0013	0.00093	0.00081	0.00054	0.0014	0.0010
Potassium (K)		0.86	0.99	0.69	0.68	1.3	1.2	1.3	1.3	1.3	1.3	1.4	1.4
Selenium (Se)	0.0010	0.00010	0.00015	0.000047	0.000037	0.00051	0.00034	0.00089	0.00064	0.00046	0.00029	0.00082	0.00060
Silver (Ag)	0.00010	0.0000030	0.0000031	0.0000034	0.0000025	0.0000066	0.0000051	0.0000099	0.0000079	0.0000067	0.0000050	0.000010	0.0000081
Sodium (Na)		4.4	5.4	2.9	3.2	5.6	5.8	5.6	5.0	5.4	5.7	5.3	4.8
Thallium (Tl)	0.00080	0.0000057	0.0000075	0.0000045	0.0000023	0.000020	0.000013	0.000036	0.000026	0.000017	0.000011	0.000032	0.000023
Uranium (U)	0.015	0.0069	0.0089	0.0038	0.0043	0.0082	0.0092	0.0065	0.0068	0.0081	0.0092	0.0065	0.0068
Zinc (Zn)	0.030	0.0011	0.00091	0.0019	0.00082	0.0027	0.0018	0.0050	0.0032	0.0026	0.0017	0.0048	0.0031

1. Shaded cells are modelled concentrations that exceed the CCME Guidelines for the protection of freshwater aquatic life. Water quality limits have not been established and the CCME guidelines are provided as a point of reference only.
2. BC Water Quality guideline for sulphate was used because CCME guidelines are not available.
3. Water quality guidelines for SO4, Cd, Cu, Pb, and Ni are hardness dependent. Values presented in this table were calculated using the median baseline hardness of Dip Creek at W5 (90 mg/L as $CaCO_3$).