HB Mine Tailings Facility Remediation and Closure Plan

Prepared for

BC Ministry of Energy, Mines and Petroleum Resources

Prepared by

1CR012.006
August 2020

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List of Abbreviations

AAP	Alternative Approval Process
AEP	annual exceedance probability
ALR	Agricultural Land Reserve
AP	acid potential
ARD	acid rock drainage
AW	Aquatic Life
AWF	Aquatic Life (freshwater)
BEC	Biogeoclimatic Ecosystem Classification
CAD	Consultative Areas Database
CAZ	Contaminant Attenuation Zone
CDA	Canadian Dam Association
CEMP	Construction Environmental Management Plan
CKISS	Central Kootenay Invasive Species Society
CLI	Canadian Land Inventory
CM	Closure Management
COPC	contaminants of potential concern
CRA	Conestoga-Rovers & Associates
CSR	Contaminated Sites Regulation
DSR	Dam Safety Review
DW	Drinking Water
EMP	Environmental Monitoring Program
EPP	Emergency Preparedness Plan
ERA	ecological risk assessment
FMEA	failure modes and effects analysis
FOS	factor of safety
FWAL	freshwater aquatic life
HHERA	Human Health and Ecological Risk Assessment
HSRC	Health, Safety and Reclamation Code for Mines in British Columbia
IAPP	Invasive Alien Plant Program
ICH	Interior Cedar Hemlock
IDF	inflow design flood
IEC	International Environmental Consultants
IPCC	Intergovernmental Panel on Climate Change
ITRB	Independent Tailings Review Board
IW	Irrigation
LW	Livestock
MCE	maximum credible earthquake

MEMPR	Ministry of Energy, Mines and Petroleum Resources
MENV	Ministry of Environment
MFA	Municipal Finance Authority
MFLNRORD	Ministry of Forests, Lands, Natural Resource Operations and Rural Development
NNP	net neutralization potential
NP/AP	neutralization potential/acid potential
NPC	net present cost
OC	Operational Certificate
OMS	Operation, Maintenance and Surveillance Plan
PDR	Preliminary Design Report
PGA	peak ground accelerations
PGA	peak ground acceleration
PMP	probable maximum precipitation
QA/QC	Quality Assurance and Quality Control
RDCK	Regional District of Central Kootenay
ROC	receptors of concern
TARP	Trigger Action Response Plan
TRM	turf-reinforcement matting
TRV	toxicity reference values
TSF	tailings storage facility
TTEBA	Tetra Tech EBA
WDA	Waste Discharge Approval
WQG	Water Quality Guidelines

1 Introduction

1.1 Purpose

This document presents a comprehensive Remediation and Closure Plan for the HB Mine Tailings Facility. This plan has been prepared in accordance with Section 10 of the *Mines Act* and the Health, Safety and Reclamation Code for Mines in British Columbia, and is designed to meet the requirements of all applicable provincial and federal legislation. This document is being submitted to the Ministry of Energy, Mines and Petroleum Resources (MEMPR) as part of a permit amendment application package in which the Regional District of Central Kootenay (RDCK) is applying to complete closure construction works, remediate and reclaim the areas formerly disturbed by historical tailings storage operations, and transition the facility through the closure active-care phase to the passive-closure phase, as defined by the Canadian Dam Association (CDA). The focus of this plan is to ensure the long-term physical and chemical stability of the facility, remediate and control tailings erosion and transport, maintain acceptable water quality, protect public health and safety, minimize environmental risk of the escape of fine tailings contamination, and restore productive end land use.

This plan is the result of collaborative closure planning efforts between personnel from SRK Consulting (Canada) Inc. (SRK), SLR Consulting Ltd. (SLR), and the RDCK. Relevant sections of the report are signed and stamped by qualified licensed professionals registered in the province of British Columbia. This report has been compiled by SRK.

1.2 Project Summary

1.2.1 Site History

A mining boom in the Salmo River watershed began in the late 1800's with numerous claims worked intermittently throughout the 1900's up to the mid 1980's. Most of the significant mines in the area are located in the Erie Creek, Wildhorse, Creek (Ymir), and Sheep Creek catchments. Many of the early mills that were developed to process the ore from the mines were located near waterways of the Salmo River valley and during the early days of mining, it was common for the tailings from the mill to be discharged into the waterways, or to be deposited immediately adjacent to the waterways without any confinement to control erosion of tailings. The impact of the historical mining operations in the local area are cumulative and long-lasting, and the RDCK acknowledges the cumulative impacts of intense historical mining on local ecology.

The HB Mine is a lead-zinc mine that was operated by Cominco Ltd. (now Teck Resources Ltd.) from 1955 to 1966 and from 1974 to 1978. The mine was the last significant mine to operate in the Salmo River Valley and was located on Aspen Creek, a tributary of Sheep Creek.

The tailings facility for the mine is located approximately 2 km south of the mine and is adjacent to the RDCK Central Landfill (Drawing 1). Approximately 6.6 million tonnes of ore were processed at a mill located adjacent to Sheep Creek. The purpose of the tailings facility was to store the by-products of ore processing and prevent the fine tailings from escaping into the environment. A flume line was used to transport the tailings from the mill to the tailings facility. A site plan of the tailings facility is provided in Drawing 03. A summary of the construction history of the dam is provided in Section 3.2.1.

Facility operations were suspended by Cominco in 1978, with the property subsequently purchased by David Minerals Ltd. in 1981. Between 1981 and 1997, ownership of the facility passed from David Minerals, to Nor-Quest Resources, then to Nu-Dawn Resources (Nu-Dawn) and Raynerd Resources, and finally to Seattle Corporation. During this time Teck continued to hold the permit for the facility as all other parties failed to acquire a permit under the *Mines Act*.

MEMPR inspected the facility in 1997 and sent requests to Teck and Nu-Dawn for the facility to be decommissioned. In February 1998, the RDCK purchased the tailings impoundment area and surrounding land to establish additional buffer zone for the adjacent Central Landfill, which is an RDCK owned municipal solid waste facility that operated from 1983 to 2014, and was formally closed to BC Landfill Criteria standards in 2016. MEMPR inspected the facility in 1998 with RDCK and Teck staff present, and again requested that the facility be closed (MEMPR 1998). MEMPR provided additional direction that they were generally satisfied that the geochemical characteristics of the tailings were benign, and wanted the focus of the closure to be on geotechnical aspects, as well as on other closure issues including revegetation, water management, and site monitoring (MEMPR 1999). The RDCK agreed to complete the decommissioning of the dam, as recommended by the province, in a joint work program with Teck as the former owner/operator of the site.

The RDCK retained BGC Engineering Inc. to undertake the decommissioning project. Investigations and engineering design were completed between 2000 and 2002. In April 2002, the RDCK was provided with *Mines Act* Permit M-218, which approved the “H.B. Mine Tailings Pond and Dyke Decommissioning Plan” (decommissioning plan) (BGC 2002). Decommissioning work was completed in 2005.

Once the facility was decommissioned, the RDCK commenced a program of active monitoring and maintenance, and developed an Emergency Preparedness and Response Plan, a Plan of Environmental Protection, and an Operations, Maintenance, and Surveillance Manual. Teck filed for a release of their permit obligations as the province had committed to close permit M-85 and return Teck’s reclamation security after the facility was satisfactorily decommissioned and reclaimed, and sampling had proven benign environmental conditions at site (MEMPR 1998). MEMPR confirmed Teck’s release of all obligations associated with the tailings facility under *Mines Act* permit M-85 in February 2016 (MEMPR 2016).

In 2011, Conestoga-Rovers and Associates finalized a Reclamation Plan for the facility, which included plans for the construction of surface water diversion channels around the tailings deposition area. The purpose of the diversion channels was to minimize surface water contact with the tailings, and to reduce the potential for erosion and sediment loading to the tailings pond. The contract for the work was awarded and an M-218 permit amendment was approved on June 29, 2012; however, the work was never completed as on July 2, 2012, a large embankment slough was identified on the downstream slope of the facility’s earthen dam. The cause of sloughing was attributed to heavy rainfall and the presence of sinkholes that were discovered while relieving pressure on the dam during the emergency response process.

As a result of the sloughing event and in accordance with frequencies outlined in the CDA Dam Safety Guidelines, Tetra Tech EBA (TTEBA) was retained in 2013 to complete a Dam Safety Review (DSR). The results of the dam break inundation study increased the consequence classification of the dam from low (significant) to very high, based on economic losses (TTEBA 2014). This change meant that the spillway size was no longer considered sufficient to pass the design flood. Minor spillway upgrades were completed to bring the facility up to the CDA guidelines required for a very high-consequence dam.

As a result of the Mt. Polley tailings dam failure and the resulting escape of fine tailings contamination into the environment, the RDCK was required to complete a Letter of Assurance in February 2015, as ordered by the Chief Inspector of Mines. RDCK retained Tetra Tech EBA to complete the Letter of Assurance, which identified glaciolacustrine material, similar to that which caused the failure at Mt. Polley, below the HB Dam (TTEBA 2015). Tetra Tech EBA recommended an additional geotechnical investigation as there had been no direct measurement of the strength parameters of the foundation material.

In October 2015, Thurber Engineering Ltd. completed the geotechnical investigation of the dam foundation material, as recommended in the Letter of Assurance. The geotechnical investigation recommended that the RDCK take steps to decommission the dam by removing the pond to prevent future water impoundment against the upstream face of the dam, or if decommissioning was not pursued, that additional geotechnical investigations be undertaken to confirm the long-term stability of the dam (Thurber 2016).

In May 2016, Tetra Tech EBA updated the stability analyses for the facility which showed that the dam does not currently meet the target factors of safety (TTEBA 2016). As a result of the stability analyses update, the RDCK elected to begin investigating decommissioning of the dam; in 2016 SRK was retained to complete a closure options assessment. This options assessment evaluated three scenarios for long-term facility management including ongoing pond management with and without repairs, passive closure, and full decommissioning with densification of the tailings via wick drains. The assessment determined that moving the facility into passive closure appropriately addresses the environmental risks of the facility and is the lowest-cost option for long-term management. The RDCK Board of Directors elected to proceed with a preliminary design for the passive closure of the dam and for remediation of the surrounding areas as environmental improvement.

1.2.2 Current Status

The current facility infrastructure consists of the tailings dam, tailings deposition area, tailings pond, spillway, stilling basin, downstream channel, access roads, instrumentation, and a small granite rock quarry. The facility has changed very little since decommissioning work was completed in 2005, with the exception of minor repair work in 2012, 2015 and 2016. Within the RDCK owned property that contains the tailings facility, there is a till borrow area and two sand and gravel borrow areas that were previously developed for landfill related use; however, for the purposes of this plan, the borrow areas are considered to be part of the existing facility infrastructure.

As the facility is owned by the Regional District, costs of facility operations are currently funded through taxation. Ongoing operations and maintenance costs are high and continue to increase. Cost of supplementary investigations and one-time repairs are less predictable but have been significant over the last ten years. Additionally, following the near-collapse in 2012 and subsequent geotechnical investigations, a number of environmental risks and liabilities associated with the facility in its current form became apparent. Section 6.3 provides a listing of the site issues and concerns related to the performance of the dam and outlines the closure components in the design that mitigate environmental risk and provide long-term stability and containment of the tailings to ensure protection of the environment and of human health.

In addition, over the course of facility operations, several releases of tailings have occurred that resulted in downstream tailings deposition and contamination. Remediation work of the downstream properties would be in jeopardy if the facility, as the source site of contamination, is not closed.

The RDCK intends to pursue closure of the facility to address the costs and historical environmental liabilities associated with the site. SRK Consulting completed the HB Mine Tailings Facility Closure and Remediation Preliminary Design Report (PDR) in July 2018. The PDR was intended to allow for a review and buy-in of the remediation concept from regulators and the Independent Tailings Review Board (ITRB). The PDR was reviewed by the ITRB, MEMPR and Ministry of Environment (MENV) staff. The preliminary design reviews provided valued insights that resulted in the re-examination of several assumptions and design components, and the incorporation of review comments and recommendations into this plan.

1.3 Regulatory Permits and Requirements

Permits issued by MEMPR under the provisions of the *Mines Act* are required for the approval of mine plans, and closure and reclamation programs. Permit M-218 was issued by the Deputy Chief Inspector of Mines on April 10, 2002 to the RDCK approving the 2002 decommissioning plan (BGC 2002) subject conditions stipulating compliance and supersedes all previous permits held for the facility. The current permitted area measures approximately 30 hectares. A copy of the permit is included in Appendix A. An amendment to Permit M-218 was awarded on June 29, 2012, approving surface water diversion channel works; however, the work was never completed due to the July 2012 slough event.

Environmental discharge permits are commonly issued by the MENV for tailings facilities under the provisions of the *Environmental Management Act* for effluent discharges from a mine site. An effluent discharge permit, PE-1853, was originally issued to Teck and was subsequently transferred to David Minerals, then to Nu-Dawn. On May 10, 2004, the permit was cancelled by MENV for non-payment of permit fees by Nu-Dawn; MENV determined the permit was no longer required as the mill was derelict and would not be resuming operations (MENV 2004). The RDCK was not made aware of the permit at the time of purchase, or that it was being cancelled. Water discharging from the facility is not currently administered by a MENV permit. The discharge of the facility is currently authorized under Operational Certificate MR-16519 (OC) for the adjacent Central Landfill, dated November 27, 2000, and amended April 2011. Section 4.2 of the OC specifies monitoring requirements; however, revisions to the monitoring program have subsequently been made with acceptance by MENV. Environmental monitoring programs (EMPs) for the facility and the adjacent landfill are currently reported under separate cover to MENV. Each year, EMPs are reviewed and revised as needed to ensure specific monitoring objectives are being achieved.

For the work outlined in this plan, the project is a non-reviewable project under Part 3 of the Reviewable Project Regulation. To support the proposed work in this plan, the RDCK will be applying for the following authorizations:

- A General Wildlife Permit under the *Wildlife Act* to complete an amphibian and reptile salvage within the tailings area prior to pond removal.
- A Scientific Fish Collection Permit under the *Wildlife Act* in support of potentially required fish salvage activities within the tailings facility.
- A Waste Discharge Approval (WDA) under the *Environmental Management Act* Waste Discharge Regulation to support draining of the tailings pond. A Technical Assessment Report and all supporting documentation required for the WDA application will be reported under separate cover and submitted to MENV.
- A Change Notification under the *Water Sustainability Act* to authorize works along the Salmo River banks to secure the end of the water discharge pipe associated with tailings pond dewatering.
- A works permit obtained through Ministry of Transportation and Infrastructure for laying the water discharge pipe through the Highway 3 right-of-way and culvert.
- An amendment to permit M-218 under the *Mines Act.*

SLR has prepared a Construction Environmental Management Plan (CEMP) to serve as a guide to ensure compliance with all applicable environmental legislation. The CEMP is included in Appendix B.

2 Project Settings

2.1 Climate

The climate for the region is characterized by warm, dry to moderately moist summers and cool, snowy winters. Snowfall typically starts accumulating in November with maximum accumulation occurring in March. Snow melt at the facility generally occurs in late March and April. Meteorological parameters are not measured at HB Mine Tailings Facility (elevation 710 m).

The closest active station to the facility is Castlegar Airport, BC (Climate ID: 1141455), located approximately 36 km northwest of the facility in an adjacent valley at an elevation of 495 m. Historically, an Environment Canada climate data station was located in Salmo, BC (Climate ID: 1146944) that operated from 1972 to 1980. The comparison of the climate data indicates that precipitation in Salmo (elevation 670 m), is slightly higher and temperatures generally cooler than in Castlegar, BC. Based on the Castlegar Airport climate normal data, the site is expected to be snow covered an average of 90 days per year. In addition, temperatures at the site are zero degrees Celsius or below for an average of 120 days per year.

A hydrological analysis of the site was undertaken to develop inputs to the hydraulic designs of the spillway and other conveyance structures at the facility. A regional analysis was implemented that included data from 22 climate stations within 150 km to establish a long-term synthetic period of record for air temperature, precipitation, wind speed, and snowmelt. Probabilistic climate change modelling was incorporated into the analysis to address climate change trends and effects that may occur at the facility in the future. The following subsections provides a summary; the complete analysis is provided in Appendix C-1.

2.1.1 Temperature and Precipitation

Mean monthly air temperatures and precipitation data for the HB Mine Tailings Facility from 1980 to 2017 are presented in Table 2-1.

Table 2-1: Mean Monthly Air Temperature and Precipitation

Month	Air Temperature (°C)	Precipitation (mm)
January	-3.6	82.2
February	-1.4	58.2
March	2.8	71.8
April	7.4	58.0
May	12.0	70.1
June	15.6	77.2
July	19.1	47.0
August	18.8	35.9
September	13.5	43.9
October	6.8	62.2
November	0.9	98.2
December	-3.2	103.3

Estimates of extreme precipitation events were prepared as part of the hydrological analysis; this included short-duration rainfall and maximum daily precipitation estimates for return periods ranging from the 1 in 2-year event to the 1 in 200-year event, as well as the 24-hour probable maximum precipitation (PMP). The 24-hour precipitation for various return period events are summarized in Table 2-2.

Table 2-2: Extreme Precipitation Estimates

Event	Depth (mm)
1 in 10-year	53
1 in 50-year	66
1 in 100-year	71
1 in 200-year	76
24-hour PMP	229

2.1.2 Wind

Available regional wind data was obtained from Environment Canada and is limited. Data from ERA interim (ECMWF 2017) was used to develop a time series for daily wind speed gust for the facility; a wind gust with a two-year period was estimated at 133 km/hr.

2.1.3 Snowmelt

An energy snowmelt model was created for the facility to evaluate the snowmelt contribution to peak flows. The snowmelt model was validated using snow pillow data at the nearby Redfish Mountain snow pillow station (MENV Station 2D14P). The model was used to estimate monthly snowmelt totals for return periods ranging from 1 in 2-year to 1 in 100-year and resulted in a maximum daily snowmelt depth of 40 mm for the 100-year snowmelt.

2.1.4 Evaporation

Evaporation estimates were not included in the hydrological analysis (Appendix C-1) as they were not required for the closure design. Table 2-3 provides mean monthly lake evaporation data measured at the Castlegar BCHPA Dam (Climate ID: 1141457) between 1981 and 2010.

Table 2-3: Mean Monthly Lake Evaporation (Castlegar BCHPA Dam, 1981–2010)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lake Evaporation (mm)	0	0	0	78.0	105.4	117.0	136.4	124.0	87.0	46.5	0	0

2.1.5 Climate Change

Climate change modeling for the Project was conducted through a compilation of Intergovernmental Panel on Climate Change (IPCC) Assessment Reports and by completing a probability analysis on the on the multiple climate models. Details of the assessment methodology are described in Munoz (2017).

The model results forecasted that by the year 2100, the mean annual air temperature would increase by +1.9% (degrees Kelvin), the mean annual precipitation would increase by 66 mm

(+9%), mean annual wind speeds would increase by 1.9%, and 100-year maximum snowmelt would increase by 35%. The modelling resulted in a revised PMP of 250 mm.

2.2 Seismic

The HB Mine Tailings Facility is located in the Southern Cordillera seismic zone as defined by the Geological Survey of Canada. The major “ductile-brittle” faults reported within this zone consist of the southern Purcell Trench fault; the Kettle River and Granby faults, the Okanagan and Eagle River faults, Slocan Lake fault, and Columbia River fault. The region is a relatively inactive seismic region of Western Canada with the largest earthquake being a magnitude 6.0 event in 1918 in the Valemont area of the Rocky Mountain Trench. In 1986, a magnitude 5.5 earthquake occurred near Prince George, causing some minor damage.

A probabilistic seismic hazard assessment was undertaken for the facility; the peak ground accelerations (PGA) values for the site are provided in Table 2-4. Site amplification effects of the earthquake ground motions from bedrock to the top surface were considered in the assessment. The soil class beneath the HB Dam was assigned a Site Class D as per the National Building Code of Canada (2015) definitions. The complete seismic hazard assessment is provided in Appendix C-2.

Table 2-4: Seismic Hazards (Site Class D)

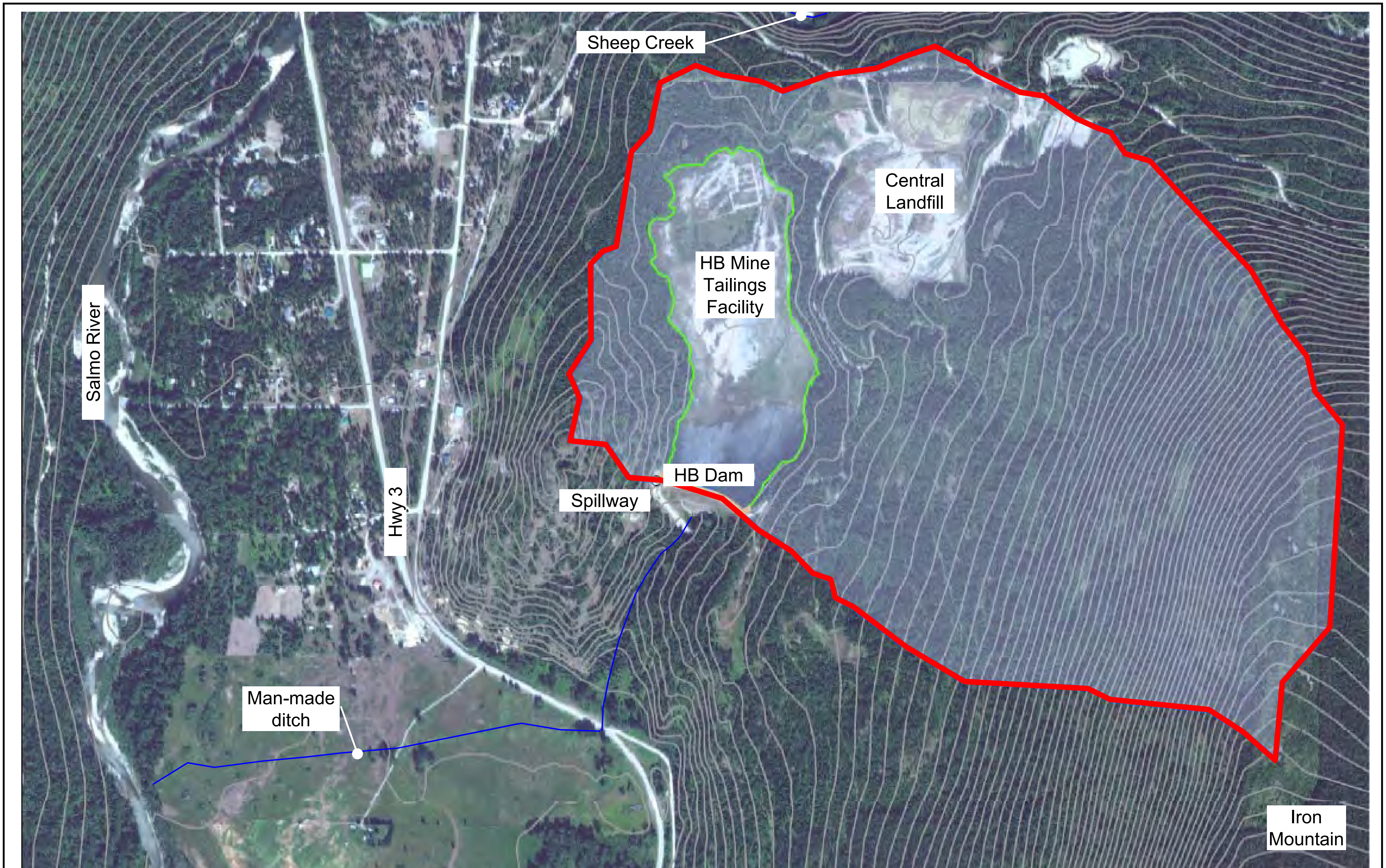
Annual Exceedance Probability	Mean PGA (g)	84^{th} Percentile PGA (g)	95^{th} Percentile PGA (g)
1 in 500-year	0.031	0.052	0.070
1 in 1,000-year	0.049	0.083	0.110
1 in 2,500-year	0.095	0.145	0.186
1 in 5,000-year	0.140	0.219	0.237
1 in 10,000-year	0.210	0.256	0.356

2.3 Physical Characteristics

2.3.1 Topography and Surface Drainage Features

The site is located between the Nelson and Barrington Ranges of the Selkirk Mountains and at the base of the western slope of Iron Mountain. Figure 1 illustrates the catchment area that reports to the tailings facility as well as the significant surface drainage features

The major drainage in the area is the Salmo River, located in the floodplain area west of the site. A bedrock ridge trending north-south separates the Salmo River floodplain from the tailings facility. Sheep Creek is located north of the site and flows westward to the Salmo River; it is located in a steeply incised bank. The Central Landfill and Iron Mountain are located east of the site on moderate well-treed slopes. The tailings deposition area measures approximately 30 ha and occupies the mid to low portion of a hanging valley that drains to the south. Water from the dam discharges towards the south in a narrow valley, crosses Highway 3, and flows through a man-made ditch system to the Salmo River.



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REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

Remediation and Closure Plan

Catchment Area and Surface Drainage Features

Date:	Approved:	Figure:
April 2019	spb	1

2.3.2 Geology

The geology underlying the facility is derived from site-specific stratigraphic data collected through numerous investigations that were carried out at and near the facility between 1999 and 2018. Referenced literature was used to augment the geological understanding of the site when available.

Bedrock

On a regional scale, the local geology is composed mainly of metamorphic rocks, including highly metamorphosed schist, gneiss, amphibolite, and quartzite, as well as unaltered siltstone, sandstone, conglomerate, limestone, and dolomite (Groundwater Resources of BC). The Geological Survey of Canada Map 1145A, indicates the bedrock in the vicinity of the site belongs to the Lower Cambrian Laib Formation and consists mainly of phyllite, schist, micaceous quartzite, and minor limestone. Granite from the Cretaceous-aged Ansley Plutonic Suite is also located within the southwestern portion of the site property boundary and is exposed in the existing spillway cut.

The majority of the tailings facility is underlain by phyllite bedrock. A granitic bedrock outcrop is present at the west abutment of the dam. An argillite bedrock outcrop is present approximately 30 m east of the east abutment of the dam. Based on test pit BGC-TP-00-5, the depth to bedrock is estimated to be at least 6 m at the east abutment. Near the centre of the dam, bedrock was encountered approximately three to six metres below the original ground surface (BGC-BH-00-1 and Golder-73-01).

Overburden

The major rivers in the region were deeply scoured by glaciers during Pleistocene time and subsequently infilled with deposits of silt, sand, gravel, and till. The native surficial sequence typically encountered at the facility consists of overburden materials (glacial and post-glacial deposits) ranging in thickness from 0 to 47.8 m (MW-02-2004(D)). The overburden generally consists of sands and gravels that overlie a silty to sandy glacial till which, in turn, mantles the bedrock surface in select areas. Where the glacial till is occasionally absent, the sands and gravels directly overlie the bedrock surface. Occasional lenses/layers of silt and/or silty clay occur within the sands and gravels.

Beneath the western half of the HB Dam, the bedrock is overlain by a dense lodgement till consisting of gravelly sand that contains some silt and traces of clay. Near the centre of the dam, the bedrock is overlain by the lodgement till, which is itself overlain by very stiff stratified glaciolacustrine deposits consisting of sands, silts, and clays. Beneath the eastern portion of the dam, the bedrock is overlain by the compact stratified glaciolacustrine material consisting primarily of sandy silt. The overburden thickness is generally shallow beneath the original dam (three to six metres) and increases in thickness south of the dam (14.3 m at MW-01-2004, located approximately 140 m down valley).

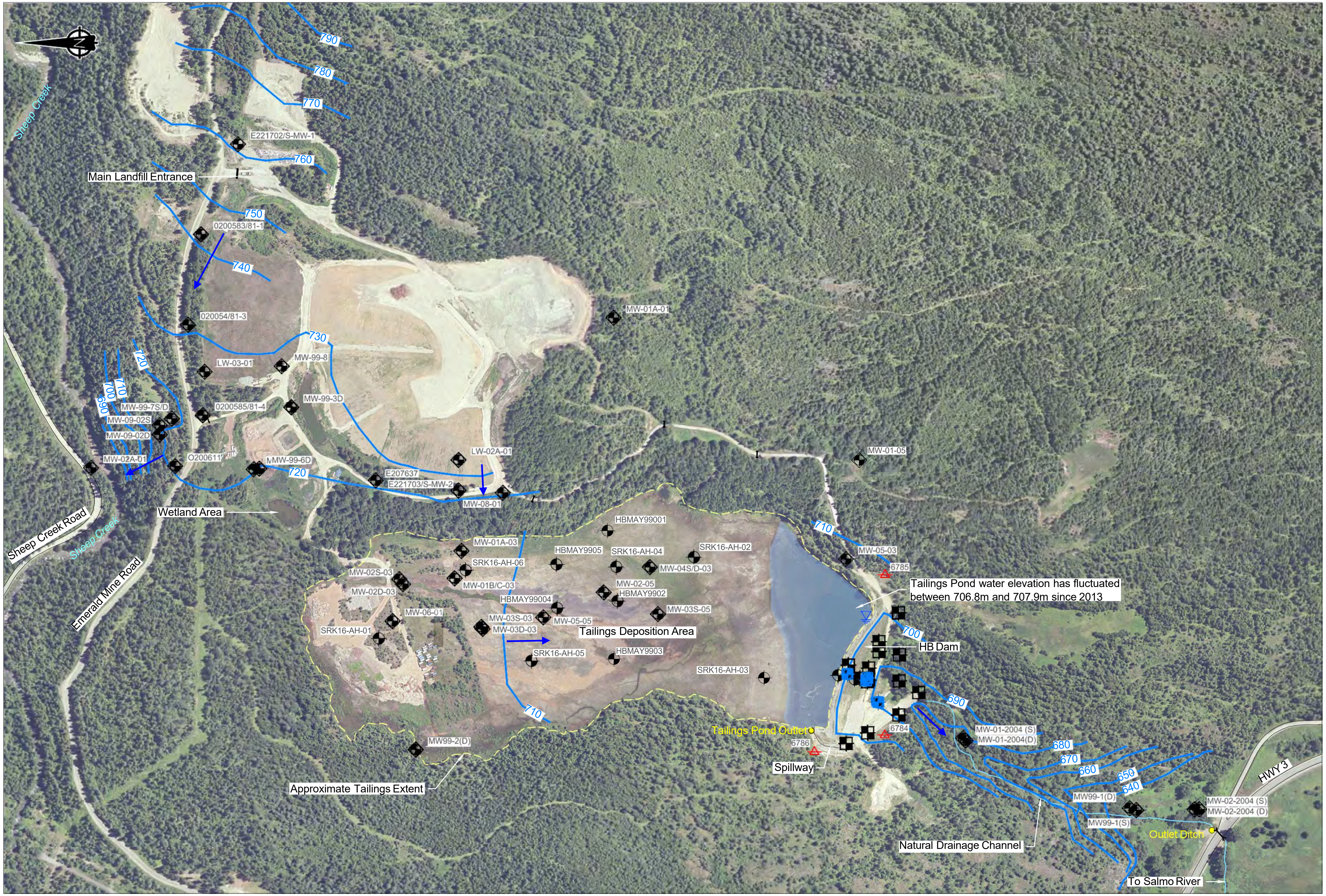
2.3.3 Groundwater Hydrogeology

Groundwater monitoring data from the landfill and tailings areas indicate that groundwater flow occurs primarily within the overburden granular/sandy soils, whereas the bedrock formation is considered generally competent and of low permeability. Much of the overburden at the site is composed of relatively permeable sands and sandy gravels. Discontinuous layers of low-permeability silts and silty clays are also evident (CRA 2005a).

Ridges east and west of the facility represent groundwater recharge areas and the tailings pond is an area of groundwater discharge. An east-west bedrock ridge underlies the landfill footprint and provides the northern boundary of the groundwater catchment. Groundwater flows primarily towards the south beneath the tailings, within the valley axis towards the valley bottom aquifer (AMEC 2014).

Between the landfill and the tailings area, single-well response tests indicate that the hydraulic conductivity of the overburden is 1.8×10^{-5} m/s, which is typical of silty sand (CRA 2005a). The calculated groundwater velocity within the tailings area is much lower (5-10 m/yr) because of the lower hydraulic gradient through the tailings deposition area and the lower hydraulic conductivity of the tailings.

Groundwater is typically encountered less than 1 m below the ground surface within the tailings deposition area and approximately 4 m below ground surface downgradient of the dam. The interpreted groundwater elevation contours in the Central Landfill and tailings areas are provided in Figure 2.



LEGEND

- Control Point
- Borehole Location
- Monitoring Well Location
- Piezometer Location
- Surface Water Monitoring Location
- Test Pit Location
- Water Elevation Reading
- Groundwater Contour
- Groundwater Direction

REFERENCES

Control points surveyed by RDCK, July 2017.

CONTROL POINTS

Point ID	Easting	Northing	Elevation
6784	481,643.28	5,441,964.94	701.75
6785	481,893.43	5,441,964.10	719.17
6786	481,617.38	5,442,074.29	721.79

0m 50 100 150 200m

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REGIONAL DISTRICT CENTRAL KOOTENAY

Remediation and Closure Plan

Interpreted Groundwater Elevation Contours

HB Mine Tailings Facility

PROJECT NO.: 1CT012.006

FILE NAME: 1CR012.006 - GW Contours.dwg

DATE: Jan 2020

Prepared by: phm

FIGURE: 2

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2.3.4 Water Quality

Biannual reclamation monitoring is conducted in the tailings area in the spring and fall of each year and has been completed at the site since 2002 at locations and frequency outlined in the EMP for the facility. The current facility EMP is included in Appendix D. As part of the reclamation monitoring program, nine groundwater wells and six surface water locations are sampled in spring and all surface water locations are sampled in the fall. The groundwater and surface water samples were submitted to ALS, a Canadian Association for Laboratory Accreditation certified laboratory in Burnaby BC for analysis of parameters listed in the EMP for the facility. To verify the reproducibility of laboratory analyses duplicate samples were submitted for analysis at a ratio of approximately 1 in 10. For assessment of water quality, the following standards and guidelines are referenced for comparison of groundwater and surface water laboratory results:

- British Columbia Contaminated Sites Regulation (CSR) Schedule 3.2 generic numerical water standards for Aquatic Life (AW), Irrigation (IW), Livestock (LW), and Drinking Water (DW) use.
- British Columbia Approved Water Quality Guidelines (WQG) for freshwater aquatic life receptors.

Where BC-Approved WQGs are unavailable, the BC Working WGQs, values for CSR Generic Numerical Water Standards (Schedule 3) Aquatic Life (freshwater) (AWF) divided by 10 or the Canadian Water Quality Guidelines for the Protection of Aquatic Life are applied. The following sections summarize surface water and groundwater quality results at the site. Hardness- and pH-dependent guidelines and standards were selected based on measured values of individual samples.

Surface Water

The surface water monitoring program for the site includes six surface-water monitoring locations: SW1-07, SW2-07, SW3-07, SW4-07, Tailings Pond Outlet, and Outlet Ditch. The monitoring locations are illustrated in Drawing 03. Surface water locations SW2-07 and SW3-07 are located along seasonal surface water drainage pathways located east of the tailings deposition area and south of the landfill. Analytical results from SW2-07 and SW3-07 have historically been used to characterize background water quality for the Facility. In October 2018 and April 2019, samples were collected from the seepage area upstream of the v-notch weir below the dam. In addition, in April 2019, three surface water samples (Tailings Pond East, Tailings Pond SE and Tailings Pond West) were collected from within the tailings pond at different depths.

Metals and nutrients including copper, iron, lead, manganese, selenium, uranium, zinc and nitrate (as N) have been detected in surface water at the site above the applicable guideline since 2016. SRK used a simple water and load balance model to predict water quality concentrations for the drainage ditch downstream of the tailings pond under post-closure conditions. The results of the predictive modelling for post-closure conditions are discussed in Section 5.4.

Concentrations of metals and nutrients in surface water at the downgradient property boundary passed the AWF, with the exception of one or more of the aluminum, cadmium and zinc parameters which were noted to exceed the AWF guidelines in samples collected from the outlet ditch from 2016 – 2018.

Groundwater

Nine groundwater monitoring locations were included in the groundwater monitoring program for the facility: MW99-1(S), MW-05-01, MW-01-2004(S) and MW-01-2004(S) are screened in overburden, and MW-02-2004(D), and MW-01-2004(D) MW99-1(D), MW99-2(S), are MW99-2(D) are screened in bedrock. One residential well, located at 8102 Hwy 3, has also historically been included in the groundwater monitoring program however, this well has not been sampled since 2015 as the property has been listed as vacant and condemned. Monitoring locations are illustrated in Drawing 03.

The groundwater plume beneath the site has been reported to be impacted by the tailings area and by the landfill located hydraulically upgradient of the site (AMEC 2014). Historically, metal (manganese and iron), and organic parameters (ammonia-N, chloride, nitrite (as N), nitrate (as N) and phosphorus) measured in—and downgradient of—the tailings area, have been mainly attributed to the landfill area; however, the tailings may also be a source of some of these parameters (AMEC 2014).

A review of the landfill hydrogeology is conducted by the RDCK every 5 years. The 2014 review concluded that the subsurface attenuation capacity near the landfill is sufficient to reduce the contaminate concentrations before receptors are encountered (AMEC 2014). The most recent results indicate that the assimilative capacity of the attenuation zone that overlaps the tailings facility has shown no evidence of being exceeded (Wood 2019).

Background overburden groundwater quality within the vicinity of the site is characterized using the analytical results for MW-02A-01, MW-03A-01, and MW-05-01. Background monitoring locations MW-02A-01 and MW-03A-01 are located on the northern side of Sheep Creek and are relevant since they sample groundwater quality from a groundwater discharge zone within the vicinity of the site and the Salmo River watershed. Analytical results reported for groundwater collected at MW99-2(D) have been used to characterize background water quality within the bedrock unit as this location is the only deep bedrock well upgradient of the tailings pond.

Downgradient water quality generally meets applicable standards in both bedrock and overburden wells. Amongst the three downgradient bedrock wells, lithium exceeded the CSR DW standards (in MW99-1(D) and MW-02-2004(D)), although it did pass the aquatic life (AW) and irrigation (IW) standards in these wells. In MW-02- 2004(D), lithium was observed to be three times higher than the CSR generic numerical drinking water standard. Concentrations of manganese exceeded the applicable CSR standard in groundwater collected from MW-02-2004(D) during the 2016 sampling program.

Results from MW-02-2004(S)/(D) therefore indicate that, with the exception of lithium and manganese in a deep well, water quality standards for groundwater are being met at the downgradient property boundary.

The source of the lithium in groundwater has not been confirmed. The concentration of lithium in the downgradient wells have historically been higher than groundwater concentrations measured within the tailings area. Lithium has been below detection limits in all soil samples collected within the tailings area (RDCK 2019), supporting this assessment.

2.4 Biological Characteristics

2.4.1 Fisheries and Aquatic Resources

The Fisheries Information Summary System was used to provide an overview of fish species and fish habitat available for the general project area. A summary of known fish presence for the closest water bodies, the Salmo River and Sheep Creek, is presented in Table 2-5 and Table 2-6.

Under the BC *Water Sustainability Act* R.S.B.C. 2016, Water Sustainability Regulation (Part 1) watercourses, streams, ditches, ponds, and wetlands that provide water, food or nutrients to fish-bearing streams are considered fish habitat, even if they do not contain fish or if they have only temporary or seasonal flows. On-site surface water features, including the retention pond, unnamed creeks and outlet ditch, are considered a “stream” defined as “a natural watercourse or source of water supply, whether usually containing water or not” under the *Water Sustainability Act*.

Table 2-5: Fish Species of the Salmo River and Their Conservation Status

Common Name	Latin	BC Status[a]	COSEWIC[b]	SARA[c]
Redside Shiner	*Richardsonius balteatus*	Yellow	-	-
Northern Pikeminnow	*Ptychocheilus oregonensis*	Yellow	-	-
Longnose Dace	*Rhinichthys cataractae*	Yellow	-	-
Brook Trout	*Salvelinus fontinalis*	Exotic	-	-
Pumpkinseed	*Lepomis gibbosus*	Exotic	-	-
Shorthead Sculpin	*Cottus confusus*	Blue	SC (2010)	1-SC
Bull Trout	*Salvelinus confluentus*	Blue	-	SC (2012)
Rainbow Trout	*Oncorhynchus mykiss*	Yellow	-	-
Slimy Sculpin	*Cottus cognatus*	Yellow	-	-
Longnose Sucker	*Catostomus catostomus*	Yellow	-	-
Westslope (Yellowstone) Cutthroat Trout	*Oncorhynchus clarkii lewisi*	Blue	SC (2016)	1-SC (2010)
Largescale Sucker	*Catostomus macrocheilus*	Yellow	-	-
Mountain Whitefish	*Prosopium williamsoni*	Yellow	-	-
Arctic Grayling	*Thymallus arcticus*	Yellow	-	-
Cutthroat Trout	*Oncorhynchus clarkii*	-	-	-

[a]BC List Status:
Blue – special concern
Yellow – not at risk
[b]COSEWIC Status and date of last review:
SC – special concern: species sensitive to human activities or vulnerable to natural events

[c]SARA Schedule:
Species at Risk Act schedule, status (definitions the same as COSEWIC) and date of last review
- no status

Notes:
[1] Health, Safety and Reclamation Code for Mines in British Columbia

Table 2-6: Fish Species of the Sheep Creek and Their Conservation Status

Common Name	Latin	BC Status[a]	COSEWIC[b]	SARA[c]
Brook Trout	*Salvelinus fontinalis*	Exotic	-	-
Bull Trout	*Salvelinus confluentus*	Blue	-	SC (2012)
Rainbow Trout	*Oncorhynchus mykiss*	Yellow	-	-
Westslope (Yellowstone) Cutthroat Trout	*Oncorhynchus clarkii lewisi*	Blue	SC (2016)	1-SC (2010)
Longnose Dace	*Rhinichthys cataractae*	Yellow	-	-
Slimy Sculpin	*Cottus cognatus*	Yellow	-	-

[a]BC List Status:
Blue – special concern
Yellow – not at risk
[b]COSEWIC Status and date of last review:
SC – special concern: species sensitive to human activities or vulnerable to natural events

[c]SARA Schedule:
Species at Risk Act schedule, status (definitions the same as COSEWIC) and date of last review
- no status

Conestoga-Rovers & Associates (CRA) personnel observed on-site aquatic life during the 2007 Formal Dam Inspection; observations included small fish within a stagnant pool of water upstream of the culvert opening, downgradient of the property boundary. In addition, trout were observed within the downstream channel between the HB Dam and the highway during a site visit in May 2019. Observations of painted turtle (*Chrysemys picta*) and amphibians in the retention pond were also made by the landfill operator, consultants and RDCK staff.

SLR completed a biological survey of the tailings pond on September 12 and 13, 2018. A total of seven baited minnow traps were deployed in the tailings pond to determine fish presence. Additionally, angling within the tailings facility was completed during a 4-hour period. During this event two SLR biologists, under approved permit and license, completed angling within the length of the tailings pond utilizing with a standard fishing rod and a baited hook. No fish were detected during this effort. No fish activity was noted during the duration of survey including during the deployment of minnow traps.

No fish were observed in the pond or captured in the minnow traps during the biological assessment. Columbia spotted frogs (*Rana luteiventris*) were observed at the northern and northeastern seepage ponds located north of the tailings area, and multiple painted turtles were also observed within the ponded area.

2.4.2 Vegetation

Terrestrial Ecosystem Mapping has not been prepared for the general project area to document pre-mining land use capabilities and to provide the basis for setting post-mine land use objectives. Instead, information was obtained at the regional ecosystem level, where the classification units are ecosections and biogeoclimatic subzones and variants, to provide a general overview of local vegetation.

The Project area occurs within the Interior Cedar-Hemlock (ICH) dry warm biogeoclimatic ecosystem classification (BEC) zone (ICDdw1) which typically contains productive forests primarily supporting species listed in Table 2-7.

Table 2-7: Project Area Species List

Common Name	Scientific Name
Tree Species	
western hemlock	*Tsuga heterophylla*
western redcedar	*Thuja plicata*
lodgepole pine	*Pinus contorta*
Douglas-fir	*Pseudotsuga menziesii*
paper birch	*Betula papyrifera*
western white pine	*Pinus monticola*
Common Shrub Species	
common snowberry	*Symphoricarpos albus*
Douglas maple	*Acer glabrum*
tall Oregon-grape	*Mahonia aquifolium*
Utah honeysuckle	*Lonicera utahensis*
thimbleberry	*Rubus parviflorus*
falsebox	*Paxistima myrsinites*
hazelnut	*Corylus cornuta*
mallow ninebark	*Physocarpus malvaceus*
and mock orange	*Philadelphus lewissii*
Herb Species	
wild ginger	*Asarum caudatum*
lady fern	*Athyrium filix-femina*
spiny wood fern	*Dryopteris expansa*
oak fern	*Gymnocarpium dryopteris*
false Solomon's seal	*Smilacina racemose*
foamflower	*Tiarella trifoliata*
stream violet	*Viola glabella*

Source: Meidinger and Pojar 1991

The Stage 1 Submission for reactivation of the HB Mill report (International Environmental Consultants [IEC] Ltd. 1982), reviewed as part of the HHERA, noted the following vegetation growing in the vicinity of the mine site listed in the Table 2-8.

Table 2-8: Project Area Vegetation List

Common Name	Scientific Name
trembling aspen	*Populus tremuloides*
black cottonwood	*Populus balsamifera*
lodgepole pine	*Pinus contorta*
western white pine	*Pinus monticola*
ponderosa pine	*Pinus ponderosa*
interior Douglas-fir	*Pseudotsuga menziesii*
paper birch	*Betula papyrifera*
timothy	*Phleum pretense*
bluebunch wheatgrass	*Pseudoroegneria spicata*
common horsetail	*Equisetum arvense*
bird’s-foot trefoil	*Lotus corniculatus*
Canada bluegrass	*Poa compressa*
red fescue	*Festuca rubra*
tall fescue	*Schedonorus arundinaceus*
red-osier dogwood	*Cornus stolonifera*
rose spp.	*Rosa spp.*
common snowberry	*Symphoricarpos albus*
redtop	*Agrostis gigantea*
alsike clover	*Trifolium hybridum*
red clover	*Trifolium pratense*
sweet clover	*Melilotus albus*

Historical planting of grasses and fescue occurred at the site prior to 1979 and 1980 as documented in the IEC report. The vegetation mix documented in the report included a variety of agronomic grass and legume species, grasses and alfalfa as well as other grass species. Observations of the vegetation present within the tailings area during site visits were consistent with the historical revegetation mix.

In 2019, Central Kootenay Invasive Species Society (CKISS) coordinated the RDCK’s invasive plant management program. On June 20th, 2019, CKISS staff and contractors conducted an invasive plant inventory at the HB Facility and associated access roads. CKISS invasive plant activities followed the guidelines established by the Invasive Alien Plant Program (IAPP) Reference Guide (MFLNRORD 2010); and the Invasive Plant Pest Management Plan for the Southern Interior of British Columbia (MFLNRORD 2019). All 2019 and 2020 survey, mechanical and chemical treatment data was entered into the BC Government Invasive Alien Plant Program database.

Ten species of invasive plants were observed at the HB Facility and associated access roads. Invasive plants noted on site included burdock species, Canada thistle, chicory, common tansy, flat pea, mullein, oxeye daisy, spotted knapweed, sulphur cinquefoil, and yellow hawkweed. All species observed are listed as either Established or Insufficient Information within the Invasive Plant Management Area, and three are either Provincially or Regionally Noxious (CKISS 2019).

In August, 2019, and June, 2020, all invasive plants along the access road were spot-treated with Clearview®. Herbicide concentrate was applied using a handgun at the recommended application rate of 0.23 L/ha. CKISS will continue to manage on-site invasives as part of a regional program at all RDCK waste facilities

2.4.3 Wildlife

The facility is located within the Interior Cedar Hemlock (ICH) Biogeoclimatic Ecosystem Classification (BEC) zone of BC. The ICH BEC zone is characterized by a relatively high species diversity owing to productive forests and its location along the lower slopes and valley bottoms (Meidinger and Pojar 1991). The cool, long, snowy winters, warm, dry summers and the dense coniferous forests that typify the ICH BEC zone are important ecological factors that influence wildlife species use of this zone (Meidinger and Pojar 1991). Typical wildlife species that occur within riparian areas, meadows, lakes and streams associated with the general project area listed in Table 2-9 below. Note that Table 29 lists the species typically occurring in the area as per Meidinger and Pojar (1991) and is not intended to be a comprehensive list.

Table 2-9: Project Area Wildlife Species List

Common Name	Scientific Name
grizzly bear	Ursus arctos
grey wolf	Canis lupus
American kestrel	Falco sparverius
ruffed grouse	Bonasa umbellus
mountain bluebird	Sialia currucoides
terrestrial garter snake	Thamnophis elegans
common loon	Gavia immer
American beaver	Castor canadensis
muskrat	Ondatra zibethicus
painted turtle	Chrysemys picta
Columbia spotted frog	Rana luteiventris
western toad	Anaxyrus boreas
moose	Alces americanus
mule deer	Odocoileus hemionus
white-tailed deer	Odocoileus virginianus
Caribou	Rangifer tarandus

An ecological risk assessment (ERA) was completed by Azimuth for the agricultural property south of the facility known as the “Ross Property” (Azimuth 2013). The ERA included the identification of receptors of concern (ROCs; including provincially and/or federally listed species at risk) applicable to the agricultural property and surrounding area. ROC selection was based on the results of two field surveys completed in 2006 and 2011 (Azimuth 2013). Based on the proximity of the property assessed in the ERA to the site, terrestrial wildlife (excluding livestock) identified in the ERA are assumed to have the potential to be present at the facility. Table 2-10 provides a list of terrestrial wildlife ROCs identified in the HHERA.

Table 2-10: Terrestrial Receptors of Concern

Common Name	Latin Name	Common Name	Latin Name
Birds			
European starling	*Sturnus vulgaris*	tree swallow	*Tachycineta bicolor*
song sparrow	*Melospiza melodia*	cliff swallow	*Petrochelidon pyrrhonota*
cedar waxwing	*Bombycilla cedrorum*	northern flicker	*Colaptes auratus*
lazuli bunting	*Passerina amoena*	barn swallow[1]	*Hirundo rustica*
American robin	*Turdus migratorius*	great blue heron[1]	*Ardea Herodias*
Mammals			
white-tailed deer	*Odocoileus virginianus*	red squirrel	*Sciurus vulgaris*
northern pocket gopher	*Thomomys talpoides*	meadow vole	*Microtus pennsylvanicus*
Columbian ground squirrel	*Spermophilus columbianus*	American black bear	*Ursus americanus*
yellow-pine chipmunk	*Tamias amoenus*	American beaver	*Castor canadensis*
coyote	*Canis latrans*	-	-
Reptiles			
garter snake spp.	*Thamnophis spp.*	-	-

Note(s):

1 - blue-listed species; threatened

A desktop review was completed to identify the potential vertebrate species-at-risk which may occur within the general project area utilizing a search of the BC Species and Ecosystem Explorer (BC CDC 2020). This included a search for vertebrate and invertebrate species listed as Endangered, Threatened or Special Concern under the *Species at Risk Act* and by the Committee on the Status of Wildlife in Canada and Provincially Red or Blue-listed species. A total of 52 listed species with the potential to occur within the ICH BEC zone and the Central Kootenay Regional District (BC CDC 2020) were identified. These include 3 amphibian, 13 mammal, 22 bird, 5 reptile and 9 fish species and sub-species. Of these 52 listed species, 35 are listed under SARA and/or COSEWIC including:

- Seven mammal species: American badger (Taxidea taxus), wolverine (*luscus* subspecies), little brown myotis (*Myotis lucifugus*), caribou (*Rangifer tarandu*s; southern mountain population), American badger (*Taxidea taxus*) and grizzly bear.
- Seven fish species: bull trout (*salvelinus confluentus),* cutthroat trout, *lewisi* subspecies (*Oncorhynchus clarkii lewisi*), columbia sculpin (*Cottus hubbsi*), shorthead sculpin (*Cottus*

confusus), Umatilla dace (*Rhinichthys umatilla*), and white sturgeon (Kootenay River population; *Acipenser transmontanus* pop. 1)

- Thirteen bird species including: common nighthawk (*Chordeiles minor*), evening grosbeak (*Coccothraustes vespertinus*), long-billed curlew (*Mumenius americanus*), Lewis's woodpecker (*Melanerpes lewis*), western screech-owl, *macfarlanei* subspecies (*Megascops kennicottii macfarlanei*), yellow-breasted chat (*Icteria virens*), barn swallow (*Hirundo rustica*), bobolink (*Dolichonyx oryzivorus*), black swift (*Cypseloides niger*), olive-sided flycatcher (*Contopus cooperi*), short-eared owl (*Asio flammeus*) and western grebe (*Aechmophorus occidentalis*).
- Eight amphibians or reptile species: Coeur d'Alene salamander (*Plethodon idahoensis*), northern leopard frog (*Lithobates pipiens),* painted turtle - Intermountain - Rocky Mountain population (*Chrysemys picta pop. 2*), western skink (*Plestiodon skiltonianus*) and western toad (*Anaxyrus boreas*), North American racer (*Coluber constrictor*), western skink (*Plestiodon skiltonianus*).

Many of these species listed have the potential to occur within the general project area; however, some species including mountain goat (*Oreamnos americanus*) and wolverine (*Gulo gulo*) are unlikely to be in the project area.

The potential for known occurrences of species at risk within the project area was reviewed through a review of iMap BC (Province of BC 2019). The search results from iMap BC did not identify known occurrence of species-at-risk within the general project area. The HHERA considered species at risk in the selection of the ecological receptors (Section 2.6 of the HHERA provided in Appendix E).

2.5 Current Land Use and Capability

2.5.1 Land Status and Use

The RDCK owns 444 hectares of industrial-zoned land which includes the RDCK Central Landfill and the facility. Approximately 2.7 hectares of the southwestern corner of the RDCK-owned property is within the Agricultural Land Reserve (ALR); however, the tailings facility project area is greater than 300 m from the ALR designated lands. Downstream of the Facility, the downstream channel passes through a culvert beneath highway 3 and through a privately-owned acreage within the ALR. The land is currently unoccupied but contains one single-family dwelling, and a water supply well. The land was previously used as a cattle ranching operation.

The existing disturbance area of the tailings facility measures approximately 34 hectares; it includes the tailings deposition area, tailings pond, dam, spillway, stilling basin, downstream discharge channel, associated access roads, granite rock quarry, and the three borrow areas. The closure project area includes the existing facility disturbances as well as the expansion of the toe berm, spillway, and two existing borrow areas located on the south and east sides of the Central Landfill. The total area of new disturbance will be approximately 6 hectares.

Transportation Corridors

There are no existing transportation routes (roads or waterways) within the property boundary; however, Provincial Highway 3 is located approximately 500 m west of the dam, and the facility's discharge channel passes through a culvert beneath the highway and onto private lands. The western portion of the RDCK property, outside of the closure project area, is within the Conditional Registration Reserve area for the Oasis, Salmo, Yahk Natural Gas Pipeline by Inland Natural Gas Co. Ltd. and the Southern Crossing Pipeline Project.

The property is partially fenced along Emerald Road, with gates across the two site access points to restrict vehicle entry. Portions of the property boundary along Emerald Road that are not fenced are ditched to prevent vehicle access. “No trespassing” signs are present at the gates, dam face, perimeter of the tailings deposition area, and at the south property boundary near Highway 3, where access is steep and inhospitable to vehicles. Because of the restricted access, recreational activities like hunting, snowmobiling, and ATV use are limited, although there is some evidence of trespassing.

Archaeology

As defined by the Archaeology Branch, the facility lies within the Interior Plateau Archaeological Cultural Area. The RDCK completed an initial Archaeological Overview Assessment which utilized the provincial archaeological predictive model. This assessment indicated that some of the project area may be within a moderate archaeological potential area, as the tailings pond was identified as a natural body of water and the tailings deposition area as natural flat plains. The RDCK engaged Tipi Mountain Eco-Cultural Services (Tipi Mtn.) to complete an Archaeological Desktop Review of the project and to investigate the archaeological potential of the project area. The Desktop Review found that one pre-contact archaeological site and 12 historical sites are within a 10 km radius of the facility, but none are situated within the property boundary (Tipi Mtn. 2018). The assessment determined that the project could proceed without resulting in negative impacts to pre-contact archaeological resources. The assessment did not include culturally significant resources or landscapes, although these items were discussed with First Nations that met with the RDCK to discuss the project. First Nations engagement activities are documented in Section 5.2.

Natural Resources

The facility is within the Selkirk Natural Resource District, and the Kootenay Boundary Natural Resource Region. There is one active licensed trapline area (Tag# TR0408T004) that covers the entire RDCK owned property. No physical traplines are present within the property boundary. There are no other licensed or permitted users such as forestry, guides and outfitters.

Ecosystems adjacent to and within the project area are discussed in the Human Health and Ecological Risk Assessment outlined in Appendix E. The assessment includes discussion of present and future receptors, including individuals and biota possibly exposed to contamination from the tailings both at the facility and downstream.

Mineral Tenure

Several mineral and placer claims occur within the outline of the RDCK-owned property, as shown on Figure 3. The RDCK has a mineral claim registered over the dam and spillway area of the site. No other claims are located within the project area.

Landfill Use

The northern half of the tailings deposition area is within the Central Landfill Operational Certificate boundary. As part of landfill operations, the tailings deposition area has historically been used for wood chip storage and several piles remain that are partially vegetated. The Central Landfill ceased daily fill operations in July 2014 and underwent formal landfill closure to BC Landfill Criteria standards, as approved by MENV, in 2015 and 2016; however, material drop-off facilities and staging areas for wood waste, scrap metal, and yard and garden waste remain in use at the landfill. The tailings deposition area is occasionally used for storage of yard and garden waste if capacity within the landfill footprint is temporarily exceeded. The RDCK has maintained the landfill Operational Certificate for ongoing use and potential future waste management needs.

2.5.2 Land Capability

The Canadian Land Inventory (CLI) mapping was used to review local land-use capability data for agriculture, forestry, wildlife, and recreation, and is provided as basic information detailed in Figure 4. It is summarized as follows:

- Agricultural – not available from CLI. Class 6 and 7 (MENV 1980): soils capable of producing perennial native forage crops or no capability for arable culture primarily due to adverse topography, shallowness to bedrock, and adverse climate.
- Forestry – Ranging from lands having no important limitation (Class 1) to slight limitations (Class 3) to the growth of commercial forests. Tailings area is identified as Class 5, defined as having moderately severe limitation to the growth of commercial forests.
- Ungulates – Class 3, slight limitation to the production of ungulates or 3w, areas having slight limitation to the production of ungulates but correspond to winter ranges on which animals from surrounding areas depend.
- Waterfowl – Class 7, severe limitations so that almost no waterfowl are produced.
- Recreational – Class 6, low capability for outdoor recreation for the majority of the site with the exception of Class 5: moderately low capability within the northern half of the property.

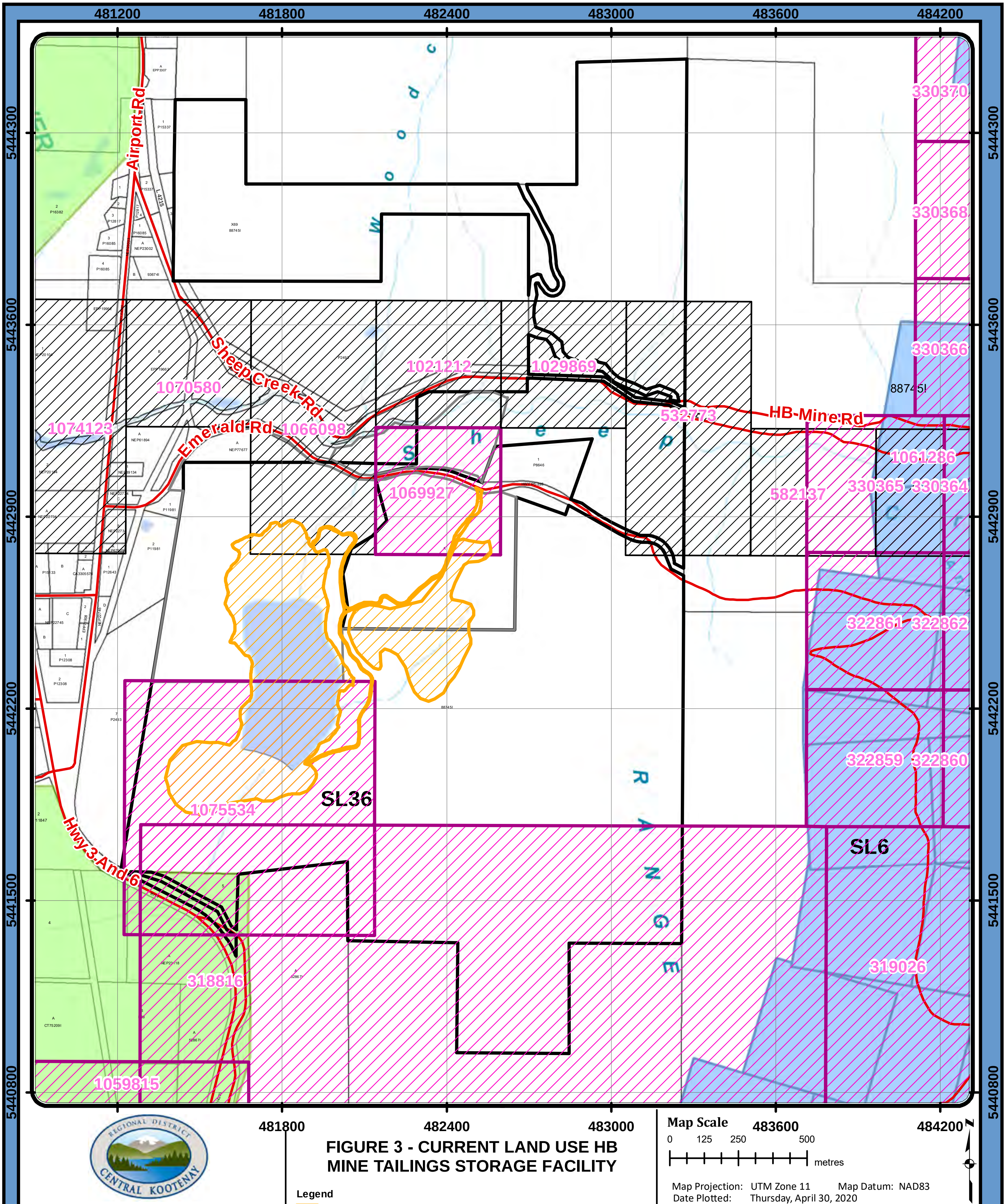


FIGURE 3 - CURRENT LAND USE HB MINE TAILINGS STORAGE FACILITY

Legend

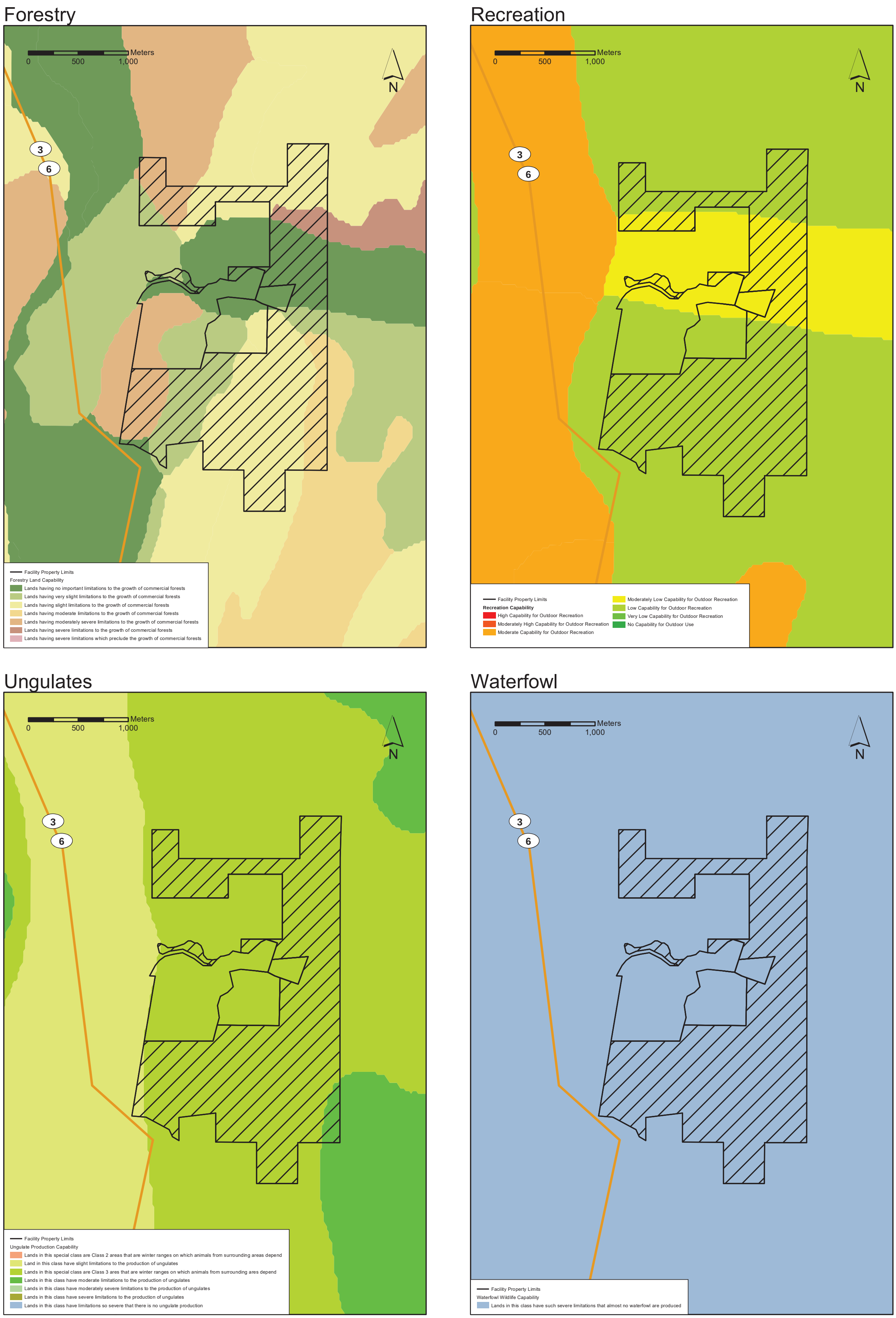
- PROJECT AREA
- Placer Claims
- Mineral Claims
- LANDFILL OPERATION CERTIFICATE AREA
- FACILITY PROPERTY BOUNDARY - ZONED HEAVEY INDUSTRIAL
- HWY/ROAD
- ALR
- CROWN GRANTED MINERAL CLAIM
- PROPERTY BOUNDARY
- DISTRICT LOT
- STREAM
- LAKE

Map Projection: UTM Zone 11 Map Datum: NAD83
Date Plotted: Thursday, April 30, 2020

Box 590, 202 Lakeside Drive, Nelson, BC V1L 5R4
Phone: (250) 352-6665 Toll-Free 1-800-268-7325 (BC)
Fax: (250) 352-9300 Internet: www.rdck.bc.ca

Data Sources

The following sources of data are updated as changes occur:
Cadastral Lot - Surveyed lots/parcels of land;
Sources: Crown Land Registry Services and RDCK
District Lot; Source: Crown Land Registry
Services, Integrated Cadastral Initiative (ICI) and RDCK
TRIM Data - Planimetry, Unsurveyed Roads, Contours; Source: Ministry of Water,
Land & Air Protection ALR - Agricultural Land Reserve; Source: BC Land Reserve Commission
Zoning - Rural Land Use, Land Use, Zoning Bylaws, where bylaws are in place; Source: RDCK
Roads - Road centerline compiled 2003; Source: RDCK



Source:
MSRM GIS topographic data courtesy of http://srmwww.gov.bc.ca/gis/arcftp.html
September 15, 2004
Land Use, Recreational Use, Ungulates, and Waterfowl courtesy of
Geogratis Canada, 2008.
http://geogratis.cgdi.gc.ca/cgi-bin/geogratis/cli/landuse.pl
August 5, 2008

REGIONDAL DISTRICT OF
CENTRAL KOOTENAY
ENVIRONMENTAL SERVICES

Figure 4
LAND USE CAPABILITY

HB MINE TAILINGS STORAGE FACILITY
Regional District of Central Kootenay

017275-00(LAY002)GIS-WA003 Tuesday, April 05, 2011

3 Current Site Components

The current existing disturbance area of the facility includes: the tailings deposition area and tailings pond, the tailings dam, spillway, downstream channel, associated access roads, granite rock quarry, and borrow areas (Drawing 03). The closure project area will include the existing facility disturbances as well as the expansion of the toe berm, spillway, rock quarry, and two existing borrow areas located on the south and east sides of the Central Landfill. Current land status and use are discussed in detail in Section 2.5.1.

3.1 Tailings Deposition Area

The HB Mine Tailings Facility contains approximately 6.3 million tonnes of tailings that cover an approximate area of 26 ha and that are impounded by the HB Dam. The tailings have an approximate maximum thickness of 20 metres near the south-central portion deposition area, immediately upstream of the dam. Tailings were spigotted from the north end of the tailings deposition area, resulting in a grain size segregation during deposition, with coarse sand tailings present at the north end of the facility, and fine silt tailings at the south end of the facility.

Trees are believed to have been harvested prior to deposition. Based on borehole evidence, tree stumps and organic material remain in the facility. Soils beneath the tailings deposition area range from silty sand to silty sand and gravel with some clay (BGC 2002).

3.2 Tailings Dam

3.2.1 Dam Construction History

This section summarizes the construction history of the dam. Further details of the construction history during operations and dam materials are provided in Appendix C-3.

The dam was initially constructed in 1955 using borrow material excavated from the east and west abutments that generally consisted of silty sand and gravel. The materials were transported into place by bulldozers, with the weight of the dozing equipment providing the only compaction. An earth-filled timber crib retaining wall was constructed at the downstream toe. The water levels in the tailings pond during the first phase of operations (1955-66) were controlled by two decant towers, with 600 mm steel pipes that discharged into the outlet creek.

In 1964, a portion of the timber crib wall failed and was reconstructed three to five metres further downstream using drains; a stabilizing berm (till) was constructed downstream of the timber crib. The dam was progressively raised as required through downstream construction methods until mine operations were suspended in 1967. Throughout this initial phase of operations, several small pipe drains were installed as required to convey seepage[1].

Prior to the restart of operations in 1974, a filter layer consisting of clean sand and gravel was added to the downstream slope. The dam was subsequently raised by ten feet in 1974–75, and

[1] The specific nature, locations, and number of drains are uncertain, but this uncertainty has been mitigated in the design as outlined in Table 6.3 in Section 6.2.

by five feet in 1977. Each of these dam raises was designed and supervised by Golder Associates.

The 1975 dam raise included placement of additional “toe protection,” consisting of gravel and waste rock, at locations where seepage was observed at each abutment and at the toe of the dam. The 1977 dam raise included the construction of a rock toe drain on the downstream toe. In addition, the two decant towers were filled with concrete and a new decant structure and 900 mm diameter pipeline outfall system were installed at the east abutment. Tailings deposition in the facility ceased in 1978 when mining at the property was suspended.

In 1981, the property was acquired by David Minerals Ltd., and the mill was upgraded to custom mill gold-bearing sulphide ore, with a second circuit added to treat molybdenite-gold ore. No dam upgrades or raises were completed by David Minerals. The mill was operated in 1982. The amount of ore processed is unclear but is believed to be insignificant. According to the BC Mineral Inventory (MINFILE), 6,350 tonnes were processed at the mill from the neighbouring Gold Belt Mine (MINFILE 082FSW044) and 1,000 tonnes of waste rock from the Velvet Mine in Rossland, BC (MINFILE 082FSW162). In addition, there is evidence that waste rock from the War Eagle Mine in Rossland was also processed at the mill in late 1982, but no record of production can be found. Due to the long-haul distance between Rossland and the HB Mill, it is unlikely that a significant quantity was processed.

Over the course of operations at the facility, several releases of tailings have occurred, resulting in downstream tailings deposition and contamination of the receiving environment. Remediation of the facility, with a focus on the containment of tailings and on minimizing transport of suspended sediments, will alleviate the potential negative environmental impacts associated with maintaining the facility in its current active closure state.

The adjacent RDCK Central Landfill operations started in 1983, and in 1998, the tailings facility was purchased by the RDCK.

In 1997 and 1998, the BC Ministry of Energy and Mines inspected the site and requested the facility be decommissioned. BGC Engineering Inc. was retained to undertake the decommissioning project; investigations and engineering design were completed between 2000 and 2002, and construction was completed in 2005. The decommissioning consisted of the following steps:

- An open channel spillway was constructed in bedrock at the west abutment; the 1977 decant structure and pipeline were decommissioned.
- A 10 m wide toe berm was constructed with a 1.5 m thick rock drain layer to improve the dam stability.
- Riprap was added to the upstream slope of the dam for erosion protection.
- The crest of the dam was regraded to drain towards the tailings pond.

In the summer of 2012, an embankment slough occurred, and two sinkholes were subsequently identified on the toe of the upstream face of the dam (Drawing 04). A 50 mm diameter standpipe was found at one of the sinkhole locations, which is believed to be a piezometer installed in Golder-73-BH-01. The standpipe was removed, and the damaged area reconstructed. The reconstruction included a shear key at the toe of the sloughed area, replacement of the core material using locally sourced till, and placement of a coarse rock layer on the downstream face of the dam. A portion of the coarse rock used in the repair works consisted of riprap sourced from the spillway. The spillway was retrofitted with replacement riprap in 2015. Further details of the slough and repairs can be found in EBA (2012).

3.2.2 Dam Material Properties

Details of the dam construction history and of previous geotechnical investigations, including the geotechnical aspects of the dam material properties and zoning, are presented in Appendix C-3.

3.2.3 Dam Decant Structures

As noted in Section 3.2.1, three decant structures were used throughout the tailings facility operations: the east and west decant towers were used between 1955 and 1977, and the east abutment decant structure was used between 1977 and 2005. The location and alignment of each decant system are shown on Drawing 04.

The original east and west decant tower system discharged water through vertical timber shafts; water was conveyed through the dam inside 0.6 m diameter corrugated metal pipes located in the dam fill (Golder 1976).

The corrugated metal pipes are reported in historical Cominco as-built drawings to have been filled with concrete following construction of the east abutment decant structure; however, no as-built documentation of the decommissioning is known to exist. The evidence that both pipes were filled with concrete consists of the following observations:

- At the east decant, sandbags are visible at the east decant pipe outlet; they have been cemented in place with no evidence of water flowing out of the pipe.
- At the west decant, two pipes are cemented in-place inside the west decant timber shaft; these were likely used to deliver the cement used to seal the decant pipe.

The outlet of the west decant pipe was exposed during the 2005 decommissioning and was found to be leaking. As the volume of leakage was considered to be minor, filter material was placed around the pipe outlet to continue to allow the water to drain, and the pipe outlet was subsequently buried with drain rock as part of the toe berm construction.

The east abutment decant structure was decommissioned in 2005; the lower portion of the decant pipeline was removed and the upper portion of the pipeline was plugged with concrete. In addition, the intake structure and surrounding area were filled with compacted low-permeability fill material to prevent any direct contact of pond water with the decant structure. Details of the 2005 decommissioning are provided in BGC (2005).

3.2.4 Dam Spillway

The current dam spillway was constructed in bedrock at the west abutment as part of the 2005 decommissioning works (BGC 2005). A plan view of the spillway is provided on Drawing 04. The spillway consists of a 90 m long side channel excavated into bedrock, and a riprap-lined outlet channel with a trapezoidal section, a bottom width of 3 m, and side slopes of 2H:1V. The average slope of the channel is approximately 20%, and the median rock size of the 900 mm thick riprap layer along the channel is 450 mm. The downstream end of the channel consists of a stilling pool intended to dissipate the energy of the water conveyed by the channel before it is discharged into the downstream channel.

3.3 Borrow Sources

Borrow investigations were completed in 2017 and 2018 in support of the remediation and closure design. The 2017 investigation included seven test pits excavated at the North Sand and Gravel Borrow area located on the north side of Emerald Road, and eight test pits excavated at the Landfill Sand and Gravel Borrow area located northeast of the Central Landfill. The 2018 borrow investigation consisted of twenty test pits excavated in the Till Borrow Area located southwest of the Central Landfill. The borrow area plans with test pit locations are provided in Drawing 19. The complete results of the 2017 and 2018 borrow investigations are provided in Appendix F-1 and F-2, respectively. A summary of the available borrow materials is provided in Table 3-1.

Table 3-1: Available Borrow Volume Estimates

Borrow Area	Estimated Available Volume (m^3)
North Sand and Gravel Borrow Area	7,800 [1]
Landfill Sand and Gravel Borrow Area	36,000 to 50,000
Till Borrow Area	169,000 to 235,000

Note:

1. The North Sand and Gravel Borrow Area is not needed for the project and is not planned to be developed.

The North Sand and Gravel Borrow area generally consists of dry sand and gravel with traces of fines (generally less than 5%). No groundwater was encountered in any of the test pits.

The Landfill Sand and Gravel Borrow area was found to be more variable compared to the North Sand and Gravel Borrow area, with material ranging from a well-graded gravel with some cobbles, to silt with sand. No groundwater was encountered in any of the test pits.

The Till Borrow Area south of the Landfill Area was last used in 2015; the excavated material was used as cover soil for the closure of the Central Landfill. The 2018 borrow investigation included test pits within the existing borrow area footprint and in potential new areas of disturbance to the southwest, south, and southeast of the borrow area. Material within the existing borrow footprint consists of silty sand (or sandy silt) with gravel and cobbles; no test pits encountered groundwater or bedrock. Materials to the south and southwest of the existing borrow area were generally coarser than in the existing borrow, with two of the test pits suspected to have encountered bedrock at a depth of 3 m. Materials encountered to the southeast of the existing borrow ranged from fine-grained lacustrine material to silty coarse sand with gravel.

As part of a separate RDCK project, a pad for a compost facility will be constructed at the north end of the Till Borrow Area (Drawing 19). The compost facility pad has been positioned such that its construction does not impact the volume of borrow available for the remediation and closure works. Soils excavated during construction of the pad will be stockpiled with the Till Borrow Area and will be available for use.

3.4 Site Infrastructure

3.4.1 Access Roads

Access to the facility is via Emerald Road, then unnamed gravel roads through the Central Landfill property. The dam is accessed from the north via the gravel road that runs towards the south along the outside limits of the landfill. The northern portion of the impoundment area is accessed via the gravel road verging to the west along the northern refuse limits of the landfill. The access roads were initially constructed during the early development of the tailings facility in 1955 and have remained unchanged since the RDCK established the Central Landfill in 1983. Access roads are plowed weekly during the winter months. Culverts and ditches are inspected prior to freshet by the landfill site operator, and repairs are completed as required. Road shoulders and ditches are well vegetated, are inspected annually for invasive weeds, and treated as required.

3.4.2 Pumps

A high-capacity 6-inch diesel pump is permanently located at the site near the east abutment of the dam. Spring and fall maintenance are completed on the pump to ensure it is in good working order. The pump has a floating intake to ensure the tailings are not disturbed in the event the pump needs to be used. A dry box containing the keys, fuel, operating procedures, and tools are stored adjacent to the pump. Due to theft on the property, the pump hoses are in a secure location at the landfill site.

4 Closure Objectives

4.1 Closure Objectives

In 2016, an assessment was undertaken to assess technically and economically feasible options for the remediation of the site to reduce liability and the resources required to maintain the facility in its current form (SRK 2016). The overall objective for the remediation of the site is to successfully limit, counteract, prevent, or mitigate the escape or migration of contamination from the facility to remove any adverse effects on the environment or human health. Based on the assessment, the RDCK elected to remediate the site by transitioning the HB Mine Tailings Facility to “passive closure” as defined by the Canadian Dam Association (CDA 2014).

The CDA defines passive closure of a mining dam as follows:

- No active operation of the dam and no changes to the dam are expected to occur.
- The dam is considered to be in steady state conditions, with sufficient experience gained through monitoring to demonstrate that no further intervention is required.
- There is no requirement for water treatment or need for personnel to manage water levels in the pond upstream of the dam.
- The site does not require operating personnel on site or regular surveillance.
- A spillway has been established to passively release water from the system.
- Potential erodible exterior slopes are covered or treated (vegetation or rockfill).
- Periodic monitoring and maintenance, geotechnical engineer inspections, dam safety reviews, and OMS Manual updates will still be required.

The remediation and closure measures presented in this report have been designed to meet the CDA requirements for passive closure and to achieve the overall objective for remediation of the site.

4.2 Land Use and Capability Objectives

The RDCK Electoral Area G Land Use Bylaw No. 2452 was adopted on September 20, 2018. In the bylaw, the 444 ha property that contains the facility is zoned M3–Heavy Industrial. Industrial objectives outlined in the bylaw include supporting and enhancing industrial uses within the Bylaw area while minimizing incompatibility with surrounding land uses through requirements for screening or landscaping.

Prior to the development of the tailings facility in 1955, the main land use of the area was wildlife habitat. Consistent with the 2011 Reclamation Plan, end land-use considerations for the facility include the following features:

- Tailings Deposition Area and Tailings Pond: mixed land use including wildlife habitat and industrial (Southern Contaminant Attenuation Zone (CAZ) for the adjacent Central Landfill operations, with rationale detailed in the report “Contaminant Attenuation Zone Evaluation: Southern Groundwater Flow Path” (CRA 2005a)).
- Abandoned roads: closed to the public and gated to restrict entry.
- Borrow areas and quarry: industrial use.

The end land-use areas are shown in Figure 5. Remediation of the tailings deposition area will result in approximately 26 hectares of grassland for wildlife/future industrial use. The reclaimed dam face will result in approximately 2 hectares of grass area for wildlife use. Productivity and capability objectives for wildlife habitat include the following goals:

- The re-establishment of a vegetation mat (food source, cover, hide, etc.) and self-sustaining native vegetation without continued dependence on fertilizer or reseeding.

- The establishment of a vegetative cover with sufficient density and species diversity to stabilize the surface against the effects of long-term erosion.
- The establishment of plant material that does not show environmentally significant uptake of metals.

Productivity and capability objectives for industrial land-use at the tailings deposition area include groundwater quality that does not degrade below applicable regulatory criteria/guidelines at the property boundary.

An industrial end land use is considered for the Till Borrow Area located immediately south of the Central Landfill as this area will be the future site of an organics composting facility, and compost curing and storage areas. The RDCK Board approved proceeding with the composting facility project with municipal partners committing to curbside collection of organics by 2022. Appropriate drainage and vegetation cover will be established as part of composting facility construction completion.

FIGURE 5 - END LAND USE OBJECTIVES

Legend

- MIXED WILDLIFE & INDUSTRIAL
- BORROW AREA - INDUSTRIAL
- ACCESS ROADS - NOT RECLAIMED
- PROPERTY BOUNDARY

Map Scale

0 40 80 160 240 320

Meters

Map Projection: UTM Zone 11 Map Datum: NAD83

Date Plotted: Monday, August 17, 2020

REGIONAL DISTRICT
CENTRAL KOOTENAY

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Data Sources

The following sources of data are updated as changes occur:
Cadastral Lot - Surveyed lots/parcels of land;
Sources: Crown Land Registry Services and RDCK
District Lot; Source: Crown Land Registry
Services, Integrated Cadastral Initiative (ICI) and RDCK
TRIM Data - Planimetry, Unsurveyed Roads, Contours; Source: Ministry of Water,
Land & Air Protection ALR - Agricultural Land Reserve; Source: BC Land Reserve Commission
Zoning - Rural Land Use, Land Use, Zoning Bylaws, where bylaws are in place; Source: RDCK
Roads - Road centerline compiled 2003; Source: RDCK

5 Remediation and Closure Planning

5.1 Historical Remediation Work

The facility was used intermittently from 1955 to 1983. The site has remained relatively undisturbed since 1978, with the exception of construction activities in 2005 associated with the approved decommissioning plan and minor construction repair works in 2012 and 2015. The following remediation development has occurred to date at the facility:

1977
- Revegetation of the "1974 borrow area" located to the east of the HB Dam, subsequent to a field study that was conducted in 1977 to evaluate and select commercially available grass and legume species for glacial till slopes.

1978
- Construction of three parallel erosion control ditches in the "1974 borrow area" to divert runoff away from the HB Dam.
- Compaction of roads within "west borrow area" excavated to 30 cm depth, ditch construction, steep till slope reduced to improve vegetation establishment.
- Planting of coniferous and deciduous tree seedlings in borrow area.

1979
- Establishment of vegetative cover within "1974 borrow area" and "west borrow area" dominated by alsike clover, red top and timothy with significant creeping red fescue, sheep's fescue, and ticklegrass.
- Satisfactory growth of tree seedling planted in the area with black cottonwood invasion.
- Initiation of tailings revegetation studies.

1980
- Maintenance fertilizer program of borrow areas in early to mid May.
- Dense and diverse vegetative cover noted throughout most of borrow areas with significant growth of native trees, shrub, and forb species on slopes along the east and west edges of area including willow, alder, poplar, service berry, Douglas fir, lodgepole pine and ticklegrass
- Maintenance and monitoring of tailings revegetation studies, initiation of field studies to assess woody plant species establishment/growth, and expansion of pilot scale testing of revegetation project.

1998
- HB Mine–Tailings Water Quality testing conducted on June 3, 1998, by Interior Reforestation Co. Ltd. on behalf of Cominco.

1999
- Geochemical sampling of tailings conducted on May 17, 1999, by Cominco.

2002
- Permit M-218 (Permit) issued by the Deputy Chief Inspector of Mines on April 10, 2002, to the RDCK approving the "H.B. Mine Tailings Pond and Dyke Decommissioning Plan" (Decommissioning Plan) (BGC 2002).

2004
- Preparation of a work plan to address the Mine Related Issues as directed by MENV (CRA correspondence dated March 19, 2004). The field component of the work plan was initiated in June 2004 and completed in February 2005. A letter report, dated December 16, 2005, was prepared by CRA that summarized the results of the work program implemented for Mine Related Issues and provided recommendations for long-term monitoring.

2005
- Undertaking of decommissioning work in the summer of 2005 in accordance with the Decommissioning Plan (BGC 2002) to bring the facility to current-day

standards; inclusion of the placement of long-term erosion protection along the upstream face of the dam, decant drain closure, open channel spillway construction, and toe berm construction.

2008
- Development of an Operation, Maintenance and Surveillance Plan (OMS) and Emergency Preparedness Plan (EPP) for the facility that were submitted to regulatory agencies and stakeholders in 2008.

2011
- Completion of formal 5-Year Reclamation Plan completed by CRA, submitted to MEMPR for permit amendment application for surface water diversion works.

2012
- Awarding of contract to begin surface water diversion channels, but work was permanently cancelled due to a large slough on the downstream side of the dam which required significant works to the facility.

2013
- Lowering of spillway sill by 0.65 m to permanently lower the pond
- Seeding of areas exposed by pond lowering

2015
- An area of seepage was identified on the downstream face of the dam near the east abutment. A specific conductance assessment of the seepage was completed which identified that the seepage was related to upstream water.
- Geotechnical investigation of the dam filter and foundation material in October by Thurber. A perforated pipe was exposed while completing a test pit on the downstream face of the dam. The pipe was excavated and the area was repaired with a weighted filter.
- Retrofitting of the erosion protection in the spillway in July by EBA

2016
- Repairs of seepage drain and buttresses in October by EBA in the seepage area identified in 2015, to reduce the risk of piping/erosion due to uncontrolled seepage
- Completion of Remediation and Closure Options Assessment Report in August by SRK
- Geotechnical and geochemical investigation of tailings properties in December by SRK, to support closure and remediation planning

2017
- Test pit investigation in December by SRK to identify borrow materials for closure

2018
- Completion of Closure and Remediation Preliminary Design Report in June by SRK.
- Completion of a preliminary vegetation metal uptake study in July by SLR

2019
- Completion of an invasive weed assessment report in June and treatment in August by CKISS

2020
- Completion of invasive weed treatment in June by CKISS

5.2 Consultation and Engagement

As regional districts are legislated under the *Local Government Act* and Community Charter, all major decisions involving the management of the facility are required to go to the Board of Directors, which consists of publicly elected representatives from electoral areas and municipalities. Boards meetings must be open to the public, except under circumstances described in the Section 90 of the Community Charter. Decisions relating to this project are presented to the Board in open public meetings where members of the public and media are often present. As a result of these open meetings, several articles regarding the works outlined in this plan have been included in local newspapers and online publications such as the Nelson Star, My Kootenay Now, The Nelson Daily, My Nelson Now, Castlegar News, and Trail Times.

To cover the cost of the work outlined in this plan, the RDCK has to complete long-term borrowing through the Municipal Finance Authority (MFA). Public consultation was completed in support of the borrowing process. The authority to proceed with long-term capital borrowing under the MFA is attained by receiving elector approval from eligible electors to adopt a Loan Authorization Bylaw. To obtain this approval, the RDCK opted to proceed with the Alternative Approval Process (AAP) to directly engage citizens about the proposed bylaw. An AAP is successful if fewer than 10% of the electors petition against the bylaw. If 10% or more of eligible electors sign and submit an elector response form during an AAP, then the issue is considered significant and a referendum is be required.

In support of the AAP, the RDCK sent a community mailer to 8,593 businesses and residences in an effort to provide project information to all 18,039 eligible voters. The mailer included a brief site history, information about the tailings facility and the closure project, and frequently-asked questions. The mailer invited residents to visit the project-specific website, and call or email the RDCKs project lead with any questions or concerns or to request for additional information. The RDCK received very few responses from the community mailer. All comments received were related to the increase in taxation rates to fund the project and Teck's level of responsibility for the contamination on site as the former owner/operator. No comments received from the general public were relevant to the works outlined in this plan.

To receive a 10% response against the adoption of the Loan Authorization Bylaw, the AAP required 1,804 responses. The AAP concluded on September 10, 2018, and only received 22 responses, which is 0.12% of eligible voters. Based on voter response, and response to the community mailer, the issue was considered insignificant, and it was deemed that further public consultation was not required. The RDCK continues to discuss the project in open public Board meetings and maintains and updates the project website as needed.

The RDCK engaged with First Nations in the fall of 2018 to provide early project information and encourage meaningful discussions, and to allow adequate response time to ensure that concerns could be addressed in this plan. The RDCK completed the consultative areas database (CAD) search, which provided a list of 12 First Nations and Bands to engage with. The CAD results were confirmed with a First Nations Relations Advisor with the Ministry of Forests, Lands, Natural Resource Operations and Rural Development. On October 19, 2018, the RDCK emailed a project introduction letter to all groups identified in the CAD search. The letter included some site background information, a scope of work for the closure project, an outline of the design process and expected schedule, a list of permits that will be applied for, the results of an archaeological overview assessment, and an invitation to discuss the project further. The following documents were attached to the letter:

- HB Mine Tailings Facility Closure and Remediation – Preliminary Design Report, SRK Consulting Ltd. (2018).

- Preliminary Design Report Figures – Site Location, Final Site Plan, Upgraded Dam Cross Section, Tailings Surface Drainage Channels Plan and Profiles. SRK Consulting Ltd. (2018).
- Archaeological Desktop Review Final Report. Tipi Mountain Eco-Cultural Services Ltd. (2018).
- Project Boundaries Figure. RDCK (2018).
- KML File of Project Boundaries. RDCK (2018).
- Key Project Contact List for RDCK.

The RDCK received three responses and met with the Shuswap Indian Band and the Ktunaxa Nation Council in December 2018 and January 2019, respectively. A log of First Nations engagement activities is included in Appendix G.

5.3 Metal Leaching/Acid Rock Drainage Assessment

5.3.1 HB Mine Geological Setting

The HB Mine is located 2 km north of the tailings facility, on Aspen Creek. The orebodies are thought to be Kootenay Arc-type carbonate hosted sedimentary exhalative deposits. The deposits are located within dolomitized limestone of the Reeves Member of the Lower Cambrian Laib Formation, correlative with limestone of the Badshot Formation. The east boundary of the Laib Formation is in fault contact with argillites of the Lower to Middle Ordovician Active Formation, with the Active Formation overthrust from the east over the Reeves Member. The mineralogy of the ore is relatively simple with pyrite, sphalerite and galena in decreasing order of abundance and local minor pyrrhotite. Other secondary minerals include calamine, smithsonite, anglesite, and the rare zinc phosphate, spencerite. The northern portion of these bodies is exposed at surface, near the original HB claim, where they are oxidized to a depth of about 100 metres. Where the ore is protected by enclosing dolomite, relatively little oxidation has occurred.

5.3.2 Tailings Characterization

Geotechnical characterization of the tailings was undertaken in May 1999 (Cominco 1999) and December 2016 (SRK 2017).

The 1999 sample results demonstrated a negligible potential for acid rock drainage (ARD) concerns based on neutralization potential/acid potential (NP/AP) ratios and net neutralization potential (NNP) greater than 4.8 and 514 kg $CaCO_3$/tonne, respectively (Cominco 1999). Metals of environmental interest reported for samples of tailings solids included lead (1228 to 2344 ppm), zinc (1945 to 4057 ppm), arsenic (45 to 135 ppm), copper (9 to 73 ppm), and cadmium (15 to 38 ppm).

The purpose of the 2016 tailings characterization program was to determine the effects of lowering the water level within the facility on water quality; the program consisted of six boreholes drilled in the tailings deposition area using a hollow-stem auger. The complete results of the assessment are provided in Appendix H.

The 2017 geochemical test results were found to be similar to Cominco's (1999) with all NP/AP ratios over 4.0. The HB tailings contain iron, lead, and zinc sulphide minerals (pyrite, galena, and sphalerite, respectively). Cadmium does not occur as a discrete sulphide mineral but is a trace component of sphalerite. Abundant calcium and magnesium carbonate minerals (calcite and dolomite, respectively) are also present. The tailings are thought to be non-acid generating in perpetuity because carbonate content far exceeds sulphide content.

Pore water chemistry, including the concentrations of heavy metals contained in the sulphides, will be controlled at relatively low levels by the non-acidic carbonate weathering environment. For example, the solubility of zinc is controlled by the mineral smithsonite ($ZnCO_3$). Under weathering conditions resulting from oxygen diffusion into the tailings, sulphide minerals will oxidize to sulphates, the acid generated will be neutralized by reaction with carbonate minerals, and the main metals of concern (cadmium, lead, and zinc) will be precipitated as carbonates. Sulphate will likely be precipitated as calcium sulphate.

Conceptually, these secondary minerals (such as smithsonite) are expected to be forming readily and controlling the concentrations of metals in the current tailings pore water. While lowering of the water table will potentially result in a greater mass of tailings being exposed to oxidation, the secondary minerals will continue to form and prevent pore water tailings concentrations from increasing above current levels.

5.3.3 Other Potential Source Terms

The upgraded spillway at the west abutment of the HB Dam requires the excavation of approximately 4,350 m^3 of granitic bedrock and placement of approximately 2,500 m^3 of riprap. The riprap is to be sourced from the spillway rock excavation and from the granite rock quarry located approximately 75 m southwest of the HB Dam. This quarry was used as the riprap source during the 2005 remediation works.

The existing riprap, quarry, and exposed bedrock face at the existing spillway were inspected by SRK in 2018. The granite unit is described as a light grey, coarse-grained equigranular granite with accessory biotite. The granite exposed in the existing spillway and quarry is predominantly fresh, unaltered, and devoid of sulphides. A localized zone of granite hosting trace fine disseminated pyrite with minor Fe-oxide coating on joint planes was identified in the quarry; it is exposed over approximately 3 m in the quarry face.

Overall, the granite has a low potential for ML/ARD and presents favourable material for use as riprap. To minimize the potential for formation of acidic conditions, it is recommended to avoid the localized zones of granite with Fe-oxide staining and minor disseminated pyrite during development of the quarry and this material should be removed from the spillway channel if it is identified during development of the channel.

5.4 Water and Load Balance

A simple water and load balance was prepared in support of the closure design. Predicted water quality was evaluated to help determine if the tailings cover will sufficiently improve water quality at the downstream property line, adjacent to Highway 3 (Outlet Ditch). Full details of the water and load balance are provided in Appendix I.

The model considered inputs from the upland landfill, runoff from upstream catchments, direct precipitation onto the facility, and outflows through the spillway and downstream seepage. The water balance made use of annual precipitation inputs and of the average monthly discharge distributions from the Salmo River to model volumetric flow rates from upstream catchment areas to the tailings storage facility (TSF). The model was calibrated by comparing the calculated flows with observed flows from select monitoring stations. The water quality parameters that are monitored seasonally (spring and fall) were further applied in the calculations of mass-balance loadings.

The mass balance accounted for loading sources within the model domain, as well as fluxes in and out of the model domain. Loading rates were estimated by assigning source water quality concentrations to the inflows for the corresponding sub-catchments estimated in the water balance. Parameter concentrations at each model node was determined by summing the parameter load reporting to that node and dividing by the total volume at that node. For most parameters, loadings were assumed to be conservative (i.e., not attenuated). Aluminum, iron, manganese, and zinc were overestimated using this approach, and estimates of attenuation, developed based on calibration with monitoring data, were applied for these parameters.

The model was set up and calibrated for existing conditions. The calibrated inputs were then applied to the current TSF configuration using average hydrological conditions and average source terms including attenuation estimates for some parameters (Current Condition), and to the post-closure TSF configuration including covered tailings. The model's assumptions were evaluated with sensitivity analyses for infiltration rates, source terms, attenuation factors, and hydrological conditions.

Screening of monitoring data at the downstream property line (Outlet Ditch) was completed to identify Contaminants of Potential Concern (COPC). Water quality predictions were developed for these parameters. The following COPCs were determined: aluminum, cadmium, chromium, copper, iron, lead, manganese, sulphate, sulphide, and zinc.

The following conclusions were based on the water quality modelling exercise:

Sources:

- The tailings material is the primary source of sulphate, cadmium, iron, lead, and zinc; the cover is predicted to reduce concentrations of these parameters at the Outlet Ditch.
- The background catchment runoff is the primary source of chromium, copper, manganese and sulphide.
- The cover material is the primary source of aluminum; however, this could be an artifact of source-term development based on total metals, which includes both the dissolved and suspended fractions. The suspended fraction will not act conservatively as water flows through the facility.

Water Quality Trends:

- For sulphate, iron, lead and manganese, the cover is predicted to improve water quality. Estimates of current conditions used to compare predictions are below the BC WQG; the cover aids in further reducing concentrations of this parameter.
- For cadmium and zinc, the cover is predicted to improve water quality. However, the reduction in load from covering the tailings is insufficient to reduce the amount of cadmium and zinc loadings to the Outlet Ditch, and these parameters are predicted to exceed BC WQG even after the cover is in place.
- For chromium, the tailings are not a significant source; the addition of cover material will increase chromium concentrations at the Outlet Ditch.
- For aluminum, the cover material is a significant source and applying the cover to the TSF will increase aluminum concentrations at the Outlet Ditch.
- For copper and sulphide, the presence of a cover makes no difference in the water quality predictions at the Outlet Ditch.

Aluminum, cadmium, chromium, sulphide, and zinc levels are predicted to exceed either the BC WQG (approved or working) or the lowest CSR.

Model results were most sensitive to source terms developed for application in the model, based on routine monitoring data. The sensitivity of the predictions to the infiltration cover rate was found to be low. The range of infiltration rates considered in the sensitivity analysis did not significantly change the predicted concentrations, and therefore had no impact on whether the respective BC WQC was exceeded or not.

The water and load balance model will be updated as part of the post-closure monitoring program as described in Section 7.2.8.

5.5 HHERA and Environmental Effects Prediction

A prospective Human Health and Ecological Risk Assessment (HHERA), based on anticipated future post-closure site configuration and assumed environmental quality, was completed for the TSF. Specifically, the HHERA assessed risks to human and ecological health once the proposed TSF soil cover (thickness of 30 cm) and surficial drainage channels, as well as other proposed upgrades to the spillway and outlet ditch, will be implemented. The HHERA assessed risks to human and ecological receptors based on measured contaminant concentrations in soil, groundwater and sediment, and predicted surface water concentrations representative of post-closure conditions (Section 5.4). Potential risks were assessed through an analysis of the quantity and distribution of those contaminants and potential exposure pathways for humans, plants, organisms, and wildlife (i.e. direct contact with soil and surface water, ingestion of surface water etc.) as well as the toxicity of individual contaminants where complete exposure pathways were identified. SRK's predicted post-closure water quality values were used in the development of the HHERA. Annual validation of the HHERA for the facility will be completed following annual data review and compilation from the post closure monitoring program. A summary of the assumptions, parameters assessed, and results of the human and ecological health assessments are provided in the subsections below. The complete HHERA is included in Appendix E.

5.5.1 Human Health

The HHERA assessed potential risks to on-site human receptors including occasional maintenance workers and recreational receptors (i.e., hikers, campers, etc.) as well as off-site residents and farmers on the surrounding properties.

Based on the expected presence of 30 cm soil cover on the surface of the facility, no complete exposure pathways were identified for direct contact with soil for recreational receptors. Since groundwater is not used as a potable water source on site, contact and ingestion of groundwater was also considered an incomplete exposure pathway.

Using predicted surface water concentrations provided by SRK, no contaminants of potential concern (COPCs) were identified for ingestion of surface water or irrigation of crops downgradient of the site. Ingestion of surface water was not considered a complete on-site exposure pathway based on the expected site use and ephemeral nature of the downstream channel. Similarly, exposure to sediment within the downstream channel was considered an insignificant exposure pathway for recreational receptors based on the limited extent of the sediment impacts and ephemeral nature of the stream.

For surrounding residents and farmers, potable water use to the north and west of the site was considered an incomplete exposure pathway based on the direction of groundwater flow, and the presence of a bedrock ridge immediately west of the facility. Since the direction of groundwater flow through the facility is predominantly to the south, exposure to off-site receptors south of the site is a potentially complete exposure pathway. However, exposure via potable water use was considered an insignificant pathway, based on the results of the historical sampling and current land uses south of the site.

A potential complete exposure pathway was identified for potential future groundwater users immediately south of the site due to the concentrations of lithium in groundwater; however, as noted in the HHERA report, the source of the lithium in groundwater has not been confirmed. RDCK indicated that the lithium concentration appeared to be stable downgradient and is unlikely to be related to groundwater quality concerns at the site (RDCK 2019). The concentration of lithium in the downgradient wells have historically been higher than groundwater concentrations measured within the tailings area. Lithium levels were below detection limits in all soil samples collected within the tailings area, (RDCK 2019), supporting the rational that high lithium values are not related to the site.

Since potentially bioaccumulative COPCs were identified in plant tissue on site (arsenic, cadmium, lead, and zinc), human recreational receptors may also be exposed to contaminants through consumption of plant life. A review of the vegetation planned for the site following closure indicated that edible plants (i.e., berries, etc.) are not planned for the site area, therefore significant foraging on site is not expected to occur, and risks to human health due to consumption of plant life is expected to be insignificant.

Should hunting occur on site, recreational receptors could in theory be exposed to COPCs in wildlife tissue. Livestock tissue sampling was completed as part of an ecological risk assessment (ERA) completed at a property immediately south of the facility, south of Highway 3 (known as the Ross Property). Based on the results of the ERA, contaminants were concluded not to be bioaccumulating in wildlife tissue at concentrations that may pose a risk to human health (HHERA Report). The ERA is expected to be more conservative than the conditions on site, as livestock tend to be confined to feeding within a particular area, continuously exposed to a single contaminant source. In addition, the planned soil cap for the site will restrict incidental ingestion and exposure to site contaminants, reducing overall exposure. Based on the results of the 2013 ERA and expected future conditions, bioaccumulation of contaminants in the human food chain is expected to be insignificant.

Since no complete or significant exposure pathways were identified for human health related to exposure to contaminants in the soil (i.e., tailings material), groundwater, or surface water under post-closure conditions, exposure to on-site contaminants is expected to be negligible for on-site and off-site receptors under post-closure conditions.

5.5.2 Ecological Risk

The HHERA assessed potential risks to terrestrial and aquatic ecological receptors on site and downgradient of the site post-closure. The HHERA quantified risks for a broad range of ecological receptors identified at the site including surrogate receptors in order to focus on the species with the highest potential to be affected. A summary of the terrestrial and aquatic effects based on the results of the HHERA is provided in the following sections.

Terrestrial Effects

Potentially complete ecological exposure pathways for terrestrial receptors included the following potential scenarios:

- Ingestion of COPCs in surface water by wildlife.
- Root contact with COPCs in subsurface soil and groundwater by plants.
- Direct contact with soil for burrowing wildlife.
- Uptake of COPCs to plants and subsequent bioaccumulation through the food chain.

No COPCs were identified for direct contact with surficial soil for soil invertebrates or wildlife. Based on the surficial cover planned for the site, surficial wildlife and soil invertebrates are unlikely to be appreciably exposed to subsurface soil; this pathway was therefore considered incomplete. Based on the expected compaction of the tailings compared to the new cap material, the majority of invertebrates are expected to be present in the top 30 cm of soil. In addition, since the borrow-pit material will consist mainly of silty sand and gravel material, organic content is expected to be low and therefore soil dwelling invertebrate populations will likely also be low.

For wildlife species, ingestion of contaminated food (e.g., as prey) represents the principal exposure pathway for bioaccumulative COPCs. Arsenic, cadmium, lead, and zinc were identified as potentially bioaccumulative COPCs in terrestrial environmental media (soil and or plant tissue). Cadmium, copper, chromium, lead, and zinc were identified as potentially bioaccumulative COPCs in surface water and/or sediment. Based on the type of habitats available on site and on the wildlife species most likely to use this habitat, the ingestion of aquatic food (by prey) is not considered to represent a significant exposure pathway for potentially bioaccumulative aquatic COPCs. The completion of an aquatic food chain model was not warranted as part of the HHERA.

Risk estimates above the risk target level hazard quotient (HQ=1) were identified for plant root contact with arsenic, lead, and zinc in subsurface soil (i.e., tailings material) and manganese, fluoride, uranium, and zinc in groundwater.

Based on the review of historical information related to vegetation at the site (Section 2.4.2), historical planting of grasses and fescue occurred at the site prior to 1982, as documented in the Stage 1 Submission for reactivation of the HB Mill report (IEC Ltd. 1982). Based on a review of historical planting activities at the site, successful vegetation growth was documented following planting activities. Therefore, risks to the vegetation species expected to be planted during closure (such as grasses, alfalfa, etc.) are expected to be negligible.

Potential wildlife exposure to consumption of arsenic, cadmium, lead, and zinc in plant tissue through the food chain was evaluated as part of the HHERA. The results of the HHERA indicated that risks to wildlife associated with soil to plant bioaccumulation, and with ingestion of site food items and soil are expected to be negligible for all wildlife receptors for arsenic and lead. Risks are also expected to be negligible for cadmium and zinc for all wildlife receptors with the exception of the song sparrow (HQ of 1.4 for cadmium and 2.1 for zinc) and American robin (zinc, HQ = 1.6), as the risk estimates were marginally above the target risk level (HQ = 1).

Due to the limited size of the available dataset, risk estimates for wildlife were calculated based on maximum plant tissue concentrations collected from the site. This may result in an overestimate of risks to plant-consuming wildlife such as the song sparrow and American robin. The HHERA defined the overall risks to plant-consuming birds as low; however, uncertainty with risks to these receptors were expected to be high due to the limited available vegetation dataset and limited on-site receptor information.

Wildlife receptors can potentially use surface water as a source of drinking water. Aluminum was identified as a COPC for ingestion of surface water by wildlife. Cadmium, copper, chromium, lead, and zinc were identified as bioaccumulative COPCs in surface water. Based on the ephemeral nature of the future surface water bodies on site, as well as the limited aerial extent of the surface water bodies compared to the site as a whole, bioaccumulation of COPCs via ingestion of surface water only is not considered to represent a significant exposure pathway at the site for wildlife.

Aquatic-dependent wildlife species may also be directly exposed to COPCs in water via dermal contact. This exposure pathway was considered to be complete, but not a source of significant exposure as the integument (e.g., fur and feathers) of mammals and birds acts as a barrier to chemical exchange (BC MOE, non-dated).

Aquatic Effects

Aluminum, beryllium, cadmium, chromium, copper, iron, lead, zinc, and nitrite were retained as aquatic-life COPCs in surface water. Direct contact with surface water COPCs is the main exposure pathway for aquatic invertebrates, aquatic plants, and fish. Amphibians may also be exposed to surface water COPCs through direct contact (via adsorption through the skin). As such, complete and potentially significant exposure pathways were identified for aquatic invertebrates, aquatic plants fish and amphibians.

Risk characterization for surface water indicated potential risks for the following combination of COPCs and ecological receptor groups:

- Aquatic plants exposed to aluminum, copper and nitrite.
- Aquatic invertebrates exposed to aluminum, copper, zinc, and nitrite.
- Fish exposed to zinc.
- Amphibians exposed to aluminum, copper, and nitrite.

In addition, exposure of aquatic life to sediment was associated with potential risks to from exposure to cadmium, lead, and zinc.

Based on the low magnitude of the HQs obtained for surface water and sediment, the ephemeral nature of the habitat provided by the channels, and the conservative assumptions made in the risk assessment (e.g., use of total metal in the exposure assessment), the potential risks are considered to be low.

5.6 FMEA

Following completion of the draft preliminary design in October 2017, a failure modes and effects analysis (FMEA) was conducted as a one-day workshop to identify all significant risks of the preliminary design, so that those risks could be considered in the detailed design presented in this report. Workshop participants include of members of the SRK project team, RDCK representative, as well as a geotechnical engineer from SRK with no prior involvement in the project. Members of the Independent Tailings Review Board were unable to attend the workshop but provided comment and review on the draft report and risk register.

Results of the FMEA workshop are documented in SRK (2018). The highest risk ratings were determined to be moderately high, which indicates that changes to the design may not be required. All risks that were rated moderate or higher were considered by the project team and resulted in the following additional assessments and modifications to the design:

- A deformation assessment was completed to investigate the effects of the long-term decay of the timber crib structure in the dam, and its impact on dam stability.

- Additional stability analyses were undertaken to assess lateral variability of the dam, sensitivity of the glaciolacustrine foundation material, and spillway side-slope stability. The additional analysis resulted in an increased size of the expanded toe berm.
- The spillway design was updated (width and alignment) to reduce blockage risks and prevent backward erosion during extreme flood events.

As part of the detailed design, the results of the FMEA workshop were used as a basis to update the risks evaluated against the design presented as part of this plan. The results of the updated risk assessment are provided in Appendix J.

Results of the risk assessment show a lower risk profile compared to the preliminary design. No risks were rated as high or very high. The number of moderately high risks was reduced from twenty-five to sixteen. Fourteen of these risks in the extreme consequence and very unlikely category, where the consequence is extreme by definition of the scenario, and the likelihood is unable to be lowered any further. The two-remaining moderately high risks are the following:

1. W5: Degradation of the geosynthetic liners in the tailings surface conveyance channel liners resulting in a need of repair; and,
2. I03: During construction, equipment working on soft tailings sink resulting in a risk to worker's safety.

In both cases, the risks are not practically able to be reduced further through changes to the design. Current estimates of the lifespan of covered liners are typically in the hundreds of years and degradation is expected to be slow, allowing ample time for detection and mitigation. The construction risk of equipment sinking into the tailings can be managed by the contractor through the following common tailings cover-construction practices: trafficability trials, use of spotters, avoidance of repeated trafficking over the same area to allow pore pressures to dissipate, and construction of temporary access roads using geosynthetics and increased fill thicknesses.

6 Closure Measures

6.1 Design Criteria

6.1.1 Tailings Dam

Dam Hazard Classification

In 2014, a dam hazard classification assessment was completed as part of the Dam Safety Review (TTEBA 2014). The dam hazard classification was increased to VERY HIGH from a LOW classification based on revised Dam Safety Guidelines (CDA 2007 revised 2013). The dam classification process considers three hazard-rating components individually: loss of life; environmental and cultural values; infrastructure and economics. The overall dam hazard rating is defined by the component with the highest (i.e., most severe) rating. The HB Dam was rated HIGH for loss of life, SIGNIFICANT for environmental and cultural loss, and VERY HIGH for economic and infrastructural loss.

SRK has reviewed the 2014 consequence classification assessment and agrees with the outcome. The BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD) has published guidelines for the interpretation of the CDA guidelines that includes additional details to quantify economic and infrastructure losses (MFLNRORD 2017). Table 1 of the MFLNRORD guidance states that a washout of a primary or secondary highway is considered to be a very high consequence. Highway 3 is designated a primary highway, and the dam break assessment completed as part of the 2014 Dam Safety Review has estimated that approximately 1 km of Highway 3 would be inundated with tailings ranging in depths up to 4 m. As the highway is located at the base of the long steep valley below the impoundment, a washout of the highway is considered likely.

Geotechnical Stability

The geotechnical stability design criteria are in accordance with requirements stipulated in CDA (2014); the minimum factor of safety (FOS) for static and seismic assessments are provided in Table 6-1. In evaluating the expanded toe berm design, higher design target FOS criterion was adopted for the post-earthquake loading conditions to mitigate deformation risk due to potential liquefaction of the original dam fill (Zone 4).

Table 6-1: Factors of Safety for Slope Stability

Loading Conditions	Minimum FOS (CDA 2014)	Design FOS	Slope
Long-term steady state	1.5	1.5	Downstream
Pseudo-static	1.0	1.0	Upstream and downstream
Post-earthquake	1.2	1.5	Upstream and downstream

Design Earthquake

Based on the dam hazard classification of VERY HIGH assigned to the HB Dam, the Annual Exceedance Probability earthquake design motion is the 1 in 10,000-year event or the maximum credible earthquake (MCE) event.

A site-specific probabilistic seismic hazard assessment was completed for the HB Mine Tailings Facility to determine the corresponding to the 1 in 10,000-year return period event (Appendix C-2). The assessment resulted in a design peak ground acceleration (PGA) of 0.256 g.

Inflow Design Flood

The CDA guidelines indicate that a VERY HIGH dam classification in passive closure should be designed to safely convey the probable maximum flood (PMF) (CDA 2014). The PMF is the highest standard outlined in the CDA design guidelines and is considered the most severe flood event that may reasonably be expected to occur.

The detailed assessment of the PMF associated with the HB Dam is presented in Appendix C-1. The procedures adapted to evaluate the PMF for the spillway sizing are consistent with the CDA guidelines (2014), and the Guidelines on Extreme Flood Analysis (Alberta Transportation 2004).

The PMF was estimated using a rainfall-runoff model approach using HEC-HMS (USACE 2016). Climate change was considered in the flow estimates conducted through a compilation of Intergovernmental Panel on Climate Change (IPCC).

The assessment determined the most severe inflow flood would be associated with a rainfall-dominated spring event under climate change conditions resulting in an inflow design flood (IDF) magnitude of 70 m^3/s.

Design Freeboard

The IDF depth, based on the spillway design, is 2.8 m and the maximum wind-induced wind set-up and wave run-up is estimated to be 0.43 m (Appendix C-5). The minimum freeboard is described as no overtopping by 95% of the waves caused by the most critical wind associated with the annual exceedance probability (AEP) event, when the reservoir is at its maximum extreme level during the occurrence of the IDF (CDA 2013).

The assessment determined a minimum freeboard depth of 0.94 m is required during the passage of the IDF, which is less than the available freeboard of 2.4 m. Table 6-2 summarizes the key elements.

Table 6-2: Design Freeboard Elements

Parameter	Elevation (m)
Spillway invert elevation	705.8
Maximum water-level elevation during Inflow Design Flood (IDF)	708.6
Minimum freeboard depth	0.9
Minimum freeboard elevation	709.6
Current dam crest elevation	711.0
Available freeboard depth	2.4

6.1.2 Spillway

The spillway is to be designed to convey the inflow design flood (IDF) magnitude of 70 m^3/s, which results in a peak spillway discharge of 58 m^3/s. The upper portion of the spillway is excavated through bedrock while the lower portion of the spillway is excavated in till. The erosion protection in the lower section of the spillway is sized to be able to withstand a flood event corresponding to the 1 in 1,000-year event. In the event of the PMF, there is a risk of movement of the riprap and erosion of the underlying soil section of the spillway.

A lower design criterion for the erosion protection in the lower portion of the spillway has been adopted due to the impracticality of producing coarser riprap that would be able to withstand larger flows. The 1 in 1,000-year event was adopted based on the BC Downstream Consequence of Failure Classification Interpretation Guideline (MFLNRORD 2017), which notes that consideration can be given to lowering the spillway design requirements to a 1 in 1,000-year event for facilities rated high or very high due to downstream highway crossings if there is a high probability that the highway would wash out at a flood much below that return period regardless of whether the dam fails or not. As the Highway 3 culvert downstream of the facility would likely wash out during a 1 in 100-year or 1 in 200-year event, the 1 in 1,000-year event design criterion is considered to be appropriate.

An erosion assessment was completed to estimate the maximum extent of backwards erosion that may occur during a PMF. The details of the assessment are presented in Appendix C-5. Results demonstrate that some erosion and undercutting of the 2012 Blast Rock Repair Area may occur, but no significant erosion of the original dam (pre-2012) and no loss of tailings are expected.

6.1.3 Water Conveyance Channels

Drainage channels are required over the tailings surface to convey flows from the Central Landfill wetland area and from two small ephemeral streams that enter the tailings deposition area. The drainage channels have been designed to convey and provide erosion protection for a 1 in 200-year event. Flows in excess of the 1 in 200-year event will overtop the channels and inundate the vegetated tailings cover. A maximum permissible PMF overland flow velocity of 1.0 m/s was adopted to reduce the risk of cover erosion.

6.1.4 Tailings Cover

The primary objective of the tailings cover system is to provide dust and erosion control and to prevent migration of the tailings due to wind and water. The cover will act as a barrier preventing direct contact of the tailings by flora and fauna and will provide a growth medium for the establishment of a sustainable vegetation to reclaim the area and meet the post-closure mixed land-use wildlife habitat and industrial objectives.

6.2 Design Considerations and Analyses

Table 6-3 lists the site issues and concerns related to the performance of the facility and outlines the closure components in the design that mitigate risk and provide long-term stability and containment of tailings to ensure protection of the environment and of human health. The resulting closure components of the remediation consist of the following features:

- Dam upgrades: toe berm expansion and upstream till beach.
- Lowered spillway and elimination of the pond upstream of the dam.
- Tailings cover.
- Lined surface water channels over the tailings facility.

Table 6-4 provides a summary of the analyses undertaken in support of the design described in the following subsections, as well as references to where further details are provided.

Table 6-3: Site Issues and Design Mitigations

Site Component	Issue	Design Mitigations
Dam	- The water level in the tailings pond under normal conditions is higher than the top of the filter blanket, resulting in the potential risk of internal erosion of the 'select impervious fill'.	- Removal of the tailings pond. - Lowering of the spillway invert elevation such that the long-term groundwater level against the dam is lower than the top of the filter.
	- The portions of 'select impervious fill' not protected by the filter may be susceptible to cracking and the development of a preferential seepage path (Thurber, 2016).	- Same as above.
	- The original dam fill placed between 1955 and 1965 is a loose, silty sand material that may be susceptible to liquefaction in the event of an earthquake.	- Assume the entire original dam fill and tailings liquefy and expand the toe berm as required to withstand this conservative scenario.
	- Granular foundation soils near the west abutment are thought to be a potential preferential seepage pathway and a contributing factor to the 2012 slough event (EBA 2012). These soils were exposed, but not removed during foundation preparation in 1975 and 1977. This area is near the feature noted during the 2015 dam inspection as potentially indicative of piping erosion (TTEBA 2016). - An armouring gravel/cobble layer was placed on the upstream slope of the dam and was subsequently buried. The two sinkholes that were observed during the 2012 slough event appeared to be in contact with the armouring gravel/cobble layer, which is believed to provide a conduit to the granular foundation layer (EBA 2012). This situation could increase the potential, under high seepage gradients, for further development of sinkholes through the tailings to the armouring gravel/cobble layer.	- Removal of the tailings pond. - Construction of an upstream beach over the tailings such that there is no direct contact between any temporary stored water during large flood events and the potential preferential seepage pathways on the upstream slope of the dam.
	- The methods used to decommission the West and East Decant structures are unclear (EBA, 2012).	- Removal of the tailings pond. - Construction of the tailings pond backfill over the east and west decant structures will be graded to ensure surface water will not pool in these areas.
	- The dam construction history is not fully understood. It is possible that additional piping or other structures that have not yet been identified are present within the dam or impoundment that could lead to future instability.	- Removal of the tailings pond. - Construction of an upstream till beach over the tailings such that there is no direct contact between any temporary stored water during large flood events and any unidentified seepage pathways.
	- Timber crib may deteriorate with time if the crib extends above the water surface.	- Deformation analysis was completed that concluded that under the worst-case scenario, where the timber completely rots, the potential for settlement along the dam crest is considered negligible.

Site Component	Issue	Design Mitigations
Tailings	- Surface water runs directly over the tailings facility resulting in erosion of the tailings and suspended solids downstream.	- Construction of lined surface-water channels to convey water over the tailings to reduce TSS and prevent erosion. - Covering of the tailings to prevent erosion.
	- Although water quality data show very low metals levels, there is a concern that metals could be mobilized if the tailings are moved or if the water level in the impoundment changes significantly.	- A tailings characterization program was undertaken in December 2016 (SRK 2017). Appendix H provides a prediction of the geochemical performance of the tailings due to lowering the water table, and concludes that the pore water would not be substantially altered.
Water Quality	- Total suspended solids (TSS) levels increase due to surface water flow over the tailings, as well as through the outlet ditch between the spillway and Highway 3. - There have been instances noted by RDCK monitoring where TSS levels measured at the outlet ditch exceed those measured at the tailings pond outlet.	- Construction of lined surface-water channels to convey water over the tailings to reduce TSS and prevent erosion. - Covering of the tailings to prevent erosion.

Table 6-4: Design Analysis Summary

Topic	Description	Appendix
Flood Routing Assessment	A HEC-RAS hydraulic analysis was completed to determine the sizing and erosion protection requirements for the spillway and tailings surface drainage channels during the respective design flood events, as well as the freeboard requirements for the HB Dam.	C-5 (Spillway) C-6 (Surface Drainage Channels)
Dam Stability Assessment	A slope stability analysis was completed in accordance with the guidelines set by CDA (2014). Material properties were selected based on a review of the material properties at the facility (Appendix C-3). The analysis determined that an expansion of the toe berm is required to satisfy pseudo-static conditions as well as post-earthquake conditions due to the potential liquefaction of the original dam-fill materials.	C-4
Deformation Assessment	A deformation assessment was completed to estimate the potential settlement of the dam crest due to the rot of wood from the timber crib wall, and to determine if the minimum required freeboard is maintained once the rot-related settlement occurs. The calculated settlement on the upstream side of the design dam crest was found to be less than 1 cm and the highest average settlement along the downstream crest was found to be 16 cm.	C-7
Dam Seepage	A seepage assessment was completed that developed a model to represent current conditions and assessed its sensitivity to various parameters, as well as predicted the resulting seepage rate and water table location under the proposed design dam geometry. The model predicted a lowered water table and reduced seepage rates.	C-8
Erosion Assessment	An erosion assessment was completed on the downstream slope of the HB Dam to gauge the sensitivity of the downstream slope to erosion and to determine if additional erosion protection is required as part of closure. A soil loss estimation analysis was completed using the RUSLEFAC method to estimate the potential soil losses due to sheet and rill water erosion over the short-term and long-term, with the results compared to commonly accepted soil loss values. The results indicated that the downstream slope of the dam has a "very low" soil erosion classification if adequate grass coverage is present, and no additional erosion protection measures were recommended.	C-9

6.3 Dam Upgrades

6.3.1 Toe Berm Expansion

As discussed in Section 6.2, an expansion of the toe berm is required to satisfy dam stability requirements. Details of the toe berm expansion are provided in Drawings 07 to 10.

The toe berm expansion raises the existing toe berm by 7 m and widens the existing berm by typically 7 m to 9 m. The expanded toe berm crest is 12 m, with a 2.8H:1V downstream slope.

Prior to fill placement, vegetation is to be cleared from the toe berm footprint and soft organics soils are to be excavated from the expanded footprint area prior to placement of the drain rock layer. The organic soils are to be excavated 1.0 m below surface, or until competent dense soils are encountered. As required, the existing toe berm is to be excavated to expose the existing drain rock to allow the existing drain layer to be extended into the expanded toe berm.

A 1.5 m thick rock drain layer is to be placed at the base of the expanded toe berm with a layer of geotextile placed as a separation layer between the rock drain layer and the overlying general fill.

The geotextile is designed to retain the overlying general fill and prevent migration of fines into the underlying drain rock. The geotextile requirements were evaluated for soil retention, permeability, clogging, and survivability.

The berm's general fill may be sourced from the spillway excavation or from one of the approved borrow areas. The berm is to be hydroseeded with a mixture of seed, fertilizer, mulch, and a tackifier as soon as possible following construction to ensure soils are stable, non-eroding, and established with self-sustaining vegetation.

6.3.2 Upstream Beach

A beach is to be constructed upstream of the dam over the tailings to mitigate concerns related to preferential pathways through the dam and foundation. The sinkholes observed during the 2012 slough event are believed to be through a buried piezometer pipe (Golder-73-01) and through an armouring gravel/cobble layer placed on the upstream slope of the dam; this layer is thought to have provided a conduit from the tailings surface to the granular foundation material near the west abutment.

A plan and a typical section of the upstream beach are provided in Drawings 09 and 10. The beach material is to consist of well-graded silty sand or other fine-grained material (till or glaciolacustrine material) and may be sourced from the spillway excavation or the Till Borrow Area. The existing upstream riprap erosion protection layer is to be removed prior to the beach construction. The beach will extend the crest approximately 7 m upstream of the existing dam and will have a 4H:1V upstream slope. The upstream beach is to be graded at 2% to drain towards the tailings impoundment. The fill material is to be placed in 0.5 m lifts (or as thin as practical) and compacted under equipment weight. Additional beach extensions (or islands) are to be placed over the location of the former east and west decant towers.

6.4 Spillway

An upgraded spillway, sized to convey the PMF, is to be constructed at the west abutment at an invert elevation of 705.8 m, which corresponds to an elevation that is 0.5 m below the top of the dam filter layer. Fill is to be placed within the tailings pond to prevent pooling of water inside the tailings facility. Because the tailings surface drainage channels are sized to convey flow up to the 1 in 200-year event, water will be stored within the impoundment only during flood events greater than the 1 in 200-year event. During the PMF event, water will only be stored within the impoundment over a one-hour period.

Drawings 11 and 12 provides a plan, profile, and section details of the spillway. Complete spillway design details are included in Appendix C-5. The spillway consists of two distinct sections:

- The upper section (Station 0+000 to 0+085) is situated on bedrock and generally follows the existing spillway alignment but is realigned starting at Station 0+070 to move the lower section of the spillway that is exacted in till as far away from the dam as practical[2]. This section of the spillway has a relatively flat longitudinal slope of 2.2% and has 0.75 H:1V side slopes that are similar to the existing slope angle in the spillway. As required, a nominal pilot channel is to be jack-hammered along the base of the channel to minimize the risk of glaciation (Drawing 12).

- The lower section (Station 0+085 to 0+220) is situated in till and is a straight chute down the western side of the valley with a slope of 19.4%. The lower soil portion of the spillway has 2H:1V side slopes, and a 1.2 m thick riprap layer with a D_{50} of 600 mm. The riprap will be underlain by a layer of nonwoven geotextile that is to include at least 300 mm overlap that is shingled towards the downstream direction.

Both sections of the spillway will have a base width of 5.0 m. The width of the channel was designed to minimize the risk of a spillway blockage and to allow equipment to clear any partial blockage.

6.5 Tailings Cover

A 0.3 m soil cover, consisting of well-graded general fill, is to be placed over all areas of exposed tailings to the extent shown on Drawing 16. The function of the cover is to provide long-term erosion protection and prevention of environmental impacts associated with tailings migration. Following cover placement and depending on availability, the cover soils may be amended with wood chips that are currently stockpiled on the north end of the tailings facility. To reduce the risks of invasive plant seeds, the wood chips have been produced from solid wood sources rather than yard and garden waste.

The following subsections present additional components of the fill placement over the tailings.

Vegetation Removal

All trees, shrubs and other large vegetation that would protrude through the cover are to be removed. The vegetation is to be cut as close to the tailings surface as practical.

Import of Tailings Affected Soil

Placement of tailings-affected soil from the “Ross Lands”[3] needs to be completed prior to cover construction. The “Ross Lands” are located south of the tailings facility immediately to the south of Highway 3; they are estimated to contain 10,000 to 24,000 m^3 of tailings-affected soil as a result of historical discharge of tailings from the TSF into surface water. Teck Resources’ preferred approach to remediate the site is to relocate the tailings-affected soil back into the tailings facility. Additional details of the Remediation Plan are provided in SNC-Lavalin (2018).

The tailings-affected soil is to be placed beneath the tailings cover. The first priority for placement is to fill those areas of the tailings impoundment that have erosion channels, gullies, and other

[2] The bedrock surface at the west abutment dips down to the south so maintaining the spillway in the bedrock further to the south is not practical without significantly deepening the spillway and increasing the rock excavation volume.
[3] Blocks 3, 4, Lot A Block 5 Plan NEP 231118 (Block 5), Block 6 and Block 7, District Lot 275, Kootenay Land District, 8102 Highway 3.

low-lying areas that could pool water. Remaining fill is to be placed in the southern end of the tailings impoundment as part of the tailings pond backfill.

Tailings Pond Backfill

The current tailings pond is to be backfilled to prevent pooling of water in the tailings impoundment and to direct surface runoff to the spillway, as shown in Drawing 13. The fill is to consist of well-graded general fill and is to be graded with an average 2% slope (minimum slope of 1%).

Tailings Area Trafficability

During SRK's site inspection on August 18, 2017, field vane testing was completed on the tailings surface to assess trafficability. Drawing 16 outlines the estimated trafficability conditions.

- In general, the area north of the historical tailings pond (prior to lowering of the spillway in 2012) is believed to be trafficable by heavy equipment, except potentially in wet areas around the facility perimeter. Within the dry north area, the field vane was unable to be pushed through the surface crust, and vane shear readings exceeded 100 kPa within the upper 0.5 m of tailings.
- The current wetted area is believed not to be trafficable by equipment in its current state. Undrained shear strengths obtained from the field vane were typically 10-15 kPa within the upper 3 m of tailings. Placement of the cover and upstream beach within this zone will need to occur following a period of dewatering, and soft-ground construction techniques will be required.
- The area between the two zones discussed above will likely require trafficability testing to be completed by the contractor prior to cover placement to confirm the extents of trafficable surface. Field vane tests completed within this zone generally resulted in undrained shear tests ranging between 20 and 60 kPa within the upper 3 m of tailings, indicating soft ground construction techniques will likely be required.

Trafficability trials are to be conducted by the contractor prior to cover placement and trafficability is to be monitored throughout cover placement.

6.6 Tailings Surface Drainage Channels

Lined surface water drainage channels are to be constructed over the tailings cover to direct surface runoff from the tailings cover and surface inflows to the tailings deposition area in a manner that will prevent erosion and prevent the fine tailings from escaping and migrating downstream. The drainage channels will direct surface water to the spillway from the landfill wetland area (Main Channel) and from two streams on the east side of the impoundment (North and South Spur Channels). The channel alignment, profile and typical sections are provided on Drawings 13 to 15.

The channels have been designed to convey the 1 in 200-year return period event: they have a base channel width of 0.5 m, 3H:1V side slopes, and a minimum channel depth of 1.0 m. The channels are to be lined with a geosynthetic liner and covered with a 0.20 m protection layer overlain by a layer of turf-reinforcement matting (TRM). The objective of the TRM is to provide short-term erosion protection until vegetation is established in the channel.

The inlets of the North and South Spur Channels are to include energy dissipation structures (Drawing 15). The structures are to be lined with a geosynthetic liner and covered with a 0.15 m protection layer and a 0.8 m thick riprap layer. The riprap may be sourced from the upstream slope of the dam, or from the existing spillway.

The Main Channel between Stations 0+700 and 0+873 and the upstream ends of the North and South Spur Channels are situated over soft tailings that are not expected to be trafficable in their current condition. Winter construction or a temporary thick cover may be required in order to complete the construction of the channel within these zones.

6.7 Monitoring Instrumentation

All efforts are to be made to preserve the existing piezometer and monitoring wells at the dam and within the tailings impoundment. The dam piezometers are to be extended accordingly. If the piezometers are destroyed because of construction, they are to be decommissioned and replaced following the completion of construction, or as directed by the Engineer of Record.

Twelve new survey hubs are to be installed along the dam crest and on the downstream slope. The survey hub locations are shown on Drawing 17 and are designed to monitor for potential movement related to long-term decay/rotting of the timber crib within the dam.

The existing seepage weir at the toe of the dam will be removed due to the expansion of the toe berm and will be replaced following construction, or as directed by the Engineer of Record.

6.8 Sediment Removal

Removal of fine sediment accumulated upstream of the silt fence located at the head of the downstream channel will be completed during construction. Monitoring of sediment accumulation will be completed following closure (Section 7).

6.9 Fish and Amphibian Salvage

During the fish salvage, completed under an approved permit, two biologists will use a seine net to block-off the upstream habitat so that no fish, if present, can enter the tailings facility. As the dewatering occurs the biologists, with the aid of an electrofisher, will salvage all fish at the edges of the tailings facility. Seine nets will also be used to isolate areas so that fish salvage can occur. Where it is deemed to likely be effective, minnow traps will also be used to capture small fish for relocation. All captured fish will be relocated downstream of the tailings facility in an area as approved by permit conditions. From earlier fish assessments, it is not expected that fish will be encountered in the tailings pond.

An amphibian and reptile (i.e., painted turtle and rubber boa) salvage program will occur concurrently with the fish salvage program. The details of the amphibian salvage program will be dependent on the timing for the dewatering process but will follow best management practices as detailed in MFLNRORD (2016). Depending on the timing of the dewatering event, the focus of the amphibian salvage may be on different life histories. If it occurs during the breeding season the focus will be on larvae and breeding adults. If the event occurs during the non-breeding season the focus will be on juveniles and adults. SLR will prepare and submit several permits and notifications that are required for the completion of the work. These include:

- Submission of General Wildlife Permit to complete amphibian salvage within the tailings facility;
- Submission of Scientific Fish Collection Permit in support of potentially required fish salvage activities within the tailings facility;
- Communication with FrontCounterBC with regards to permits and authorizations; and
- Submission of self-assessment under the Fisheries Act.

As part of the development of permits for submission under the BC Wildlife Act, details on handling procedures and proposed relocation sites include Rosebud Lake, Erie Lake, Nellestijn Property (203 Boulder Pit Road), Jonkheid-Steenberg Property (1226 Airport Road) and Peebles Property (1126 Airport Road). Water quality monitoring of the relocation sites will be completed in advance of salvage operations to ensure that the water quality parameters (i.e., dissolved oxygen, pH, temperature and salinity) are the similar or more suitable for amphibians than at the current tailings storage facility. Should water quality monitoring identify sub-optimal conditions at a proposed relocation site, and alternative site will be used that meets water quality parameters.

In addition, post-release survival monitoring will be completed focusing on amphibian larval survival and growth and painted turtle survival. For amphibian larval monitoring, larval amphibian growth and dispersal mass will be monitored at the release sites as well as a paired control site. The actual species monitored will be determined based on the species that are salvaged. During bi-weekly monitoring, though until metamorphosis is completed, events a sub-sample of larvae from each of the release sites, as well as the control sites, will be assessed for Gosner stage, weight and overall health. These data will be used to assess the overall condition of larvae within the release sites and the control sites. At emergence the mass of metamorphs will be assessed at both the release sites and the control sites.

Prior to release, the carapace of each painted turtle will be uniquely marked with non-toxic paint. During subsequent bi-monthly site visits these unique markings will be used as visual cues to help assess the survival of these turtles. Survival monitoring is expected to occur for a minimum of three months.

6.10 Reclamation

Reclamation efforts of all exposed soils and disturbed areas will focus on supporting the establishment of grass species.

The RDCK has wood chips and coarse woody debris stockpiled on the north end of the tailings facility for reclamation purposes. Several other stockpiles of coarse woody debris are located near the borrows, access roads, and dam area. The wood chip and coarse woody debris stockpiles and surrounding areas will be inspected for invasive weeds, and if no invasive weeds are present, the materials will be spread after cover placement to aid in vegetation establishment. Coarse woody debris will also be spread in areas of the tailings cover with low potential for future maintenance (i.e. in areas of away from the Tailings Surface Drainage Channels where flood routing modeling indicates low flow velocities during extreme flood events). Coarse woody debris will be spread in low enough density to allow vehicle and equipment travel across the tailings cover, in the event that repairs or maintenance activities are required.

Native grass and legume species most suited for reclamation at the site, including species that provide good to excellent erosion control, will be used for revegetation and will be sourced from a local seed-supplier specializing in native plant production. Table 6-5 details the proposed seed mix that will consist of a 50-50 mix of Blends 1 and 2 and be applied at a rate of 100 kg/ha. This list may be modified depending on the availability of native seed and natural recruitment of native species is also expected to occur.

Table 6-5: Proposed Seed Mix for Revegetation

Common Name	Scientific Name	Seed Mix Proportion (%)	Notes
Slender Wheatgrass	*Elymus trachycaulus*	14%	Blend 1
Pubescent wheatgrass	*Thinopyrum intermedium*	8%	
Perennial Ryegrass	*Lolium perenne*	16%	
Alfalfa	*Medicago sativa*	9%	
Sheep fescue	*Festuca ovina*	11%	
Creeping Red fescue	*Festuca rubra*	10%	
Canada Bluegrass	*Poa compressa*	16%	
Redtop	*Agrostis gigantea*	16%	
Coated Fringed Brome	*Bromus ciliatus*	8%	Blend 2
Annual ryegrass	*Lolium multiflorum*	13%	
Coated Tufted Hairgrass	*Deschampsia cespitosa*	19%	
Slender Wheatgrass	*Elymus trachycaulus*	7%	
American Slough grass	*Beckmannia syzigachne*	29%	
June grass	*Koeleria macrantha*	24%	

In addition to identifying the species of grasses with the highest potential to become established on mine tailings, revegetation will also include soil preparation and amendments to maximize the probability of establishment. Soil preparation will include a light raking of compacted surfaces to produce interstitial spaces to promote seed germination. Amendments will also include the one-time addition and incorporation of nitrogen, phosphorus, and potassium prior to, or at the time of, seeding at the following recommended application rates:

- Nitrogen (N) at 56 kg/ha
- Phosphorus (P_2O_5) at 200 kg/ha
- Potassium (K_2O) at 50 kg/ha

The proposed grassland tailings cover surface will provide an improvement to wildlife habitat compared to the current vegetated state. While the proposed closure measures do not return the site to the pre-mining ecosystem function, measures allow the RDCK flexibility for other potential future uses of the site.

6.11 Borrow Area Development and Decommissioning

The Landfill Sand and Gravel Borrow Area and the Till Borrow Area shown on Drawing 03 will be developed to obtain the borrow for the project. The North Sand and Gravel Borrow Area will not be developed due to its small size and location across the public Emerald Mine Road. The development and decommissioning of the borrow sources will be conducted in accordance with the project's Construction Environmental Management Plan.

Trees within the borrow footprints are to be cleared and grubbed. Stumps and vegetation will be removed and temporarily stockpiled. Topsoil will be excavated as part of the tailings cover material. As part of a separate project, the north end of the Till Borrow Area will be excavated to create a pad for a compost facility prior to the HB Mine Tailings Facility closure works. The pad construction does not impact the volume of borrow available. The soils excavated for the pad construction will be temporarily stockpiled within the Till Borrow Area footprint use on the HB project.

Following development, all slopes are to be regraded to 2H:1V or flatter. The bottom of each of the borrow areas is to be graded to achieve a minimum slope of 2% in a manner that will prevent ponding. Stockpiled vegetation will either be spread at the borrow area, after RDCK completes composting facility construction, or over the tailings cover, with the final disposal location to be determined by the RDCK.

7 Post-Closure Monitoring and Maintenance

7.1 Environmental Monitoring Plan and Closure Management Manual

As per Section 10.1.3 of the Health, Safety and Reclamation Code for Mines in British Columbia (HSRC), an environmental monitoring and surveillance program is required to demonstrate that the reclamation standards and objectives are being met. Following the 2005 decommissioning activities, a Post-Closure Environmental Monitoring Plan (EMP) was developed for the facility (CRA 2005b) that was approved by the BC Ministry of Environment with subsequent implementation in 2006. The EMP was updated in 2012 as part of a hydrogeological assessment completed for the Central Landfill and the tailings facility (AMEC 2014) and is reviewed annual as part of the annual reclamation reporting.

As per Section 10.6.9 of the HSRC, a Closure Management (CM) manual is required when a mine requires ongoing mitigation, monitoring, and maintenance. The manual describes and documents key aspects of the ongoing mitigation, monitoring, and maintenance requirements, and tracks important changes to components of the system that affect long-term mitigation, monitoring, and maintenance requirements.

The Operations, Maintenance, and Surveillance (OMS) manual will serve as the Closure Management (CM) Manual because all the requirements of the CM Manual are addressed within the existing OMS Manual for the tailings facility (RDCK 2019), and because there are no other components of the site that are typically included in the CM Manual (e.g. waste rock dumps, open pits, underground openings, etc.).

Following construction, the routine inspection, monitoring, and maintenance are to follow the current existing schedule and procedures that are documented in the latest OMS Manual and EMP, as summarized in the following sections. The frequency of monitoring and inspection will be regularly reviewed as part of the dam safety inspections; following a demonstration of physical and chemical stability at the site, it may be reduced at the discretion of the Engineer of Record.

7.2 Monitoring

7.2.1 Geotechnical Monitoring

Routine Visual Inspections

RDCK staff must carry out weekly visual inspections taking note of settlement, pooling of water within the impoundment, spillway blockages, signs of seepage and turbidity (particularly along the dam toe), or vandalism to instrumentation. Visual inspections for sediment accumulation at the head of the downstream channel will also be completed. Records of these inspections must be documented on the visual inspection form prepared for the facility (RDCK 2019).

An inspection for evidence of erosion of the tailings cover is to be completed annually after snowmelt has occurred, or after a severe weather or seismic events.

Annual Dam Safety Inspections

Annually, the Engineer of Record for the facility will undertake a personal physical inspection of the dams. The inspection must be carried out in snow-free conditions and must culminate in a detailed Dam Safety Inspection Report prepared as per BC Ministry of Energy, Mines and Petroleum Resource guidelines (MEMPR 2013). The report must include findings and recommendations on the dam performance taking into account the personal inspection observations, interviews with RDCK staff, as well as a review and analysis of all detailed monitoring data for the dam.

Dam Instrumentation

The design for the monitoring instrumentation is to maintain or replace the existing piezometer instrumentation present at the facility, to continue monitoring of the v-notch weir at the base of the dam, and to establish new survey monitoring points to monitor long-term deformation that may occur as a result of rotting of the wooden features in the dam.

The locations of the dam instrumentation are provided in Drawing 17. The proposed survey hub locations were selected considering the predicted deformation presented in Appendix C-7. In addition to the current dam piezometers, the monitoring of the water elevations in monitoring well MW-03S-05 (located to the north of the existing tailings pond) is proposed, in order to evaluate variations in water elevation within the tailings.

Downstream Channel Inspections

Semi-annual inspections of the downstream channel between the HB Dam and the Outlet Ditch Culvert at Highway 3 are to be completed by RDCK staff to inspect for signs of natural erosion and sedimentation, as well as channel migration and blockages. Inspections are to be completed post-freshet in the spring and during the dry season prior to the onset of winter in the summer or fall. If significant sediment deposition is observed, the RDCK will seek a Qualified Environmental Professional to evaluate if sediment sampling is required. If other issues are noted during the inspections, the RDCK will engage a Qualified Professional to assess the channel.

7.2.2 Water Quality

During tailings pond dewatering, as required by the Waste Discharge Regulation under the Environmental Management Act, water quality will be monitored by RDCKs Environmental Monitor to ensure that all surface water leaving the work site meets the concentration thresholds as outlined in a BC ENV Waste Discharge Approval for dewatering of the tailings pond. In the event the concentration thresholds are exceeded, the dewatering system will be immediately shut down. The surface water data set will be re-evaluated to determine a revised discharge strategy such as reduced discharge rate to meet permitted criteria within the Salmo River.

Following dewatering of the tailings pond, surface water leaving the work site will also be compared to the generic numerical water standards of Schedule 3.2 of the CSR for all water uses and to the BCWQG for freshwater aquatic life (FWAL).

Post-construction, detailed water quality monitoring will be required to ensure the constructed works are performing as intended and that there are no adverse effects on the environment or human health. The monitoring program generally follows the existing Environmental Monitoring Program, which is detailed in the site’s Annual Reclamation Report (RDCK 2018). Water quality results are to be reviewed annually as part of both the annual dam safety inspection and annual reclamation report as to evaluate the chemical stability of the tailings. The surface water results will be compared to the generic numerical water standards of Schedule 3.2 of the CSR for all water uses and to the BCWQG for fresh water aquatic life (FWAL) as well as the toxicity reference values (TRVs) selected as part of the HHERA (Report: Section 3.4; Appendix E).

For the surface water samples, the focus of the analytical review should be on exceedances of the applicable standards/guidelines/TRVs and any trends (e.g. temporal variance) that suggest an increase in contaminant loadings between the inflows and outflows of the tailings facility. For the groundwater samples, the focus of the analytical review should be on exceedances of the applicable standards/guidelines and any trends that might suggest an increase in contaminate loadings. If significant negative trends are clearly evident at any time, taking into account seasonal variability, the data should be reviewed by a qualified geochemist. The parameters and plot types used to evaluate temporal variance will be chosen to comply with MEM's Annual Reclamation Report Format Requirements. If a significant increase in contaminants concentrations or in frequency of exceedances is observed, additional investigations will be implemented (e.g. additional environmental sampling and remedial activities).

Surface Water Monitoring Locations

The recommended surface water sampling locations have been selected to correspond to previous sampling locations; this allows for comparisons of water quality with pre-construction values. Figure 6 provides the surface water sampling locations and Table 7-1 provides location descriptions.

Table 7-1: Surface Water Sampling Locations

Sampling ID	Location Description
TMF Surface Water Sampling Locations	
SW1-07	Central Landfill outflow collected immediately upstream of the tailings facility
SW2-07	Collected from the seasonal stream located upstream of the North Spur Channel Energy Dissipation Structure on the east side of the tailings facility
SW3-07	Background sample collected from the seasonal stream located upstream of the South Spur Channel Energy Dissipation Structure on the east side of the tailings facility
SW5-19	Background sample collected from the seasonal stream located upstream of the North Spur Channel Energy Dissipation Structure on the east side of the tailings facility
Seepage Weir	Collected from seepage upstream of the v-notch weir below the dam
Spillway Inlet	Collected in the spillway inlet area at a location downstream of the tailings
Spillway Outlet	Collected immediately downstream of the stilling basin
Outlet Ditch	Collected upstream of the culvert crossing Highway 3
Salmo Surface Water Sampling Locations	
Salmo – Upstream	Collected approximately 100m upgradient of the point of discharge where the downstream channel intersects the Salmo River
Salmo - Downstream	Collected approximately 100m downgradient of the point of discharge where the downstream channel intersects the Salmo River

Notes:

1. Co-ordinates of the Salmo River upstream and downstream sampling locations are approximate and will be confirmed prior to construction. Co-ordinates are in UTM Zone 11.

LEGEND

- MONITORING WELL
- SURFACE WATER SAMPLE
- WATERCOURSE
- TAILINGS DEPOSITION AREA
- SITE BOUNDARY - HB TAILINGS MANAGEMENT FACILITY
- TAILINGS POND

0 100 200 400 Meters

1:7,500

WHEN PLOTTED CORRECTLY AT 11 x 17 PAGE SIZE
NAD 1983 UTM Zone 10 U

THIS DRAWING IS FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY AND NOT ALL STRUCTURES ARE SHOWN.

REGIONAL DISTRICT OF CENTRAL KOOTENAY
HB MINE TAILINGS MANAGEMENT FACILITY
SALMO, BC

POST CLOSURE MONITORING PLAN

SURFACE WATER AND GROUNDWATER MONITORING AND SAMPLING LOCATIONS

Date: February 28, 2020	Figure No. 6
Project No. 204.03242.00005	

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Surface Water Sampling Methodology

Surface water sampling will be conducted by RDCKs Environmental Monitor at each sampling location above the height of the sediment-water interface utilizing a peristaltic pump or grab sampling method at depth specific intervals. A pump will be used to first purge all water present within the tubing, and then draw water through a flow through cell to establish clarity of the sample and retain parameter observation. Field parameters including temperature, pH, conductivity, DO, and ORP will be recorded using a YSI multi-meter and turbidity readings will be measured will a turbidity meter. Between measurements, the probes will be cleaned using a solution of tap water and Alconox and then rinsed with water. Surface water samples will be placed in ice-filled coolers and delivered or shipped to Bureau Veritas (or alternative accredited laboratory) along with completed chain of custody forms within the acceptable sample holding time.

Receiving Environment Monitoring Locations

The Salmo River receiving environment will be monitoring and sampled post-closure by RDCKs Environmental Monitor. A baseline assessment will be completed to determine Spring background concentrations prior to conducting the dewatering program as described in the WDA. The baseline assessment will include collection of samples upstream and downstream of the point of discharge where the drainage channel intersects the Salmo River. The samples will be analyzed for CPOCs associated with the TMF listed in Table 7-3. Samples both upstream and downstream will be collected in similar locations to those historically sampled approximately 100 m upstream and downstream of the point of discharge. The specific sampling locations are depicted on the site plan included in the WDA submission for reference. The post closure assessment will include sampling the same upstream and downstream locations and analysis as the baseline assessment. The post closure sampling program will consist of an annual event in Spring to coincide with peak discharge flows in the channel as the discharge channel is ephemeral and flows are only expected to reach the Salmo River during freshet.

Groundwater Monitoring Locations

The groundwater sampling locations have been selected to correspond to previous sampling locations to allow for water quality comparisons to be made to pre-construction values. Figure 6 provides the groundwater sampling locations and Table 7-2 provides well descriptions.

Table 7-2: Groundwater Sampling Locations

Sampling ID	Location Description
MW99-1 (S) and (D)	Downgradient to the south of the tailings facility, approximately 144 m north of Highway 3. The shallow well (S) is screened in overburden, and the deep well (D) is screened in bedrock.
MW99-2 (S) and (D)	Immediately northwest of the tailings area and downgradient along the southern flow path. Both wells (S) and (D) are screened in bedrock.
MW-01-05	Background well is screened in overburden located approximately 200 m east of the current tailings pond.
MW-01-2004 (S) and (D)	Downgradient to the south of the tailings facility, approximately 144 m north of Highway 3. The shallow well (S) is screened in overburden, and the deep well (D) is screened in bedrock.
MW-02-2004 (S) and (D)	Downgradient to the south of the tailings facility approximately 45 m north of Highway 3. The shallow well (S) is screened in overburden, and the deep well (D) is screened in bedrock.

Water Quality Analyses

The parameters for laboratory and field analyses of water quality samples are summarized in Table 7-3.

Table 7-3: Water Quality Analyses

	Laboratory Analysis Parameters	Field Analysis Parameters
TMF Surface Water Analyses	• pH • Anion chromatography package (total alkalinity, chloride, bromide, sulphate, nitrate, nitrite) • *Un-ionized sulfide* • Total and dissolved metals (by ICP-MS, sufficient to meet BC Aquatic Life criteria), *speciated chromium analysis* • Total organic and inorganic carbon • Phosphate • TKN (measures ammonia and organic nitrogen) • *Total suspended solids (TSS)*	• Temperature • Conductivity • Dissolved oxygen • pH • Sulfide • *Turbidity* • *Flow rate (visual estimates only).*
Salmo River Surface Water Analyses	• pH • Anion chromatography package (total alkalinity, chloride, bromide, sulphate, nitrate, nitrite) • *Un-ionized sulfide* • Total and dissolved metals (by ICP-MS, sufficient to meet BC Aquatic Life	• Temperature • Conductivity • Dissolved oxygen • pH • Sulfide • *Turbidity* • *Flow rate (visual estimates only).*

	criteria), *speciated chromium analysis* • Total organic and inorganic carbon • Phosphate • TKN (measures ammonia and organic nitrogen) • *Total suspended solids (TSS)*	
Groundwater Analyses	• pH • Total dissolved solids (TDS) • Sulphate • Total and dissolved metals (by ICP-MS, sufficient to meet BC Aquatic Life criteria) • Nitrate/nitrite • Ammonia • Orthophosphate	• Temperature • Conductivity • Dissolved oxygen • pH • Sulfide • *Water elevation*

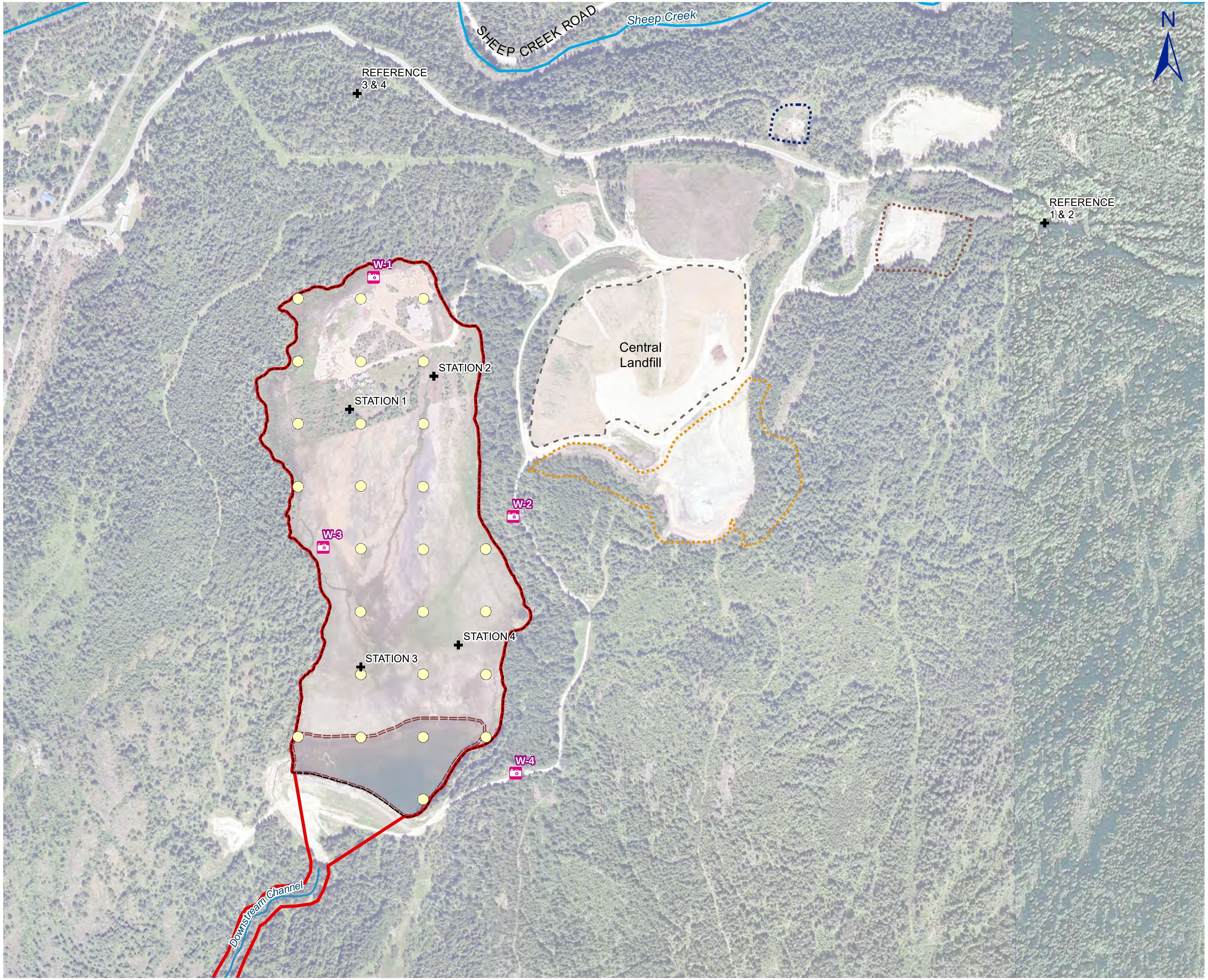
Note:

(1) Differences between surface and groundwater analyses have been italicized.

7.2.3 Vegetation Metal Uptake

The results of a previous plant uptake investigation indicated that arsenic, cadmium, lead, and zinc were found in higher concentrations in plant tissue samples obtained from the facility than from reference locations. Tissue lead and zinc concentrations also appeared to demonstrate a reasonable correlation with soil levels.

The monitoring of uptake of metals by vegetation will be completed by RDCKs Environmental Monitor and will consist of collection and analysis of representative plant species from the areas that have been seeded and replanted. Samples for analysis will be collected in conjunction with the revegetation monitoring at Year 2 post closure. Samples will be collected from three plant species at four locations atop the TSF; samples will consist of plant parts likely to be consumed by wildlife. Up to four sample locations from reference areas representing differing geological conditions in the vicinity of the TMF will also be collected. Tissue samples will be analyzed for arsenic, cadmium, lead, and zinc. The results will be compared to pre-closure concentrations and reported in conjunction with the annual revegetation monitoring described below. Samples of each component part will be composited separately by species and submitted to a certified laboratory for analysis of metals. The results of the vegetation metals uptake monitoring will be used to determine if woody vegetation should be allowed to establish through succession and inclusion of woody vegetation should be added to future monitoring programs. Monitoring locations are shown on Figure 7.



LEGEND

- VEGETATION TISSUE AND SOIL SAMPLE LOCATION
- REVEGETATION MONITORING PLOT LOCATION
- WILDLIFE CAMERA MONITORING LOCATION
- EPHEMERAL WATERCOURSE
- SITE BOUNDARY
- TAILINGS DEPOSITION AREA
- TAILINGS POND
- LANDFILL SAND AND GRAVEL BORROW
- NORTH SAND AND GRAVEL BORROW
- BORROW PIT

0 75 150 300 Meters

1:6,000

WHEN PLOTTED CORRECTLY AT 11 x 17 PAGE SIZE
NAD 1983 UTM Zone 11 U

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REGIONAL DISTRICT OF CENTRAL KOOTENAY
HB MINE TAILINGS MANAGEMENT FACILITY
SALMO, BC

POST CLOSURE MONITORING PLAN

METALS UPTAKE, RE-VEGETATION AND WILDLIFE MONITORING LOCATIONS

Date: February 28, 2020	Figure No. 7
Project No. 204.03242.00004	

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7.2.4 Revegetation Monitoring

To assess the survival, vigour, and diversity of planted grasses within the reclaimed areas, permanent sample plots will be established and monitored by RDCKs Environmental Monitor at a rate of one per hectare, for a total of approximately 26 plots. These sample plots will be marked with labelled wooden stakes to enable annual remeasurements. During each annual monitoring event, targeted for June of each year (starting in year one post-closure and continuing until adequate vegetation is established), a 1 x 1 m plot square will be placed at each plot location. An observer will record species and percent cover for all grass species plants within the plot. Each plant will also be assessed visually for vigour and level of browse and given a numerical vigour score from (1 to 4) and a browse value (1 to 3) (Table 7-4). A photograph of each plot will also be taken. This monitoring will also be used to document the occurrence of invasive species. Vegetation monitoring will start at Post Closure Year 1. If drought conditions exist in the spring/summer of Post Closure Year 1 during the early part of seed establishment, a water truck will be used to irrigate the tailings surface on a bi-weekly basis, as needed. Monitoring will continue annually until adequate vegetation has been established, and the vegetative cover is considered self-sufficient (80% survival and a minimum average of 80% cover). If revegetation monitoring identifies inadequate vegetation in an area, the RDCK will proceed with topdressing, seeding, scarifying, and/or fertilizing areas that require treatment, as per recommendations from the revegetation monitoring consultant. Monitoring locations are shown on Figure 7.

To support the enumeration of natural regeneration of trees and shrubs, a nested 5.64 m plot will also be established at each of the 26 plot locations, Observers will record species and percent cover for all shrubs and trees within the plot. Each plant will also be assessed visually for vigour and level of browse and given a numerical vigour score from (1 to 4) and a browse value (1 to 3) (Table 7-4). A photograph of each plot will also be taken.

Table 7-4: Vegetation Monitoring – Vigour and Browse Codes

Vigour		Browse	
Code	**Description**	**Code**	**Description**
1	**Dead**: Stem breaks with light to moderate pressure. No visual signs of plant being alive noted. At least 75% of the plant is dead.	1	**Heavy**: More than 50% of the vegetative matter has some visual sign of browse
2	**Poor**: Plant is showing signs of poor health including loss of leaves, poor plant form, and/or signs of drought or nutrient deficiency (end of leaves wilted or turning brown). At least 50% of the plant appears to be alive.	2	**Light**: Less than 50% of the vegetative matter shows sign of browse.
3	**Moderate**: Plant is showing minor signs of stress included issues associated with water and nutrient availability. At least 75% of the plant is in good health.	3	**None**: No browse noted
4	**Good**: Plant shows good vigour including good stem and leaf growth and condition. At least 90% of the plant is in good health.		

After its determined that adequate vegetation has established across the site (>80%) no additional revegetation monitoring will be completed. To ensure potential future impacts on vegetation from climate change are appropriately identified once revegetation monitoring is finished, environmental monitors completing water quality monitoring will be asked to provide an update on general vegetation cover around the monitoring wells across the tailings surface which will provide indication if further revegetation assessments are required. Monitoring locations are shown on Figure 7.

7.2.5 Wildlife Monitoring

To monitor the use of the site by wildlife, ecology observations will be made during weekly visual inspections of the facility by RDCK representative as well as RDCKs Environmental Monitor during revegetation monitoring events in which all wildlife seen and/or heard will be recorded. Observations will be used to identify any patterns of habitat use and occurrences of species-at-risk. Wildlife observations will be documented on the inspection forms and will be reported on annually in the facility's Annual Reclamation Report.

In addition, post-closure monitoring will also include seasonal wildlife monitoring to quantify the use of the area by wildlife. During these monitoring events, observers will enumerate the presence of several species and species groups following provincial Resource Inventory Standards Committee protocols. These surveys will occur concurrent with revegetation monitoring events and will focus on the occurrence of species-at-risk (i.e., western toad, western screech owl and great blue heron) but will also include general surveys for waterfowl, amphibians, reptiles and ungulates.

Four Reconyx HyperFire 2 Professional HP2X digital infrared cameras will also be deployed across the project area. Two cameras will be deployed targeting furbearers (i.e., American badger, American black bear, coyote) with cameras deployed at approximately 50 cm above the ground and will be placed in areas that are attractive for furbearer movement (i.e., along old roads and trails). Two cameras will be deployed targeting ungulates with cameras deployed at between 1.5 and 1.8 m above the ground and will be placed in areas that are attractive for ungulate movement (e.g., wildlife trails, roads and important habitat features). Cameras will be attached to the trunks of trees or on fence posts with the surrounding vegetation cleared such that branches or leaves will not obscuring the camera's field of view and to prevent inadvertent triggering of the camera. Monitoring locations are shown on Figure 7.

7.2.6 Invasive Plant Management

Noxious/invasive weeds known to occur within the Kootenay Region include: blueweed (*Echium vulgare*), common bugloss (*Anchusa officinalis*), common tansy (*Tanacetum vulgare*), field scabious (*Knautia arvensis*), Orange hawkweed (*Hieracium aurantiacum*), hoary alyssum (*Berteroa incana*), perennial pepperweed (*Lepidium latifolium*), several knapweed species (*Centaurea* spp.), and plumeless thistle (*Carduus acanthoides*). Invasive species currently identified on site are discussed in Section 2.4.2. CKISS will continue to conduct a program of annual monitoring at the site, and will complete treatment as required. Monitoring for these species will also occur during the revegetation monitoring (see Section 7.2.3).

7.2.7 Monitoring Frequencies

Table 7-5 presents the initial monitoring frequencies to be implemented post construction. The monitoring frequencies will be reviewed as part of the annual dam safety inspections and are expected to be reduced to an annual frequency in the long-term, once it can be demonstrated that the facility is physical and chemically stable. The monitoring objectives include collection and interpretation of monitoring data to assess the post closure conditions of dam safely, wildlife, vegetation and water quality at the facility. All environmental monitoring data will be reviewed at the frequency outlined in Table 7-5 by the appropriate environmental professional, and will be reported on as a component of the Annual Reports for the facility submitted to EMPR and ENV annually by March 31. All monitoring data will be made available on request.

Table 7-5: Monitoring Frequency

Item	Frequency
Dam Instrumentation	
Piezometers	Weekly during freshet, otherwise monthly
V-Notch Measurement Weir	Weekly during freshet, otherwise monthly
Survey hubs	Annually until stable trend line is observed, every five years thereafter.
Wildlife	
Wildlife Ecology Inspection	Weekly
Wildlife Monitoring	Seasonal (2 events per year)
Wildlife Cameras	Year-round, quarterly maintenance
Revegetation and Invasive Species	
Monitoring Plots	Annually (Summer)
Water Quality	
TMF Surface Water	Quarterly
Salmo River Surface Water	Quarterly
Groundwater	Quarterly
Water and Load Balance Review	Post-closure years 3, 6, and 9 [1]
Inspections	
Visual Inspections	Weekly
Routine Inspections	Monthly
Dam Safety Inspections	Annually
Downstream Channel Inspections	Semi-annually
Dam Safety Review	Every 5 years as per HSRC [2] requirements.
Vegetation	
Vegetation Tissue Sampling	Once, two years after closure

Notes:

1. A review of the water and load balance update frequency will be completed after the year 9 update.
2. Health, Safety and Reclamation Code for Mines in British Columbia.

7.2.8 Effectiveness Monitoring

Post Closure monitoring of TSF surface water quality, Salmo River surface water quality, groundwater quality, wildlife, vegetation and metals uptake and will include an effectiveness monitoring with quantitative sampling targets. The water and load balance will be periodically updated to validate the risk assessment results. The specific targets for each monitoring aspect will be developed during the monitoring program to allow for management of measured results rather than prospective results post closure.

7.2.9 Quality Assurance/ Quality Control

Water Quality Monitoring

A quality assurance and quality control (QA/QC) program will be followed to ensure that the sampling and analytical data are interpretable, meaningful and reproducible. Two stages of QA/QC will be completed, with one stage completed by the laboratory and the other as part of field procedures performed by SLR. The soil, groundwater, surface water and vegetation samples will be analyzed by a Canadian Association for Laboratory Accreditation recognized laboratory that use BC ENV recognized methods to conduct laboratory analyses. As conveyed by the laboratory, method blanks, control standards samples, certified reference material standards, method spikes, replicates, duplicates and instrument blanks are routinely analyzed as part of their QA/QC programs.

As an internal quality control, the project laboratories routinely report the results of the laboratory duplicate analyses. The results of the laboratory QA/QC are reported in the laboratory certificates. SLR will verify that the laboratory internal QA/QC results fell within the lab's own specified acceptance criteria.

To verify the reproducibility of the laboratory analyses and to demonstrate that the field sampling techniques utilized by field personnel are capable of yielding reproducible results, blind field duplicate (BFD) samples will be submitted for laboratory analysis at a ratio of approximately 1 BFD for every 10 samples. The relative percent difference (RPD – the absolute difference between the two values, divided by the mean) of duplicate analyses is used to evaluate the sample result variability. Where the concentration of a parameter is less than five times the laboratory method detection limit (LMDL), the results are less precise and the RPD is not calculated. For parameters with concentrations less than five times the LMDL, the absolute difference between samples should be less than two times the LMDL. If the RPD for a sample and its duplicate do not meet RPD standards for the parameters analyzed, an explanation is required to qualify the difference in values. The acceptable RPD values for inorganic parameters are soil (+/- 45%) and water (+/- 30%).

Wildlife and Revegetation Monitoring

All field surveys will be led by an experienced Registered Professional Biologist (RPBio) or under the direct supervision of an experienced RPBio. In order to further ensure quality of data collection, experienced RPBio's will be assigned to lead surveys in which they hold primary experience. Field surveys will follow standard, accepted survey protocols and best management practices.

Data quality assurance will be completed following data entry to identify any issues with the following:

- Incompleteness;
- Accuracy;
- Precision; and
- Missing/unknown data.

All data that are determined to be unreliable, incomplete, not accurate or precise will be removed from reportable data sets.

7.3 Trigger Action Response Plan

A trigger action response plan (TARP) has been developed specifically for the HB dam to address plausible dam failure modes that are presented in the OMS Manual for the facility (RDCK 2019).

Due to the uncertainties and assumptions in the current water quality model and predictions of post-closure water quality, Table 7-6 presents a TARP developed to provide performance thresholds for water quality downstream of the site and guidance for appropriate responses.

‘Alert’ performance thresholds have been conservatively selected to provide early warning to initial mitigation. The required mitigation measures will depend on the severity of the potential water exceedance and the potential adverse effect, but mitigation options are likely to consider:

- additional monitoring and investigation to better understand the cause of any exceedance,
- completion of an appropriate risk assessment,
- additional engineering controls (ex. upstream diversions, tailings cover maintenance or upgrades),
- water treatment.

Table 7-6: Response Plan for Degradation of Downstream Water Quality

Trigger/Performance Threshold	Response/Actions
Normal Operations Continuation of current water quality conditions that considers seasonal fluctuations, or a decreasing trend.	No action required.
Alert Threshold Any degradation in water quality conditions measured downstream of the tailings facility that is detected over a period longer than 6 months or 5 sampling events, whichever is shorter.	Engage a Qualified Professional to review water monitoring data (including trend analysis) and develop recommendations that include an evaluation of potential mitigation options.
Action Threshold Trend analysis indicates a year over year increase in concentration of COPC for 2 consecutive years.	Implement mitigation option recommended by a Qualified Professional.

7.4 Maintenance

A program of routine maintenance on the dam, spillway, and cover system is expected to be required following construction. The maintenance will be predictive or event-driven and will rely upon the routine inspections to identify tasks needed to be completed. In the short term, maintenance is likely to be required to address erosion issues until vegetation is established and potentially to address tailings settlement and ponding caused by the loading of the tailings cover. In the long term, maintenance is expected to be minimal as the design should leave the facility self-sustaining and close to maintenance-free.

Routine long-term maintenance is expected to consist of the following tasks:

- Maintenance of spillway and tailings surface drainage channels to keep the spillway free from obstructions, excessive vegetation, able to resist erosion, and protected from deterioration.
- Animal control to remove burrowing animals near the dam, or beavers near the spillway or tailings surface drainage channels.
- Dam crest maintenance (regrading, placement of surfacing material, etc.) to prevent pooling, rutting, and water flow over the downstream dam slope. Additional fill placement may also be required in the long term due to future settlement as a result of decay of the wooden timber crib.
- Dam slope maintenance (regrading, revegetating, or removing excessive vegetation, etc.) to ensure the dam face is stable and to ensure that visual inspections can be effective.
- Tailings cover maintenance to fill areas of ponding, repair damage due to erosion, or to revegetate additional areas to prevent erosion.
- Access road maintenance to ensure maintenance and surveillance activities can be conducted as required.

- Instrumentation maintenance to ensure the instrumentation is in proper condition and readings are accurate.

8 Closure Implementation

8.1 Construction

8.1.1 Materials

The construction material specifications are presented in Drawing 02. The following list outlines the preferred borrow locations for the design; the borrow locations are provided in Drawing 03.

- Riprap material may be sourced from the spillway excavation or from the quarry located southwest of the west abutment of the HB Dam. Riprap from the existing spillway and from the upstream slope of the dam may also be used where suitable.
- Drainage material for the toe berm expansion will be sourced from undersized material from the riprap quarry, the spillway rock excavation, or will be sourced off site.
- General fill for the toe berm expansion and upstream beach may be sourced from the spillway excavation or from the Till Borrow Area located at the Central Landfill.
- Tailings cover material will be sourced from the Till Borrow Area.

8.1.2 Equipment

Construction is expected to proceed using conventional earthworks equipment. Work over the wet areas of the tailings may require low-ground pressure equipment or additional ground stabilization measures, such as temporary fill or geosynthetics, to construct the tailings surface drainage channels or to place the tailings cover. Drawing 16 provides a preliminary assessment of trafficability over the tailings impoundment based on site observations dated August 2017. The contractor is to verify ground conditions prior to construction in order to determine the appropriate construction equipment and the best material placement strategy.

Conventional rock quarrying and screening equipment will be used to excavate the spillway through rock and produce the riprap material required for the closure construction activities.

Placement of the geotextile and turf reinforcement mat does not require specialized equipment, whilst the seaming of the geosynthetic liner will require specialized equipment and trained personnel.

8.1.3 Quality Control and Quality Assurance

Complete details of the Quality Assurance and Quality Control (QA/QC) procedures to be followed for the construction activities will be included in the Technical Specifications to be provided prior to construction. Quality Control will be the responsibility of the construction contractor and/or the equipment and materials manufacturer. The Engineer of Record or approved designate will carry out the Quality Assurance. Complete documentation of all QA/QC data will be provided in the relevant as-built report.

8.1.4 Quantities

Material quantities are presented in Table 8-1. The quantities are in-place, neat line quantities, and do not account for bulking during excavation, shrinkage during placement and compaction, or overlap/wastage of geosynthetics.

Table 8-1: Material Quantities

Area	Material	Quantity
Spillway	Rock excavation volume (m^3)	4,350
	Soil excavation volume (m^3)	4,900
	Geotextile (m^2)	3,100
	Riprap (m^3)	2,500
Tailings Cover	0.3 m cover volume (m^3)	58,800
	Upstream Beach (m^3)	6,050
	Tailings Pond Backfill	33,800
Tailings Surface Drainage Channels	Excavation volume (m^3)	7,100
	Geosynthetic Liner (m^2)	9,200
	Geotextile (m^2)	2,300
	Protection layer (m^3)	2,400
	Turf Reinforcement Mat	10,800
	Riprap (m^3)	550
Toe Berm Expansion	Vegetation and soft soil removal footprint (m^2)	500
	Rock drain layer (m^3)	900
	General fill (m^3)	10,500
	Geotextile (m^2)	600

Source: J:\01_SITES\HB_Mine\1CR012.006_TSF 2019 Design Support\999_CostEstimate\HB_RemediationCosttEstimate_rev11_phm.xlsx

8.1.5 Methods and Sequencing

The final construction methods and sequencing of the closure and remediation design will be determined by the main construction contractor. To achieve a feasible design, preliminary construction methods and sequencing were assessed with a conceptual construction sequence outlined below.

SRK is satisfied that sufficient and appropriate field characterization has been done in support of the dam design presented in this report. However, as is normal in earthwork construction, ongoing field verification of conditions will be done as construction starts and proceeds by means of excavation. There are, however, no conditions anticipated that would result in significant deviation of the designs.

Most of the construction activities must occur during the dry summer months with construction primarily occurring between June and October. A summary of the anticipated construction steps is provided below.

Site Preparation

- Felling of trees and large vegetation from the dam and spillway footprint. The trees and vegetation are to be removed to a disposal area approved by the RDCK. This task will be completed in the winter and early spring prior to construction to avoid the migratory bird regional nesting period.
- Borrow Development. Access to the rock quarry and Till Borrow Areas are to be upgraded as required. Rock excavation at the spillway will be followed by blasting at the rock quarry to confirm the volume of remaining riprap needed for construction.

Pond Dewatering

- Fish and Amphibian Salvage: a fish and amphibian salvage program will be completed concurrent with, and immediately prior to, dewatering of the tailings pond, as well as in support of any related construction activities. This includes a minimum of two days of salvage in support of required in-water works during construction activities and a minimum of five days of salvage activities during dewatering.
- Pond dewatering and set-up of water management systems. The tailings pond is to be dewatered and by-pass systems installed as required to minimize surface inflows to the tailings impoundment. A pump is to be used to control the lowering of the tailings pond. Efforts are to be made to prevent an increase in concentration of total suspended solids in the discharged water by using a sediment trap downstream from the spillway. Sumps and/or coffer dams are to be installed as required to capture run-on channels located upgradient of the three tailings surface-conveyance channels; the run-on water is then to be pumped either downstream of the tailings facility or to an upstream infiltration basin. An inline filtration system will also be used to reduce TSS prior to discharge if required.
- Alternative dewatering methods may be employed under the guidance of a Qualified Environmental Professional and will follow best management practices for dewatering and sediment management. Tailings pond water may be managed within the boundaries of the tailings deposition area using non-invasive storage methods to create evaporation ponds. Stored water may be discharged through a sprinkler system over the uncovered tailings to act as dust suppressant. If alternative dewatering works are utilized, the tailings pond water will not be discharged outside of the tailings deposition area.

Spillway and Toe Berm Expansion

- Construction of the spillway and the Toe Berm Expansion are the first major construction tasks and will likely occur concurrently. Excavation and blasting of soil and rock from the spillway construction will create material needed to expand the toe berm.
- Organic soils stripped from the footprints may be placed within the tailings impoundment for use as a cover.
- Excavation of bedrock at the spillway will require drilling and blasting. The blasted material is to be sorted to produce spillway riprap and the toe berm drain rock. Inorganic soil excavated from the spillway excavation will then be placed as general fill for the toe berm expansion.

Upstream Beach and Tailings Pond Backfill

- The upstream beach is to consist of a low-permeability material (till or glaciolacustrine sediments), while the tailing pond backfill material is to consist of general fill. Both materials may be sourced from the spillway excavation or from the Till Borrow Area.

Tailings Surface Drainage Channels

- The tailings surface drainage channels are to be constructed following completion of the spillway and concurrently with the placement of the tailings cover.

Tailings Cover

- Tailings cover placement can generally occur at any time throughout the project following site preparation activities, keeping in mind the following considerations:
  - Tailings-affected soils imported from the "Ross Lands" are to be used to fill erosion gullies and channels prior to covering with cover soils.
  - Wetter portions of the impoundment near the dam will require a period of drying before allowing cover placement to occur.

Revegetation

- The dam and tailings cover surfaces are to be hydroseeded following construction and prior to the onset of winter.

8.2 Schedule

Closure of the site is proposed to start in 2021. Remediation and closure activities are expected to be completed in one year during the summer and fall. A conceptual schedule is presented in Table 8-2, with the final timing and sequencing of construction to be determined by the main construction contractor.

The predicted frequency of post-closure monitoring and maintenance requirements is described in Section 7.

Table 8-2: Remediation and Closure Schedule

	May	Jun	Jul	Aug	Sep	Oct	Nov
Site Preparation	x	x					
Spillway		x	x	x			
Dam Toe Berm Expansion		x	x				
Upstream Beach and Tailings Pond Backfill				x	x		
Tailings Cover			x	x	x	x	
Tailings Surface Drainage Channels				x	x		
Revegetation					x	x	

Source: J:\01_SITES\HB_Mine\1CR012.006_TSF 2019 Design Support\999_CostEstimate\GB_RemediationPlanCostEstimate_rev11.xlsx

8.3 Cost Estimate

Estimates of the remediation and closure costs have been prepared and are summarized in Table 8-3. Details of the cost estimate bases, sources, and assumptions are provided in Appendix K. The cost estimate includes undiscounted closure implementation costs in 2021, and post-closure monitoring and maintenance costs up to the end of 2121. The post-closure costs were discounted using net present cost (NPC) calculations that applied discount rates of 1.5% for the first two years, 2% for the next three years, and 3% thereafter.

Table 8-3: Remediation and Closure Cost Summary

Category	Cost
Site Preparation	$212,000
Spillway	$901,000
Dam Upgrades	$148,000
Tailings Surface Conveyance Channels	$485,000
Tailings Cover	$689,000
Revegetation	$340,000
Instrumentation	$85,000
Indirect Costs	$555,000
Contingency	$427,000
Subtotal - Closure Implementation	**$3,841,000**
Post-Closure Monitoring and Maintenance (NPC)	$2,770,000
TOTAL NET PRESENT COST	**$6,611,000**

9 Closure

This Remediation and Closure Plan for the HB Mine Tailings Facility was prepared by the Regional District of Central Kootenay and external consultants SRK Consulting (Canada) Inc. and SLR Consulting. The work developed by consultants is primarily included as appended reports and technical memorandums and is summarized within the main body of this report. The qualified professionals responsible for completing the various components of the Remediation and Closure Plan are listed in Table 9-1.

Table 9-1: Qualified Professionals and Relevant Components of Closure Plan

Component of Closure Plan	Qualified Professional(s)
Geotechnical design	Peter Mikes, MEng, PEng (SRK) Cam Scott, MEng, PEng (SRK) Arcesio Lizcano, PhD (SRK)
Spillway design	Sarah Portelance, MEng, PEng (SRK) Victor Munoz, MEng, PEng, (SRK)
Effluent source term prediction Tailings geochemistry	Christina James, MSc (SRK) Stephen Day, MSc, PGeo (SRK)
Water balance modelling	Christina James, MSc (SRK)
HHERA	Kathryn Matheson, MEnvSc, PGeo, QPRA Cindy Ott, MSc, PAg GeoL,PChem (SLR)
Reclamation–revegetation and soil management	Dustin Oaten, MSc, RP Bio (SLR) Benjamin Foulger, PAg (SLR)
Reclamation cost estimate	Peter Mikes, MEng, PEng (SRK)

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Drawings and Appendices can be accessed at:

https://van.files.srk.com/nextcloud/index.php/s/H4fdQLtzWfyXw4n

Drawings

Regional District of Central Kootenay

Closure Design Engineering Drawings for the Closure of the HB Mine Tailings Facility

Drawing Number	Drawing Title	Issue	Date	Revision
1	Site Location	Issued for Review	June 30, 2020	F
2	Construction Specifications	Issued for Review	June 30, 2020	F
3	HB Mine Tailings Facility - Current Conditions	Issued for Review	June 30, 2020	F
4	HB Dam - Current Conditions	Issued for Review	June 30, 2020	F
5	HB Dam Current Conditions Cross Sections	Issued for Review	June 30, 2020	F
6	HB Dam - Final Site Plan	Issued for Review	June 30, 2020	F
7	Toe Berm Expansion - Site Preparation Plan	Issued for Review	June 30, 2020	F
8	Upgraded Dam Final Contours	Issued for Review	June 30, 2020	F
9	HB Dam - Upgraded Dam Cross Sections (1 of 2)	Issued for Review	June 30, 2020	F
10	HB Dam - Upgraded Dam Cross Sections (2 of 2)	Issued for Review	June 30, 2020	F
11	Upgraded Spillway - Plan and Profile	Issued for Review	June 30, 2020	F
12	Upgraded Spillway - Cross Sections and Details	Issued for Review	June 30, 2020	F
13	Tailings Surface Drainage Channel Plan	Issued for Review	June 30, 2020	F
14	Tailings Surface Drainage Channel Profiles and Tailings Pond Backfill Section	Issued for Review	June 30, 2020	F
15	Tailings Surface Drainage Channel Sections and Energy Dissipation Structures	Issued for Review	June 30, 2020	F
16	Tailings Cover Plan	Issued for Review	June 30, 2020	F
17	Instrumentation and Monitoring Plan	Issued for Review	June 30, 2020	F
18	Instrumentation and TRM Details	Issued for Review	June 30, 2020	F
19	Borrow Area Plan View and Typical Sections	Issued for Review	June 30, 2020	F

SRK Job No. 1CR012.007

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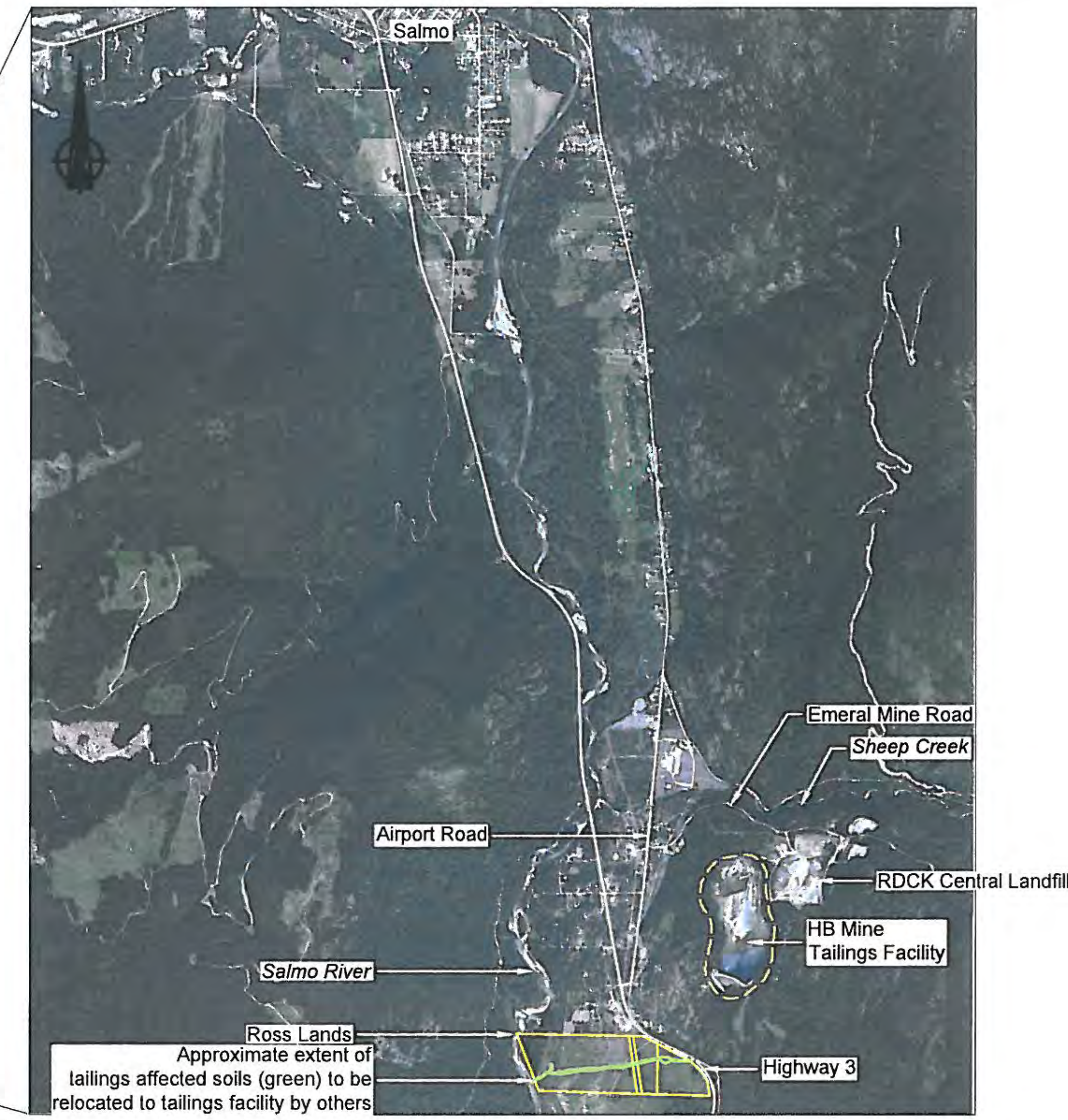
Regional Map

0km 50 100 200 300



Site Location

0m 500 1000 1500 2000

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DRAWING NO	DRAWING TITLE
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REFERENCE DRAWINGS

NO.	DESCRIPTION	CHK'D	APP'D	DATE
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NO.	DESCRIPTION	CHK'D	APP'D	DATE
F	Issued for Review	PM	—	20/06/30
E	Issued for Permitting	PM	—	20/01/31
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C	Issued for Remediation Plan	PM	AH	19/07/12
B	Issued for Review	PM	—	19/05/08
A	Issued for Review	PM	—	18/12/05

REVISIONS

PROFESSIONAL OF PROVINCE BRITISH COLUMBIA ENGINEER
P. H. MIKES
33319
8/14/20

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DESIGN PHM	DRAWN TAH	REVIEWED CS
CHECKED MMM	APPROVED PHM	DATE June 30, 2020

FILE NAME 1CR012.006 - Site Location.dwg

REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

SRK JOB NO. 1CR012.006

Closure Design

DRAWING TITLE
Site Location

DRAWING NO.	SHEET	REVISION NO
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TABLE 1: MATERIAL QUANTITIES

Feature	Material	Quantity
Spillway	Soil Excavation Volume (m³)	4,900
	Rock Excavation Volume (m³)	4,350
	Geotextile (m²)	3,100
	Riprap (m³)	2,500
Tailings Cover	Tailings affected soil import volume ("Ross Lands") (m³)	10,000 to 15,000
	General Fill - Tailings Pond Backfill (m³)	33,800
	Tailings Cover Volume (m³) (See Note 1)	58,800
Tailings Surface Drainage Channels	Excavation Volume (m³)	7,100
	Geosynthetic Liner (m²)	9,187
	Liner Protection Material (m³)	2,400
	Turf Reinforcement Mat (m²)	10,800
	Riprap (m³)	550
	Geotextile (m²)	2,260
Toe Berm Expansion	Vegetation clearing footprint (m²)	2,750
	Vegetation and soft soil removal footprint (m²)	500
	Toe Berm Drain Rock (m³)	900
	General Fill (m³)	10,500
	Geotextile (m²)	600
	Removal of existing riprap (m³)	1,100
Upstream Beach	Upstream Beach Material (m³)	6,050
Revegetation	Tailings Cover (m²)	196,000
	Dam Area (m²)	7,200

NOTES

1. Tailings cover volume assumed an average thickness of 0.3m.

TABLE 2: SPILLWAY RIPRAP GRADATION REQUIREMENTS

Characteristic Diameter (% Passing)	Diameter (mm) Minimum	Recommended	Maximum
D_{15}	160	200	300
D_{30}	330	400	500
D_{50}	500	600	700
D_{85}	550	650	750
D_{100}	750	900	1050

See Technical Specifications for full particle size distribution curves.

TABLE 3: ENERGY DISSIPATION STRUCTURE RIPRAP GRADATION REQUIREMENTS

Characteristic Diameter (% Passing)	Diameter (mm) Minimum	Recommended	Maximum
D_{15}	100	140	200
D_{30}	200	270	350
D_{50}	300	400	500
D_{85}	350	450	550
D_{100}	450	600	750

See Technical Specifications for full particle size distribution curves.

TABLE 4: TOE BERM DRAIN ROCK GRADATION REQUIREMENTS

Characteristic Diameter (% Passing)	Diameter (mm) Minimum	Recommended	Maximum
D_{15}	50	75	100
D_{30}	30	90	135
D_{50}	75	125	200
D_{85}	125	200	250
D_{100}	150	225	275

See Technical Specifications for full particle size distribution curves.

GENERAL NOTES

1. All drawings should be read in conjunction with the latest technical specifications document ("Technical Specifications HB Mine Tailings Facility Closure and Remediation" prepared by SRK). The Engineer should be consulted to determine what the latest revision of the Technical Specifications is. Any items that are unclear to the contractor are to be brought to SRK's attention for clarification.
2. The Owner is responsible to ensure all licenses, permits, and approvals are obtained prior to the start of construction.
3. All dimensions in meters unless stated otherwise.
4. The contractor shall comply with all local, provincial and federal laws that are pertinent to this work.
5. All works are to be set-out prior to any excavation or fill placement to confirm the grades and elevations conform to the design requirements. All variances between site topography and construction drawings shall be brought to the attention of SRK.
6. The location of debris, excavated waste material, and temporary stockpiles are to be approved by the RDCK. Materials in direct contact of the tailings are not to be relocated outside the tailings footprint.
7. All materials used for construction must be non-acid generating, and non-metal leaching.
8. Notes on this drawing apply to all other active drawings.

SEDIMENT AND EROSION CONTROL

1. The contractor is responsible to develop and implement an erosion and sediment control plan.
2. Erosion and sediment control measures are to be implemented prior to, and in conjunction with all clearing and grading activities.
3. Erosion and sediment control measures should be inspected daily during construction to ensure proper performance.

GEOTEXTILE

1. The toe berm geotextile is to consist of a Nilex 4510 non-woven geotextile, or equivalent that meets the product specifications provided in the Technical Specifications.
2. The spillway geotextile is to consist of a Nilex 4516 non-woven geotextile, or an equivalent that meets the product specifications provided in the Technical Specifications.
3. Any substitution of geotextile products are to be approved by the Engineer prior to installation.
4. Geotextile is to be transported, sorted, and installed as per manufacturer's instructions.

GEOSYNTHETIC LINER

1. The geosynthetic liner for the tailings conveyance channels shall consist of a minimum 40mil geosynthetic liner that meets or exceeds the product specifications provided in the Technical Specifications.
2. All geosynthetic products are to be approved by the Engineer prior to installation.
3. The geosynthetic liner is to be transported, sorted, and installed as per manufacturer's instructions.

TURF REINFORCEMENT MAT

1. The turf reinforcement mat (TRM) is to consist of a Nilex C350 VMAX³ or equivalent, that meets or exceeds the product specifications provided in the Technical Specifications.
2. Any substitution of TRM is to be approved by the Engineer prior to installation.
3. The TRM is to be transported, sorted, and installed as per the manufacturer's requirements, and as detailed in the drawings and Technical Specifications.

RIPRAP

1. All riprap shall consist of sound and durable angular quarry stone, that is resistent to weathering and water action without fractioning.
2. All riprap shall meet the particle size requirements listed in Tables 2 and 3.
3. The contractor shall verify and sort (as required) the riprap material to meet the design specified gradation.
4. The riprap may be sourced from the designated quarry and spillway rock excavation, the upstream slope of the dam (where not in contact with tailings), and existing spillway.
5. The contractor shall place riprap to the thickness and details as indicated in the Drawings. Riprap placement in channels should commence along the downstream channel invert first, then the toe of the slope and continue placement upslope and upstream.

TOE BERM DRAIN ROCK

1. The drain rock shall consist of sound and durable angular quarry stone, be resistant to weathering and water action without fractioning.
2. The drain rock shall meet the particle size requirements listed in Table 4.
3. The contractor shall verify and sort (as required) the drain rock material to meet the design specified gradation.
4. The drain rock may be sourced from the riprap in the spillway excavation or designated quarry, the existing spillway or upstream slope of the dam, or from an approved off-site source as approved by the Engineer.

GENERAL FILL

1. General fill shall be well graded and free from organic debris, tailings, or other deleterious materials.
2. The fill may be sourced from the spillway or dam excavations, one of the approved on-site borrow sources, or from an off-site source as approved by the Engineer.

TAILINGS COVER MATERIAL

1. The tailings cover material shall consist of well-graded material source from the borrow areas or excavations, and shall be free of frozen soil, snow and ice.
2. The cover material shall have a minimum fines content of 10% unless approved by the Engineer.
3. The maximum allowable grain size for the cover material is 300mm. Boulders larger than the maximum diameter shall be removed at the source or scaled from the fill during placement and pushed away from the working area.

LINER PROTECTION LAYER

1. The liner protection material shall be well-graded sand sourced from one of the approved on-site borrow sources or from and approved off-site source as approved by the Engineer.
2. The material shall have a maximum fines content of 30% and a maximum particle size of 100mm.

NOT FOR CONSTRUCTION

DRAWING NO	DRAWING TITLE
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REFERENCE DRAWINGS

NO	DESCRIPTION	CHK'D	APP'D	DATE
F	Issued for Review	PM	–	20/06/30
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B	Issued for Review	PM	--	19/05/08
A	Issued for Review	PM	--	18/12/05

REVISIONS

PROFESSIONAL ENGINEERS STAMP: PROFESSIONAL ENGINEER, PROVINCE OF BRITISH COLUMBIA, P. H. MIKES # 33319, 8/7/20

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DESIGN PHM | DRAWN TAH | REVIEWED CS
CHECKED MMM | APPROVED PHM | DATE June 30, 2020
FILE NAME 1CR012.006 - Material Specs.dwg

REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

SRK JOB NO. 1CC012.005

Closure Design

DRAWING TITLE: Construction Specifications

DRAWING NO 02 | SHEET 2 OF 19 | REVISION NO F

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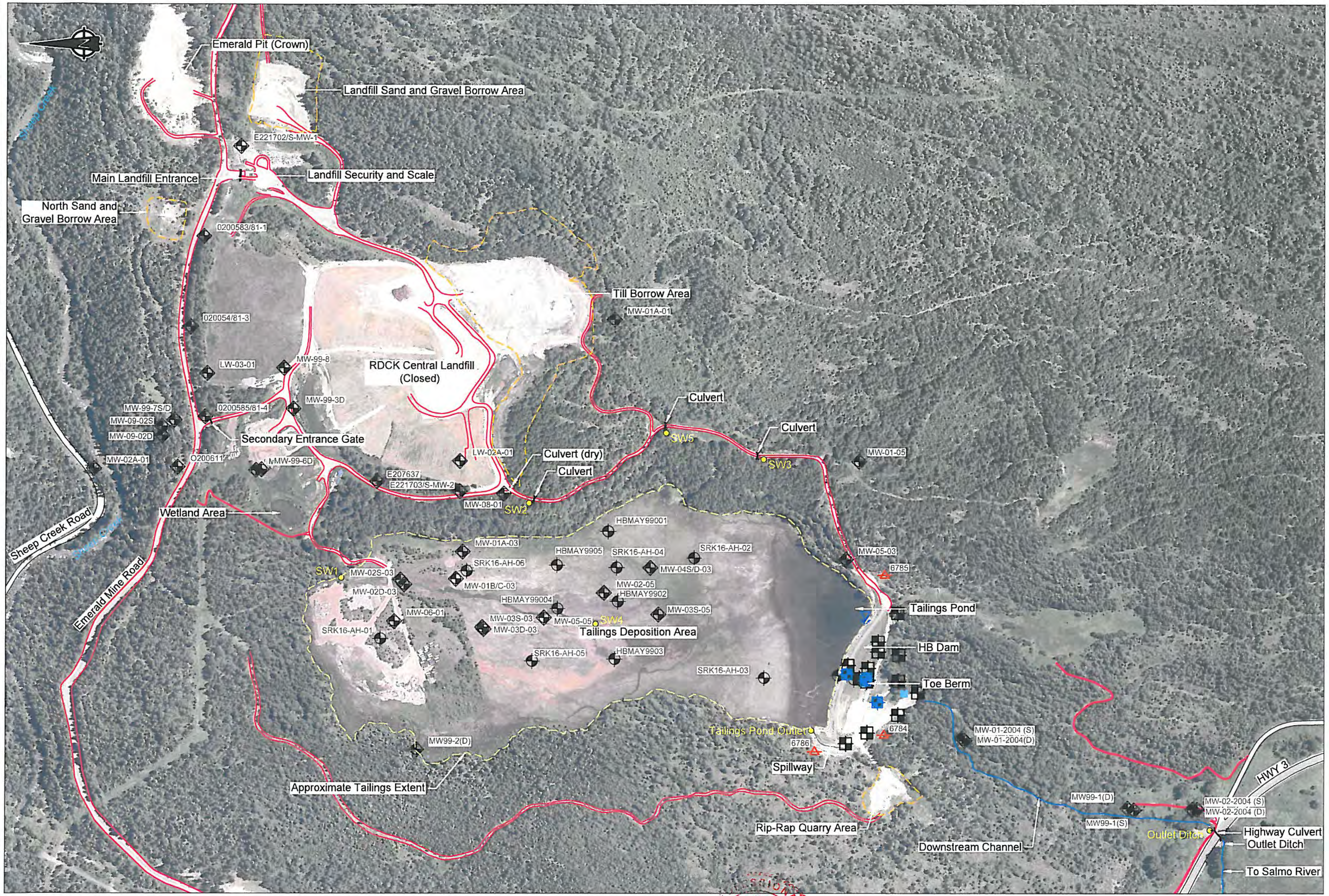

LEGEND

- Control Point
- Borehole Location
- Monitoring Well Location
- Piezometer Location
- Surface Water Monitoring Location
- Test Pit Location
- Water Level Gauge
- Seepage Measurement Weir
- Existing Access Road
- Proposed Borrow Sources

REFERENCES

Control points surveyed by RDCK, July 2017.

CONTROL POINTS

Point ID	Easting	Northing	Elevation
6784	481,643.28	5,441,964.94	701.75
6785	481,893.43	5,441,964.10	719.17
6786	481,617.38	5,442,074.29	721.79

NOT FOR CONSTRUCTION

0m 50 100 150 200m

DRAWING NO.	DRAWING TITLE
-	-

REFERENCE DRAWINGS

NO.	DESCRIPTION	CHK'D	APP'D	DATE
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NO.	DESCRIPTION	CHK'D	APP'D	DATE
F	Issued for Review	PM	–	20/06/30
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A	Issued for Review	PM		18/12/05

REVISIONS

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8/14/20

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CHECKED MMM	APPROVED PHM	DATE June 30, 2020

FILE NAME 1CR012.006 - EC.dwg

REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

SRK JOB NO. 1CR012.006

Closure Design

DRAWING TITLE HB Mine Tailings Facility - Current Conditions

DRAWING NO. 03 | SHEET 3 OF 19 | REVISION NO F

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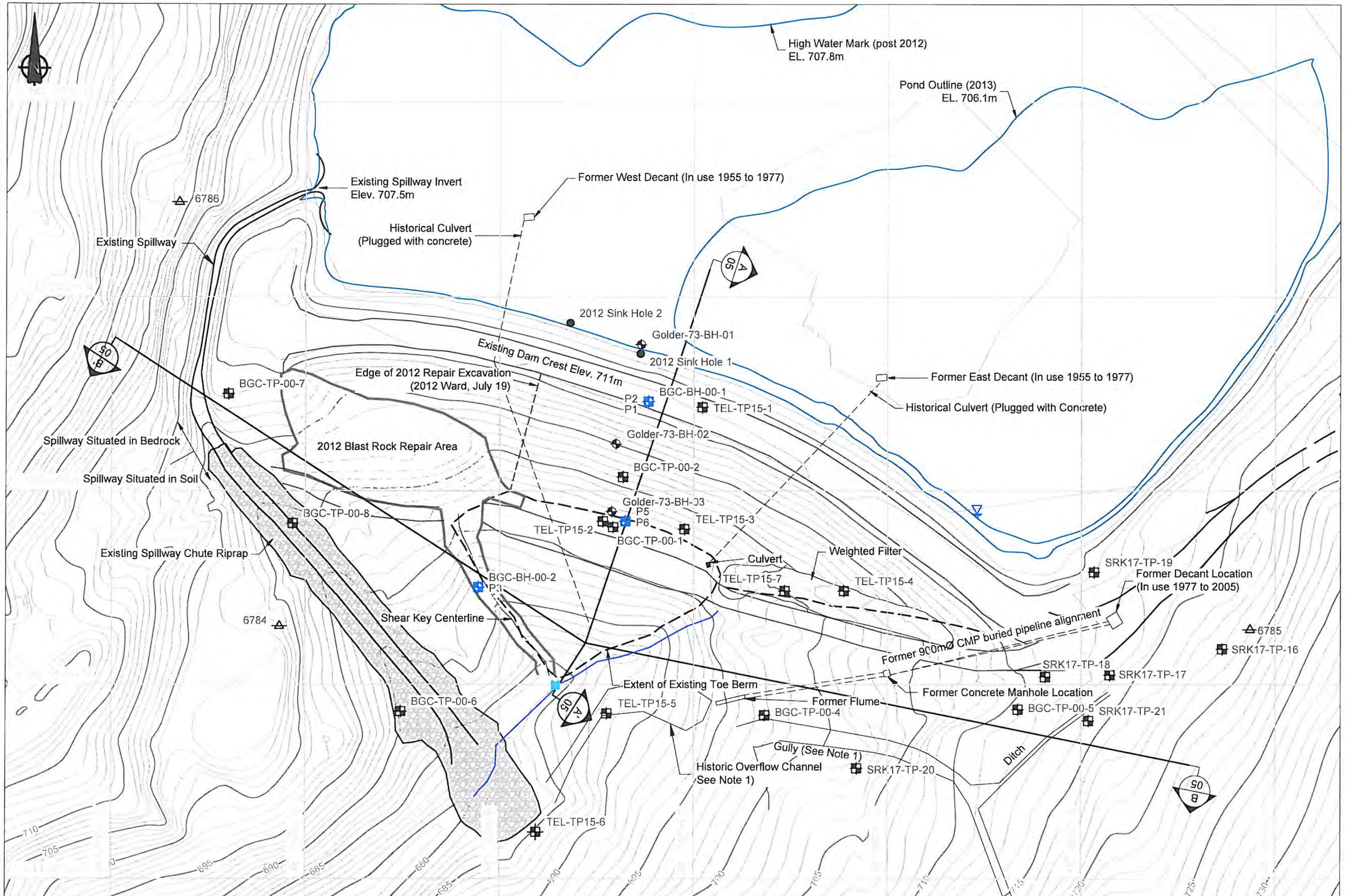

LEGEND

- Control Point
- Borehole Location
- Monitoring Well Location
- Piezometer Location
- Test Pit Location
- Water Level Gauge
- Seepage Measurement Weir
- Historical Dam Features
- 2012 Blast Rock Repair Area
- Riprap
- Weighted Filler

NOTES

1. Historical decant and pipeline outfall features were digitized from "Drawing 4, Borehole and Testpit Locations" produced by BGC Engineering Inc, April 2005. Drawing number: 0268-001-08. The operating decant, Flume, and 900mmØ CMP were removed in 2005.
2. Weighted filter extents digitized from "Left Buttress As-Constructed". Produced by Regional District of Central Kootenay Environmental Services, observed by Tetra Tech. Professional Engineer seal dated March 15, 2017.

REFERENCES

Control points surveyed by RDCK, July 2017.

CONTROL POINTS

Point ID	Easting	Northing	Elevation
6784	481,643.28	5,441,964.94	701.75
6785	481,893.43	5,441,964.10	719.17
6786	481,617.38	5,442,074.29	721.79

NOT FOR CONSTRUCTION

0m 10 20 30 40 50 60

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REFERENCE DRAWINGS

DRAWING NO.	DRAWING TITLE
0268-001-08	BGC Engineering Inc.: Borehole and Testpit Locations, April 2005
K13103109-05	HB Dam Spillway Design_RECORD.dwg

REVISIONS

NO.	DESCRIPTION	CHK'D	APP'D	DATE
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D	Issued for Tender	MM	PM	19/10/23
C	Issued for Remediation Plan	PM	AH	19/07/12
B	Issued for Review	PM		19/05/08
A	Issued for Review	PM		18/12/05

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DESIGN	PHM	DRAWN	TAH	REVIEWED	CS
CHECKED	MMM	APPROVED	PHM	DATE	June 30, 2020

FILE NAME 1CR012.006 - Dam EC.dwg

REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

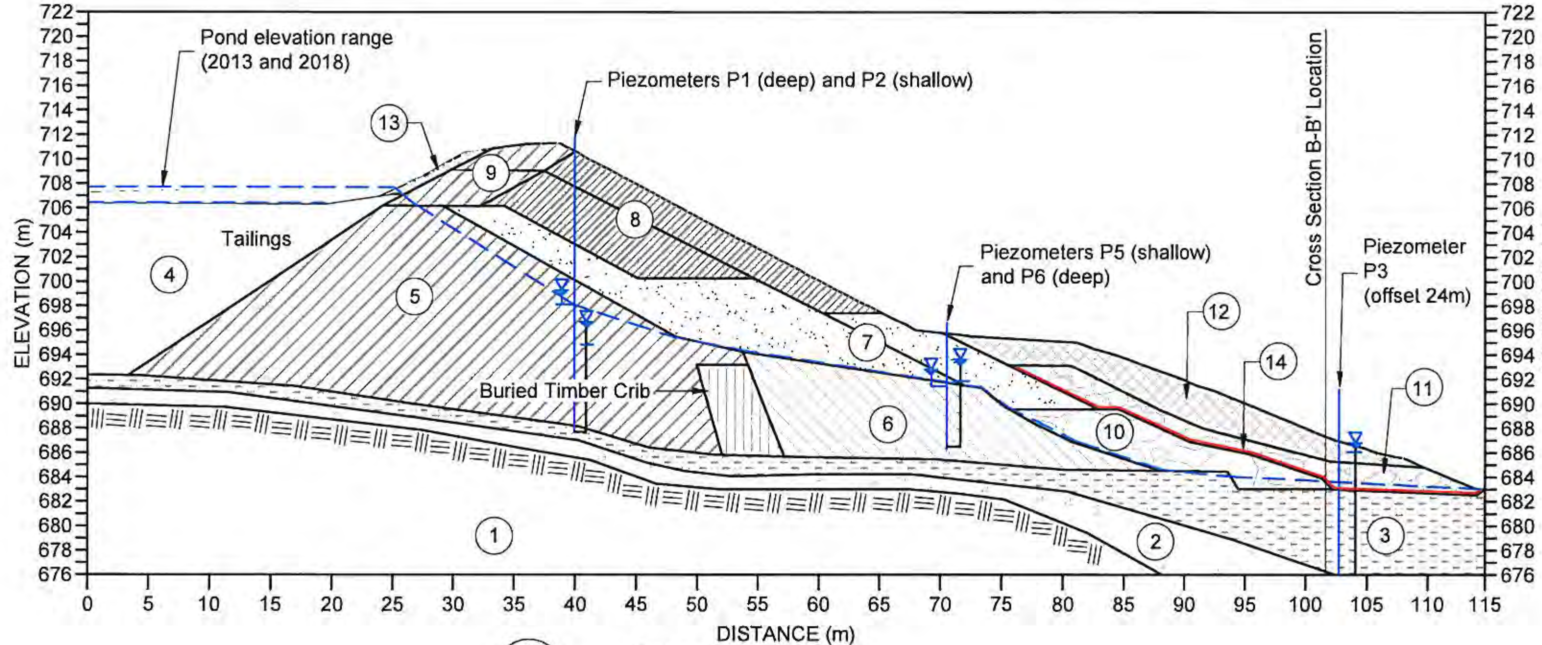
SRK JOB NO 1CR012.006

Closure Design

DRAWING TITLE

HB Dam - Current Conditions

DRAWING NO 04 | SHEET 4 OF 19 | REVISION NO F



A 04 **Cross Section A-A'**

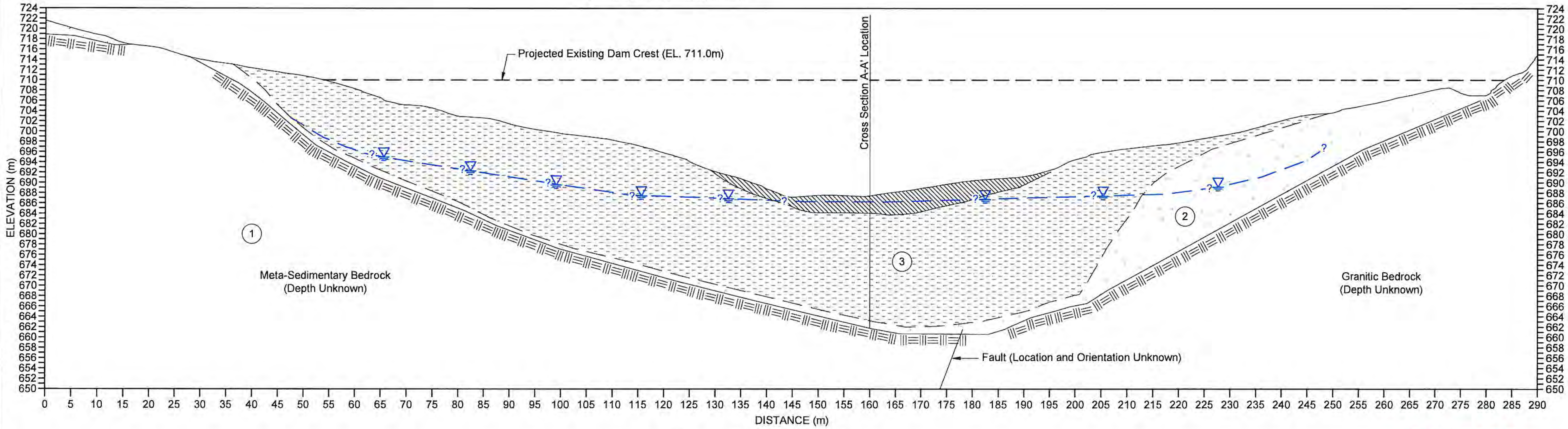
0m 6 12 18 24

LEGEND

- Zone 1 - Bedrock
- Zone 2 - Native Till
- Zone 3 - Native Glaciolacustrine
- Zone 4 - Tailings (1955 - 1978)
- Zone 5 - Original Dam (1955 - 1967)
- Zone 6 - Stabilizing Berm (1964 - 1967)
- Zone 7 - Filter Blanket (1974/75 and 1977)
- Zone 8 - Common Fill (1975 and 1977)
- Zone 9 - Select Impervious Fill (1975 and 1977)
- Zone 10 - Rock Toe Drain (1977)
- Zone 11 - Rock Drain (2005)
- Zone 12 - Till Toe Berm (2005)
- Zone 13 - Riprap (2005)
- Zone 14 - FII Filter (0.2m thick) (2005)
- Organics and Fill
- Bedrock
- Approximate Phrealic Surface

NOTES

1. Locations of stratigraphic boundaries are interpreted based on limited surface and sub-surface observations, and on previous engineering reports by others that were provided by the owner. The location of all stratigraphic boundaries should be considered approximate and actual conditions may vary.
2. Cross section B-B' digitized from "Interpreted Valley Geologic Section" from BGC Engineering Inc. Project No. 0268-001-08, Drawing 6, Rev 1, dated April 2005.



B 04 **Cross Section B-B'**

0m 5 10 15 20 25 30

NOT FOR CONSTRUCTION

DRAWING NO	DRAWING TITLE
0268-001-08	BGC Engineering Inc. Borehole and Testpit Locations, April 2005
K13103109-05	HB Dam Spillway Design_RECORD.dwg

REFERENCE DRAWINGS

NO.	DESCRIPTION	CHK'D	APP'D	DATE
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REVISIONS

PROVINCE OF BRITISH COLUMBIA P. H. MIKES # 33319 ENGINEER 30/06/20

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PHM	TAH	CS
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FILE NAME 1CR012.006 - Dam EC.dwg

Regional District of Central Kootenay

HB Mine Tailings Facility

SRK JOB NO. 1CR012.006

Closure Design

DRAWING TITLE HB Dam Current Conditions Cross Sections

DRAWING NO. 05 SHEET 5 OF 19 REVISION NO. F

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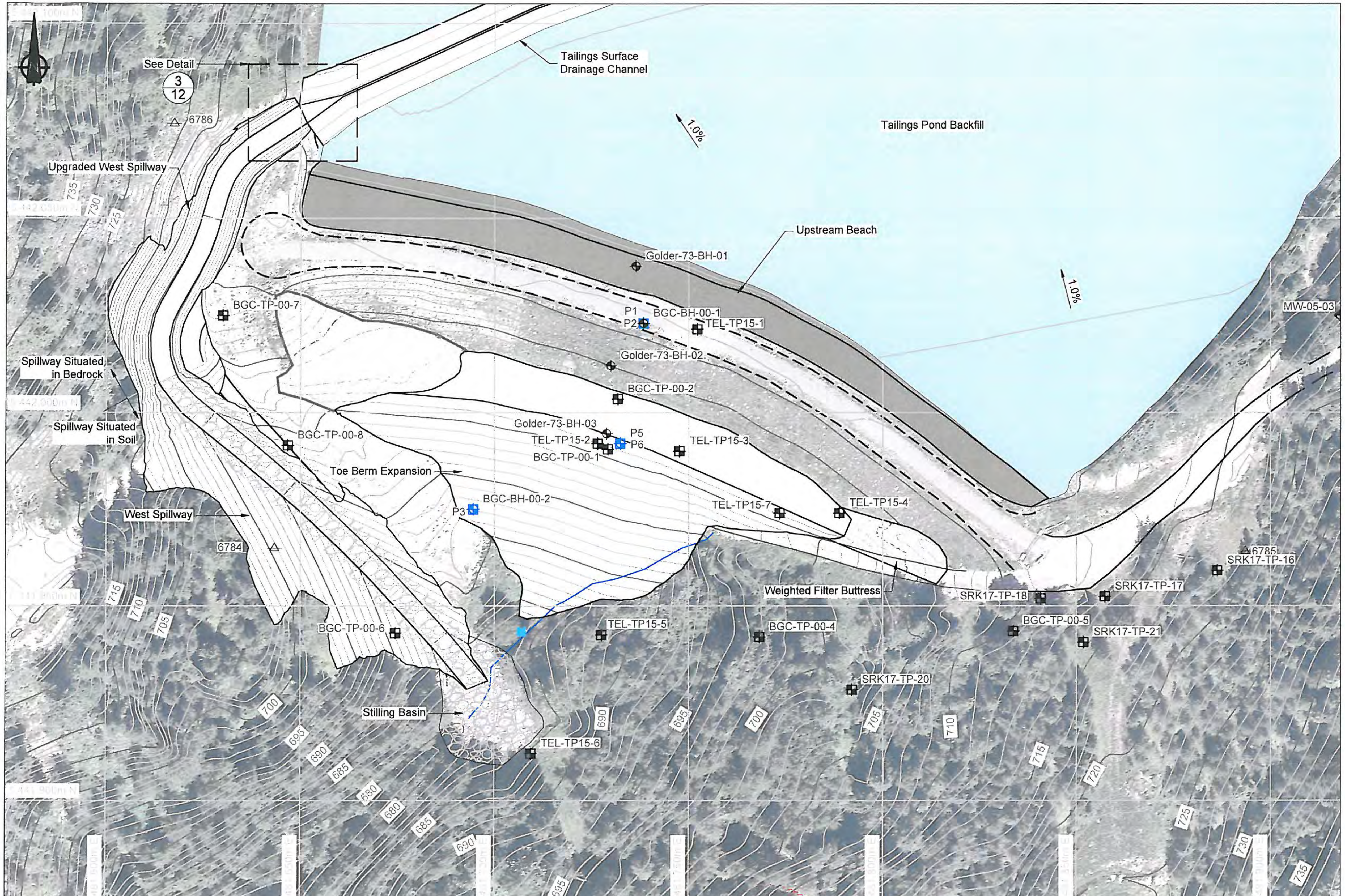

LEGEND

- Control Point
- Borehole Location
- Monitoring Well Location
- Piezometer Location
- Test Pit Location
- Seepage Measurement Weir
- Coarse Rock Repair Area / Weighted Filter
- Riprap
- Upstream Beach
- Tailings Cover
- Toe Berm Expansion

NOTES

1. Contours shown at 1.0m intervals.

REFERENCES

Control points surveyed by RDCK, July 2017.

CONTROL POINTS

Point ID	Easting	Northing	Elevation
6784	481,643.28	5,441,964.94	701.75
6785	481,893.43	5,441,964.10	719.17
6786	481,617.38	5,442,074.29	721.79

NOT FOR CONSTRUCTION

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							C	Issued for Remediation Plan	PM	AH	19/07/12
0268-001-08	BGC Engineering Inc.: Borehole and Testpit Locations, April 2005						B	Issued for Review	PM		19/05/08
K13103109-05	HB Dam Spillway Design_RECORD.dwg	-	-				A	Issued for Review	PM		18/12/05

REFERENCE DRAWINGS | REVISIONS

PROVINCE OF BRITISH COLUMBIA
P. H. MIKES
33319
ENGINEER
8/14/20

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CHECKED: MMM | APPROVED: PHM | DATE: June 30, 2020
FILE NAME: 1CR012.006 - Dam FC.dwg
SRK JOB NO.: 1CR012.006

REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

Closure Design

DRAWING TITLE: HB Dam - Final Site Plan

DRAWING NO.: 06 | SHEET: 6 OF 19 | REVISION NO: F

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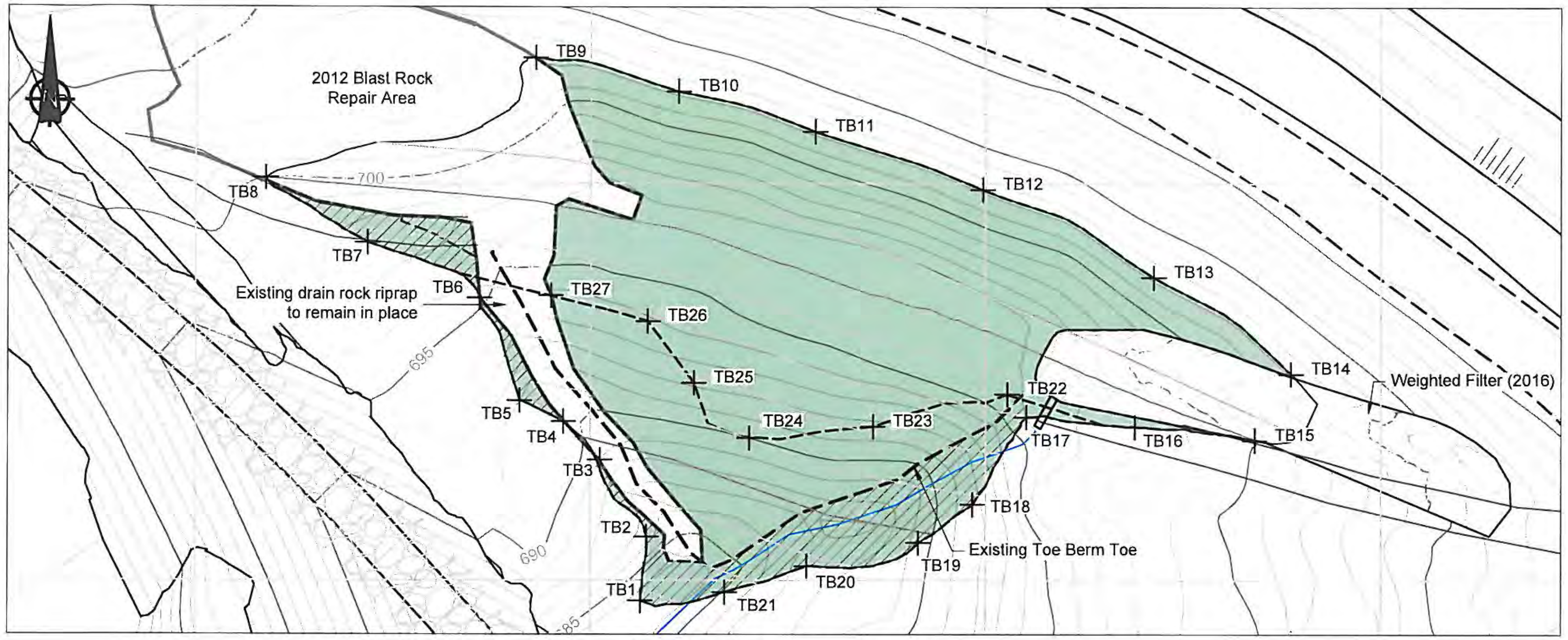
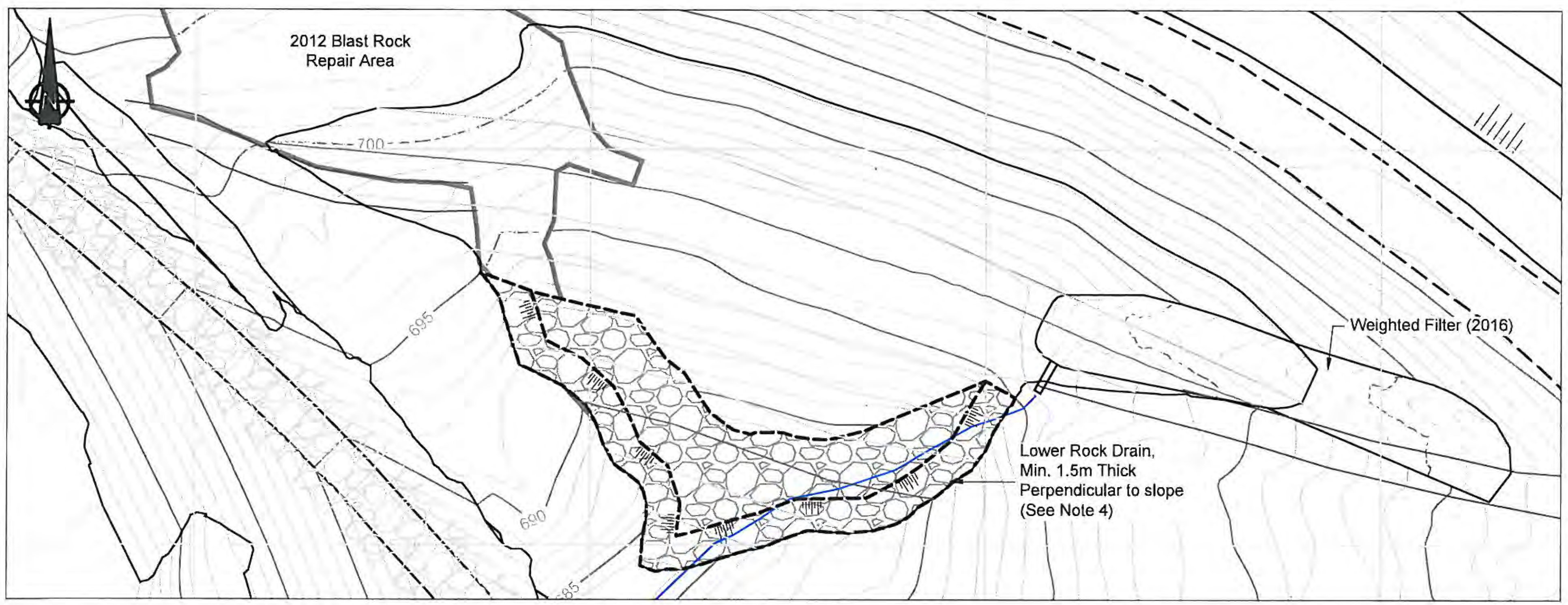


Toe Berm Site Preparation Plan



Toe Berm Drain Rock Placement Plan

LEGEND

- Current Toe Berm Toe
- Extent of Replaced Road Surfacing
- Vegetation Clearing
- Vegetation and Soft Soil Removed
- Drain Rock Placement
- Riprap

NOTES

1. Toe berm foundation preparation:
   All vegetation is to be removed from the toe berm footprint. Soft organic overburden is to be excavated to a minimum depth of 1.0m or until competent dense material is exposed as directed by the Engineer.
2. The dam organic surface must be removed and the 2005 Toe Berm Rock Drain exposed before placing rock drain and fill materials.
3. The conditions of the 2005 Toe Berm Rock Drain are to be confirmed during construction.
4. The Rock Drain must be placed at least 1.5m thick perpendicular to the slope over the expanded to berm footprint and must tie into the 2005 Toe Berm.
5. Drain rock to consist of clean, well-graded, sound, durable angular rock that is free from deleterious material and meets the sizing requirements listed on Drawing 02.

STAKEOUT POINTS

ID	Northing	Easting	Elev. (m)
TB1	5441947.38	481706.35	683.50
TB2	5441955.48	481707.11	686.31
TB3	5441965.19	481701.21	689.00
TB4	5441970.05	481696.58	690.50
TB5	5441972.67	481691.00	691.00
TB6	5441985.60	481685.87	695.51
TB7	5441992.57	481671.81	697.50
TB8	5442000.70	481658.88	700.00
TB9	5442015.85	481693.01	702.25
TB10	5442011.60	481711.15	702.23
TB11	5442006.55	481728.37	702.23
TB12	5441999.24	481749.61	702.24
TB13	5441988.16	481771.28	702.21
TB14	5441976.02	481788.58	702.13
TB15	5441967.65	481784.01	699.89
TB16	5441969.32	481768.90	698.00
TB17	5441970.59	481755.07	696.00
TB18	5441959.56	481748.32	691.56
TB19	5441954.70	481741.48	689.50
TB20	5441951.76	481727.34	687.50
TB21	5441948.43	481717.03	685.14
TB22	5441973.47	481752.67	695.55
TB23	5441969.38	481735.74	691.73
TB24	5441967.95	481720.09	690.00
TB25	5441974.89	481713.11	692.15
TB26	5441982.66	481707.25	693.86
TB27	5441985.90	481694.99	693.82

NOT FOR CONSTRUCTION

0m 5 10 15 20 25 30

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REFERENCE DRAWINGS

DRAWING NO	DRAWING TITLE
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REVISIONS

NO.	DESCRIPTION	CHK'D	APP'D	DATE
F	Issued for Review	PM	–	20/06/30
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A	Issued for Review	PM		18/12/05
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srk consulting

DESIGN	PHM	DRAWN	TAH	REVIEWED	CS
CHECKED	MMM	APPROVED	PHM	DATE	June 30, 2020

FILE NAME 1CR012.006 - TBE - SitePrep.dwg

Regional District Central Kootenay

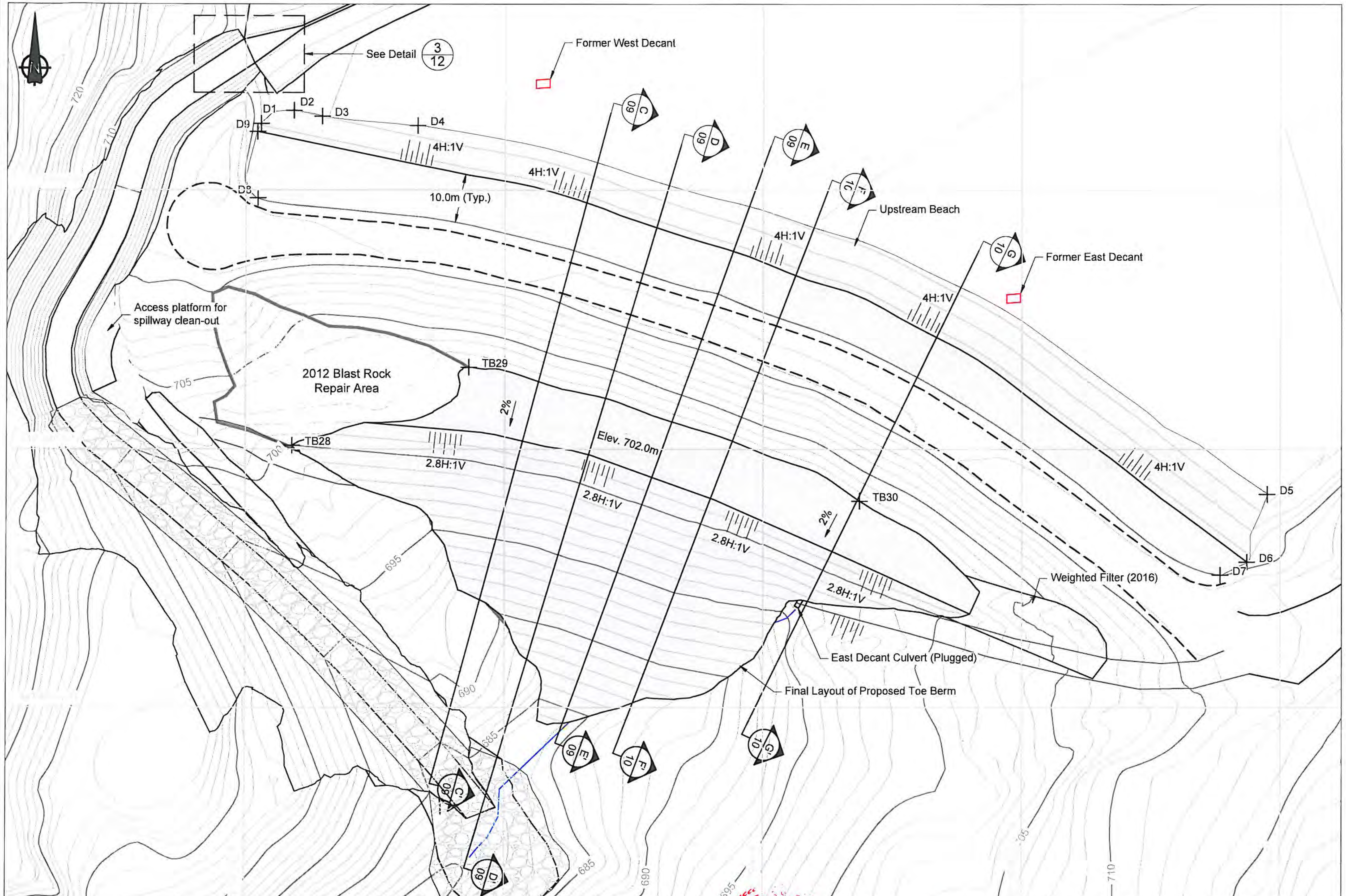
HB Mine Tailings Facility

SRK JOB NO 1CR012.006

Closure Design

DRAWING TITLE Toe Berm Expansion - Site Preparation Plan

DRAWING NO 07 | SHEET 7 OF 19 | REVISION NO F



LEGEND

- Stake Out Point
- Extent of Replaced Road Surfacing
- Top of Drain Rock
- Riprap
- Toe Berm Expansion / Upstream Beach

NOTES

1. Toe berm general fill to be compacted in maximum lifts of 0.5m to 95% Standard Proctor.
2. Upstream beach fill to consist of till or glaciolacustrine soil.
3. Prior to toe berm general fill placement, a layer of geotextile is to be installed at all locations where the general fill will be placed directly over the drain rock layer.
4. The non-woven geotextile is to meet the specifications provided in the Technical Specifications.
5. Tailings surface shown in drawing is prior to the backfill of the tailings pond.

STAKEOUT POINTS

ID	Northing	Easting	Elev. (m)
D1	5442062.79	481652.90	708.91
D2	5442065.29	481659.18	707.98
D3	5442064.19	481664.66	707.98
D4	5442062.41	481683.17	707.48
D5	5441991.24	481847.45	706.11
D6	5441978.09	481843.47	709.34
D7	5441975.54	481838.32	710.00
D8	5442048.47	481652.26	710.00
D9	5442061.24	481652.18	709.33
TB28	5441995.92	481704.93	699.89
TB29	5442000.70	481658.88	702.25
TB30	5442015.85	481693.01	702.00

NOT FOR CONSTRUCTION

0m 5 10 15 20 25 30

DRAWING NO.	DRAWING TITLE

REFERENCE DRAWINGS

NO.	DESCRIPTION	CHK'D	APP'D	DATE
F	Issued for Review	PM	–	20/06/30
E	Issued for Permitting	PM	–	20/01/31
D	Issued for Tender	MM	PM	19/10/23
C	Issued for Remediation Plan	PM	AH	19/07/12
B	Issued for Review	PM		19/05/08
A	Issued for Review	PM		18/12/05

REVISIONS

PROFESSIONAL ENGINEERS STAMP: PROFESSIONAL ENGINEER, PROVINCE OF BRITISH COLUMBIA, P. H. MIKES # 33319, 8/14/20

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DESIGN PHM	DRAWN TAH	REVIEWED CS
CHECKED MMM	APPROVED PHM	DATE June 30, 2020

FILE NAME 1CR012.006 - TBE - FC.dwg

Regional District of Central Kootenay

HB Mine Tailings Facility

SRK JOB NO 1CR012.006

Closure Design

DRAWING TITLE
Upgraded Dam Final Contours

DRAWING NO. 08 | SHEET 8 OF 19 | REVISION NO. F

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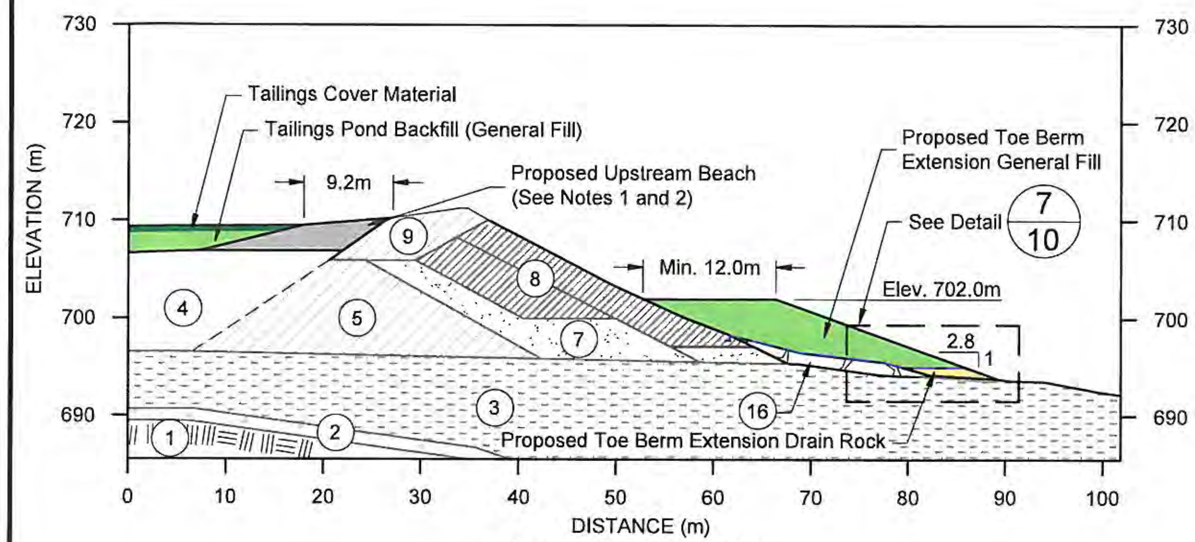
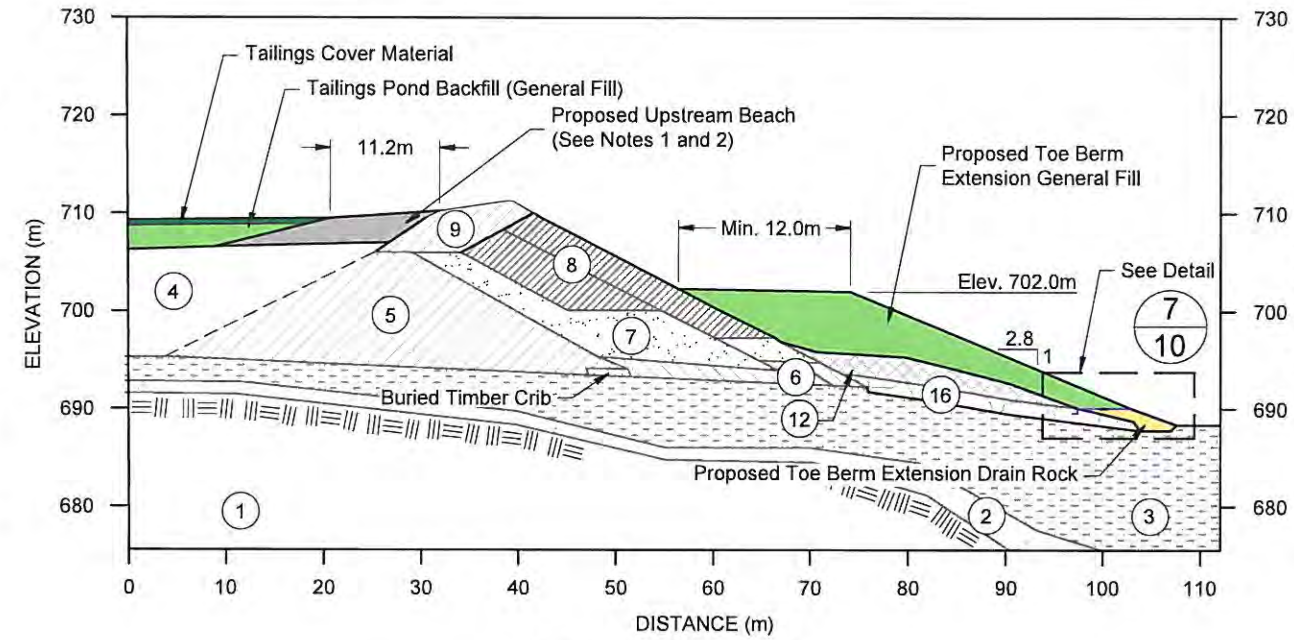


Cross Section C-C'



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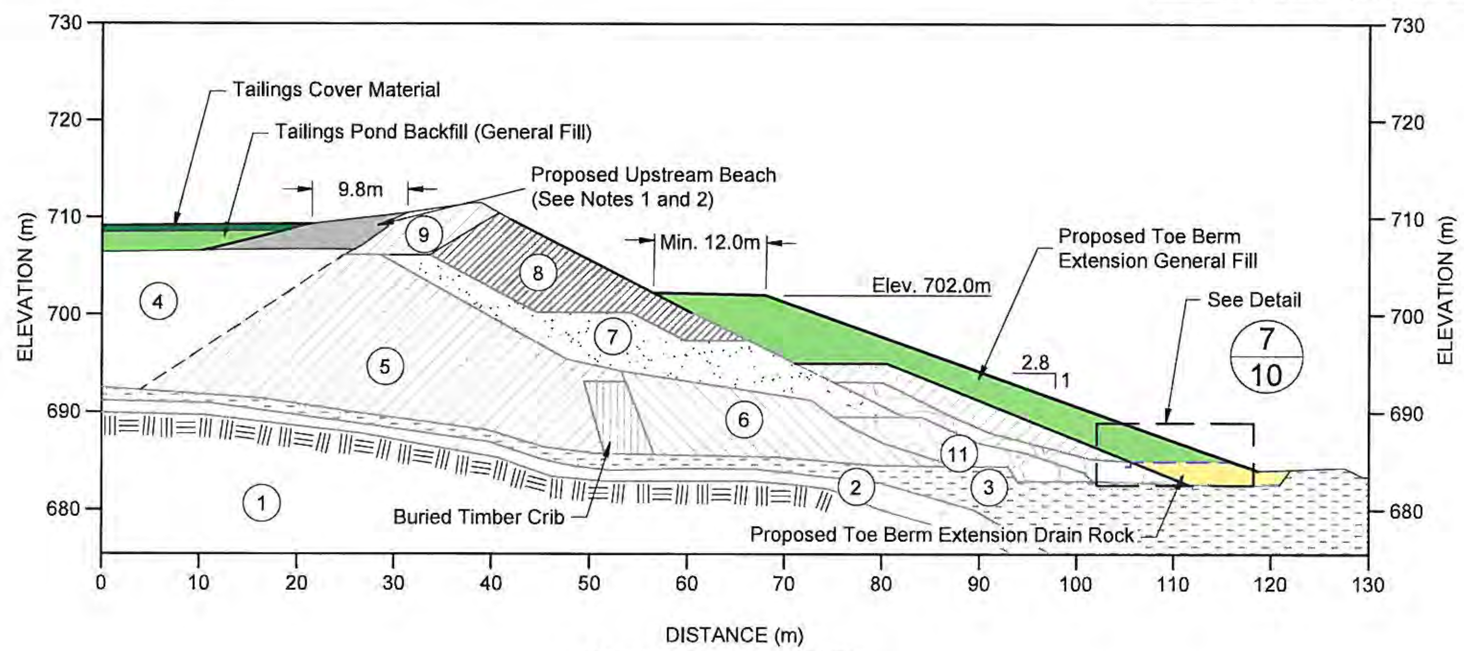


Cross Section E-E'

LEGEND

EXISTING MATERIALS

- Geotextile
- Zone 1 - Bedrock
- Zone 2 - Native Till
- Zone 3 - Native Glaciolacustrine
- Zone 4 - Tailings (1955 - 1978)
- Zone 5 - Original Dam (1955 - 1967)
- Zone 6 - Stabilizing Berm (1964 - 1967)
- Zone 7 - Filter Blanket (1974/75 and 1997)
- Zone 8 - Common Fill (1975 and 1977)
- Zone 9 - Select Impervious Fill (1975 and 1977))
- Zone 10 - Rock Toe Drain (1977)
- Zone 11 - Rock Drain (2005)
- Zone 12 - Till Toe Berm (2005)
- Zone 13 - Riprap (2005)
- Zone 14 - Repaired Filter Blanket (2012)
- Zone 15 - Repaired Till Fill (2012)
- Zone 16 - Coarse Rock Blanket and Shear Key (2012)
- Zone 17 - Weighted Filter (2016)

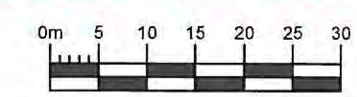
PROPOSED MATERIALS

- Tailings Cover Material
- General Fill
- Toe Berm Drain Rock
- Upstream Beach Material

NOTES

1. Riprap on the upstream slope of the dam is to be salvaged prior to dam excavation for re-uses elsewhere on the project.
2. The upstream beach fill is to be placed in 0.5m lifts and compacted under equipment weight.
3. Existing berm crest surface to be graded to drain prior to rock drain placement.

NOT FOR CONSTRUCTION



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E	Issued for Permitting	PM	—	20/01/31
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REVISIONS

DRAWING NO. | DRAWING TITLE — REFERENCE DRAWINGS

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DESIGN: PHM | DRAWN: TAH | REVIEWED: CS
CHECKED: MMM | APPROVED: PHM | DATE: June 30, 2020

FILE NAME: 1CR012.006 - Stability Sections.dwg

HB Mine Tailings Facility

SRK JOB NO: 1CR012.005

Closure Design

DRAWING TITLE: HB Dam - Upgraded Dam Cross Section (1 of 2)

DRAWING NO: 09 | SHEET: 9 OF 19 | REVISION NO: F

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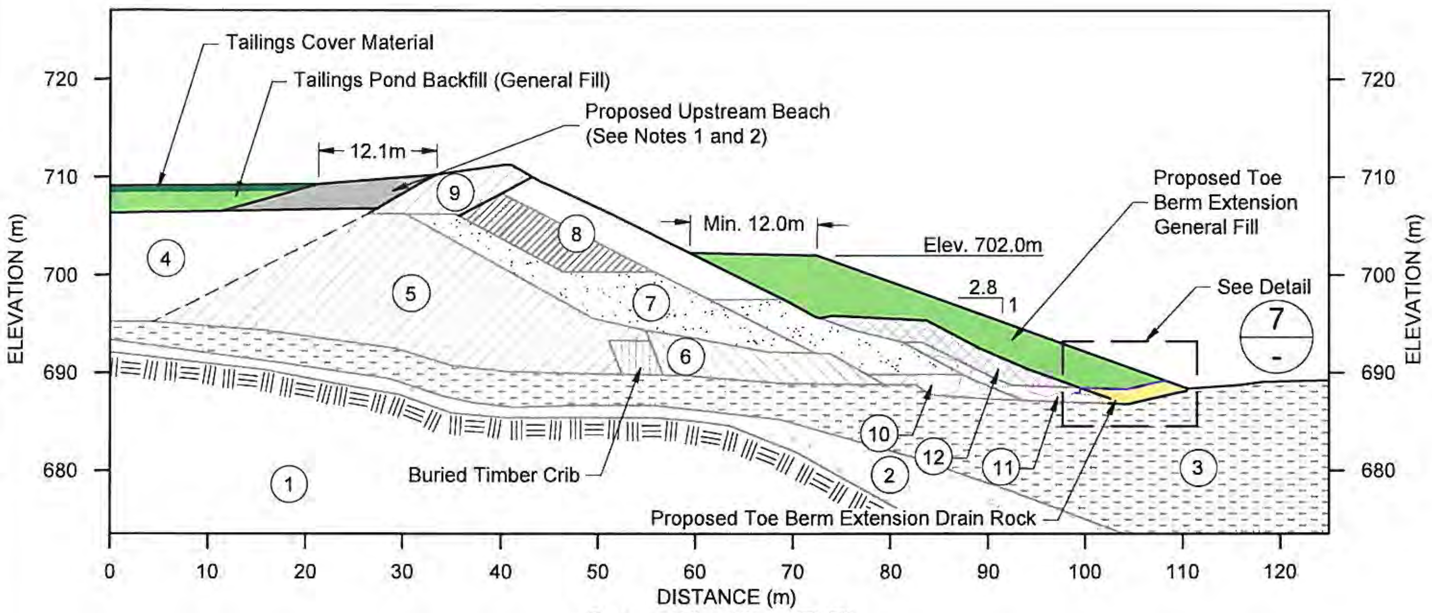
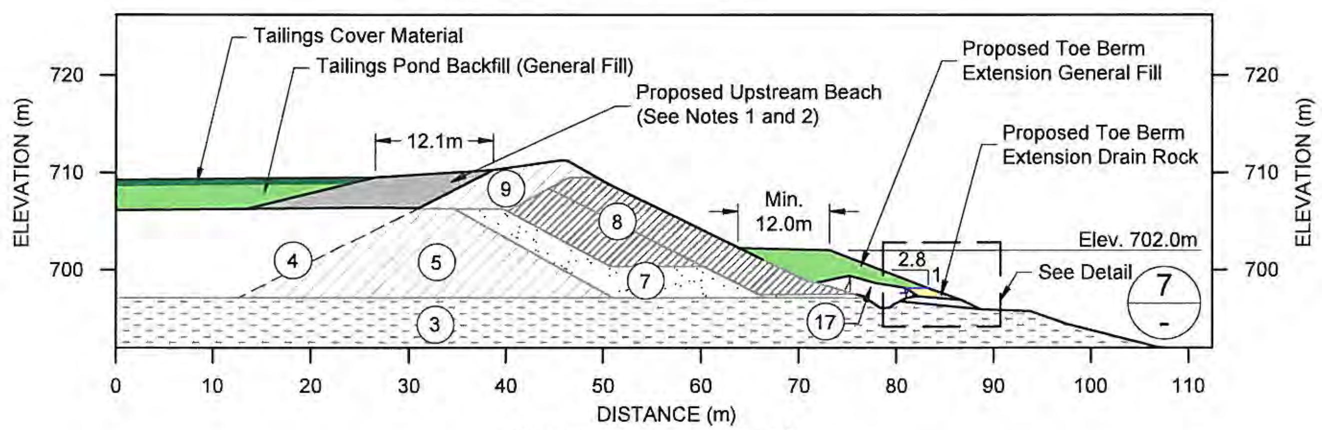
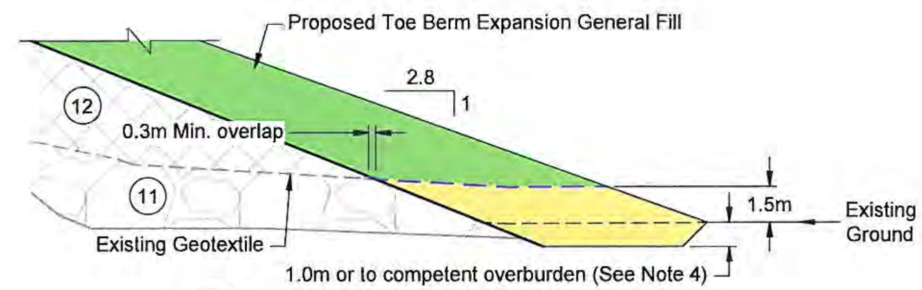


Cross Section F-F'



Cross Section G-G'



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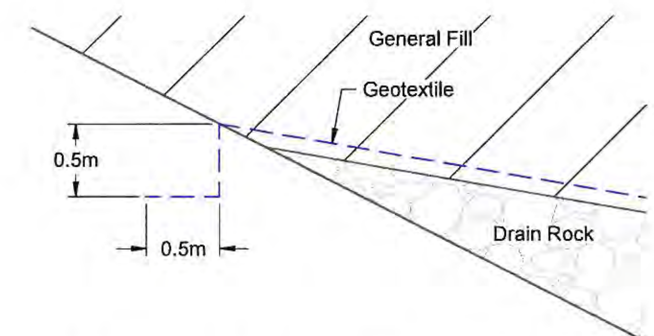
Typical Lower Berm Detail



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12

Typical Geotextile Anchor Trench

Not To Scale

LEGEND

EXISTING MATERIALS

- Geotextile
- Zone 1 - Bedrock
- Zone 2 - Native Till
- Zone 3 - Native Glaciolacustrine
- Zone 4 - Tailings (1955 - 1978)
- Zone 5 - Original Dam (1955 - 1967)
- Zone 6 - Stabilizing Berm (1964 - 1967)
- Zone 7 - Filter Blanket (1974/75 and 1997)
- Zone 8 - Common Fill (1975 and 1977)
- Zone 9 - Select Impervious Fill (1975 and 1977))
- Zone 10 - Rock Toe Drain (1977)
- Zone 11 - Rock Drain (2005)
- Zone 12 - Till Toe Berm (2005)
- Zone 13 - Riprap (2005)
- Zone 14 - Repaired Filter Blanket (2012)
- Zone 15 - Repaired Till Fill (2012)
- Zone 16 - Coarse Rock Blanket and Shear Key (2012)
- Zone 17 - Weighted Filter (2016)

PROPOSED MATERIALS

- Tailings Cover Material
- General Fill
- Toe Berm Drain Rock
- Upstream Beach Material

NOTES

1. Riprap on the upstream slope of the dam is to be salvaged prior to dam excavation for re-uses elsewhere on the project.
2. The upstream beach fill is to be placed in 0.5m lifts and compacted under equipment weight.
3. Existing berm crest surface to be graded to drain prior to rock drain placement.
4. All soft soils and organics are to be excavated from the expanded toe berm footprint until competent dense soils are encountered, or to a depth of 1.0m below original ground surface. Should the excavation depth reach the full 1.0m, a layer of geotextile is to be placed at the base of the excavation prior to placement of the drain rock.

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NO	DESCRIPTION	CHK'D	APP'D	DATE
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REFERENCE DRAWINGS (DRAWING NO, DRAWING TITLE) — REVISIONS

PROFESSIONAL ENGINEERS STAMP: PROFESSIONAL, PROVINCE OF BRITISH COLUMBIA, P. H. MIKES # 33319, ENGINEER, 8/4/20

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DESIGN	PHM	DRAWN	TAH	REVIEWED	CS
CHECKED	MMM	APPROVED	PHM	DATE	June 30, 2020

FILE NAME: 1CR012.006 - Stability Sections.dwg

HB Mine Tailings Facility

SRK JOB NO: 1CR012.005

Closure Design

DRAWING TITLE: HB Dam - Upgraded Dam Cross Section (2 of 2)

DRAWING NO: 10 | SHEET: 10 OF 19 | REVISION NO.: F

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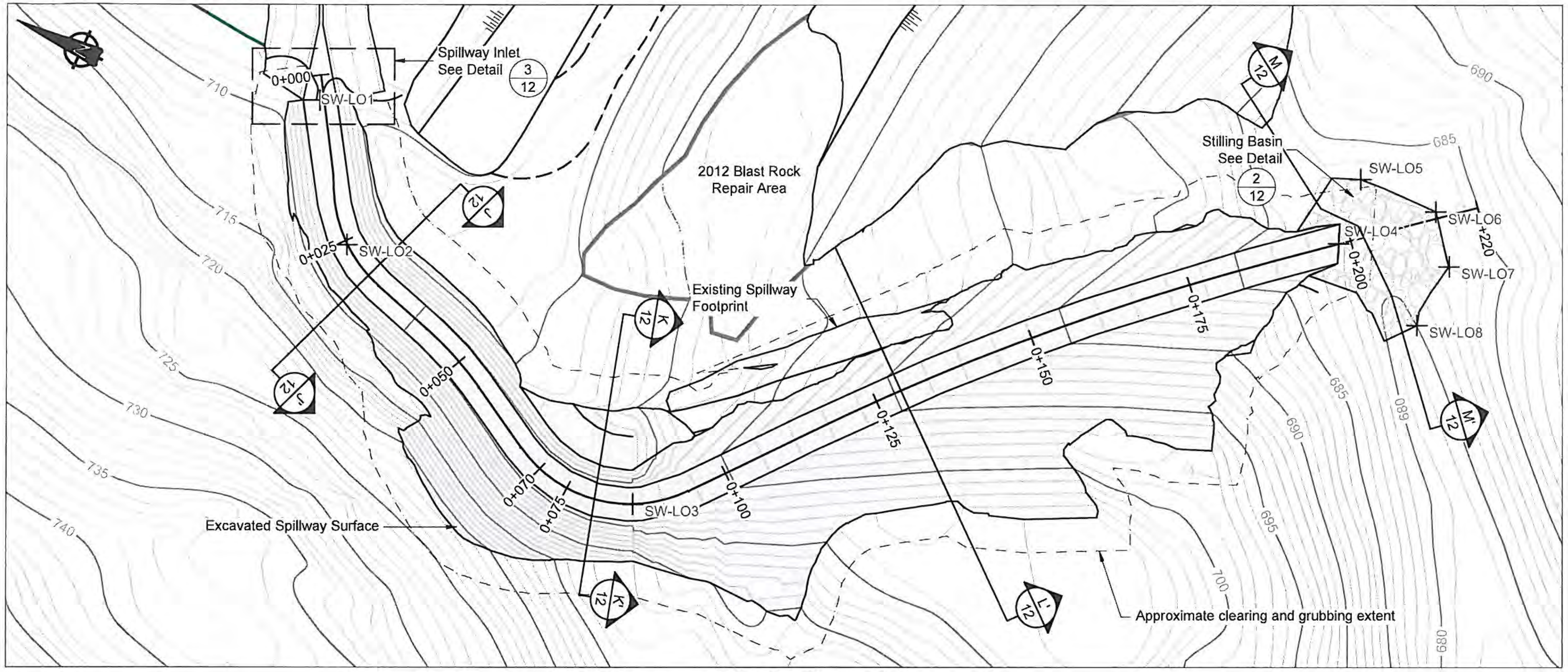
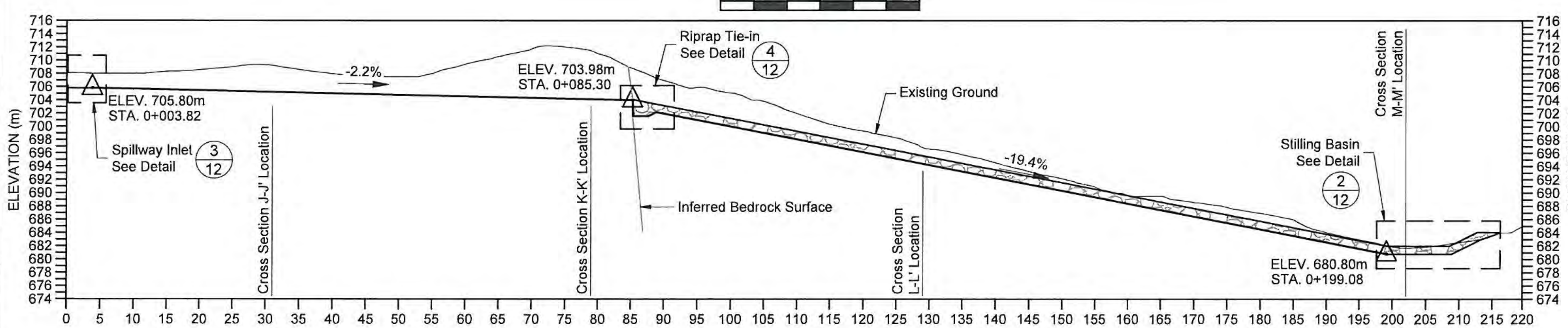


West Spillway Plan

0m 5 10 15 20 25 30



West Spillway Profile

0m 5 10 15 20 25 30

LEGEND

- Clearing and Grubbing Extent
- Riprap
- Tailings Cover
- Erosion Extent

NOTES

1. Contours shown at 1.0m intervals.
2. All dimensions in meters unless stated otherwise.
3. Excavation boundaries are approximate and may vary depending on the depth of bedrock.
4. Depth to bedrock shall be confirmed prior to excavation between 0+070 and 0+100.
5. The contractor shall use controlled blasting methods to minimize damage to the abutment rock and to ensure the stability of the dam embankment.
6. A blast plan is to be submitted and approved by the Engineer and requires to be submitted to EMPR for approval a minimum 30 days prior to the planned start of blasting.
7. A blast monitoring station shall be placed on bedrock within 50m of the spillway at the dam centerline. Blast monitoring data, including the distance to the monitoring station, the vibration frequency, and peak particle velocity shall be reported to the Engineer following each blast.
8. The peak particle velocity must be kept below 2.5 cm/second.
9. Additional excavation may be required to remove rock deemed by the Engineer to be a potential future spillway blockage risk.
10. Spillway riprap to have a median particle size (D_{50}) of 600mm and meet the material specifications provided in Drawing 02.
11. The geotextile is to meet the product specifications provided in the Technical Specifications.
12. Geotextile panels are to have a minimum 0.3m overlap, with the upstream panel placed over the downstream panel.

LAYOUT POINTS (CHANNEL CENTERLINE)

ID	Northing	Easting	Channel Base Elevation (m)	Top of Riprap Elevation(m)
SW-LO1	5442076.71	481650.52	705.80	-
SW-LO2	5442063.97	481632.76	705.34	-
SW-LO3	5442008.78	481615.78	704.00	705.20
SW-LO4	5441929.61	481695.63	682.17	683.37
SW-LO5	5441930.66	481705.71	-	683.13
SW-LO6	5441918.46	481706.05	-	683.09
SW-LO7	5441913.21	481699.50	-	683.00
SW-LO8	5441913.87	481689.54	-	680.04

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REFERENCE DRAWINGS — DRAWING NO. | DRAWING TITLE

REVISIONS

PROFESSIONAL OF PROVINCE P. H. MIKES # 33319 BRITISH COLUMBIA ENGINEER
8/14/20
PROFESSIONAL ENGINEERS STAMP

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CHECKED MMM | APPROVED PHM | DATE June 30, 2020
FILE NAME 1CR012.006 - Spillway.dwg

REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

SRK JOB NO 1CR012.006

Closure Design

DRAWING TITLE
Upgraded Spillway - Plan and Profile

DRAWING NO. 11 | SHEET 11 OF 19 | REVISION NO F

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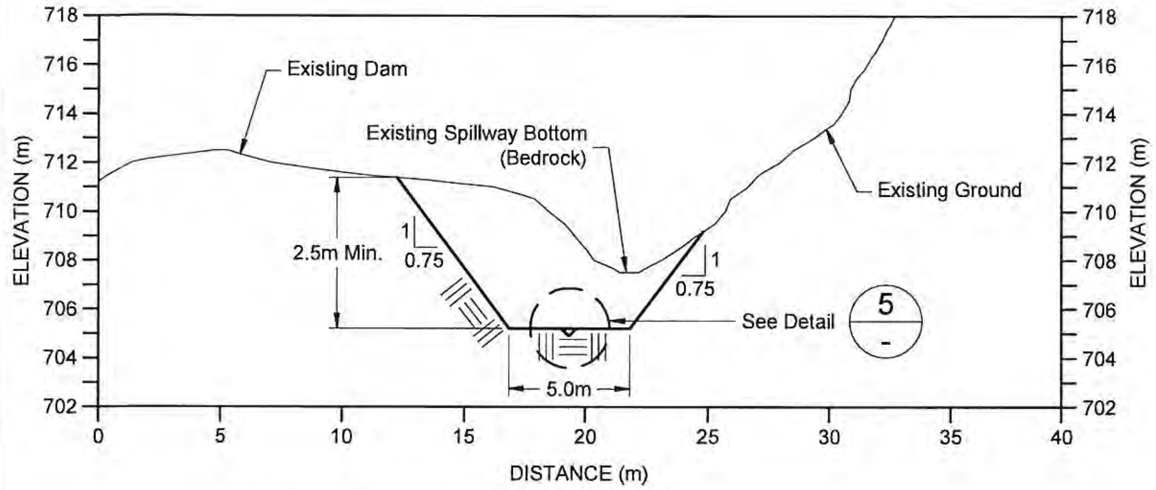
LEGEND

- Geotextile
- Geosynthetic Liner
- Turf Reinforcement Mat
- Liner Protection Layer
- Riprap
- Concrete
- General Fill
- Bedrock
- Natural Ground

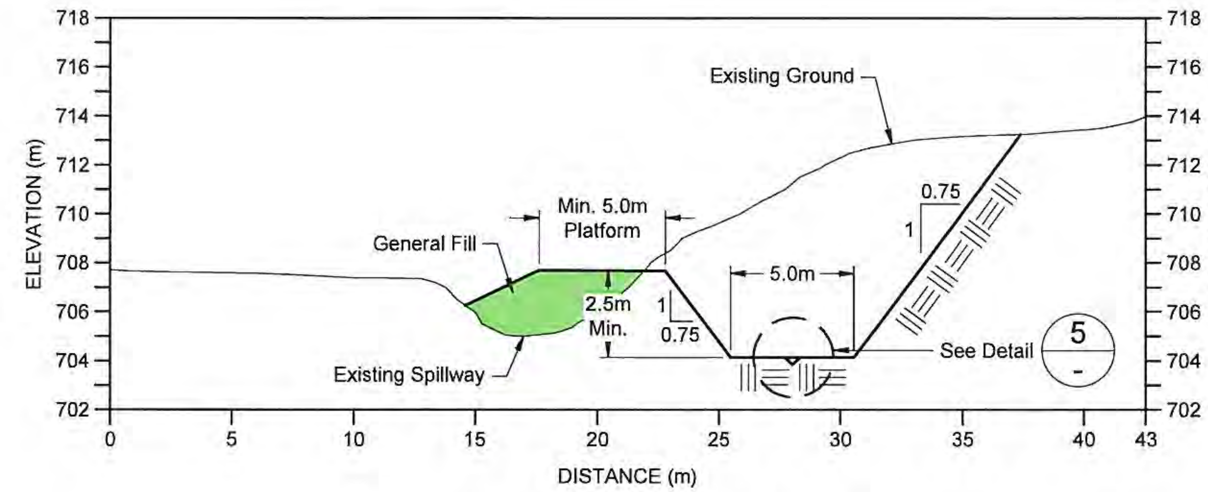
NOTES

1. All dimensions are in meters unless stated otherwise.
2. Final spillway invert width: 5.0m.
3. Minimum depth of channel in rock: 2.5m
4. Side-slope in rock: 0.75H:1V
5. Side-slope in soil: 2H:1V
6. Allow a 1m 'bench' at rock/soil interface.
7. Riprap thickness measured perpendicular to slope.
8. Depth to bedrock to be confirmed prior to excavation between 0+070 and 0+100.
9. As directed by the Engineer, a pilot channel to be jackhammered into the bedrock to prevent localized ponding and minimize risk of glaciation.
10. Cement bages to be placed overtop of liner, hydrated, and covered with a thin layer of soil



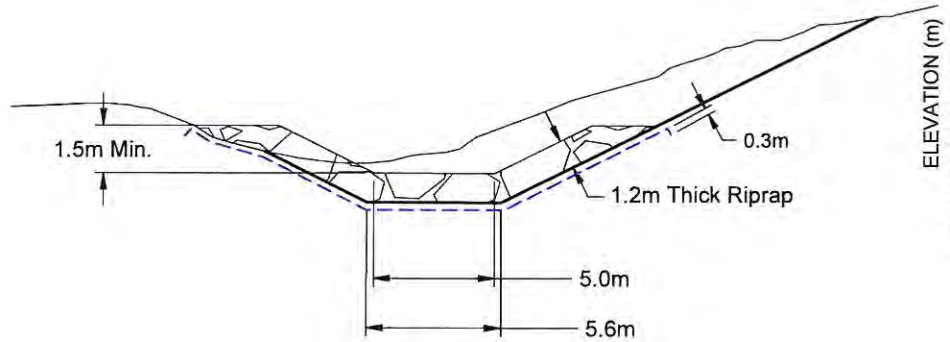
J 11 **Cross Section J-J'**

0m 5 10 15 20



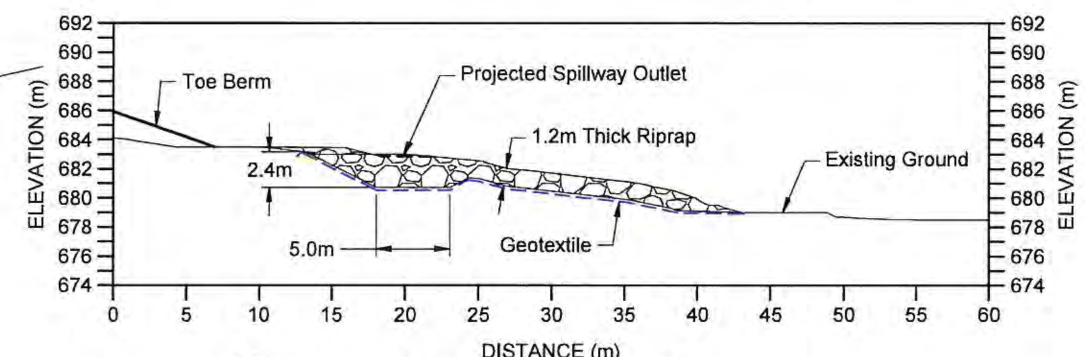
K 11 **Cross Section K-K'**

0m 5 10 15 20



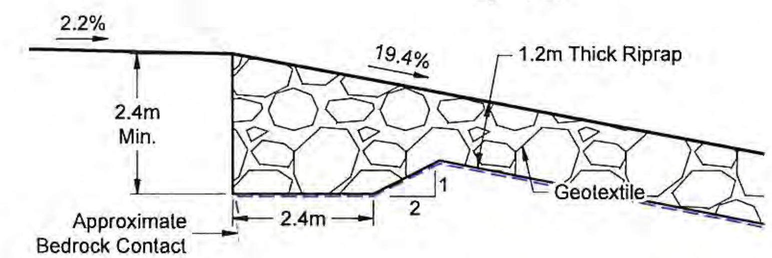
L 11 **Cross Section L-L'**

0m 3 6 9 12



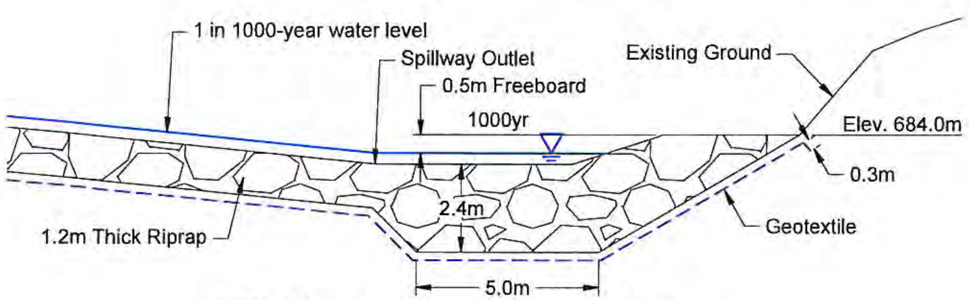
M 11 **Cross Section M-M'**

0m 5 10 15 20 25 30



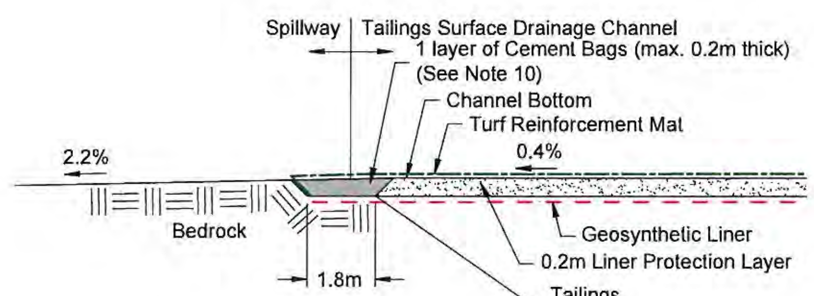
4 11 **Detail 4 - Riprap Tie-in**

0m 1 2 3 4 5



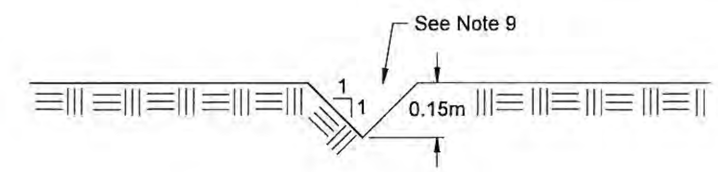
2 11 **Stilling Basin Typical Detail**

0m 5 10 15 20



3 11 **Spillway Inlet Typical Detail**

0m 5 10 15 20



5 - **Bedrock Pilot Channel Typical Detail**

0 200 400 600 800mm

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REVISIONS

DRAWING NO. | DRAWING TITLE — REFERENCE DRAWINGS

PROFESSIONAL ENGINEERS STAMP: PROFESSIONAL PROVINCE OF BRITISH COLUMBIA P. H. MIKES # 33819 ENGINEER 8/4/20

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FILE NAME 1CR012.006 - Spillway.dwg

REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

SRK JOB NO 1CR012.006

Closure Design

DRAWING TITLE: Upgraded Spillway - Cross Sections and Details

DRAWING NO 12 | SHEET 12 OF 19 | REVISION NO F

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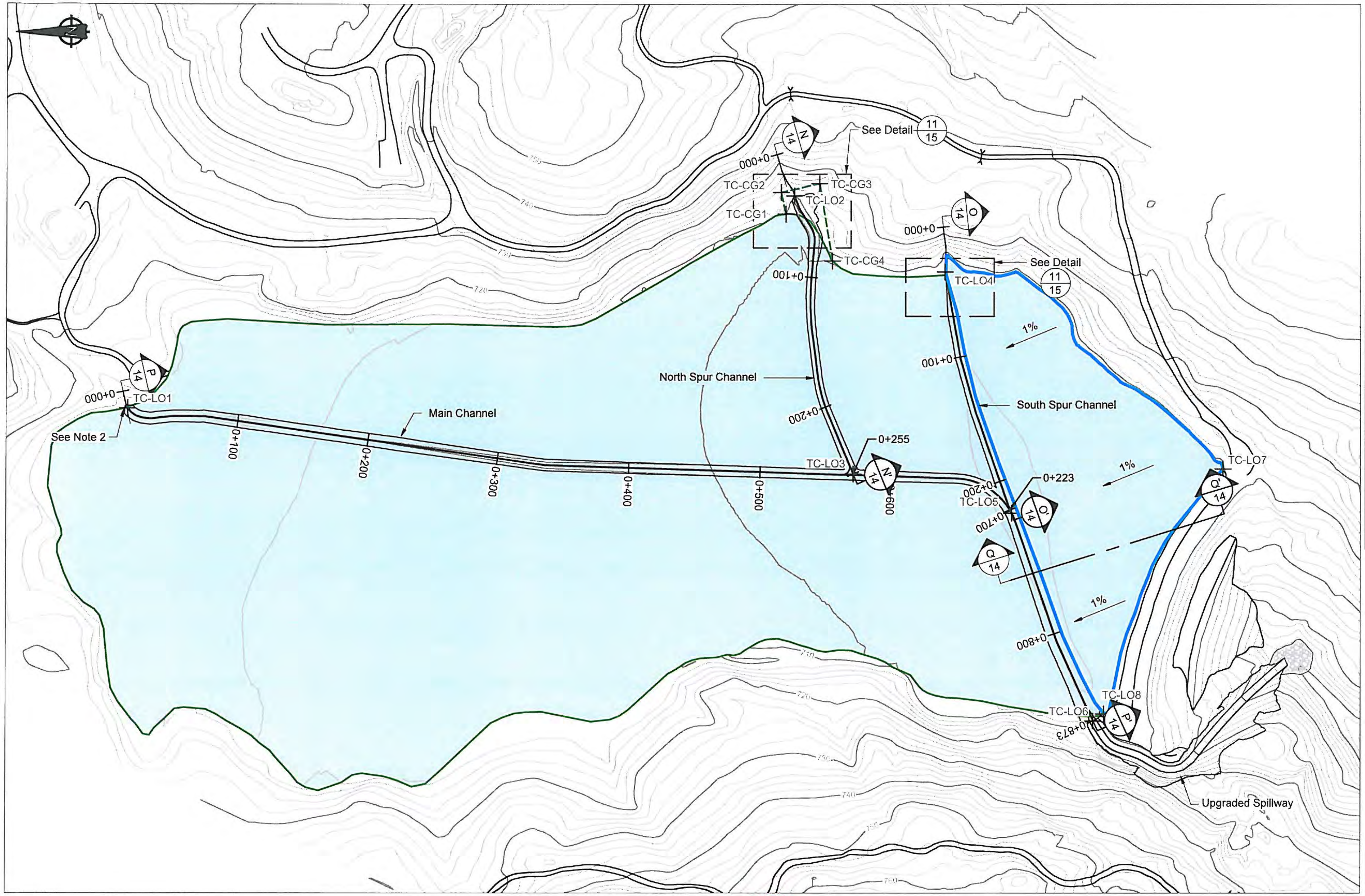

LEGEND

- Clearing and Grubbing Extent
- Tailings Soil Cover
- Tailings Pond Backfill General Fill Extent

NOTES

1. Contours shown at 2.0m intervals.
2. Main Channel inlet to be field fit with the liner extending a minimum 2m upstream of the tailings.
3. The tailings pond is to be backfilled with General Fill and covered with 0.3m of Tailings Cover Material to direct surface runoff to the Tailings Surface Drainage Channels with a typical 1% slope.

LAYOUT POINTS

ID	Northing	Easting	Elev. (m)
TC-LO1	5442812.14	481889.14	713.12
TC-LO2	5442304.60	482050.79	710.43
TC-LO3	5442259.47	481838.85	708.29
TC-LO4	5442189.92	481993.09	708.55
TC-LO5	5442138.60	481808.955	706.45
TC-LO6	5442076.71	481650.52	705.80
TC-LO7	5441977.72	481842.77	709.43
TC-LO8	5442068.53	481655.81	708.23
TC-CG1	5442311.17	482036.98	710.08
TC-CG2	5442314.69	482053.44	713.12
TC-CG3	5442285.38	482060.17	714.38
TC-CG4	5442275.34	482001.38	709.79

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0m 30 60 90 120

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DRAWING NO.	DRAWING TITLE
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F	Issued for Review	PM	–	20/06/30
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FILE NAME	1CR012.006 - DC.dwg				

Regional District of Central Kootenay

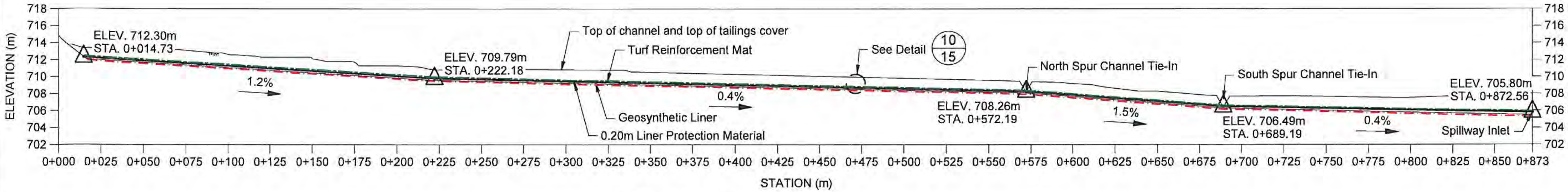
HB Mine Tailings Facility

SRK JOB NO. 1CR012.006

Closure Design

DRAWING TITLE: Tailings Surface Drainage Channel Plan

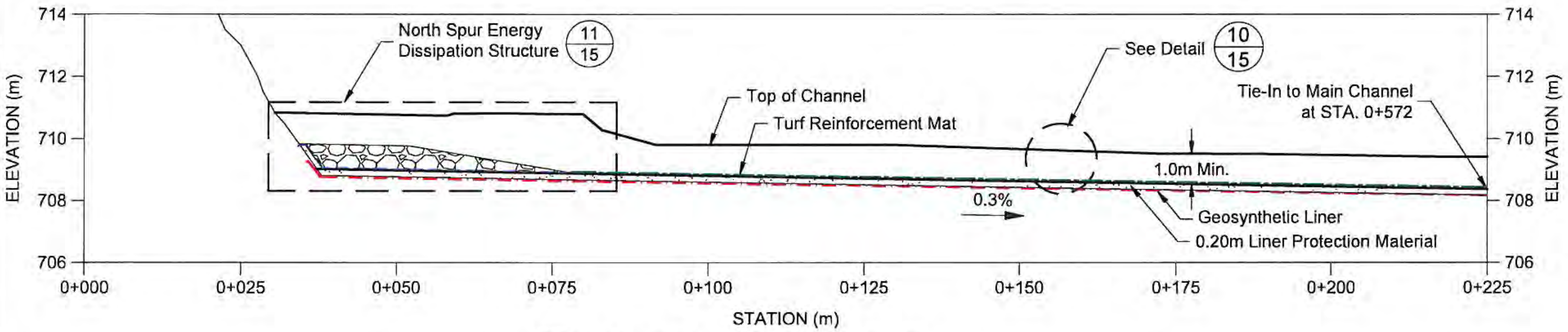
DRAWING NO. 13 | SHEET 13 OF 19 | REVISION NO F



M/13 **Main Channel Profile**

5X Vertical Exaggeration

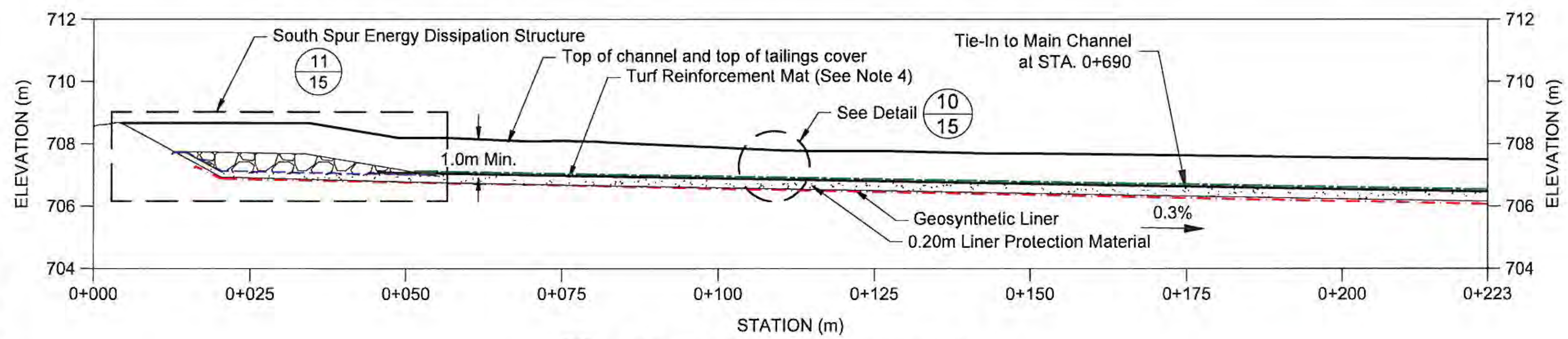
0m 20 40 60 80 100



N/13 **North Spur Channel Profile**

5X Vertical Exaggeration

0m 10 20 30 40



O/13 **South Spur Channel Profile**

5X Vertical Exaggeration

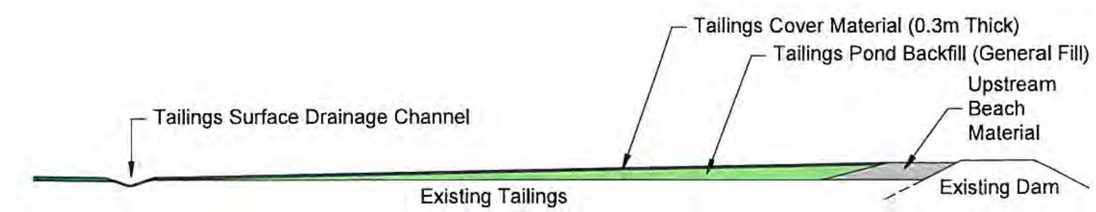
0m 10 20 30 40

LEGEND

Geosynthetic Liner	Geotextile
Liner Protection Material	Turf Reinforcement Mat
Riprap	Tailings Cover Material

NOTES

1. All dimensions are in meters unless otherwise stated.
2. The channel grades may be adjusted to suit field conditions but shall not be less than 0.2 % or greater than 3% in all cases unless approved by the Engineer.
3. Excavated tailings are to be disposed within the tailings impoundment in a manner not to imped surface runoff or result in pooling.
4. The geosynthetic liner and turf reinforcement mat are to be installed as per manufacturers instructions and meet the product specifications provided in the Technical Specifications.
5. The riprap in the North and South Spur Energy Dissipation Structures have a median particle size (D50) of 400mm and meet the material specifications provided on Drawing 02.
6. The liner protection material is to consist of a well-graded sand that meets the specifications provided on Drawing 02.
7. Prior to Turf Reinforcement Mat (TRM) deployment, all subgrade surfaces shall be broadcast seeded and be free of sharp protruding rocks.
8. TRM panels shall have a minimum 0.15m overlap and follow the stapling patterns provided on Drawing 15.
9. The TRM panels are to be shingled such that the upstream panel is overtop of the downstream panel.



Q/13 **Typical Tailings Pond Backfill Section**

0m 10 20 30 40

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NO.	DESCRIPTION	CHK'D	APP'D	DATE
F	Issued for Review	PM	–	20/06/30
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A	Issued for Review	PM		18/12/05

REVISIONS

DRAWING NO.	DRAWING TITLE

REFERENCE DRAWINGS

PROFESSIONAL ENGINEER PROVINCE OF BC P.H. MIKES # 33319 8/14/20

PROFESSIONAL ENGINEERS STAMP

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CHECKED	APPROVED	DATE
MMM	PHM	June 30, 2020

FILE NAME: 1CR012.006 - DC.dwg

Regional District of Central Kootenay

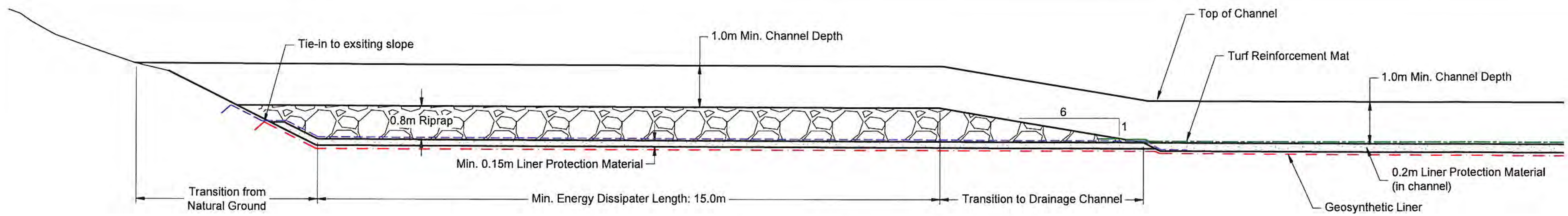
HB Mine Tailings Facility

SRK JOB NO.: 1CR012.006

Closure Design

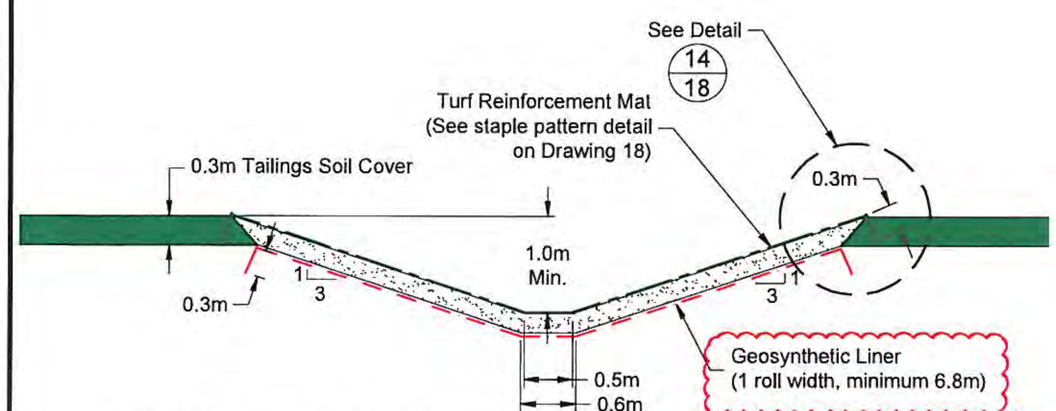
DRAWING TITLE: Tailings Surface Drainage Channel Profiles and Tailings Pond Backfill Section

DRAWING NO.: 14 | SHEET: 14 OF 19 | REVISION NO.: F



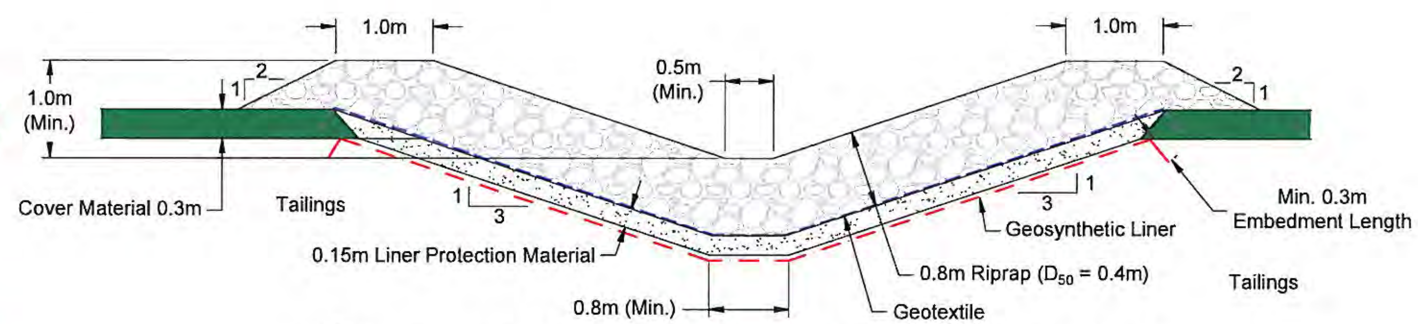
11 / 13,14 **Typical Energy Dissipation Structure Profile Detail**

0m 1 2 3 4



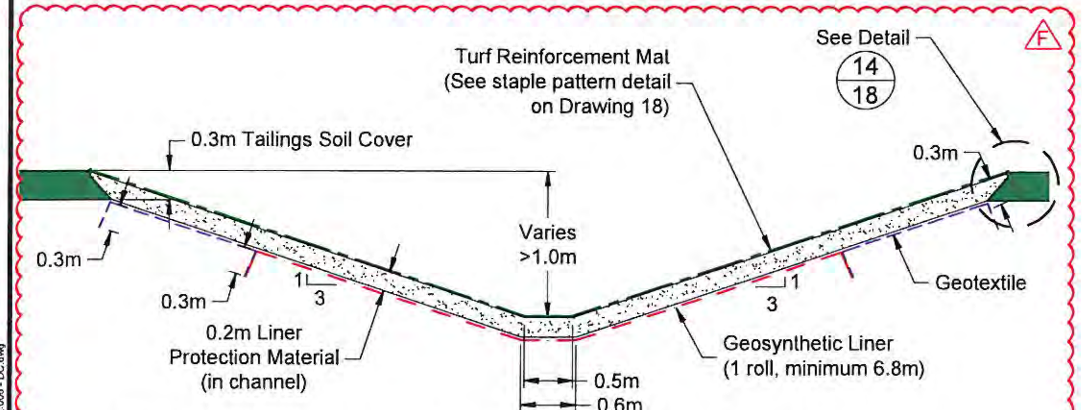
10 / - **Tailings Surface Drainage Channel Typical Section (1.0m Deep)**

0m 0.5 1.0 1.5 2.0 2.5 3.0



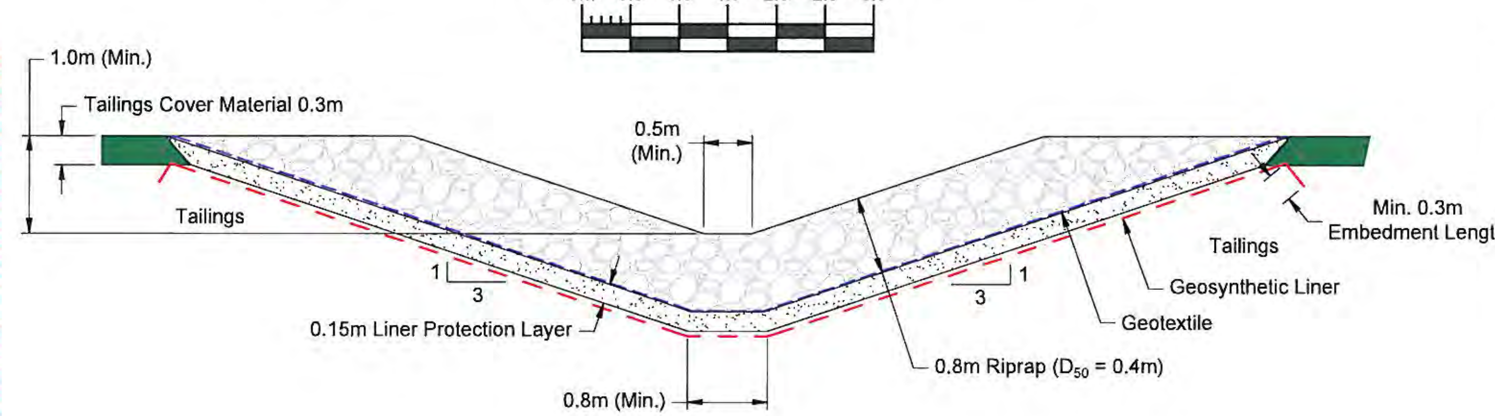
11 / 13,14 **Energy Dissipater Section Detail in Areas Requiring Build Up for Minimum Channel Containment**

0m 0.5 1.0 1.5 2.0 2.5 3.0



10 / - **Tailings Surface Drainage Channel Typical Section (Deeper Channel - Sta. 0+800 to 0+873)**

0m 0.5 1.0 1.5 2.0 2.5 3.0



11 / 13,14 **Energy Dissipation Structure Section Detail**

0m 0.5 1.0 1.5 2.0 2.5 3.0

LEGEND

- Geosynthetic Liner
- Turf Reinforcement Mat
- Geotextile
- Liner Protection Material
- Riprap
- Tailings Cover Material

NOTES

1. All dimensions are in meters unless otherwise stated.
2. Geosynthetic products to meet the material specifications provided in the Technical Specifications.
3. The transition from natural ground and the upstream end of the Energy Dissipation Structure is to be field fit.
4. Geotextile panels are to have a minimum 0.3m overlap, with the upstream panel placed over the downstream panel.
5. The liner protection material is to consist of well-graded sand that meets the specifications provided on Drawing 02.
6. Riprap in both energy dissipation structures to have a median particle size (D_{50}) of 400mm and meet the material specifications provided on Drawing 02.

NOT FOR CONSTRUCTION

DRAWING NO.	DRAWING TITLE
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REFERENCE DRAWINGS

NO.	DESCRIPTION	CHK'D	APP'D	DATE
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NO.	DESCRIPTION	CHK'D	APP'D	DATE
F	Issued for Review	PM	–	20/06/30
E	Issued for Permitting	PM	–	20/01/31
D	Issued for Tender	MM	PM	19/10/23
C	Issued for Remediation Plan	PM	AH	19/07/12
B	Issued for Review	PM		19/05/08
A	Issued for Review	PM		18/12/05

REVISIONS

PROFESSIONAL PROVINCE OF B.C. R.H. MIKES # 33319 ENGINEER
06/16/20

PROFESSIONAL ENGINEERS STAMP

srk consulting

DESIGN	SP	DRAWN	TAH	REVIEWED	CS
CHECKED	MMM	APPROVED	PHM	DATE	June 30, 2020

FILE NAME 1CR012.006 - DC.dwg

Regional District of Central Kootenay

HB Mine Tailings Facility

SRK JOB NO. 1CR012.006

Closure Design

DRAWING TITLE Tailings Surface Drainage Channel Sections and Energy Dissipation Structures

DRAWING NO. 15 | SHEET 15 OF 19 | REVISION NO. F

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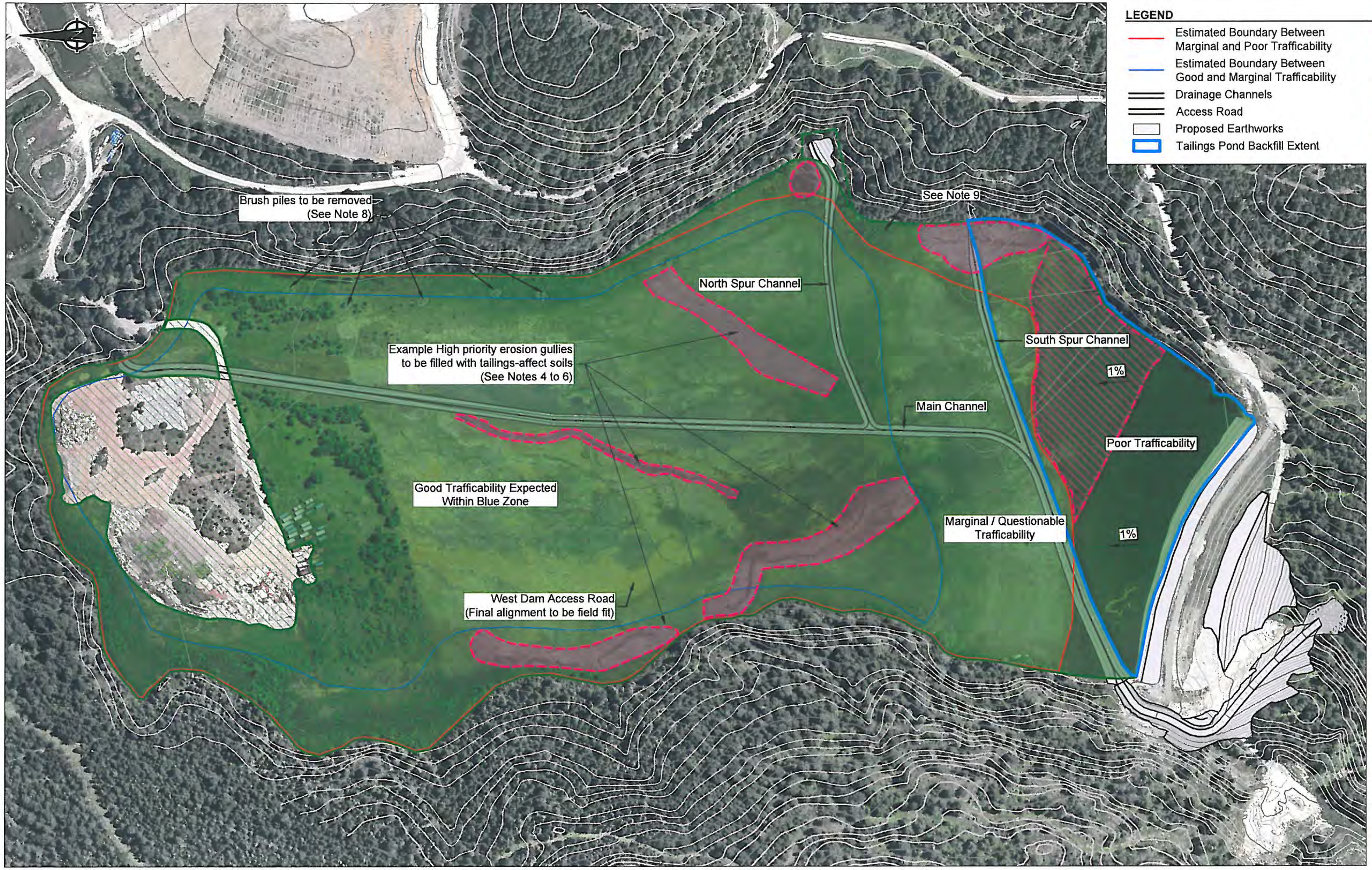

LEGEND

- Estimated Boundary Between Marginal and Poor Trafficability
- Estimated Boundary Between Good and Marginal Trafficability
- Drainage Channels
- Access Road
- Proposed Earthworks
- Tailings Pond Backfill Extent
- Priority Area for "Ross Lands" Soils
- Secondary Priority Area for "Ross Lands" Soils
- Tailings Cover
- Area of Existing Cover Placement (See Note 10)
- Clearing and Grubbing Required

NOTES

1. Orthophoto taken in 2016 and provided by the RDCK.
2. Trafficability assessment based on site observations and limited vane shear tests on August 16, 2017. The contractor is to verify conditions prior to construction and determine the most appropriate equipment for cover placement.
3. The tailings cover is to have a nominal thickness of 0.3m ± 0.15m in the vertical direction, with the average of 10 quality control checks (completed on a 10m grid) not be less that 0.25m thick.
4. Tailings-affected soil from the "Ross Lands" are to be imported to the site and covered beneath the tailings cover. The priority for placement of this estimated 10,000 to 15,000m³ of material is as follows:
   a. Filling of erosion channels, gullies, and low lying areas on the western and eastern side of the tailings area.
   b. Placement in the poor trafficability area as part of the Tailings Pond Backfill. Material not to be placed within the Upstream Beach footprint.
5. Not all erosion gullies and low-lying areas have been identified on the Drawing. These areas are to be identified during construction prior to the import of the tailings affected soil
6. All erosion gullies and low-lying areas are to be filled prior to placement of tailings-affected soils in secondary priority areas except as approved by the Engineer.
7. The location of the East Decant is unknown and has been approximated on Drawing 04 based on historical drawings. The Engineer is to verify the location and document the condition of the East Decant following dewatering of the pond and prior to placement of the Tailings Pond Backfill.
8. Brush piles are to be removed and spread on top of the placed cover. Care is to be taken not to disturb the tailings surface when loading the the brush piles.
9. Trees and shrubs are to be cut as close to the tailings surface as practical and removed without disturbing the tailings surface.
10. Cut trees and shrubs are to be temporarily stockpiled in areas where cover has been placed over the tailings. Following tailings cover construction, the vegetation stockpiles are to be spread over the cover surface.
11. The existing cover placed in the north end of the tailings area is to remain, with additional soil cover placed as required to meet the overall cover thickness specification.

NOT FOR CONSTRUCTION

0m 30 60 90 120

DRAWING NO.	DRAWING TITLE	NO.	DESCRIPTION	CHK'D	APP'D	DATE	NO.	DESCRIPTION	CHK'D	APP'D	DATE
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							F	Issued for Review	PM	–	20/06/30
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		-	-				A	Issued for Review	PM		18/12/05

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PROFESSIONAL OF PROVINCE P. H. MIKES # 33919 BRITISH COLUMBIA ENGINEER

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FILE NAME 1CR012.006 - TCP.dwg

REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

SRK JOB NO. 1CR012.006

Closure Design

DRAWING TITLE

Tailings Cover Plan

DRAWING NO 16 — SHEET 17 OF 19 — REVISION NO F

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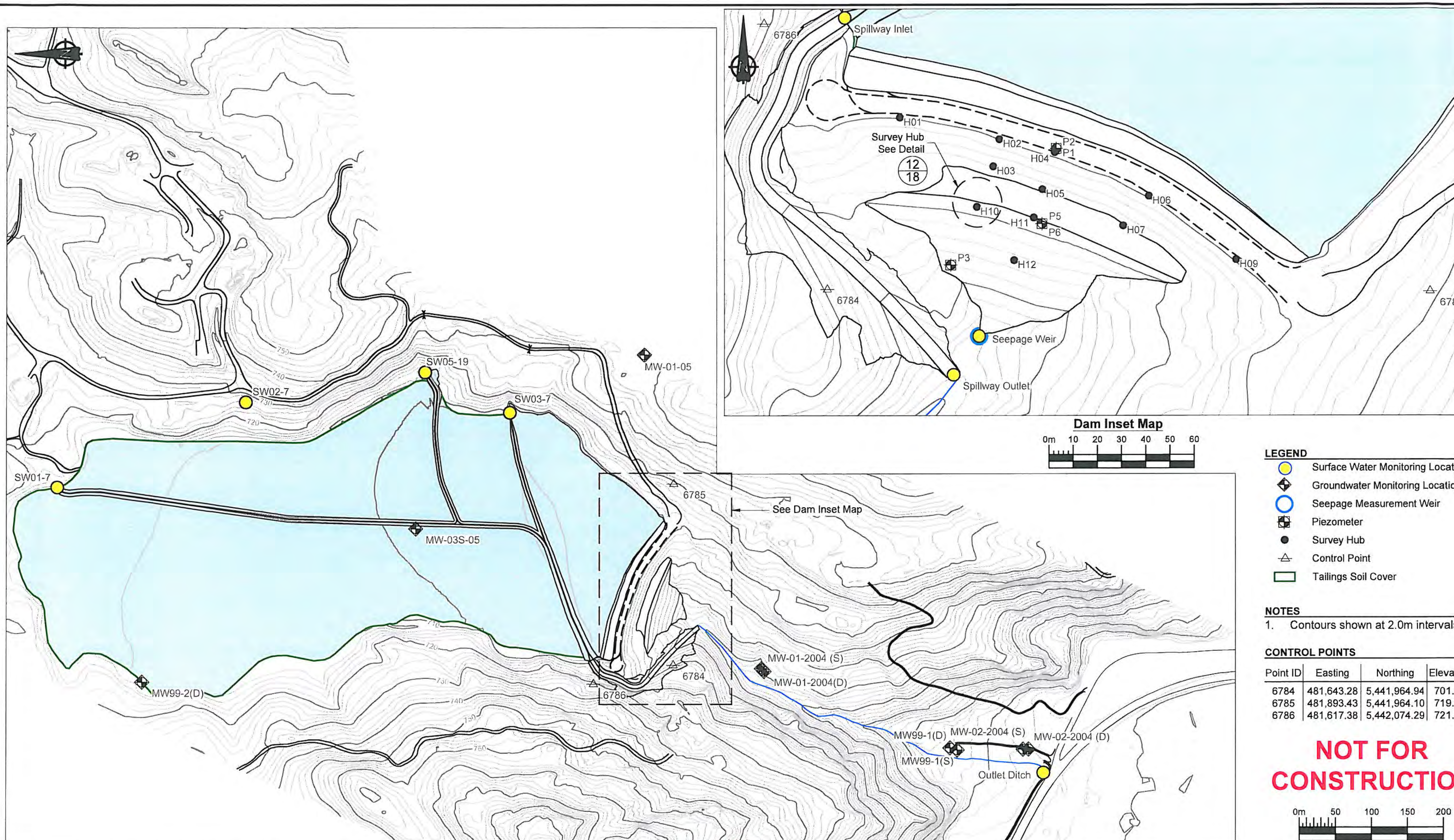

Dam Inset Map

0m 10 20 30 40 50 60

LEGEND

- Surface Water Monitoring Location
- Groundwater Monitoring Location
- Seepage Measurement Weir
- Piezometer
- Survey Hub
- Control Point
- Tailings Soil Cover

NOTES

1. Contours shown at 2.0m intervals.

CONTROL POINTS

Point ID	Easting	Northing	Elevation
6784	481,643.28	5,441,964.94	701.75
6785	481,893.43	5,441,964.10	719.17
6786	481,617.38	5,442,074.29	721.79

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0m 50 100 150 200

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A	Issued for Review	PM		18/12/05

REVISIONS

PROVINCE OF BRITISH COLUMBIA
P. H. MIKES
33319
ENGINEER
8/14/20

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DESIGN PHM	DRAWN TAH	REVIEWED CS
CHECKED MMM	APPROVED PHM	DATE June 30, 2020

FILE NAME. 1CR012.006 - Monitoring and Instrumentation Plan.dwg

REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

SRK JOB NO 1CR012.006

Closure Design

DRAWING TITLE

Instrumentation and Monitoring Plan

DRAWING NO 17 | SHEET 17 OF 19 | REVISION NO F

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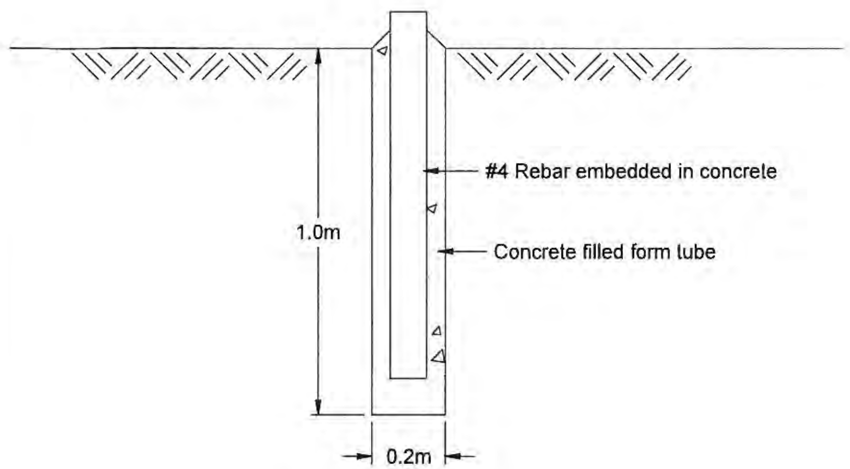
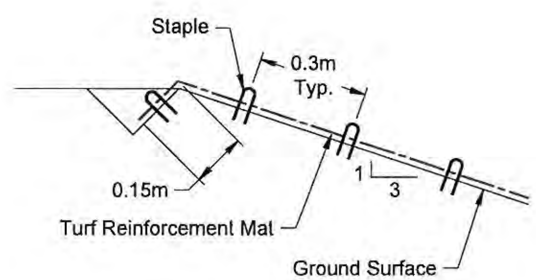


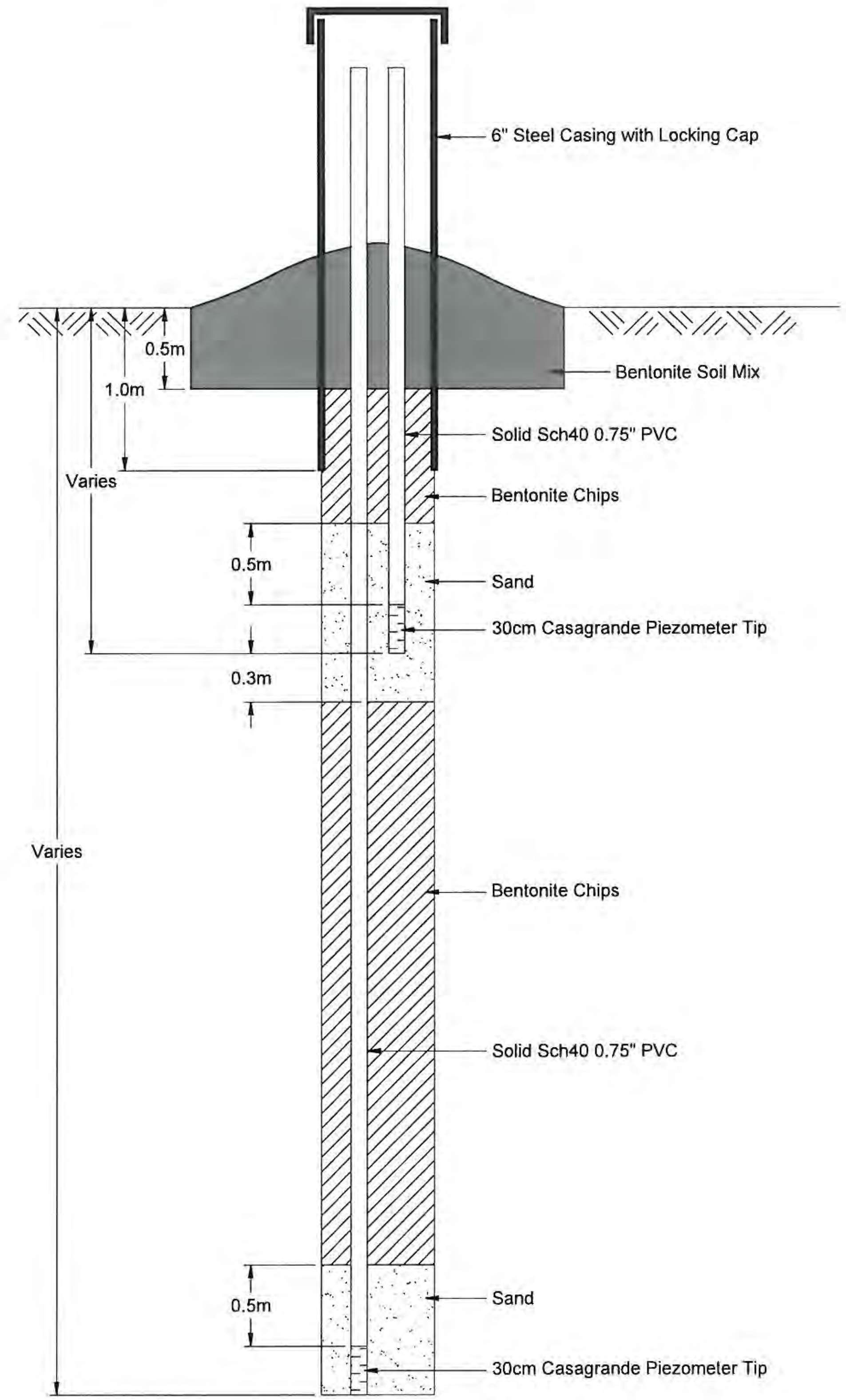
12/17 **Survey Hub Detail**

Not To Scale



14/14 **TRM Anchor Trench Detail**

Not To Scale



13/17 **Typical Piezometer Detail**

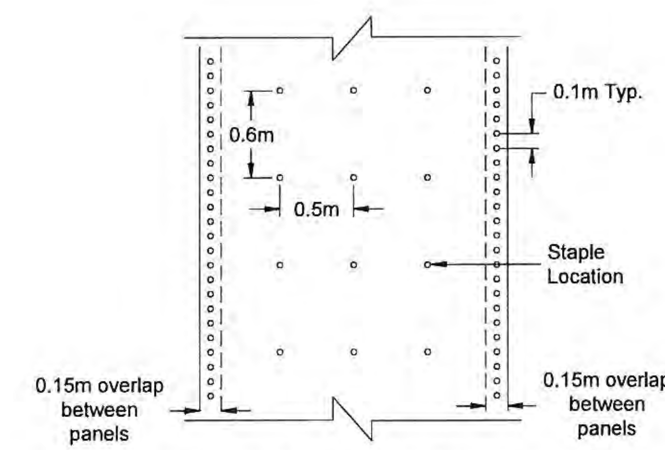
Not To Scale

NOTES

1. Existing piezometers are to be preserved by extending the PVC pipe as required, or replaced if damaged. This detail provides typical details should the piezometer require to be replaced.
2. Replacement piezometers are to be installed such that the base of the Casagrande piezometer pipes match the elevations provided in Table 1.
3. If the piezometer locations require to be moved from current locations, the Casagrande pipe elevations are to be confirmed with the Engineer.

TABLE 1

Piezometer	Casagrande Pipe Bottom Elevation (m)
P1 and P2	687.74 and 698.24
P3	673.38
P5 and P6	691.40 and 696.45



Channel TRM Staple Pattern

0m 0.5 1.0 1.5 2.0

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0m 2 4 6 8

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P. H. MIKES
33319
ENGINEER
8/7/20

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DESIGN PHM	DRAWN TAH	REVIEWED CS
CHECKED MMM	APPROVED PHM	DATE June 30, 2020

FILE NAME 1CR012.006 - Stability Sections.dwg

Regional District of Central Kootenay

HB Mine Tailings Facility

SRK JOB NO. 1CR012.005

Closure Design

DRAWING TITLE Instrumentation and TRM Details

DRAWING NO. 18 | SHEET 18 OF 19 | REVISION NO. F

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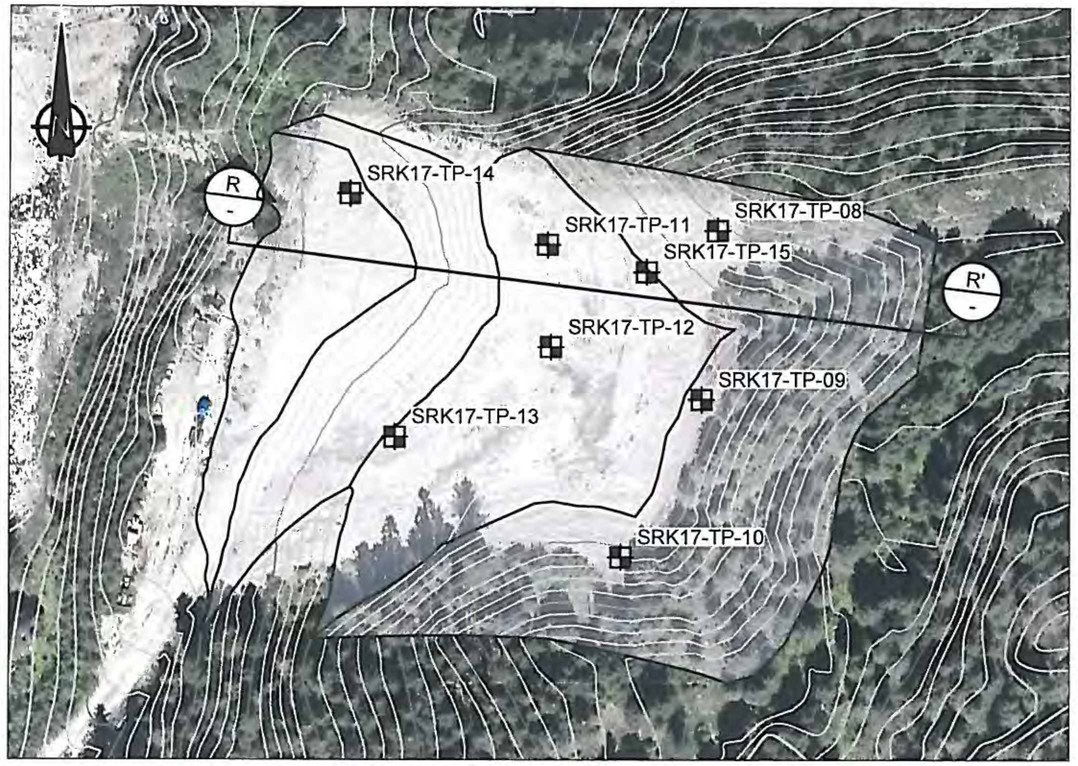
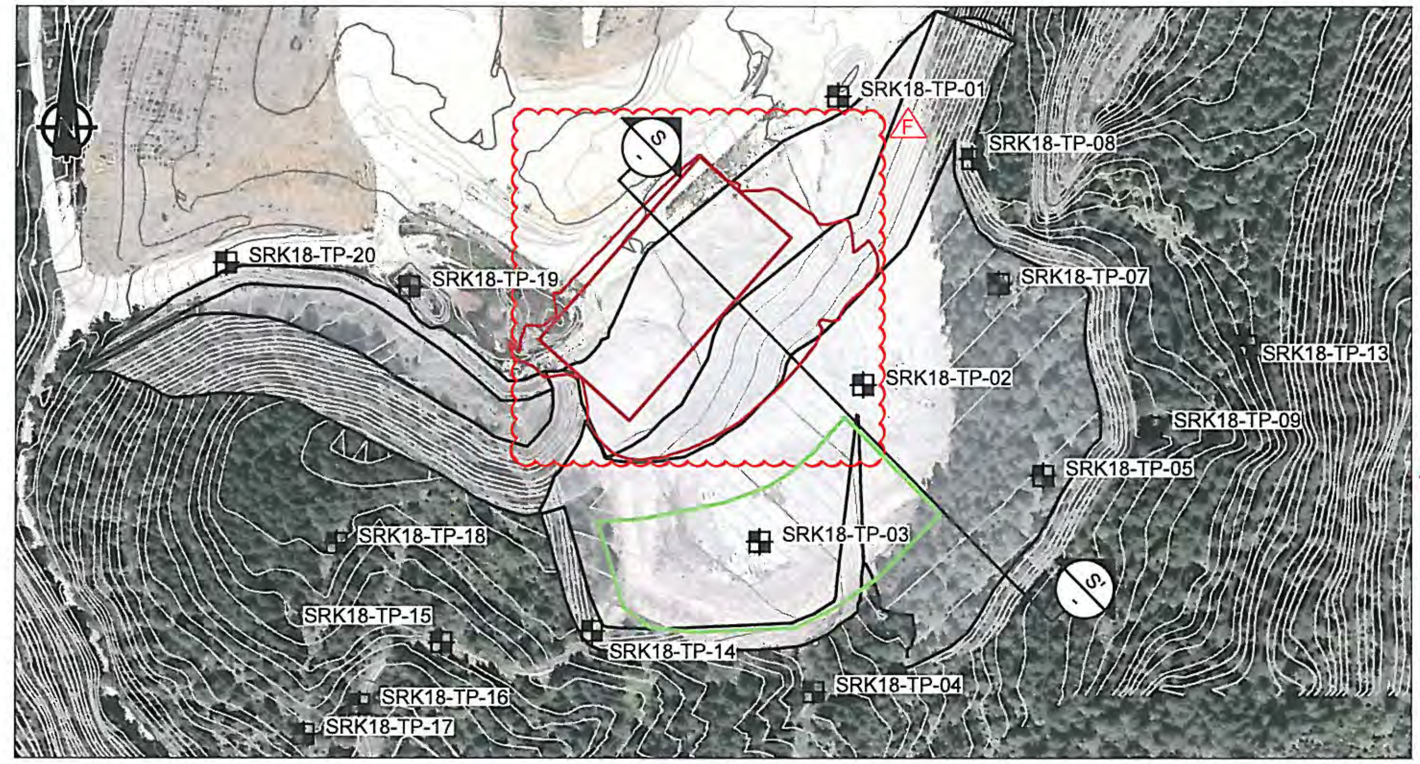


Sand and Gravel Borrow Area



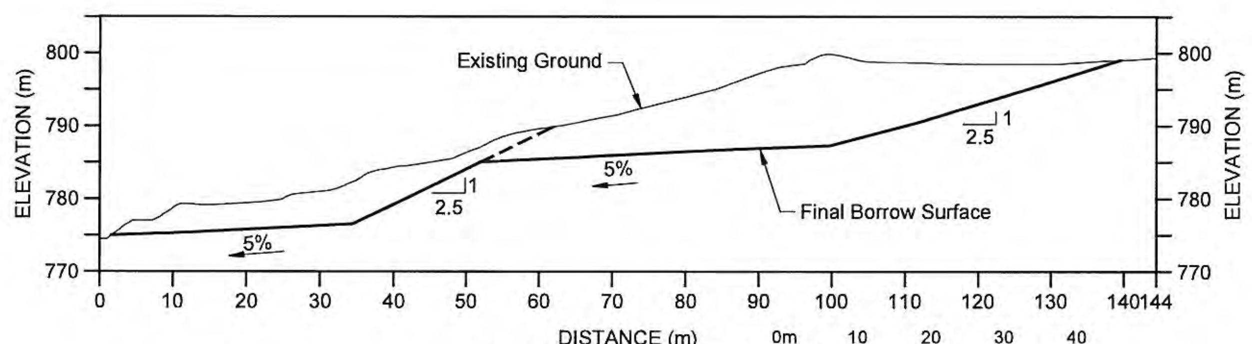
Existing Borrow Area Expansion

LEGEND

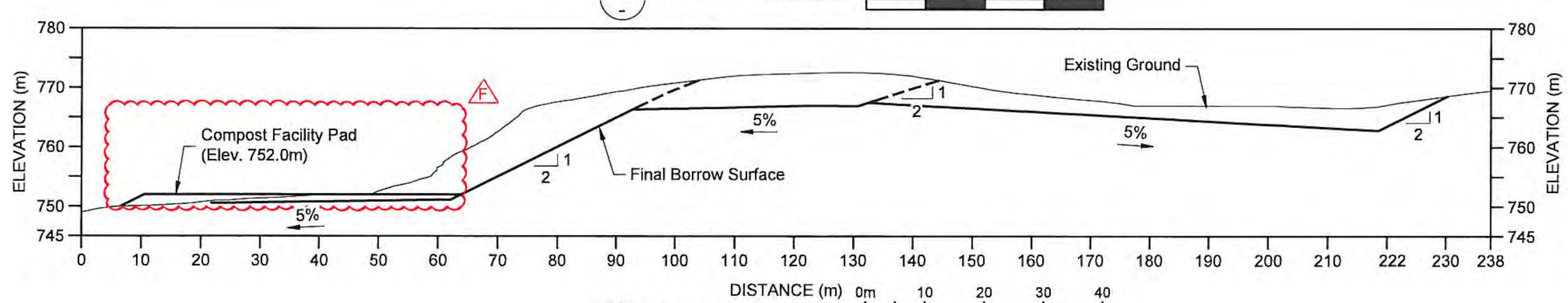
- Test Pit Location
- Approximate Temporary Stockpile Extent
- Borrow Area
- Future RDCK Compost Facility (design by others)

NOTES

1. Contours shown at 1.0m intervals, and are indicative of proposed excavation final contours.
2. The base grade of the borrow area to have 5% slope to ensure positive runoff. Following completion of borrow excavation, all slopes are to be regraded to 2H:1V or shallower.
3. RDCK Compost Facility pad site grading expected to be completed in 2020.
4. Soils from the Compost Facility Pad site grading excavation to be stockpiled within the Till Borrow Area.



Cross Section R-R'



Cross Section S-S'

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REVISION NO.	DESCRIPTION	CHK'D	APP'D	DATE
F	Issued for Review	PM	--	20/06/30
E	Issued for Permitting	PM	--	20/01/31
A	Issued for Tender	MM	PM	19/10/23

REFERENCE DRAWINGS: DRAWING NO -- ; DRAWING TITLE --

PROFESSIONAL ENGINEERS STAMP: P. H. MIKES # 33319 PROVINCE OF BRITISH COLUMBIA 8/14/20

srk consulting

DESIGN	DRAWN	REVIEWED
PHM	TAH	PHM
CHECKED	APPROVED	DATE
MMM	PHM	June 30, 2020

FILE NAME: 1CR012.006 - Borrow Areas.dwg

REGIONAL DISTRICT OF CENTRAL KOOTENAY

HB Mine Tailings Facility

SRK JOB NO: 1CM012.006

Closure Design

DRAWING TITLE: Borrow Area Plan View and Typical Sections

DRAWING NO: 19 | SHEET: 19 OF 19 | REVISION NO: F

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Appendix A – Permit M-218

BRITISH
COLUMBIA

RECEIVED
APR 16 2002
REGIONAL DISTRICT OF
CENTRAL KOOTENAY
NELSON, B.C.

April 10, 2002

FILE: 14745-40/HB/01
Permit No.: M-218

Regional District of Central Kootenay
Box 590, 202 Lakeside Drive
Nelson, BC
V1L 5R4

Attention: Mr. Reinhard Trautmann, A.Sc.T.
Services & Waste Management Supervisor

Dear Sir:

Re: Permit M-218 - Approving Tailings Pond and Dyke Decommissioning Plan

Your permit approving the Tailings Pond and Dyke Decommissioning Plan was issued by the Deputy Chief Inspector of Mines on April 10, 2002 and is enclosed. Your attention is drawn to the conditions which form an integral part of the permit.

If you have any questions or concerns, please do not hesitate to contact me at (250) 952-0485.

Yours truly,

Chris Carr, P.Eng.
Manager, Geotechnical Engineering

CC/vh

Enclosure

cc: A. Whale/R. Rosentreter, MEM Cranbrook
R. Berdusco, MEM Fernie

PROVINCE OF BRITISH COLUMBIA
MINISTRY OF ENERGY AND MINES

PERMIT

APPROVING WORK SYSTEM AND RECLAMATION PROGRAM
(Issued pursuant to Section 10 of the **Mines Act** R.S.B.C. 1996, c.293)

Permit: **M-218**

Issued to: **Regional District of Central Kootenay**
Box 590, 202 Lakeside Drive
Nelson, BC
V1L 5R4

for work located at the:

HB Mine

Issued at Victoria, British Columbia this 10th day of April in the year 2002.

John C. Errington, Ph.D., P.Ag.
Deputy Chief Inspector of Mines

PREAMBLE

An application dated March 18, 2002 for approval of the Tailings Pond and Dyke Decommissioning Plan (Plan) was submitted to the Chief Inspector of Mines on March 25, 2002, in accordance with Part 9.3.5 of the Health, Safety and Reclamation Code for Mines in British Columbia (Code). A report prepared by BGC Engineering Inc. entitled "H. B. Mine Tailings Pond and Dyke Decommissioning Plan Final Report," dated February 5, 2002 was submitted to the Chief Inspector of Mines on February 20, 2002 and forms part of the application.

CONDITIONS

The Chief Inspector of Mines (Chief Inspector) hereby grants permission to commence work subject to compliance with the following conditions:

General

1. Compliance with **Mines Act** and Code

   All work shall be in compliance with all sections and parts of the **Mines Act** and Code and the owner, agent or manager (herein called the Permittee) shall obey all orders issued by the Chief Inspector or his delegate.

2. Departure from Approval

   The Permittee shall notify the Chief Inspector and the District Inspector in writing of any intention to depart from the Plan to any substantial degree, and shall not proceed to implement the proposed changes without the written authorization of the Chief Inspector.

Geotechnical

1. Construction

   (a) The closure works shall be completed in accordance with the design criteria and specifications prepared by BGC Engineering Ltd. (the design consultant) and to the lines and grades shown on the Construction Drawings.

   (b) Construction and quality control testing shall be supervised by the design consultant or by a qualified engineer under the supervision of the design consultant.

   (c) An as-built report for construction of the closure works shall be submitted by March 31, 2003.

2. Monitoring and Maintenance

(a) An Operation, Maintenance and Surveillance Manual (OMS) for the closed facility shall be prepared. The OMS manual shall be submitted prior to completion of the closure works.

(b) Additional instrumentation shall be installed on the tailings dam as determined by the design consultant.

3. Annual Report

Pursuant to Part 9.3.2 of the Code, an annual dam safety inspection report shall be submitted to the Chief Inspector. The submission date for the annual report is March 31 of the year following the inspection.

Reclamation Program

1. Water Quality Monitoring

(a) Prior to construction, the Permittee shall submit a program for surface and groundwater monitoring for both the construction and post-construction periods. The program shall be designed to assess metal and contaminant loadings from the tailings facility and shall detail analytical parameters, analytical methods and detection limits, frequency, and locations.

(b) Subsequent to closure works, the Permittee shall install a staff gauge in the impoundment to monitor water levels.

(c) Subsequent to closure works, the Permittee shall initiate and maintain an inventory of water levels in the impoundment over time. The inventory shall include monthly water levels and minimum and maximum water table heights.

(d) An assessment of surface and ground water quality data and water levels in the impoundment shall be included in the annual dam safety inspection report.

Appendix B – Construction Environmental Management Plan

SLR

global environmental solutions

CONSTRUCTION ENVIRONMENTAL MANAGEMENT PLAN

HB Mine Tailings Facility Closure and Reclamation

Regional District Central Kootenay

June 2019

SLR Project No.: 204.03242.00003

CONSTRUCTION ENVIRONMENTAL MANAGEMENT PLAN

HB MINE TAILINGS FACILITY CLOSURE AND RECLAMATION

SALMO, BRITISH COLUMBIA

SLR Project No.: 204.03242.00003

Prepared by
SLR Consulting (Canada) Ltd.
8 West St. Paul Street
Kamloops, BC V2C 1G1

for

Regional District of Central Kootenay
Box 590, 202 Lakeside Drive
Nelson, BC V1L 5R4

19 June 2019

Prepared by:

Glenn Sidwell, B.N.R.S., B.I.T.
Staff Ecologist

Reviewed by:

Dustin Oaten, M.Sc., R.P.Bio.
Western Canada Ecology Team Lead

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Distribution: 1 PDF copy – Regional District of Central Kootenay
1 copy – SLR Consulting (Canada) Ltd.

TABLE OF CONTENTS

TABLES

APPENDICES

1.0 INTRODUCTION

The HB Mine Tailings Facility (the Property) is located near Salmo, British Columbia (BC) and has been under the care of the Regional District Central Kootenay (RDCK) since 1998. The Property was originally purchased to provide a buffer and attenuation zone for groundwater from the Central Landfill located northeast of the Property.

In 2012, a sloughing event occurred along the dam embankment of the tailings facility resulting in significant monitoring, maintenance, upgrades, and investigations. As a result of this, the RDCK has elected to remediate the site by transitioning the Property to "passive closure" (as defined by the Canadian Dam Association) with the intent to reduce liability and the resources required to maintain the facility. The overall site remediation is intended to successfully limit, counteract, prevent or mitigate the escape or migration of contamination from the facility to remove any adverse effects on the environment or human health (SRK 2018[1]).

In support of this work, this Construction Environmental Management Plan (CEMP) has been developed to serve as a guide to ensure compliance with environmental protection and mitigation requirements during this work. Specifically, this CEMP will:

- Identify any elements of the work that could present a risk to the environment;
- Describe the work procedures to be undertaken to minimize and mitigate adverse impacts to the environment resulting from the implementation of this project; and
- Describe work procedures to be undertaken to contain and limit impacts to the environment in the event of an incident;

This CEMP is intended as a living document and subject to change as required and in accordance with alteration to the scope of work.

1.1 Scope of Work

SRK (2018)[1] developed a draft detailed design report that summarizes the following major components of the proposed work at the Property:

- Construction of an upgraded spillway at the western abutment and tailings pond backfill placement to eliminate the pond upstream of the HB Dam and convey the probable maximum flood through the impoundment;
- Expansion of the HB Dam toe berm to improve stability during seismic events and in the event that liquefaction occurs within the original dam fill;
- Construction of a till beach upstream of the dam to mitigate the risk of internal erosion and piping; and
- Construction of a tailings cover and lined channels to convey surface drainage over the tailings facility and to prevent the erosion, escape, and migration of the fine tailings from the tailings facility, remove the direct contact exposure pathway for human and most ecological receptors, and to provide a final surface that will aid in revegetation.

[1] SRK Consulting (Canada) Ltd. (SRK). 2018. HB Mine Tailings Facility Closure and Remediation – Detailed Design Report - Draft. Prepared for: Regional District of Central Kootenay.

1.2 Changes to Scope of Work

Any changes to the work by Construction Company or others shall be brought to the attention of the Environmental Monitor (EM) and the RDCK in advance of the work. The EM shall update this CEMP to reflect the changes in the work plan and schedule and recommend appropriate environmental protection measures.

1.3 Project Contacts and Responsibilities

Table 1: Project Contacts, Responsibilities and Contact Information

Name	Company/ Association	Title	Telephone	Email	Responsibility
Alayne Hamilton	RDCK	Environmental Technologist	250-352-1519	ahamilton@rdck.bc.ca	Provide project oversight and management for the RDCK.
Amy Wilson	RDCK	Resource Recovery Manager	250-352-8178	awilson@rdck.bc.ca	Provide project oversight and management for the RDCK.
Peter Mikes	SRK Consulting	Senior Consultant	604-601-8489	pmikes@srk.com	Provide updates to the detailed closure and remediation plan, as applicable.
TBD	Construction Company	Construction Manager	TBD	TBD	Complete project activities in compliance with this CEMP.
TBD	Construction Company	TBD	TBD	TBD	Provide support for the completion of project activities in compliance with this CEMP.
TBD	Construction Company	TBD	TBD	TBD	Provide support for the completion of project activities in compliance with this CEMP.
Ben Foulger	SLR	Lead EM	250-777-4144	bfoulger@slrconsulting.com	Serve as the primary EM and will ensure compliance with this CEMP.
Glenn Sidwell	SLR	Alternate EM	250-851-6630	gsidwell@slrconsulting.com	Serve as the secondary EM and will ensure compliance with this CEMP.
Dustin Oaten	SLR	QEP	250-682-0799	doaten@slrconsulting.com	Provide general oversight to EM's.

provides an emergency contact list that shall be visible at all times and shall be posted by Construction Company in a suitable location prior to the start of work.

2.0 ENVIRONMENTAL MONITORING

In order to comply with applicable Federal, Provincial and contractual environmental requirements SLR Consulting (Canada) Ltd. (SLR) will provide experienced EMs that will monitor key project activities. SLR's EM experience shall include sediment and erosion control, construction monitoring, waste management, contaminated soil and water management and spill response. SLR's EMs will be identified as a Qualified Environmental Professional (QEP) or will work under the direct supervision of a QEP meeting the following requirements:

- Being registered and in good standing in BC with an appropriate professional organization;
- Having relevant expertise related to the project's environmental requirements; and
- Acting within that individual's area of expertise.

SLR's EM shall perform site inspections and provide Construction Company instructions or guidelines to implement appropriate mitigation measures. SLR's EM will discuss and outline the approach to environmental monitoring activities with Construction Company before construction begins. This will include a review of high-risk environmental activities and the frequency of EM site visits. SLR's EM will be available throughout the duration of the Project and will also visit the site in keeping with the following:

- A minimum of two site visits per week are expected;
- Prior to vegetation clearing activities, in order to complete a pre-clearing survey to identify and provide protective measures for wildlife and wildlife habitat features;
- When Project activities occur near areas with high erosion potential;
- Immediately upon notification of any environmental incidents;
- During work within 30 m of a waterbody;
- During installation of sediment control measures;
- During all environmentally sensitive work (e.g. working in special management areas);
- At all times during periods of heavy rainfall (i.e., greater than 25 mm of rain in a 24-hour period); and

Table 1: Project Contacts, Responsibilities and Contact Information

Name	Company/ Association	Title	Telephone	Email	Responsibility
Alayne Hamilton	RDCK	Environmental Technologist	250-352-1519	ahamilton@rdck.bc.ca	Provide project oversight and management for the RDCK.
Amy Wilson	RDCK	Resource Recovery Manager	250-352-8178	awilson@rdck.bc.ca	Provide project oversight and management for the RDCK.
Peter Mikes	SRK Consulting	Senior Consultant	604-601-8489	pmikes@srk.com	Provide updates to the detailed closure and remediation plan, as applicable.
TBD	Construction Company	Construction Manager	TBD	TBD	Complete project activities in compliance with this CEMP.
TBD	Construction Company	TBD	TBD	TBD	Provide support for the completion of project activities in compliance with this CEMP.
TBD	Construction Company	TBD	TBD	TBD	Provide support for the completion of project activities in compliance with this CEMP.
Ben Foulger	SLR	Lead EM	250-777-4144	bfoulger@slrconsulting.com	Serve as the primary EM and will ensure compliance with this CEMP.
Glenn Sidwell	SLR	Alternate EM	250-851-6630	gsidwell@slrconsulting.com	Serve as the secondary EM and will ensure compliance with this CEMP.
Dustin Oaten	SLR	QEP	250-682-0799	doaten@slrconsulting.com	Provide general oversight to EM’s.

- Prior to demobilization from site following completion of activities, SLR's EM will conduct a final site visit and sign-off stating the site meets all the requirements of the CEMP. The sign-off must be included in the site's daily inspection report.

SLR will provide environmental monitoring for all construction activities, which includes environmental support in the event of an environmental incident.

Note that SLR has the authority to provide stop-work notice should any activities result in known or potential impacts to the environment. SLR will first report this recommendation to the RDCK prior to implementation.

2.1 Monitoring and Reporting

All workers are required to report all incidents of potential environmental impairment to SLR's EM or other appropriate representative. In the case of a spill and as required, environmental professionals will need to be retained to ensure all spill-impacted soil is removed and that the incident is documented appropriately.

Inspections of all work areas will be conducted by SLR's EM during all phases of the Project to identify and rectify any potential sources of environmental impairment. Inspections will include all waste (e.g., hazardous, construction materials, and domestic refuse) storage areas, all hazardous materials storage areas, vehicle refuelling/maintenance/storage areas, general equipment inspections, and inspections of all active work areas. Inspections should also include inspections of erosion/sediment control devices and areas of exposed soil. Records of all inspections will be filed on-site, and any potential sources of environmental impairment or appropriate actions taken will be immediately reported to the RDCK and the Construction Manager.

A final environmental completion report will be prepared following the conclusion of Project activities describing compliance with the CEMP and any reportable environmental incidents, including responses to incidents that may have occurred during the Project.

2.1.1 Environmental Monitoring Reports

Environmental monitoring reports will be submitted on a daily basis summarizing construction activities and mitigation measures. These reports will include:

- Date;
- Project name/geographic location;
- Prime contractor firm name/contact;
- Environmental monitor name/contact;
- Summary of Project activities during the reporting period;
- Summary of environmental issues encountered during the reporting period;
- Summary of mitigation measures implemented during the reporting period;
- Summary of planned corrective measures to address site deficiencies that arose during the reporting period;
- Summary of any incident reports during the reporting period;
- Representative site photographs taken during the reporting period; and

- Schedule of planned activities for the next reporting period.

Additional reporting elements will be included as needed:

- Results from any water or soil chemical analyses; and
- Communications required with any regulatory agencies.

During inspections, SLR's EM may recommend improvements or changes to RDCK and the Construction Manager. These recommendations will be included on the monitoring forms. A template for the daily environmental monitoring report form is presented in Appendix A.

2.1.2 Environmental Incident Reporting

2.1.2.1 *Spill Response*

A spill is an unauthorized discharge or release of a material or substance into the environment that is equal to or exceeds the regulated amount for that deleterious substance. Spill management is designed to reduce the risk of a harmful exposure to individuals and the surrounding environment. Requirements for reporting spills are defined in the Federal *Transportation of Dangerous Goods Act*[2] and *Canadian Environmental Protection Act*[3].

2.1.2.2 *Emergency Spill Response*

All emergency spill response plans and activities on the site should follow the BC Guidelines for Industry Emergency Response Plans[4]. A more detailed spill response plan is provided in Appendix B. Key spill response activities include:

- Report the Spill – Applicable parties, including, but not limited to SLR's EM and the RDCK. In the case of a reportable spill, Construction Company will call the 24-hour Emergency Management BC hotline at 1-800-663-3456. A reportable spill is any volume of a substance spilled that exceeds the quantities outlined in Schedule 1 of the BC Spill Reporting Regulation;
- Stop the Source, if possible – If it is safe to proceed, the Construction Manager or SLR's EM will direct preventative measures to remove or immobilize the source of the spill;
- Contain Spill Material – If it is safe to proceed, the Construction Manager will direct spill containment methods and identify the spill material, spill volume, and the potential hazards to people and the environment;
- Protect Area – Spill containment measures will remain in place until the spilled material is removed from the Site and no longer poses a risk to people or the surrounding environment. The site Supervisor will ensure that spill kits are restocked as required with material for future use;
- Remove material to an approved location for storage and/or disposal – It is advised an independent contractor be used for spill clean-up. All contaminated soil and clean up

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[2] *Transportation of Dangerous Goods Act*, includes SOR.2011-210 (Amendment 10) and SOR/2011-239 (Amendment 8).

[3] *Canadian Environmental Protection Act*, 1999, includes SOR/2009-197 and SOR/2011-90.

[4] BC Ministry of Environment, 1992, including amendments up to 2002. BC Guidelines for Industry Emergency Response Plans.

material shall be managed according to the *BC Environmental Management Act*[5] and Contaminated Sites Regulation[6] (CSR). Waste should be transported only by a licensed hazardous waste hauler and disposed of only at an approved waste facility; and

- Prepare a Spill Report – Construction Company will complete an Environmental Incident Report for any on site spill (Appendix C).

3.0 ENVIRONMENTAL TRAINING AND ORIENTATION

The purpose of the Environmental Training/Orientation Program is for all personnel associated with the Project to be knowledgeable about environmental issues related to the Project, appropriately trained, and competent to identify and implement potential environmental requirements to minimize environmental impacts associated with and resulting from the Project. This will be achieved through general environmental training and site orientation. At the end of orientation, personnel will receive a hard hat sticker for quick identification in the field that all personnel have attended the orientation. Environmental considerations and issues will be included as a component of the Project kick-off, site coordination and regular tailboard meetings.

On-site environmental orientation will be conducted by Construction Company on a per request basis and also take place at the Project kick-off meeting. All Construction Company employees and subcontractors are required to participate in environmental training before commencing work. Environmental training will be provided to the crews during pre-work orientation so that they are made aware of the regulatory permits-conditions and environmental standards and requirements for their scope of work. All training received will be documented and will be signed and dated by the trainee. The Construction Company will provide on-going communication of the principles and procedures throughout the duration of the Project activities.

3.1 Environmental Orientation

Prior to mobilization and the initiation of construction activities, all Construction/Project Managers and crew leads must review and sign an Environmental Orientation Record (EOR). The Construction Company is responsible for delivering the environmental orientation, ensuring that the Project environmental risks and protection requirements related to the work is reviewed and that a record of the discussion is documented in the EOR. By signing the EOR all Construction/Project Managers and crew leads indicate that they are aware of and understand the environmental requirements of the contract and the required protection measures. Additional EORs must be completed if there is a significant change in scope, a new phase of work commences, or if new subcontractors mobilize to site.

3.2 Training

As required, Construction Company will provide direction for construction staff in the use of environmental protection practices. Construction Company shall ensure that their staff and associated sub-contractors have the training and materials to assist them on site and have completed the EOR and any required training prior to beginning work. Environmental direction may include the following environmental considerations:

[5] BC *Environmental Management Act*, 2003, including amendments up to 2016.

[6] British Columbia Contaminated Sites Regulation, 1997, including amendments up to B.C. Reg. 6/2013, May 2013.

- Environmental orientation and training;
- Environmental impact awareness during construction;
- Fundamentals of environmental impact management;
- Construction impacts, including sediment and erosion control and soil handling;
- Waste management;
- Spill response and incident reporting;
- Fuel and hazardous materials management; and
- Compliance assessments and follow-up reporting.

4.0 EROSION AND SEDIMENT CONTROL

SLR's EM will work with RDCK and the Construction Manager to manage soil and water effectively and implement several key Erosion and Sediment Control measures to reduce erosion and sediment generation at the site. Erosion and Sediment Control measures are developed following guidance within Ministry of Transportation and Infrastructure (MOTI's) Best Management Practices (BMP) Section 6.1[7] and Land Development Guidelines for Protection of Aquatic Habitat[8] and include:

- Retaining existing vegetation and ground cover where possible;
- Restricting vehicle access to sensitive areas of the site;
- Slope texturing on exposed soils;
- Installing and maintaining filter fabric bags inside any catch basins, as applicable, collecting runoff from the site;
- Ensure a contingency supply of erosion and sediment control supplies is on hand and available for deployment as required;
- Installing sediment fencing to ensure no sediment laden runoff enters any waterbodies. A buffer zone should be maintained by placing the sediment barrier upslope of existing vegetation. Sediment fencing must be installed as outlined as described in Van Osch Innovations Ltd.[9];
- Sediment fencing should be removed at project completion only if the risk of erosion and/or sediment release has been eliminated through re-vegetation or the application of other appropriate ground cover at the site.
- Excavated soil must be staged on 10 mil poly and when inactive, completely cover and secure with 10 mil poly;
- Do not stockpile soil within 30 m of any watercourse, riparian area or wetland;
- Application of water can be used for dust suppression;

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8 Fisheries and Oceans Canada. 1993. Land Development Guidelines for Protection of Aquatic Habitat. 129 pp.

9 Van Osch Innovations Ltd., 2009. Erosion and Sediment Control Participant's Manual, Vancouver Island University, Natural Resources Extension Program.

- Erosion and sediment control measures will be inspected within 24-hours after heavy rainfall events (greater than 15 mm of rain in a 24-hour period) and maintained/repaired as necessary;
- No storage of fuels or fuelling of equipment within 30 m of any watercourse;
- Fell trees away from any watercourse;
- Avoid the use of ground-based machinery within 15 m of the top-of-bank of any watercourse;
- Direct runoff and stormwater away from construction areas, wherever possible;
- Prohibit siting access roads or temporary laydowns within riparian areas; and
- If sediment fencing is used on-site it must be inspected and maintained. On a regular basis, sediment fencing should be:
  - Inspected daily and following each rain event;
  - Immediately repaired and replaced if fabric has fallen or been torn or degraded and support posts broken; and
  - Accumulated sediment must be removed and disposed of in a location where it cannot be re-entrained, when depth is half the height of the fence or 0.2 m high.

4.1 Erosion and Sediment Control Monitoring

Monitoring for erosion at the site will be conducted on a daily basis to ensure preventive measures for silts and debris entering waterbodies are in place. SLR's EM on-site will ensure preventive measures are in place in the event of heavy rainfall events (>15 mm of rain in a 24-hour period) and maintained/repaired as necessary.

The following rainfall shutdown guidelines will be utilized during all ground-based Project activities:

- Delay 24-hours following a rainfall event of 45 mm in 24 hours;
- For lower slope positions return to work is based on rainfall recovery of 15 mm in a 24-hour period;
- For middle slope positions return to work is based on rainfall recovery of 30 mm in a 24-hour period; and
- Work will remain suspended until the accumulated rainfall minus the recovery is below 45 mm in 24-hours.

5.0 GENERAL HOUSEKEEPING

All work areas will be maintained and kept clean and free from debris and construction materials. The following measures will be employed to ensure good housekeeping:

- Equipment laydown and material storage areas will be designated on site and have the following equipment available:
  - Spill kits in all equipment;
  - Larger spill kits are to be located within the project office trailers and hazardous materials storage locations;

  - o Solid waste bin storage;
  - o Lay down and storage of cables, storm and sewer components, beams, footings, structural steel, building materials etc.;
  - o Recycling for construction and industrial materials; and
  - o Parking area for non-essential vehicles/equipment.
- Authorization from SLR's EM is required if additional items are brought to the work site or if additional laydown areas are required.

5.1 General Waste

General waste accumulated throughout the Project area will be stored at a designated location prior to removal. Measures to ensure that appropriate care is given to general waste are as follows:

- Remove surplus construction material and waste from work sites, and dispose of in appropriately authorized facility;
- Decommission erosion and sediment control materials and features if no longer required and where it is appropriate to do so and dispose of properly;
- Monitor access and the work site to determine if there are areas of invasive plant introduction and overall site stabilization;
- Contractor shall arrange for appropriate disposal of sanitary facilities. During use, these facilities will be secured as to prevent toppling and will be placed at least 30-m from any watercourse;
- No waste shall be stored at temporary access points; and
- All waste material (i.e. wood, cardboard, steel, concrete) shall be separated into individual steel containment bins and taken off-site to a certified disposal facility or recycling facility.

5.2 Hazardous Materials Management

Hazardous waste will be managed to prevent contamination of soils or waterways from accidental spills and to prevent uncontrolled or accidental fires. Hazardous materials include "Dangerous goods and "Controlled products", these include but are not limited to fuels, oils, solvents, paints, greases, asbestos, Polychlorinated Biphenyl (PCB) oils, and batteries.

Hazardous materials used during Project activities will be stored and handled in accordance with all applicable legislation and best management practices, including the *Transportation of Dangerous Goods Act* and product-specific Safety Data Sheets (SDS).

General storage, handling and disposal requirements for hazardous waste include:

- SDSs for any hazardous materials used during the Project will be provided to RDCK at the start of the Project;
- Construction Company will ensure that all staff and subcontractors are adequately trained in handling and transportation of any hazardous materials they encounter during their job activities;
- Storage and handling of hazardous materials will be conducted to avoid loss and provide containment in the event of a spill;

- Transfer and temporary storage of hazardous materials and wastes will occur only in an area designated for this purpose. The designated area will be clearly labelled and controlled using barriers, anchored tarps, and/or separate storage containers;
- All containers used for storage or transfer will be labelled, handled and transported in accordance with the *Transportation of Dangerous Goods Act*;
- Disposal of hazardous wastes during the course of the Project will be in compliance with *Environmental Management Act*, the *Transportation of Dangerous Goods Act* and the *Hazardous Waste Regulation*. Hazardous wastes include asbestos materials, grease, lubricants, solvents, batteries, PCBs, paints, bitumen, dust suppressants, waste fuel, filters, spill clean-up materials, and oil destined for recycling or waste. It is understood that new insulating oil is not a regulated product and does not require a *Transportation of Dangerous Goods Act* shipping document or a waste manifest; and
- Construction Company will maintain records for all hazardous waste/materials including: Inventories of types and quantities of waste generated, stored or removed; Hazardous Waste Manifests identifying licensed waste haulers and disposal destinations; and disposal certification documents.

5.2.1 Fuel, Oil and Coolant Handling and Storage

SDSs should be provided for all chemicals, lubricants and other controlled substances brought to site and should be available to workers at all times.

Construction Company will adhere to the following procedures for dealing with waste at the site. Measures to ensure proper fuel, oil and coolant handling and storage include:

- All large construction equipment (i.e. excavators, bobcats), which remain static for at least two hours must have secondary containment (drip trays) placed under the engine compartment;
- Secondary containment is to be covered with a tarp, equipped with a roof, or with a "rain-drain" or equivalent hydrocarbon filter when not in use;
- Secondary containment must be used at the staging area as well as when parked at all temporary access points;
- All heavy equipment will be equipped with a spill kit containing:
  - 20 – Absorbent pads (oil);
  - 2 – 3” x 4’ Absorbent socks (oil);
  - 1 – Epoxy putty stick (i.e. JB weld steelstik putty);
  - 2 – Heavy Duty Hazmat bags;
  - 1 – 8’x8’ 6 mil poly sheet;
  - 2 – 5-gallon buckets;
  - 1 – bucket lid; and
  - 1 – Label stating “Emergency Spill Kit” in a bright contrasting colour.
- Oily and/or solvent soaked rags, if generated, should be stored in metal drums with secure fitting lids and should be disposed of at an appropriate location by a qualified waste disposal company;

- Recyclable and non-recyclable waste should be separated and stored in appropriately labelled, covered, waterproof containers for storage and transport;
- All waste material should be removed from site in a timely manner on an as needed basis and at a minimum at the completion of the project;
- Recyclable materials should be removed from site by an approved waste management company and taken to the appropriate facilities;
- Disposal plans for equipment and materials will be removed from site should consider decontamination for hydrocarbons or solvents, identify lead paint and prioritized recycling where appropriate;
- The fuel storage and handling facility shall comply with A Field Guide to Fuel Handling, Transportation and Storage[10];
- Fuel containers are to be placed in spill containment bins or other such spill containment devices;
- Locate fuel containers, re-fuelling, equipment maintenance and repair sites on flat, stable ground, >30 m away from environmentally sensitive areas or ditches;
- Store all tanks, barrels and containers >23 L containing hydrocarbon products within impermeable containment area designated to contain 110% of the volume of the largest container. Surround the storage area with barricades to prevent damage from delivery trucks;
- Vehicles and equipment, including their hydraulic fittings, shall be inspected daily to ensure that they are in good condition and free of leaks;
- Operate storage areas so that containment systems are effective during wet weather;
- All fuel supply trucks, stationary fuel tanks and vehicle tidy tanks shall be clean and well maintained at all times. All fuel or grease spills occurring from their use or operation is to be cleaned immediately. Poorly maintained fuel storage tanks will be taken off-site immediately and replaced with a new clean tank;
- The site trailer shall have a written Spill Contingency Plan posted on the information board with the required specifications and will include the names of those to be contacted;
- Containers shall not leak, and shall be sealed with a proper fitting cap or lid;
- Containers >23 L, including 205 L drums must be transported upright and secured to prevent shifting and toppling;
- If fuels are pumped to storage tanks through pipes or hoses from road accessible locations, all piping shall be adequately supported, and properly joined to prevent displacement and leakage. The piping shall be pressure tested in accordance with applicable legislation;
- The fluid transfer system shall contain an accepted overflow preventer which will cut off fuel delivery prior to the tank becoming completely full. Absorbent pads shall be kept available at all areas where fuelling occurs;

[10] https://www2.gov.bc.ca/assets/gov/environment/waste-management/industrial-waste/industrial-waste/oilandgas/fuel_handle_guide.pdf

- Inspect all temporary and permanent oil storage tanks to ensure there are no potential leaks prior to, during and after filling;
- Wrap hose connections with absorbent material to catch any leaks and drips during oil transfer to/from the storage tanks;
- If leak is observed from any equipment while on-site, stop the equipment and place drip trays and/or sorbent matting under the leak immediately. A sign stating the following will be placed above the leaking area: "Repair the Leak, or Replace the Tank, Hose or Connector Assembly";
- Do not fill tanks to the top. Leave adequate head-space to ensure that overfilling does not occur;
- Temporary on-site storage of oil tanks or oil shall be stored in designated areas with oil containment provided or temporary storage areas constructed with heavy grade, ultra-violet resistant polyethylene liner adequately bermed at the sides to provide containment;
- Containment areas shall be covered by a tarp to avoid rainwater accumulation. All containment basins shall be inspected daily for leaks and wear points;
- Containment basins shall be cleaned regularly and any accumulated waters removed;
- Where leaks or wear points are found, they shall be repaired promptly to restore full containment; and
- Additional major spill kits are to be located in Project office trailers or at a common mobilization site.

5.2.2 Construction-related Wastes

Construction wastes (i.e., lumber, shrink wrapping, welding rods, cut-off wheels, empty product containers, etc.) will be recycled where possible or disposed of in an environmentally acceptable manner (i.e., permitted landfill). Construction debris and other waste will not be deposited in waterbodies or storm drains or discarded to the environment.

5.3 Source Material

Designated material source locations have been identified as per SRK (2018)[1] for construction works and the Construction Company shall keep with the following:

- Rip-rap material may be sourced from the spillway excavation or from the quarry located southwest of the west abutment of the HB Dam. Rip-rap from the existing spillway and upstream slope of the dam may also be used where suitable.
- Drainage material for the toe berm expansion will be sourced from undersized material from the rip-rap quarry, spillway rock excavation, or from off-site.
- General fill for the toe berm expansion and upstream beach may be sourced from the spillway excavation, or from the Till Borrow Area located at the Central Landfill.
- Tailings cover material will be sourced from the till borrow area.

No alternative locations may be used for source material without the written consent from RDCK.

6.0 SOIL MANAGEMENT

The following sections provide a general overview of the soil management environmental requirements associated with Project activities.

6.1.1 Temporary Storage

Soil management is considered a primary environmental concern; therefore, the following procedures have been designed to ensure environmental compliance:

- All soil stockpiles must be located to avoid slumping or erosion of the material into ditches, drains, culverts and all other water bodies;
- Excavated soil must not be placed closer than 4.0 m from the edge of a slope and will have a maximum height of 2.0 m;
- Excavated soils must be stockpiled 15 m away from any drainage features and 30 m away from any waterbody or watercourse;
- Excavated soil must be staged on 10 mil poly and when inactive covered with 10 mil poly, weighted down to secure the cover; and
- If there is any indication that soil is contaminated then soil must be placed on and completely covered by polyethylene sheets and SLR's EM contacted immediately.

Soil and material stockpiles left on the site for more than 24-hours or during or prior to inclement weather shall be covered with plastic, which shall be securely fastened in place. Should material piles become a source of siltation, the Construction Manager shall immediately remedy the situation as necessary. Materials must not be stockpiled on roadways without appropriate authorization.

6.1.1.1 *Sampling and Characterization*

Any surplus soil that has indication of contamination requires off-site disposal must be chemically characterized prior to leaving the site. Soil must be tested and characterized with regards to federal *Transportation of Dangerous Goods Act*[2], and the BC Contaminated Sites Regulation[5] and Hazardous Waste Regulation[11].

If contamination is encountered during the Project, as identified by odours, staining, buried debris or sheen on groundwater infiltration, Construction Company shall suspend work and contact SLR's EM immediately. If there is potential for contaminated soils at the site, Construction Company must segregate these soils from un-contaminated soil during excavation and separately stockpile them on top of and covered by polyethylene sheeting. Soil samples must be taken from suspected contaminated stockpiles by SLR's EM and submitted to an accredited laboratory in order to properly classify soil for disposal purposes. Soil testing should be completed for BC CSR Soil Metals, Light Extractable Petroleum Hydrocarbons, Heavy Extractable Petroleum Hydrocarbons PCBs. Further analysis of other parameters may be required if other contaminants are suspected.

[11] British Columbia Hazardous Waste Regulation, 1988, including amendments up to B.C. Reg. 63/2009, April 1, 2009.

6.1.1.2 *Soil Disposal*

Surplus soil must only be disposed of at a pre-approved licensed receiving facility authorized under Municipal, Provincial or Federal legislation to accept the material being delivered. The following procedures must be followed before any soil leaves the site:

- Care will be taken to ensure that truck access to areas with contaminated or suspected contaminated material is limited. If required, a decontamination facility should be constructed on-site to eliminate the unwanted transfer of contaminated material off site;
- Soil that has indication of contamination should not leave the site until laboratory analysis has been conducted and results have been reviewed by SLR's EM and RDCK;
- Surplus soils removed from the site need to be accompanied by material designation paperwork;
- SLR's EM is responsible for completing soil waybill, soil manifest documents or both; and
- If off-site disposal of contaminated soil is required a Soil Relocation Agreement may be required as per the BC Ministry of Environment CSR. The Soil Relocation Agreement would be provided by SLR and reviewed by one of SLR's Contaminated Sites Approved Professionals.

7.0 CONSTRUCTION WATER MANAGEMENT

7.1 Groundwater

In the event that groundwater seeps into an excavation, SLR's EM will be notified as it is understood that samples may need to be collected and submitted for chemical analysis prior to disposal or discharge into the environment. This requirement will be determined on a case by case basis and will be highly dependent on location. Depending on results of chemical analysis, a temporary water-storage tank or drum may need to be retained on site to collect the contaminated groundwater during dewatering.

Upon confirmation that groundwater quality is acceptable, should testing be required, RDCK may remove accumulated excavation water for discharge to an appropriate area. It should be noted that discharge should occur at least 30 m from the perimeter of the work area and excavation water is not to be discharged off property. Additional measures include:

- Any water discharge points must include appropriate sediment and erosion control;
- No water shall be discharged near the top of a slope;
- No water shall be discharged directly into any waterbody;
- If groundwater is highly turbid, an on-site retention or infiltration pond may be required to hold water for a sufficient length of time to allow sediment to settle out prior to discharge. Any stored water should be tested prior to discharge. RDCK should contact SLR's EM prior to the implementation of any water retention activities; and
- Implement a construction water monitoring program as per Section 7.4.

7.2 Surface Water

The following considerations for surface water will be adhered to:

- Drainage channels constructed over the tailings cover directing surface run-off from the tailings cover will be inspected to ensure fine tailings are not escaping and migrating downstream;
- Erosion and sediment control measures will be inspected within 24-hours after rainfall events of more than 25 mm of rain and maintained/repaired as necessary. The frequency of inspection will be increased if rainfall exceeds 25 mm in 24-hours;
- Any water discharged, or rainfall run-off from Project works that flow into the environment (e.g., watercourse) must comply with the criteria outlined in the waste discharge approval and/or the BC Working Water Quality Guidelines and the BC Approved Water Quality Guidelines;
- Turbidity-related water quality change associated with the Project in discharge watercourse/waterbody can vary from background of no more than 8 Nephelometric Turbidity Units (NTUs) at any one time for a duration of 24-hours in all waters during clear flows or in clear waters;
- Turbidity-related water quality change associated with a Project in discharge watercourse/waterbody can vary from background of no more than 5 NTUs at any time when background is 8 NTUs - 50 NTUs during high flows or in turbid waters;
- Turbidity measurements will be included in daily environmental monitoring reports;
- pH of discharged water must be between 6.5 and 9 units;
- Any water discharged from the Project site is to be managed for the full duration of the execution of the work. Discharges include those to the environment (e.g., waterbody, watercourse) and to managed watercourses;
- Any artesian conditions (e.g., flowing groundwater) encountered during construction must be immediately reported to the EM, who will provide direction on site-specific mitigation. Discharge of water will comply with all applicable drainage/sewer use bylaws, permits or surface water protection regulations;
- Perform construction activities in a manner that prevents the release of oil, fuel, coolant, waste and other pollutants into soil, groundwater, manholes, ditches, rivers, streams, lakes or other watercourses (flowing or dry). Waste and other pollutants include, but are not limited to, refuse, garbage, sewage effluent, contaminated soil, sediment, site run-off (if it exceeds the BC Approved and Working Water Quality Guidelines), hydrocarbon or coolant spills, construction waste and chemicals;
- Sediment control systems including ditches, retention ponds and settling ponds shall be designed by a QEP. Erosion and sediment control structures (e.g., straw bales, vegetation matting) shall be certified weed-free;
- If discharge as a result of utilizing pumps is required, discharge points shall be discussed with the EM prior to these activities occurring: and
- Implement a construction water monitoring program as detailed in Section 7.4.

7.3 Tailings Pond Dewatering

As noted in SRK (2018)[12] a major component of the project will be the dewatering of the existing tailings pond which will be completed under a waste discharge approval. Many of the mitigation measures described in Section 7.2 and 7.3 will apply to this activity. Specific sampling parameters and monitoring frequency for the tailings pond dewatering will be outlined in the waste discharge approval. The waste discharge approval will only be applicable to the tailings pond dewatering.

7.4 Groundwater and Surface Water Monitoring

Water quality monitoring will occur prior to and during construction following dewatering of the tailings pond to ensure the constructed works are performing as intended and that there are no detectable adverse effects on the environment or human health and will include both surface and groundwater sampling. The frequency of monitoring events following the tailings pond dewatering will occur on a weekly basis however, in the event of a heavy rainfall event or failure of erosion and sediment control mitigation additional monitoring events will occur. A baseline upgradient water quality sample will be collected prior to the start of construction and samples will be analyzed field monitored for pH and turbidity. Additional sampling parameters may be included following review of upgradient baseline concentrations.

8.0 WILDLIFE HABITAT ALERATION, DISTURBANCE AND LOSS

Construction Company will conduct activities in a manner that is sensitive to wildlife and wildlife habitat. General measures to mitigate wildlife impacts include:

- Do not feed, attract or harass wildlife;
- Food waste and garbage will be disposed of immediately in bear-proof containers;
- Nuisance bears within the Project area will be reported to SLR's EM and through the 24-hour Report All Poachers and Polluters (RAPP) hotline at 1-877-952-7277;
- Firearms will not be allowed on site, however bear spray is permitted;
- All staff and subcontractors will be educated about safety procedures and precautions for working in bear and other wildlife habitat;
- All staff and subcontractors will adhere to maximum highway speed limits and be alert while driving to avoid potential wildlife-vehicle collisions;
- If found on the site, roadkill will be removed to avoid attracting predators. All mortality events will be reported to SLR's EM;
- Select project activities are expected to occur within the general nesting periods (early-April to mid-August) for most migratory birds that are protected under the *Migratory Birds Convention Act* however vegetation stripping and tree removal will occur in the winter prior to the start of the bird nesting window. In the event that a bird nest is identified SLR's EM will be notified and all protection will be afforded to the nest. Should any vegetation (including grasses) trimming or removal be required between early-April to mid-August, a scientifically sound bird nest assessment must be undertaken no earlier than five days

[12] SRK Consulting (Canada) Ltd. (SRK). 2018. HB Mine Tailings Facility Closure and Remediation – Detailed Design Report - Draft. Prepared for: Regional District of Central Kootenay.

prior to the required clearing. A bird nest assessment protocol will be developed in accordance with recommendations from Environment Canada;

- Raptor nests are protected year-round and therefore are not to be disturbed. If a raptor nest is identified additional strategies for nest management may also be required at the direction of SLR's EM;
- If species-at-risk or provincially rare species are observed on the site, SLR's EM will be notified immediately;
- No interaction with the animal shall occur unless required and under appropriate Provincial or Federal permit;
- No chemicals are permitted for use on access roads or site (e.g. dust suppressants);
- Lighting will be limited to only essential work areas and night work will be avoided whenever possible;
- SLRs EM's will work to complete pre-clearing surveys in advance of vegetation clearing activities. During these pre-clearing surveys the proposed areas to be cleared, and a 50 to 100-m buffer, will be visually searched for the presence of wildlife and wildlife habitat features. The presence of other environmentally sensitive features (i.e., watercourses) will also be noted. These features will be marked in the field with flagging tape and UTM coordinates taken. No clearing of vegetation will occur prior to the completion of pre-clearing activities;
- Implement Best Management Practices for Raptor Conservation during Urban and Rural Land Development in BC[13]. This will include completing pre-clearing surveys for the presence of raptor nests. Any identified raptor nests will be protected from disturbance utilizing buffers as described in Best Management Practices for Raptor Conservation during Urban and Rural Land Development in BC. A raptor nest search will be completed within five-days of clearing activities. Should clearing not occur within that time frame the pre-clearing survey will be required to be redone;
- Amphibian salvage operations will be timed so that detectability and capture rate is optimized and will occur at minimum one-week before project works. The extensive salvage operation will allow for the animals to be relocated to a new site within an appropriate time frame. Appropriate equipment (e.g. funnel traps, dip netting) and techniques (e.g. visual encounter surveys with hand capture, dewatering with dip netting) will be used to maximize capture efficiency. Repeated salvage sampling will ensure that all animals are captured. Relocation areas will be comprised to suitable habitat for the captured species. Exclusion fencing will be employed to prevent entry of individuals to the salvage area;
- Western painted turtle (*Chrysemys picta*) salvage operations will be timed so that detectability and capture rate is optimized. The extensive salvage operation will allow for the animals to be relocated to a new site within an appropriate time frame (e.g. before overwintering activity occurs). Appropriate equipment (e.g. baited hoop traps, seine netting) and techniques (e.g. hand captures) will be used to maximize capture efficiency. Repeated salvage sampling will ensure that all animals are captured. Relocation areas will be comprised of suitable habitat for western painted turtle. Exclusion fencing will be employed to prevent entry of individuals to the salvage area;

[13] http://www.env.gov.bc.ca/wld/documents/bmp/raptor_conservation_guidelines_2013.pdf

- Rubber boa (*Charina bottae*) salvage operations (in the quarry area and other appropriate locations) will be timed so that detectability and capture rate is optimized and will occur at minimum one-week before project works occur. The extensive salvage operation will allow for the animals to be relocated to a new site within an appropriate time frame (e.g. before overwintering activity occurs). Appropriate equipment (e.g. pit fall traps, coverboards) and techniques (e.g. hand captures, visual surveys, searching under potential cover) will be used to maximize capture efficiency. Trained and skilled searches will be used to ensure no individuals are overlooked. Repeated salvage sampling will ensure that all animals are captured. Relocation areas will be comprised of suitable habitat for rubber boa. Exclusion fencing will be employed to prevent entry of individuals to the salvage area;
- All salvage activities will be completed under an approved permit under the BC *Wildlife Act*;
- Minimize the use and ensure proper storage of potential wildlife attractants such as food, garbage, petroleum products or other materials with strong odours;
- Conduct construction activities in a manner that is sensitive to the wildlife and wildlife habitat;
- Notify the appropriate authorities should active denning sites or burrows be identified within the Project area;
- Domestic pets (i.e., dogs) are not allowed on the Project;
- Any wildlife sightings will be recorded in an incidental wildlife log and included in the daily EM report. The Construction Manager shall keep a log of all incidental observations, which will be passed on to SLRs EM;
- To prevent wildlife entrapment, excavations must be fenced (in addition to any safety related actions) if left unattended;
- The Construction Manager shall inform workers of all issues associated with working in bear, cougar and wolf country to reduce potential conflicts. No interaction with any wildlife is permitted. All observations of these species will be noted;
- Construction activities should be restricted to daylight hours as much as possible. Artificial lighting should not be used;
- Use existing old road surfaces and disturbed areas or areas of low habitat value as much as possible for temporary construction access roads and laydown and storage areas, where applicable; and
- Clearly limits will be strictly adhered to ensure that disturbance to vegetation is minimized.

9.0 FISH AND FISH HABITAT

The following measures will be employed to protect fish and fish habitat (herein defined as all rivers, streams, ditches and ephemeral crossings). These features are primarily associated with the tailings pond and downstream watercourses:

- Follow all of Fisheries and Oceans Canada's Measures to Avoid Causing Harm to Fish and Fish Habitat[14];

[14] http://www.dfo-mpo.gc.ca/pnw-ppe/measures-mesures/index-eng.html;

- Follow the Ministry of Environment's A User's Guide to Working In and Around Water http://www.env.gov.bc.ca/wsd/water_rights/cabinet/working_around_water.pdf;
- Sufficient vegetation to ensure bank stability, maintain ground cover and prevent erosion must be retained within 30 m of the high water mark of any watercourse;
- All selective clearing of trees and shrubs within 30 m of watercourses must be completed utilizing hand tools, where practical;
- Where possible, root masses and stumps should be left in place within 30 m of any watercourse to ensure slope integrity;
- No debris, soil or other deleterious material will be allowed to enter any watercourse;
- No machinery crossing (fording) of any watercourse will be permitted;
- Clearly flag or otherwise delineate riparian areas throughout all phases of construction. When working during periods of heavy or prolonged rainfall, isolate the area of work and install appropriate sediment controls to prevent the release of sediment-laden water or any other deleterious substances into surface water;
- Isolate work area from any flowing water that may be present. Temporarily divert flows around the work area;
- Do not remove rocks from below the ordinary high water mark of any watercourse;
- Operate machinery on land above the high water mark to minimize disturbance to the banks and bed of any watercourse;
- Do not remove coarse woody debris from any watercourse;
- Prevent the transport of sediment through the installation of appropriate erosion and sediment control when work involves the disturbance of soils or the use of erodible materials (e.g., sands, topsoil);
- Avoid the use of ground-based machinery within 15 m of the top-of-bank of any watercourse;
- No equipment fuelling nor fuel storage is to occur within 30 m of any watercourse; and
- Use existing old road surfaces and disturbed areas or areas of low habitat value as much as possible for temporary construction access roads and laydown and storage areas.

10.0 VEGETATION MANAGEMENT, DISTURBANCE OR REMOVAL

The following measures are provided to limit the impact of Project activities on vegetation:

- Clearing limits will be strictly adhered to ensure that disturbance to vegetation is minimized;
- Noxious/invasive weeds known to occur within the Kootenay Region include: blueweed (*Echium vulgare*), common bugloss (*Anchusa officinalis*), common tansy (*Tanacetum vulgare*), field scabious (*Knautia arvensis*), Orange hawkweed (*Hieracium aurantiacum*), hoary alyssum (*Berteroa incana*), perennial pepperweed (*Lepidium latifolium*), several knapweed species (*Centaurea* spp.) and plumeless thistle (*Carduus acanthoides*). Several other invasive species are also known to occur.
- All equipment will arrive on site, clean and free of noxious/invasive weeds;

- Prior to moving to new sites, all equipment will be inspected for all weeds and suspect plants will be removed from equipment and vehicles to prevent spread of invasive species;
- All vegetation will be removed and transported to an approved disposal area at the discretion of the RDCK;
- Cleared material containing invasive/noxious species will be separate from other cleared material with the invasive species containing material disposal of at an appropriate transfer facility;
- Loads will be covered during transport to help prevent spores or seeds from falling out of the vehicle;
- Conduct an inspection of any fill material source to identify any potential invasive species issues;
- Machinery will keep to designated routes and access roads to reduce damage to surrounding vegetation;
- Limit stripping of vegetation and soils to those areas required for Project activities;
- Ensure excavated material, construction waste, stock piles or materials are positioned to limit the impact to vegetation;
- Machinery will not be parked within the drip line of trees;
- Restore bare soil as quickly as possible after disturbance;
- Use existing old road surfaces and disturbed areas or areas of low habitat value as much as possible for temporary construction access roads and laydown and storage areas.

11.0 WEED MANAGEMENT

In addition to the measures as detailed in Section 10.0, the following considerations will be made to limit the spread of weeds within the Project area:

- Prior to moving to new sites, all equipment will be inspected for all weeds and suspect plants will be removed from equipment and vehicles to prevent spread of invasive species. These plants will be properly disposed of at an appropriate transfer facility;
- Cleared material containing invasive/noxious species will be separate from other cleared material with the invasive species containing material disposal of at an appropriate transfer facility;
- Loads will be covered during transport to help prevent spores or seeds from falling out of the vehicle; and
- Use existing old road surfaces and disturbed areas or areas of low habitat value as much as possible for temporary construction access roads and laydown and storage areas.

12.0 ARCHAEOLOGY AND CULTURAL RESOURCES

The Construction Manager shall protect and preserve the remains or items of geological or archaeological interest or value encountered on-site and must take all reasonable precautions to prevent damage or unauthorized removal of items by any personnel. In the event that sites or artifacts of heritage or archaeological importance are discovered, the Construction Manager shall stop work immediately and contact appropriate authorities. All construction activities involving surface or sub-surface disturbance should not commence until clearance under the *Heritage Conservation Act*[15] has been secured.

In the event that sites or artifacts of heritage or archaeological importance are discovered, Construction Company shall stop work immediately and contact SLR's EM and RDCK. If evidence of cultural artifacts is found (i.e. human bones, stone tools, and shell deposits) the following procedures are to be followed:

- Immediately stop work in the vicinity of the suspected archaeological find and notify SLR's EM and the RDCK as soon as possible.
- Ensure no one touches any suspected archaeological, paleontological or cultural artifact.
- Do not undertake any further work that could disturb the site. Do not move soil from the vicinity of the site. Do not move or collect the artifacts.
- Secure the area and mark it as a "No-Activity-Area" by staking or flagging off the affected location to prevent additional disturbances.

If human remains are encountered on site, the following procedures are to be followed:

- Immediately stop work within the vicinity of the suspected archaeological find and notify SLRs EM and the RDCK.
- Do not disturb the site.
- Treat the remains will full dignity and respect. Cover any bones with plastic sheeting, blankets or other clean coverings until the RCMP arrive.
- Assign an employee to maintain watch over the remains until the RCMP arrive.
- Do NOT backfill the area.

13.0 NOISE

All work should comply with local noise bylaws unless exemptions have been obtained prior to commencing any site works. The site should be developed with care and in compliance with the Environmental Guidelines for Urban and Rural Land Development in British Columbia[16]. The following noise control measures should be implemented during construction:

- Equipment should be maintained in good working condition. Fleet vehicles should be maintained according to manufacturer's guidelines. Vehicles and equipment should be inspected on a regular basis and maintained as required;
- Standard practices and use of "Best Available Control Technologies" should be implemented to control equipment, including hand-held, and vehicle noise. Noise levels will be managed through the use of standard noise reduction mufflers. Mufflers are to be maintained in good working condition to meet their warranted operating efficiency;
- All personnel, contractors and suppliers will adhere to a maximum of 30 km/hour for all vehicles at all times along unpaved roads to reduce noise and potential collisions with wildlife;

[15] *Heritage Conservation Act*, [RSBC 1996] CHAPTER 187.

[16] Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development in British Columbia, 2014. Ministry of Environment, Ecosystems Branch.

- The Construction Manager shall comply with any applicable local noise bylaws, or exemptions must obtained prior to the start of any work (e.g. blasting);
- Avoid unnecessary engine revving and use of engine brakes and minimize vehicle idling to the extent feasible;
- Blasting should be scheduled, where possible, to avoid the general raptor breeding season with care taken to ensure no physical damage occurs to vegetation and key habitat features. Blasting is of particular concern during courtship and egg-laying periods (broadly January 5 – July 20). If blasting must occur at this time, a minimum 1,000 m (1 km) buffer from the nest site should be maintained[17].

14.0 AIR QUALITY AND DUST CONTROL

Air quality may be affected by construction activities. Construction equipment and vehicles may temporarily emit greenhouse gases and deleterious substances and will emit particulate matter. In order to minimize the potential impacts to air quality, the following measures should be implemented:

- Control of blast dust through the use of using appropriate blast hole patterns and stemming to prevent venting;
- All personnel, contractors and suppliers will adhere to a maximum of 30 km/hour for all vehicles at all times along unpaved roads to reduce dust generation;
- Apply water to dry soils, access roads, lay down areas, work areas and disposal areas during periods of high wind and/or dry weather if there is evidence that wind erosion is a problem (e.g., drifting of topsoil or stockpiles) or if dust control is required. When using water, caution shall be used to prevent run-off into adjacent watercourses;
- Do not use oils or other dust suppressants;
- Ensure that all equipment is maintained in good working order and has properly functioning emission controls;
- Minimize engine idling;
- Implement speed limits for all equipment;
- Use modern machinery and commercially available low sulphur fuels;
- Soil stockpiles should be covered with 10 mil polyethylene sheets;
- Adhere to all posted speed limits;
- Cover loads when hauling; and
- Load trucks so that loads do not spill during movement.

14.1 Idle Reduction Strategies

In order to minimize greenhouse gas emissions during construction activities, the following practices should be implemented:

[17] BC Ministry of Forests. 2013. Guidelines for Raptor Conservation during Urban and Rural Land Development in British Columbia. 151 pp.

- Ensure that all equipment is maintained in good working order and has properly functioning emission controls;
- Locate operating vehicles away from sensitive receptors;
- Minimize vehicle idling to the extent feasible; and
- Establish a staging zone for trucks that are waiting to load or unload material in the Project area, away from sensitive receptors.

15.0 TRAFFIC MANAGEMENT

Traffic should be managed during construction to ensure safe access near the HB Mine Tailings Facility. The following traffic control measures should be implemented during construction:

- Train staff and conduct tailgate meetings prior to commencing Project activities to review access and traffic management, specifically road access to and from the site;
- Vehicle traffic should be limited to designated “roads” as much as practical;
- Install safety signs and flashing lights to notify highway traffic of construction works and associated dangers of construction vehicles entering and leaving the site; and
- Prior to transporting any decommissioned equipment off of the site, calculate the equipment height to determine the appropriate truck required for transport, determine the best transportation route, and check with municipal permits for potential over-height restrictions.

16.0 SITE RESTORATION

The following measures will be employed to support site restoration and to minimize impacts:

- Minimize activities that cause soil compaction and rutting (e.g., minimize vehicle traffic and use of equipment on exposed soils, use existing roadways or disturbed areas to travel within site, use equipment of low bearing weight or low-pressure tires or tracked vehicles within sensitive areas etc.);
- Compacted soils must be rehabilitated similar to existing site conditions;
- Decommission and remove temporary structures used during construction within the construction season when they are deemed to be no longer required;
- Upon completion of construction activities, remove surplus materials and wastes from the work sites and dispose of at appropriate facilities;
- Install and maintain appropriate sediment control measures until such time that natural vegetation becomes established;
- Prior to hydroseeding the containment cover surface will be loosened via harrowing.
- Hydroseed areas disturbed during work to a stable vegetated condition prior to the onset of winter, a tackifier will be used on dam slopes;
- Seed mixtures and associated application rates must be confirmed by a QEP prior to application;
- Upon completion of restoration activities, remove all remaining sediment and erosion control measures, unless they are necessary to protect areas where vegetation is naturally establishing; and

- Remove all equipment, supplies and materials associated with the work.

17.0 POST CONSTUCTION GROUNDWATER AND SURFACE WATER MONITORING

Water quality monitoring will occur following completion of construction to ensure the constructed works are performing as intended and that there are no detectable adverse effects on the environment or human health and will include both surface and groundwater sampling.

Surface water sampling will focus on any trends that suggest an increase in contaminate loadings between the inflows and outflows of the tailings facility. Groundwater sampling will focus on any trends that might suggest an increase in contaminate loadings. Tables 2 and 3 below provide an overview of the water quality parameters to be collected in the field and submitted for laboratory analysis as well as monitoring frequencies.

Table 2
Water Quality Analyses Parameters

Analyses Type	Laboratory Analysis Parameters	Field Analysis Parameters
Surface Water Analyses	• pH; • Anion chromatography package (total alkalinity, chloride, bromide, sulphate, nitrate, nitrite, un-ionized sulphide); • Total and dissolved metals; • Total organic and inorganic carbon; • Phosphate; • TKN (measures ammonia and organic nitrogen); and • Total suspended solids.	• Temperature; • Conductivity; • Dissolved oxygen; • pH; • Sulphide; • Turbidity; and • Visual estimate of flow rate.
Groundwater Analyses	• pH; • Total dissolved solids; • Sulphate • Total and dissolved metals; • Nitrate/nitrite, • Ammonia; and • Orthophosphate.	• Temperature; • Conductivity; • Dissolved oxygen; • pH; • Sulphide; and • Water elevation.

Table 3
Monitoring Frequencies for Surface Water and Groundwater

Item	Frequency
Dam Instrumentation	
Piezometers	Weekly during freshet, otherwise monthly
V-Notch Measurement Weir	Weekly during freshet, otherwise monthly
Survey hubs	Annually until stable trend line observed, every five years thereafter
Water Quality	
Surface Water	Quarterly
Groundwater	Quarterly

Note that post construction monitoring requirements and frequencies outlined in Tables 2 and 3 will be updated in the site Operation, Maintenance and Surveillance Manual and will supersede the information provided in Section 17 of this report.

18.0 LIMITATIONS

This CEMP has been prepared for the work referred to in this plan being undertaken by RDCK. It is intended for the sole and exclusive use of RDCK and their authorized agents for the purpose(s) set out in this plan. Any use of, reliance on or decision made based on this plan by any person other than RDCK for any purpose, or by RDCK for a purpose other than the purpose(s) set out in this plan, is the sole responsibility of such other person or RDCK. SLR makes no representation or warranty to any other person with regard to this plan and the work referred to in this plan and they accept no duty of care to any other person or any liability or responsibility whatsoever for any losses, expenses, damages, fines, penalties or other harm that may be suffered or incurred by any other person as a result of the use of, reliance on, any decision made or any action taken based on this plan or the work referred to in this plan.

Any conclusions or recommendations made in this plan reflect SLR's judgment based on an understanding of Project activities. While efforts have been made to substantiate information provided by third parties, SLR makes no representation or warranty as to its completeness or accuracy.

If site conditions change or if any additional information becomes available at a future date, modifications to the findings, conclusions and recommendations in this plan may be necessary.

Nothing in this CEMP is intended to constitute or provide a legal opinion. SLR makes no representation as to the requirements of or compliance with environmental laws, rules, regulations or policies established by federal, provincial or local government bodies. Revisions to the regulatory standards referred to in this plan may be expected over time. As a result, modifications to the findings, conclusions and recommendations in this plan may be necessary.

Other than by RDCK and as set out herein, copying or distribution of this plan or use of or reliance on the information contained herein, in whole or in part, is not permitted without the express written permission of SLR.

Notwithstanding the stated limitations, RDCK may submit this plan to Environmental Regulatory Authorities (Municipal, Provincial, and Federal) and/or other designated persons of authority (collectively called "Authorities"). Furthermore, those Authorities may rely on this plan for review and comment purposes on matters pertaining directly to this plan or to the subject Project

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APPENDIX A
Environmental Monitoring Report Form

Construction Environmental Management Plan
HB Mine Tailings Facility and Remediation
SLR Project No.: 204.03242.00000

DAILY Environmental Monitoring Report:
HB Mine Tailings Facility 204.03242

Date		
Environmental Monitor/Company/Contact #		
Start and End Times		
Construction Phase		
Activities Conducted		
Weather		
Potential for rain or snow?		
Did it rain or snow overnight?		
Sensitive Habitat	Work near Sensitive Habitat?	
	Distance from Work (m)	
	Description	
Wildlife Observed		
Sediment and Erosion Control	Silt laden runoff visible on site?	
	Silt laden runoff discharging to sensitive habitat?	
	Stockpiled material or steep slopes eroding?	
	Coverage of piles or steep slopes required?	
	Silt fencing required?	
	Measures Implemented	
	Discussed with:	
	Corrective Actions	
Construction Equipment Inspection	Type(s)	
	Leaks?	
	Weeds?	
	Spill kits available?	
	Other	

DAILY Environmental Monitoring Report:
HB Mine Tailings Facility 204.03242

Spill	Spill/ Stain/ Fluid observed?	
	Type?	
	Cleanup Measures Requested by EM*	
	Discussed with:	
	Contractor has cleanup supplies?	
	Machinery Repair requested by EM*	
	Corrective Actions	

Other Notes:

APPENDIX B
Emergency Spill Response Plan

Construction Environmental Management Plan
HB Mine Tailings Facility and Remediation
SLR Project No.: 204.03242.00000

Emergency Spill Response Plan

In the event of any release of fuel, lubricant, sludge, or other industrial chemical (including gases), Construction Company shall adhere to the following spill response procedures. Construction Company shall be responsible for ensuring personnel are competent to adequately respond to a spill. Construction Company shall report any spill **immediately** to the RDCK.

Spill Response Procedures:

1. Ensure safety.
2. Stop the flow (when possible).
3. Secure the area.
4. Contain the spill.
5. Notify/report.
6. Clean-up.

All spills, regardless of volume, and other environmental incidents, shall be reported to SLR's EM. Construction Company is responsible for ensuring personnel know when to contact the Provincial Emergency Program (PEP) and/or Fisheries and Oceans Canada (DFO).

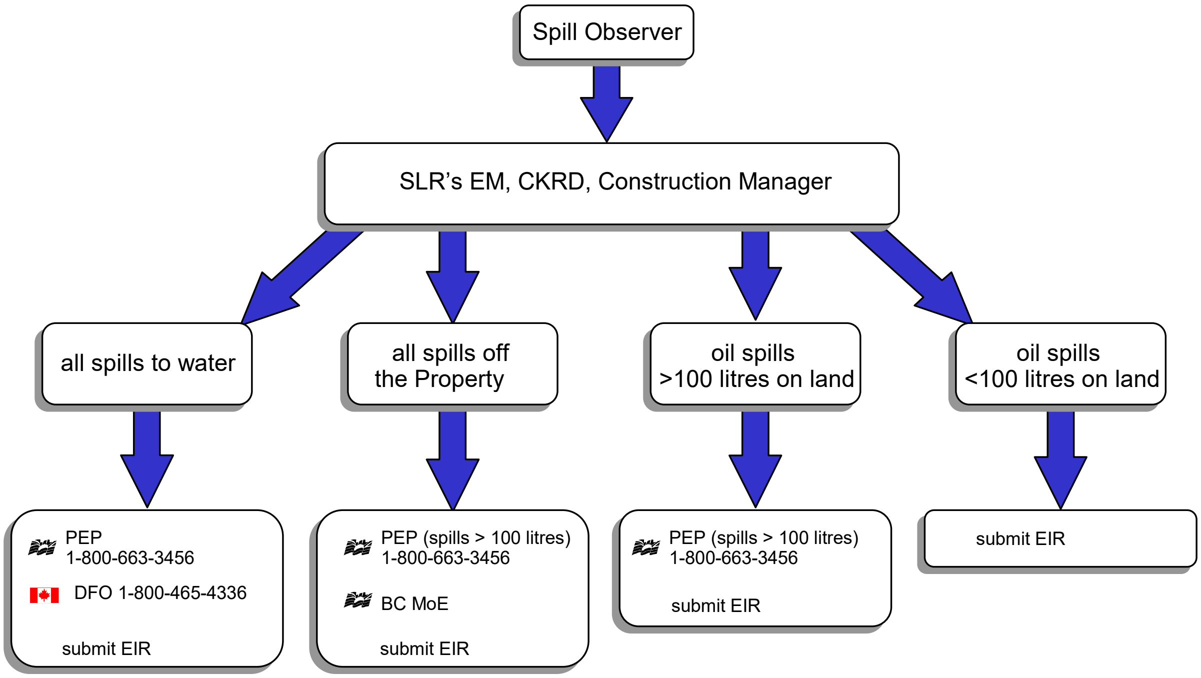
It is the responsibility of Construction Company to report spills in excess of the quantities included in the table below to the appropriate environmental agency.

Reportable Spill Quantity List *
(**list of externally reportable quantities for commonly used** substances**)**

Product	Quantity
Class 2.1 - flammable gas (e.g. propane)	10 kg or 10 min.
Class 2.2 - non-flammable gas (e.g. SF6, CO2)	10 kg or 10 min.
Class 3 - flammable liquids	100 litres
Class 8 - corrosive liquid acids and caustics (e.g. battery acid)	5 kg or 5 litres
Class 9 - environmentally hazardous (e.g. used ethylene glycol)	25 kg or 25 litres
Class 9 - environmentally hazardous (friable asbestos)	25 kg or 25 litres (for transportation purposes), else 50 kg
Oil, 2 or more ppm PCBs from in-service equipment	containing 1 g pure PCB
Oil, 2 or more ppm PCBs from NOT in-service equipment	any quantity
Solids, 50 or more ppm PCBs, NOT from in-service equipment	any quantity
Oil and Waste Oil	100 litres
Leachable toxic waste (e.g. abrasive blasting material)	25 kg or 25 litres
Other Substances (e.g. wash water)	200 kg or 200 litres
Pesticides and Herbicides	5 kg or 5 litres

* Quantities are subject to change. Refer to Regulations for latest figures

*****ALL SPILLS TO WATER ARE REPORTABLE*****



Key spill response activities include:

- **Report the Spill** – Applicable parties, including, but not limited to, SLR's EM and Construction Manager will be contacted as soon as it is safe to do so. Any reportable spill should be **immediately** reported to the EM, who will then notify BC Ministry of Environment, as required under the BC Spill Reporting Regulation[1]. A reportable spill is any volume of a substance spilled that exceeds the quantities outlined in Schedule 1 of the BC Spill Reporting Regulation;

- **Stop the source, if possible** – If it is safe to proceed, the Site Construction Manager and/or SLRs EM will direct preventative measures to remove or immobilize the source of the spill;

- **Contain Spill Material** – If it is safe to proceed, the Site Construction Manager will direct spill containment methods and identify the spill material, spill volume, and the potential hazards to people and the environment;

- **Protect Area** – Spill containment measures will remain in place until the spilled material is removed from the Site and no longer poses a risk to people or the surrounding environment. The Site Supervisor will ensure that spill kits are restocked as required with material for future use;

- **Remove material to an approved location for storage and/or disposal** – It is advised an independent contractor be used for spill clean-up. All contaminated soil and clean up

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[1] British Columbia Spill Reporting Regulation, 1990, includes amendments up to B.C. Reg. 976/2008, December 9, 2008.

material shall be managed according to the BC *Environmental Management Act*[2] and Contaminated Sites Regulation[3]. Waste should be transported only by a licensed hazardous waste hauler and disposed of only at an approved waste facility; and

- **Prepare a Spill Report** – Construction Company will complete an Environmental Incident Report form for ANY onsite spill.

[2] British Columbia Environmental Management Act, SBC 2003.

[3] British Columbia Contaminated Sites Regulation, 1997, including amendments up to B.C. Reg. 6/2013, May 2013.

APPENDIX C
Environmental Incident Report Form

Construction Environmental Management Plan
HB Mine Tailings Facility and Remediation
SLR Project No.: 204.03242.00000

SLR
global environmental solutions

ENVIRONMENTAL INCIDENT REPORT FORM

Incident Date:	Incident Time:
Project:	Client:

Incident Information:

Incident Location:
Incident Description:
Immediate Corrective Actions Taken:
Future Mitigation Actions Required:
Weather Conditions:

Equipment Type:	Material Released:
Area of Impact: ☐ Air ☐ Asphalt ☐ Surface Water or Ditch ☐ Soil ☐ Drainage System ☐ Watercourse	Was the incident reported to an external agency? ☐ YES ☐ NO
NOTES:	

SLR

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Yellowknife, NT X1A 3R8
Canada
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Appendix C – Closure Design Memos

Appendix C-1 – Hydrological Analysis

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Memo

To:	Amy Wilson, RDCK	**Client:**	Regional District of Central Kootenay
From:	Sarah Portelance PEng., MEng., Mark Sumka, EIT	**Project No:**	1CR012.006
Cc:	Peter Mikes (SRK)	**Date:**	December 12, 2019
Subject:	HB Mine Tailings Facility Closure Design – Hydrological Analysis		

1 Introduction

SRK Consulting (Canada), Inc. is providing engineering services to the Regional District of Central Kootenay (RDCK) to remediate and close the HB Mine Tailings Facility (the Facility) by transitioning the HB Dam to passive closure as defined by the Canadian Dam Association (CDA). The remediation will include upgrades to the dam and spillway, a tailings cover, and surface water conveyance structures over the tailings cover to direct surface run-on into the facility to the spillway.

The facility is located approximately 7 km south of the Village of Salmo and 33 km southeast of Castlegar, BC.

This memo describes the methods and the results of the hydrological analysis for the project. Results of the analysis will be an input to the hydraulic designs of the spillway and other conveyance structures at the Facility.

2 Methodology

In 2014, a dam hazard classification assessment was completed as part of the Dam Safety Review (TTEBA 2014). The dam was assigned a “Very High” classification based on revised Dam Safety Guidelines (CDA 2007 revised 2013). The CDA specifies that mining dams with a “Very High” classification in passive closure are to be designed to safely convey the probable maximum flood (PMF) (CDA 2014). The PMF is considered the most severe flood event that may reasonably be expected to occur.

The procedures adapted in this analysis are consistent with the Canadian Dam Association (CDA) Guidelines (CDA, 2014) and the Guidelines on Extreme Flood Analysis (Alberta Transportation, 2004). The PMF was estimated using a rainfall-runoff model approach using HEC-HMS (USACE, 2016). Losses were accounted for using a Curve Number calibrated to peak flows observed in the Salmo River. Climate change was considered in the flow estimates conducted through a compilation of Intergovernmental Panel on Climate Change (IPCC)

Assessment Reports and through a probability analysis on the multiple climatic models using a purpose-built script developed by SRK using R Software (CRAN 2016).

3 Climatic Conditions

3.1 Sources

Meteorological parameters are not measured at HB Mine Tailings Facility. A regional analysis was implemented to evaluate hydrological conditions. This section presents the data analyses used to establish long-term synthetic period of record for air temperature, precipitation, wind speed, and snowmelt.

Available meteorological data from Environment and Climate Change Canada (ECCC) and National Oceanic and Atmospheric Administration (NOAA) in the United States were investigated. Figure 3-1 illustrates the location of the 22 stations investigated with more than 10 years of available precipitation and temperature data. Table 1 summarizes the metadata of the selected regional climate stations.

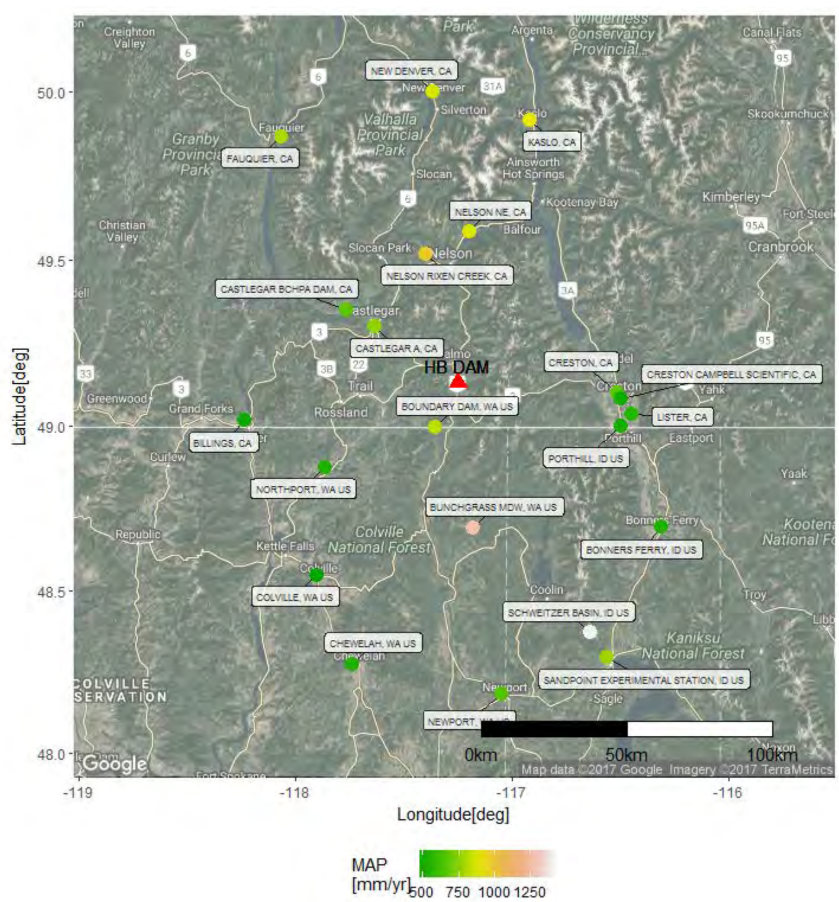

Figure 3-1: Regional Meteorological Stations

Table 3-1: Summary of Regional Climate Station Metadata

Station ID	Station Name	Longitude (degrees)	Latitude (degrees)	Elevation (m)	First Year	Last Year
USC00450844	Boundary Dam (US)	-117.35	48.99	559.9	1965	2017
CA001141455	Castlegar A (CA)	-117.63	49.30	496.0	1965	2017
USR0000WCEC	Cedar Creek Washington (US)	-117.67	48.98	1325.9	1995	2017
CA001145M29	Nelson Cs (CA)	-117.30	49.48	535.0	1992	2017
USR0000ISAD	Saddle Pass Idaho (US)	-116.73	48.94	1560.6	1985	2017
CA00114EMDM	Nelson Rixen Creek (CA)	-117.40	49.52	760.0	1990	2017
CA001141457	Castlegar BCHPA Dam (CA)	-117.77	49.35	435.0	1969	2017
USR0000WDEE	Deer Mountain Washington (US)	-117.61	48.80	1005.8	1985	2017
USS0017A01S	Bunchgrass Mdw (US)	-117.18	48.69	1524.0	1980	2017
CA001145442	Nelson Ne (CA)	-117.20	49.58	570.0	1983	2017
USC00455946	Northport (US)	-117.87	48.87	450.2	1899	2017
CA001142160	Creston (CA)	-116.52	49.10	610.0	1912	2015
CA00114B1F0	Creston Campbell Scientific (CA)	-116.50	49.08	646.0	1993	2017
USC00107264	Porthill (US)	-116.50	49.00	548.3	1892	2016
CA001144635	Lister (CA)	-116.45	49.03	660.0	1956	2015
USR0000IPRL	Priest Lake Idaho (US)	-116.96	48.58	792.5	2001	2017
CA001140876	Billings (CA)	-118.23	49.02	510.0	1984	2017
USC00451630	Colville (US)	-117.90	48.55	495.9	1899	2017
USR0000IBOF	Bonners Ferry Idaho (US)	-116.34	48.68	536.4	2002	2017
USC00101079	Bonners Ferry (US)	-116.31	48.69	632.5	1907	2017
CA001143900	Kaslo (CA)	-116.92	49.92	600.0	1894	2017
USC00107386	Priest River Experimental Station (US)	-116.84	48.35	722.7	1898	2017

Source: compiled in text from R code, Z:\01_SITES\HB_Mine\1CR012.004_TSF Closure Design\200_Hydrotechnical\R Code HB Closure

The regional meteorological station data was complemented with data obtained from reanalysis. Reanalysis creates data sets, extending for several decades, for the entire planet by combining satellite information, land records and numerical models that simulate the earth's climatic conditions. Reanalysis can provide meteorological data including precipitation, temperature, wind speed, solar radiation; and, relative humidity.

State-of-the-art publicly available reanalysis data was obtained from ERA-Interim. ERA-Interim provided by the European Centre for Medium-Range Weather Forecast (ECMWF). ERA-Interim includes sub-daily data from 1979 to present (2017) for the entire world, based on a 0.75 degree latitude by 0.75 degree longitude grid.

3.2 Temperature

Regionally, it was found that temperatures have historically increased over time. Figure 3-2 illustrates the regional temperature regression analysis post-1980 with respect to elevation. For an average watershed elevation of 800 m, the mean annual temperature at the Facility is expected to be approximately 7.4 °C.

The Castlegar Airport station is the closest station with a near complete period of record. Missing daily data from this station was patched using Creston and Priest River data. This time series was corrected for the Facility using the linear regression equation for elevation presented in Figure 3-2.

The linear regression for annual temperature was applied to determine the mean annual temperature at the HB site (7.4 °C). The long-term time series from 1980 to 2017 for HB was developed by applying a correction factor to the daily temperature record of Castlegar A. The correction factor was optimized to ensure the final mean annual temperature for the site is 7.4 °C.

Table 3-2 provides a summary of the monthly temperature percentiles at the site based on the site-adjusted temperature record from 1980 to 2017. A boxplot with the monthly temperature range is presented in Figure 3-3.

Table 3-2: Monthly Statistics for Air Temperature for HB Mine Tailings Facility from 1980 to 2017 [deg C]

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0%	-10.3	-6.2	-0.2	4.9	9.2	12.8	15.5	15.9	10.6	4.9	-5.9	-7.6
25%	-4.9	-2.7	1.9	6.7	11.2	14.6	18.0	18.2	12.5	6.1	0.0	-4.6
50%	-3.6	-1.3	2.6	7.3	12.1	15.3	19.1	19.0	13.6	6.6	1.1	-2.7
75%	-1.8	-0.3	3.9	8.1	12.9	16.6	20.2	19.7	14.6	7.4	2.1	-1.7
100%	0.4	2.2	5.6	10.9	14.9	19.4	22.9	22.0	17.1	9.2	4.9	0.1
Mean	-3.6	-1.4	2.8	7.4	12.0	15.6	19.1	18.8	13.5	6.8	0.9	-3.2
SD	2.3	1.9	1.4	1.2	1.3	1.4	1.6	1.3	1.6	1.0	1.8	2.0

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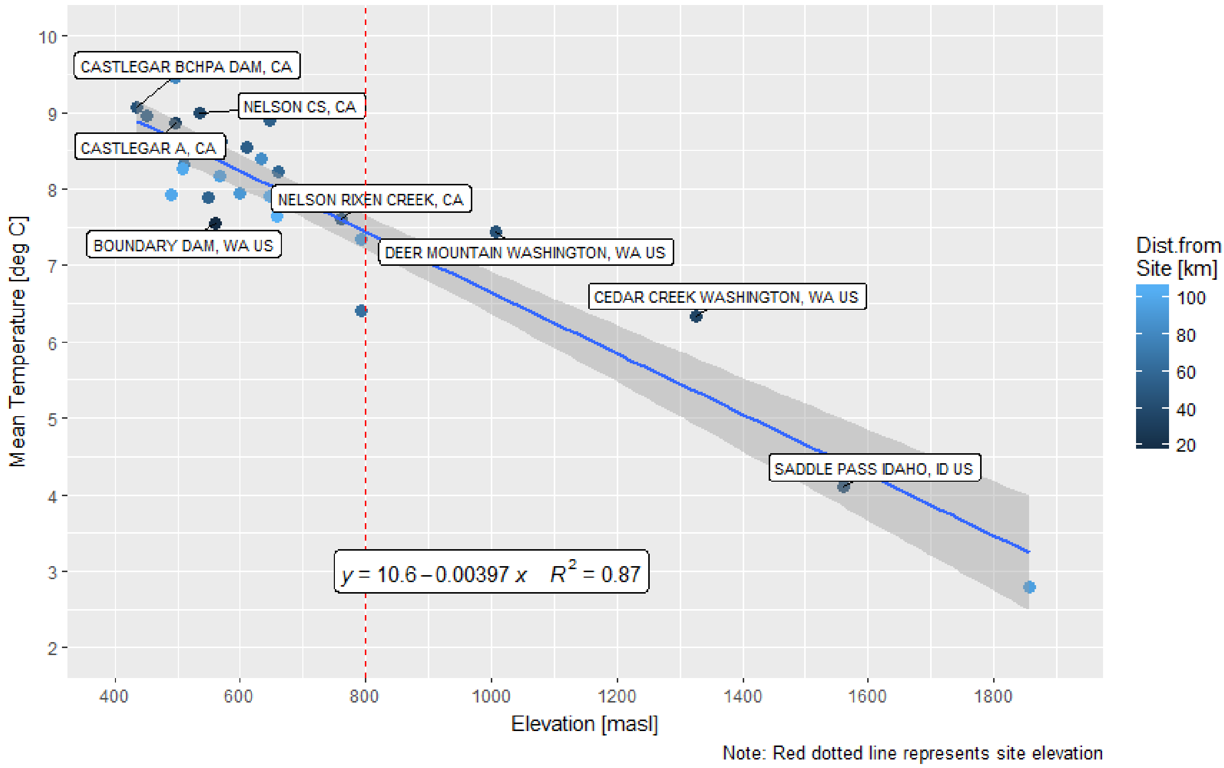

Figure 3-2: Regional Regression for Mean Air Temperature (1980-2017)

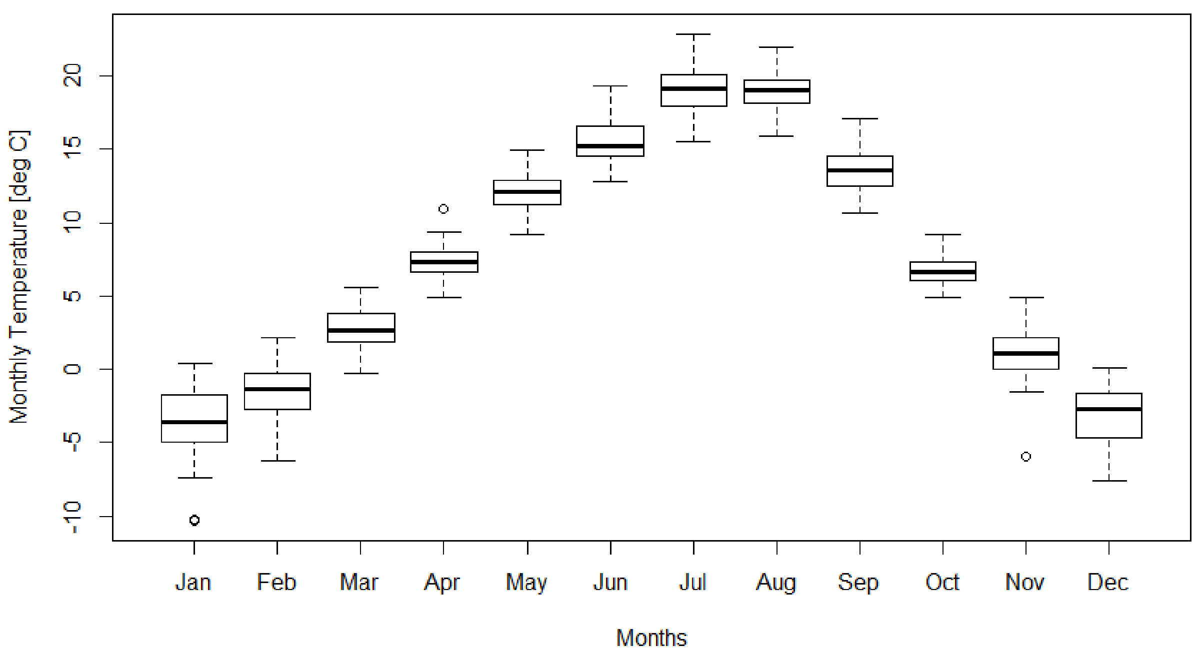

Figure 3-3: Monthly Air Temperature Boxplot at HB Mine Tailings Facility

3.3 Precipitation

Figure 3-4 illustrates the mean annual precipitation (MAP) regression with elevation where the MAP for the Facility was determined to be 808 mm.

Missing daily Castlegar Airport precipitation data was patched with measured daily precipitation data from Creston and interpolated. The patched time series was corrected for the Facility using the precipitation regression equation illustrated in Figure 3-4. Table 3-3 provides a summary of the mean monthly precipitation at the site based on the synthetic record from 1980 to 2017. A boxplot of the average monthly precipitation is presented in Figure 3-5. This figure presents similar monthly variability of the precipitation during the year, with slightly higher precipitation in November to December and lower precipitation records during the summer period of July to September.

Table 3-3: Monthly Statistics for Precipitation at HB Mine Tailings Facility from 1980 to 2017 [mm]

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0%	9.9	9.2	22.8	14.1	18.7	13.9	0.0	0.0	1.8	2.4	15.1	21.9
25%	60.5	35.3	44.8	36.1	46.3	54.5	20.3	11.7	22.3	42.1	70.2	68.1
50%	78.6	57.0	68.9	57.3	58.5	75.3	44.1	22.1	34.4	56.5	89.9	105.4
75%	103.5	71.3	91.5	72.0	88.2	94.9	66.7	53.7	59.9	77.9	122.5	132.2
100%	184.5	178.3	159.6	114.7	172.6	249.6	157.0	153.5	134.8	230.4	205.2	213.9
Mean	82.2	58.2	71.8	58.0	70.1	77.2	47.0	35.9	43.9	62.2	98.2	103.3
SD	34.8	32.8	33.7	23.7	34.3	37.4	33.7	32.7	31.8	40.9	45.0	44.0

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Based on climate normal from 1981 to 2010, “Climate WNA” (UBC 2018) suggests that the MAP for the site is approximately 802 mm, this is approximately 8% greater than that developed for the site. Figure 3-6 below illustrates the annual precipitation distribution based on the site adjusted method and Climate WNA (UBC 2018) for the HB site location.

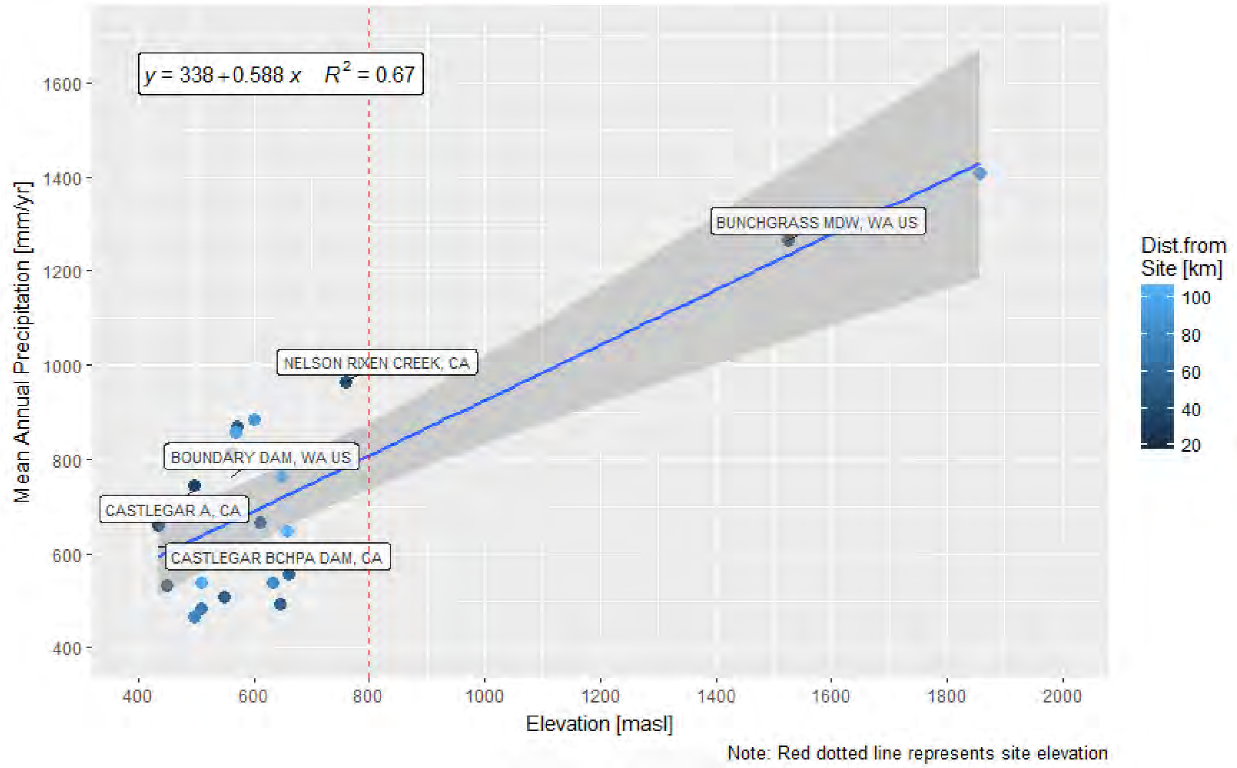

Figure 3-4: Regional Precipitation Regression (1980-2017)

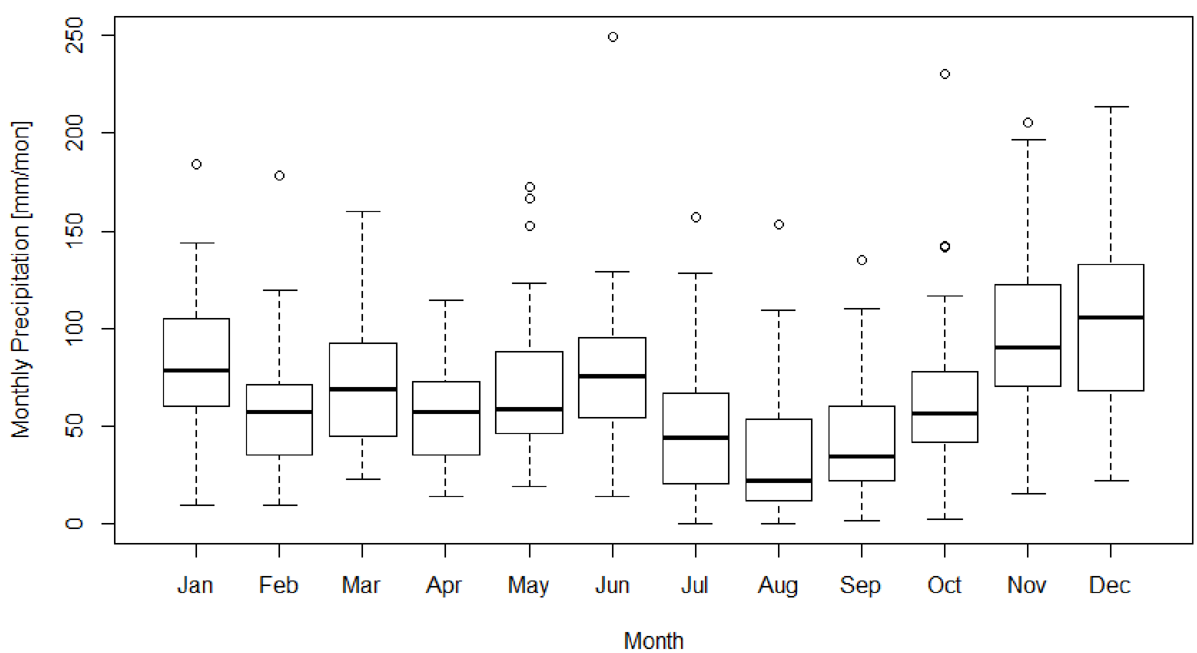

Figure 3-5: Monthly Precipitation Boxplot at HB Mine Tailings Facility

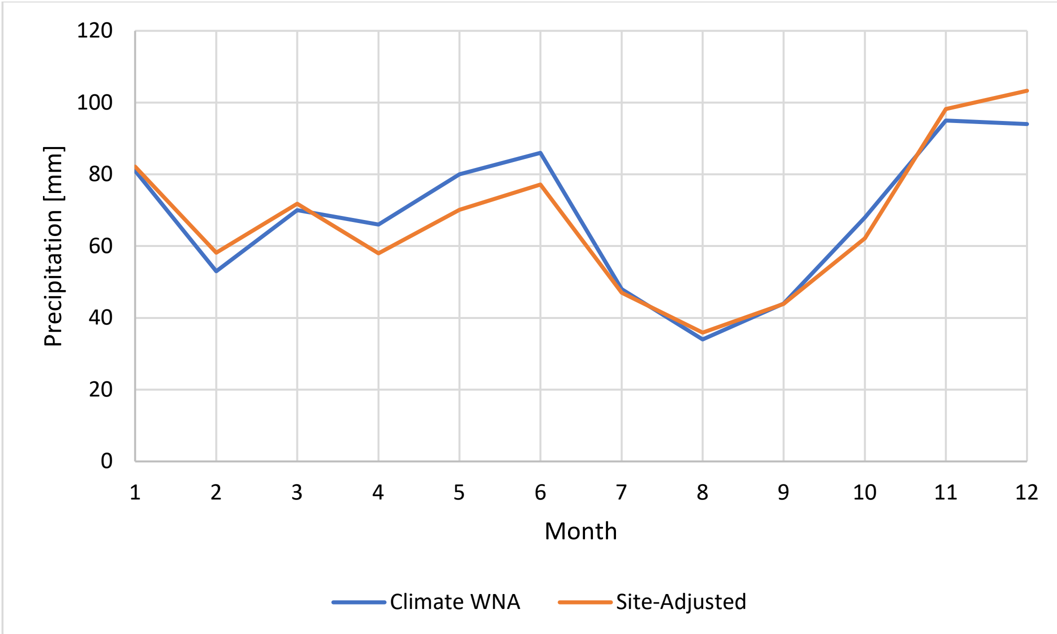

Figure 3-6: Annual Precipitation Distribution

3.3.1 Maximum Daily Frequency Analysis

Table 3-4 summarizes the maximum daily precipitation frequency analysis where 24-hour depths were calculated based on a factor of 1.13 (NOAA, 2006). The Pearson Type 3 distribution was determined to provide the best fit to the annual maximum data.

Table 3-5 summarizes frequency analysis for monthly daily precipitation depths where the 100-year maximum daily precipitation in June is approximately 59.1 mm. Table 3-6 summarizes the frequency analysis for monthly 24-hour precipitation depths.

Table 3-4: HB Mine Tailings Facility Frequency Analysis - Precipitation Depths

Return Period	Maximum Daily Precipitation [mm]	Max 24-hour Precipitation [mm]
200	67.5	76.3
100	63.0	71.2
50	58.3	65.9
25	53.5	60.5
20	51.9	58.7
10	46.9	53.0
5	41.6	47.0
2	33.5	37.9

Source: Z:\01_SITES\HB_Mine\1CR012.004_TSF Closure Design\200_Hydrotechnical\ PMP_rev03_spb.xlsm

Table 3-5: HB Mine Tailings Facility - Monthly Maximum Daily Frequency Analysis

Return Period	Maximum Daily Precipitation [mm/day]											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
200	38.6	43.3	45.0	46.9	54.3	65.4	61.7	49.9	30.9	50.2	55.2	56.0
100	36.1	38.4	41.2	42.0	48.7	59.1	55.1	44.7	30.4	45.2	49.8	51.0
50	33.4	33.6	37.2	37.2	43.1	52.7	48.5	39.3	29.5	40.3	44.4	45.9
25	30.6	29.0	33.3	32.6	37.5	46.3	41.9	33.9	28.2	35.3	39.2	40.8
20	29.7	27.6	32.0	31.1	35.7	44.3	39.7	32.1	27.6	33.7	37.5	39.1
10	26.6	23.2	27.8	26.5	30.0	37.7	32.9	26.4	25.4	28.5	32.2	33.9
5	23.1	18.8	23.3	21.8	24.2	30.9	25.8	20.4	22.0	23.2	26.8	28.5
2	17.2	12.7	16.3	15.0	16.4	20.6	15.1	11.4	14.2	15.1	18.8	20.2

Source: compiled in text from R code, Z:\01_SITES\HB_Mine\1CR012.004_TSF Closure Design\200_Hydrotechnical\R Code HB Closure\HB Closure Hydrotechnical\ Precip-Rev3_SP_VM.Rmd

Table 3-6: HB Mine Tailings Facility - Monthly Maximum 24-hour Frequency Analysis

Return Period	Maximum Daily Precipitation [mm/day]											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
200	43.6	49.0	50.9	53.0	61.3	73.9	69.7	56.4	35.0	56.7	62.4	63.3
100	40.7	43.3	46.5	47.4	55.0	66.7	62.3	50.5	34.3	51.1	56.2	57.6
50	37.7	38.0	42.1	42.1	48.7	59.6	54.8	44.4	33.3	45.5	50.2	51.8
25	34.6	32.8	37.6	36.8	42.4	52.4	47.3	38.3	31.8	39.9	44.3	46.1
20	33.5	31.2	36.1	35.1	40.3	50.0	44.9	36.3	31.2	38.0	42.3	44.2
10	30.0	26.2	31.4	29.9	33.9	42.6	37.2	29.8	28.7	32.3	36.4	38.3
5	26.1	21.2	26.3	24.6	27.4	34.9	29.1	23.0	24.8	26.2	30.3	32.2
2	19.4	14.4	18.4	17.0	18.5	23.3	17.0	12.9	16.0	17.1	21.2	22.9

Source: compiled in text from R code, Z:\01_SITES\HB_Mine\1CR012.004_TSF Closure Design\200_Hydrotechnical\R Code HB Closure\HB Closure Hydrotechnical\ Precip-Rev3_SP_VM.Rmd

3.3.2 Short Duration Rainfall

A precipitation-duration-frequency curve for return periods of 2 to 100 years is available for the Castlegar A station (EC 2015). This information was modified for the Facility given the frequency analysis presented in Table 3-4 for a duration of 24-hours. Table 3-7 summarizes the corrected precipitation-duration-frequency (PDF) curve for the Facility.

Table 3-7: HB Mine Tailings Facility – Precipitation Duration Frequency

Duration [min]	Precipitation [mm]					
	2-year	5-year	10-year	25-year	50-year	100-year
5	5.3	8.2	10.2	12.8	14.7	16.6
10	7.3	11.0	13.5	16.6	19.0	21.3
15	8.5	12.6	15.4	18.9	21.5	24.0
30	10.4	15.8	19.4	24.1	27.5	30.9
60	12.6	20.5	25.9	32.8	38.0	43.0
120	16.0	24.0	29.5	36.5	41.7	46.7
360	23.8	32.7	38.7	46.3	51.8	57.3
720	30.7	39.5	45.4	52.7	58.1	63.3
1440	37.9	47.0	53.0	60.5	65.9	71.2

Source: Z:\01_SITES\HB_Mine\1CR012.004_TSF Closure Design\200_Hydrotechnical\ PMP_rev03_spb.xlsm

Note: The 100-year PDF distribution was applied for the 200-year return period and PMP

3.3.3 Probable Maximum Precipitation

The probable maximum precipitation (PMP) was calculated using the Hershfield methodology (Hershfield 1965; WMO 2009). The mean and standard deviation of the site-adjusted annual maxima precipitation values were evaluated and adjusted for maximum observed events, sample size and time intervals (i.e. 24-hour duration). Using these data, the PMP was estimated to be 202 mm.

The PMP was also estimated for the local region using the regional precipitation database. Figure 3-7 illustrates the regional relationship between PMP and elevation, with closer stations represented as small dots and further stations represented as larger dots. In this relationship plot, a PMP for Facility at an elevation of 800 m was determined to be 229 mm and is within the 95% confidence band (grey band).

Given that the PMP of 202 mm is on the lower end of the confidence band, the site PMP was adjusted based on the regional values to 229 mm. This value is considered as appropriate for the Facility PMP.

The PMP estimate of 229 mm represents the annual PMP value. In order to evaluate the probable maximum flood (PMF) for spring and summer (see Section 5.4), the PMP value of 229 mm was conservatively assumed for the summer and adjusted to 198 mm for the spring/winter when snow is typically still present on the ground at the HB site (October to March).

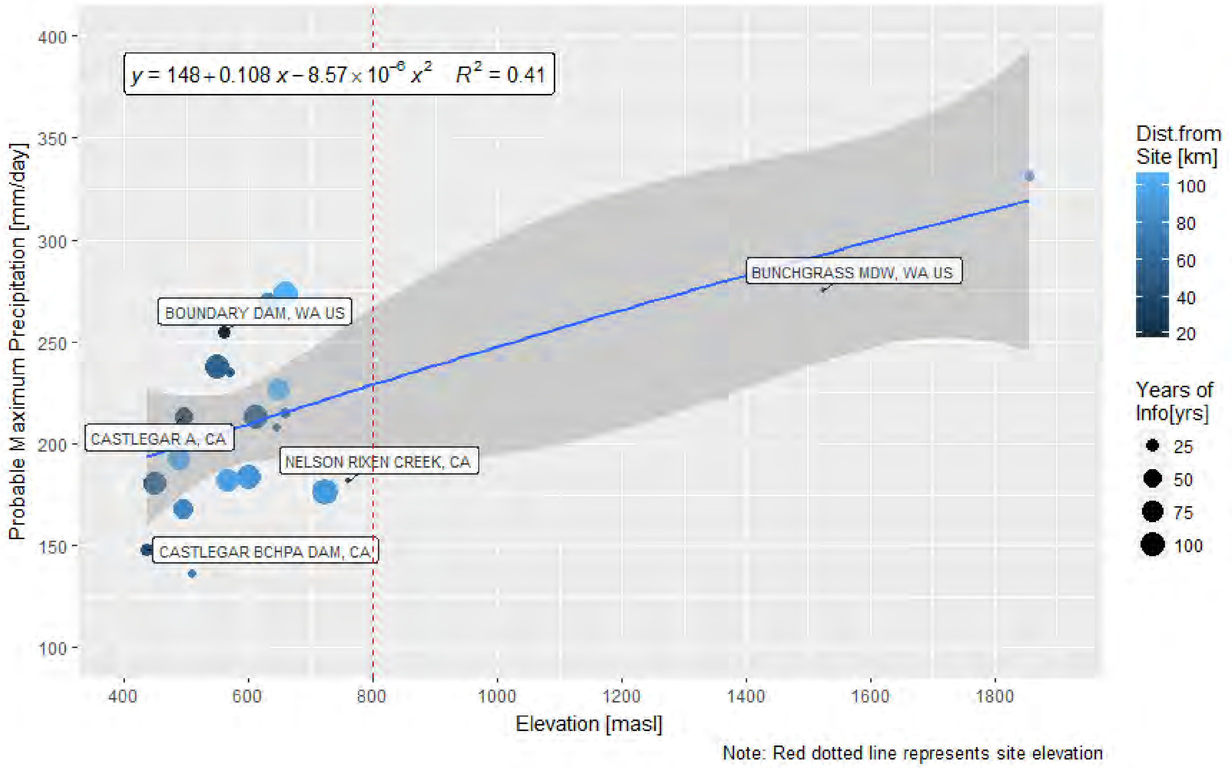

Figure 3-7: PMP regional regression for HB Mine Tailings Facility

3.4 Wind Speed and Wind Gust

Regional data for hourly wind speed and daily wind gust speed were obtained from EC. The available regional wind data was found to be extremely scarce, with a weak regional relationship between these stations for use at the Facility. Data from ERA interim (ECMWF, 2017) was obtained to create a daily wind speed gust timeseries for the Facility. Table 3-8 provides a summary of the wind gust frequency analysis where a wind gust with a 2-year return period was determined to be 133 km/hr.

Table 3-8: Wind Gust Frequency at HB Mine Tailings Facility

Return Period	Wind Gust [km/hr]
100	175
50	168
25	161
20	159
10	152
5	144
2	133

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3.5 Snowmelt Model

Snowmelt was estimated using a subroutine in R (CRAN 2016) called SnowMelt from the library EcoHydRology (Walter et al. 2005), which is a daily energy snowmelt model. This hydrological model is based on meteorological parameters, such as daily maximum and minimum air temperatures, wind speed and total precipitation.

The energy snowmelt model was created for the Facility to evaluate the snowmelt contribution to peak flows. The snowmelt model was validated using snow pillow data at the nearby Redfish Mountain snow pillow station (BCANWSN, 2017). Figure 3-8 and Figure 3-9 illustrates the model validation for snow water equivalent (green line) and snow depths measured at Redfish Mountain (blue line).

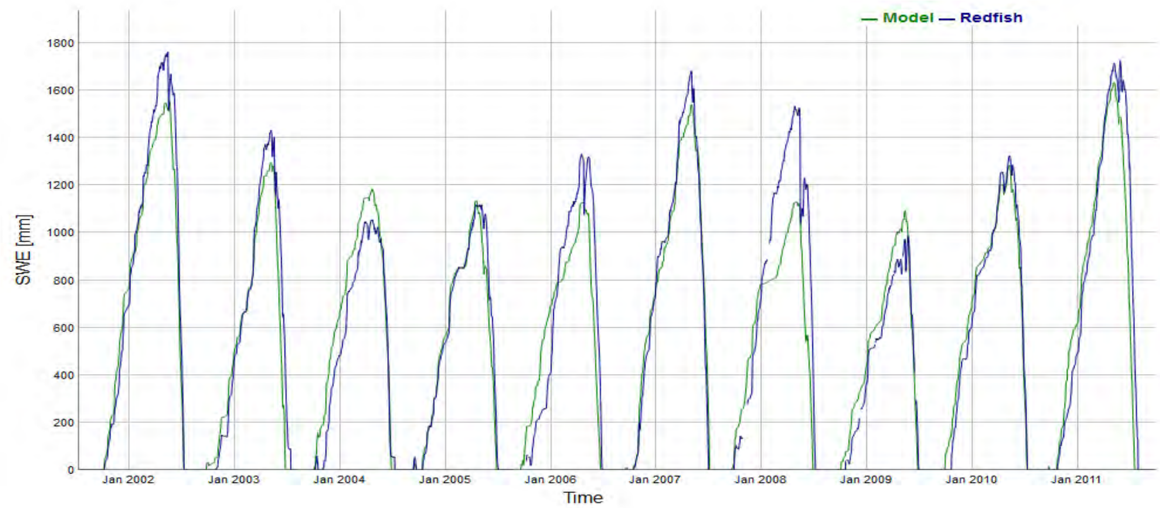

Figure 3-8: Redfish Mountain SWE Model Validation

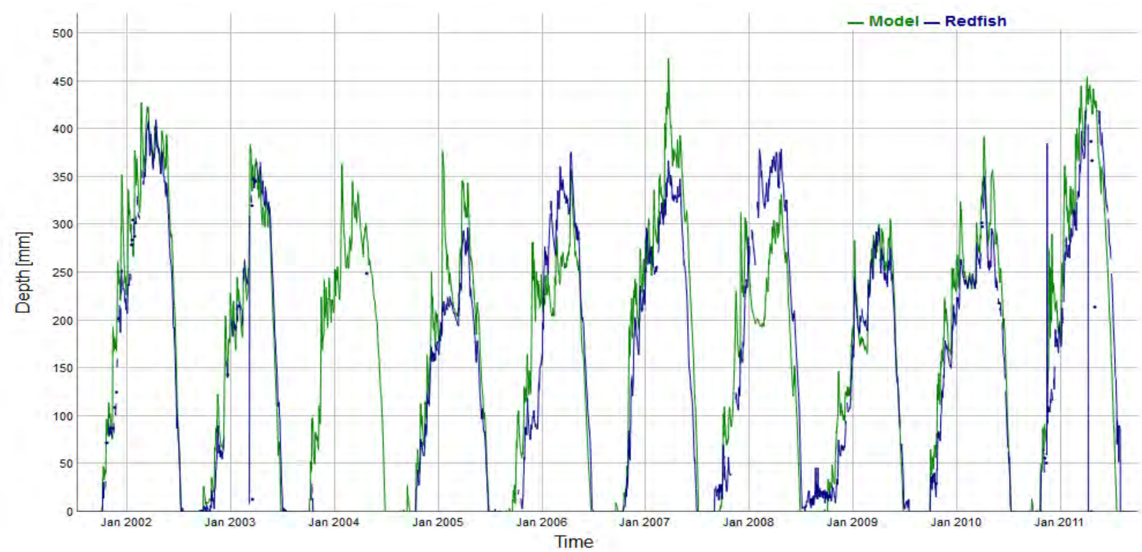

Figure 3-9: Redfish Mountain Snow Depth Model Validation

The snowmelt model was applied for the Facility using the daily synthetic maximum and minimum temperatures, precipitation, and wind speed. Figure 3-10 illustrates average monthly snowmelt depths where typically snowmelt occur during the months of October to March. Table 3-9 provides a summary of the maximum daily snowmelt depths where the maximum 100-year snowmelt expected in a day is 40.2 mm.

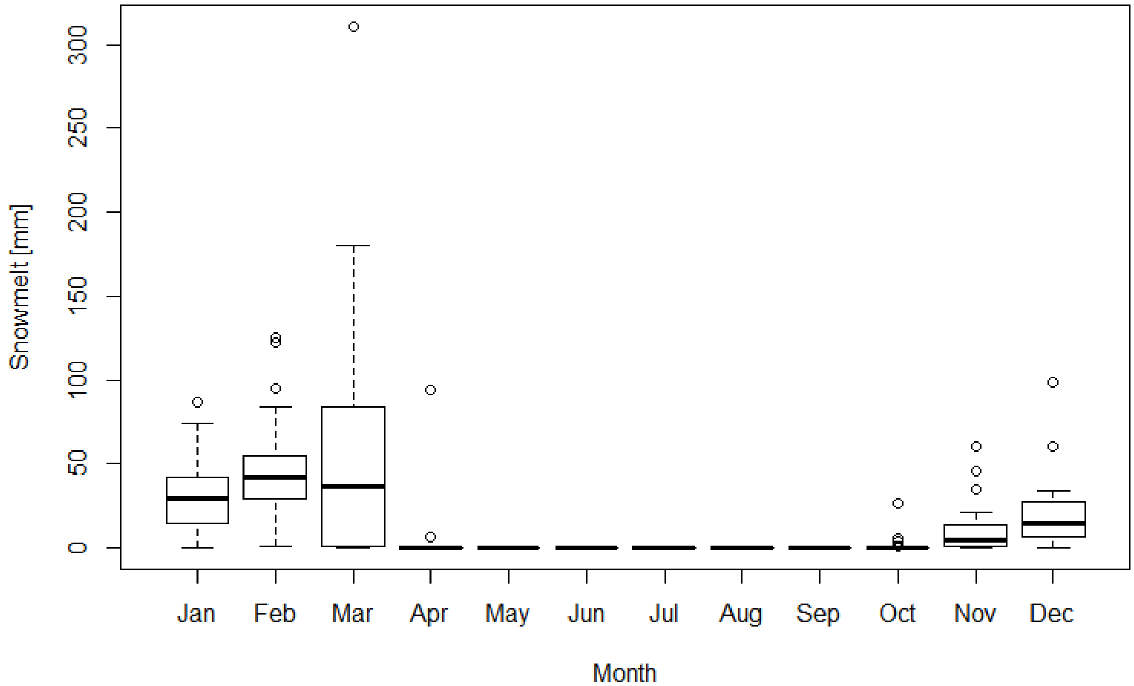

Figure 3-10: Monthly Snowmelt Boxplot at HB Mine Tailings Facility

Table 3-9: Snowmelt Frequency Analysis

Return Period	Snowmelt Depth [mm]
100	40.2
50	36.9
25	33.5
20	32.4
10	28.8
5	24.8
2	18.3

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4 Climate Change Projections

The section below addresses climate change trends and effects that may occur at the Facility in the future. This analysis includes the evaluation of the mean annual air temperature, mean annual precipitation and wind speed and its effects on snowmelt.

4.1 Climate Change Model

Climate change modeling for the Project was conducted through a compilation of Intergovernmental Panel on Climate Change (IPCC) Assessment Reports and by completing a probability analysis on the multiple climatic models using a purpose-built script developed by SRK using R Software (CRAN 2016). The results of the analysis provide an estimate of the expected change of different climatic parameters for a specific longitude and latitude with respect to baseline conditions.

There are five Assessment Reports from the IPCC that present monthly climate change modelling predictions for any location globally:

- First Assessment Report (FAR) (IPCC 1990)
- Second Assessment Report (SAR) (IPCC 1995)
- Third Assessment Report (TAR) (IPCC 2001)
- Fourth Assessment Report (AR4) (IPCC 2007)
- Fifth Assessment Report (AR5) (IPCC 2014)

The Assessment Reports incorporate 58 global climate models with an average of three climatic scenarios for more than 160 climate change predictions. Climate change models presented in these reports assume the application of radiative forces (energy flux) from different anthropogenic sources that results in discharge of varying concentrations of atmospheric greenhouse gases. These radiative forces are not constant through time, as they are based on global anthropogenic behavior. To eliminate bias when choosing a specific climate scenario, all available climate change models are weighted equally in the analysis and present a single climate change design parameter based on a rational statistical evaluation of the overall cumulative results. The goal of the climate change analysis is to obtain one engineering design value which includes the variability of all the different global circulation model (GCM) scenarios available and combines a simple understanding of actual historical conditions with the use of reanalysis data.

IPCC-TGICA (2007) suggests that the best correlated models with present day measurements may not necessarily be the GCM models providing the most reliable predictions. Further, sources of uncertainty (not including bias) are incorporated from estimations for future greenhouse gas and aerosol emissions, global climate sensitivity, and regional climate changes and these cannot be accurately predicted. These are actual sources of uncertainty inherent in the models. To best manage these uncertainties and model variability, SRK has included as many models as possible which allows a quick exploration of the range of consequences based on these scenarios using a concept of a "one-model-one-vote", where every climate change model-scenario is considered to be equally as likely to occur as the others.

The climate predictions are presented up to the year 2100, which is deemed the maximum reasonable timeframe in which to extend predictions.

4.2 Mean Annual Air Temperature

The temperature change with respect to baseline conditions were evaluated based on a percent change in degrees Kelvin. By the year 2100, the temperature is expected to increase by +1.9%. The change in the mean annual air temperature with respect to the baseline value of 7.8°C (Section 3.2), is predicted to increase to 13.2°C.

4.3 Mean Annual Precipitation

The change in the total MAP with respect to the baseline value of 808 mm from Section 3.3, is forecasted to increase by 66mm (+9%) by the year 2100.

The PDF distribution for the Castlegar Airport Station under climate change condition (FIDS 2016) was used to update the Facility PDF.

Table 4-1 provides a summary of the updated PDF curves and the PMP is expected to increase to 250 mm under climate change conditions.

Table 4-1: HB Mine Tailings Facility PDF Under Climate Change Effects

Duration [min]	2-year	5-year	10-year	25-year	50-year	100-year
5	7.7	10.9	13.1	16.0	18.0	20.1
10	10.1	14.1	16.9	20.5	23.1	25.7
15	11.6	16.0	19.1	23.0	25.9	28.7
30	14.6	20.5	24.6	29.7	33.5	37.3
60	19.3	27.9	34.0	41.7	47.3	52.8
120	22.2	31.0	37.1	44.9	50.6	56.2
360	29.5	39.2	45.9	54.3	60.4	66.4
720	35.1	44.7	51.1	59.1	65.0	70.7
1440	41.3	51.2	57.8	65.9	71.8	77.6

Source: Z:\01_SITES\HB_Mine\1CR012.004_TSF Closure Design\200_Hydrotechnical\ PMP_rev03_spb.xlsm

Note: PDF distribution based on the Castlegar A distribution of the 1971 to 2100 RCP 8.5 climate change scenario (FIDS 2016)

4.4 Mean Annual Wind Speed and Wind Gust

The mean annual wind speed at the Facility is projected to increase by 1.9% for the period of 2071 to 2100.

Under the assumption that mean annual wind speed will be corrected in similar magnitude with maximum daily wind gust, Table 4-2 summarizes the frequency analysis for maximum daily wind gust under climate change conditions in 2100.

Table 4-2: Wind Gust Frequency at HB Dam under Climate Change

Return Period	Wind Gust [km/hr]
100	178
50	171
25	164
20	162
10	155
5	147
2	136

4.5 Snowmelt Model

The synthetic timeseries for temperature, precipitation and wind previously described in Section 3 was corrected for climate change conditions. Table 4-3 provides a summary of the maximum snowmelt depth frequency analysis under climate change conditions. The 100-year maximum snowmelt in a day is expected to increase to 54.5 mm.

Table 4-3: Snowmelt Frequency Analysis Under Climate Change

Return Period	Snowmelt Depth [mm/day]
100	54.5
50	45.8
25	37.7
20	35.3
10	28.0
5	21.3
2	12.8

Source: compiled in text from R code, Z:\01_SITES\HB_Mine\1CR012.004_TSF Closure Design\200_Hydrotechnical\R Code HB Closure\HB Closure Hydrotechnical\CC_Snowmelt_Rev1.Rmd

5 Hydrologic Model

The estimation of the Facility PMF was based on the snowmelt parameters, PDF and PMP estimated in Section 3.

The PMF upstream of the HB Dam was modelled the hydrology software HEC-HMS version 4.2 developed by the U.S. Army Corps of Engineers (USACE 2016).

Methods and assumptions for the HEC-HMS model parameter inputs are discussed below.

5.1 Time of Concentration

In support of the preliminary closure design, catchment delineation for each inlet channel on the tailings surface was delineated and routed on the tailings cover (Figure 5-1). Time of concentrations were evaluated for each catchment using the empirical equation developed by Watt and Chow (1985). Table 5-1 presents the time of concentration for each watershed. The basin lag time (T_{lag}) was determined using a relationship to the time of concentration. The National Resource Conservation Service (NRCS) suggests using $T_{lag} = 0.6*T_c$ (2010).

Table 5-1: Time of Concentration Inputs and Results

Catchment ID	Catchment Area (km^2)	Elevation Difference (m)	Path Length (m)	Average Slope (%)	Time of Concentration (min)
1a	0.85	440	2200	20%	27
2	0.47	480	1600	30%	18
1b	0.17	70	900	8%	19
3a	0.61	510	1400	36%	15
3b	0.07	90	600	15%	11

Source: \\VAN-SVR0\Projects\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\302_HydrotechDesign\Inlet_Channel_Design\ Channel Design_Rev01_West_Spillway.xlsm

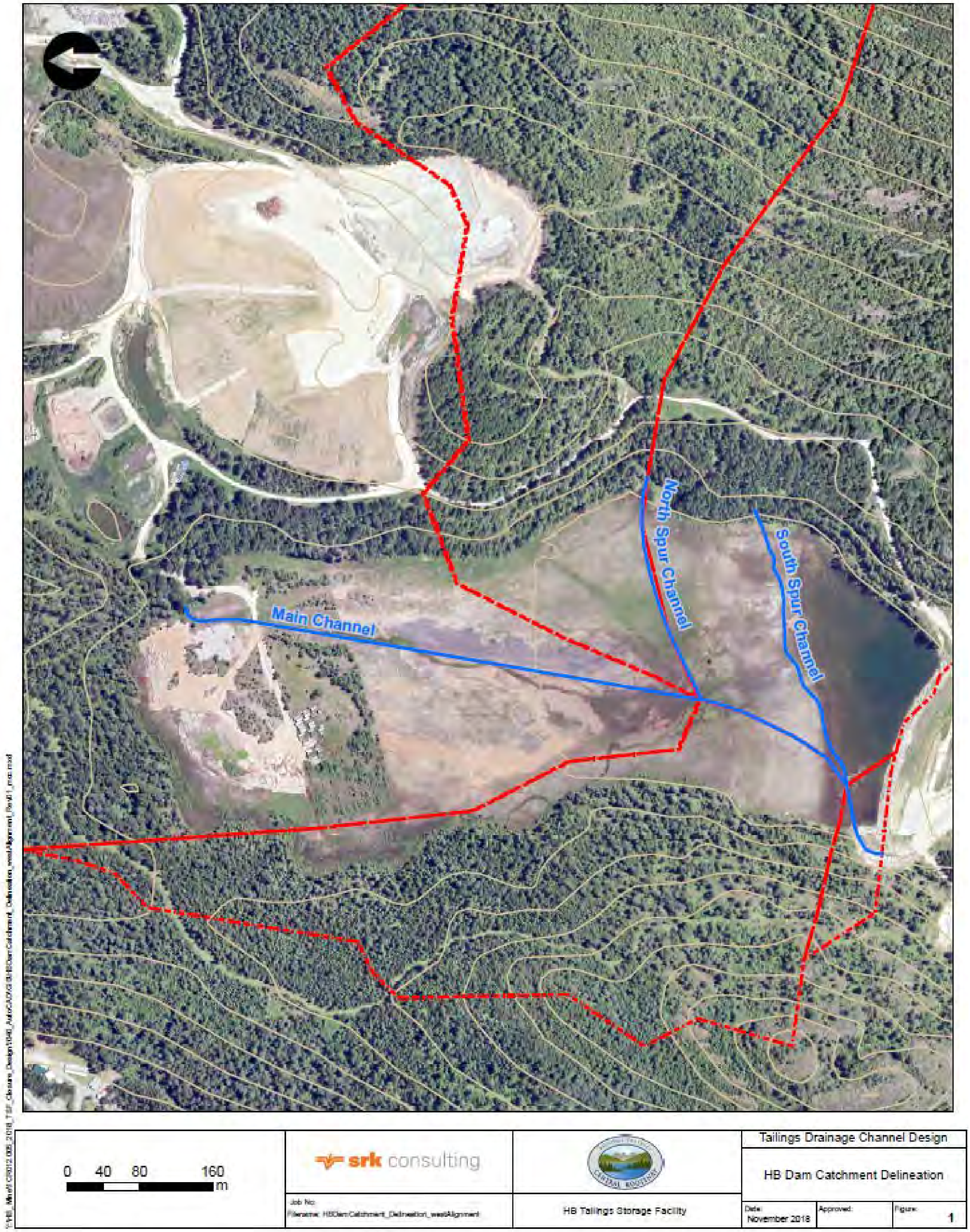

Figure 5-1: Catchment Delineation for the Inlet Drainage Channels

5.2 Critical Storm Hyetograph

The development of a hydrograph from precipitation data requires the development of a storm hyetograph based on two critical components: the storm distribution and storm duration.

The Alternating Block method is a simple hyetograph definition which is derived using the intensity-duration-frequency rainfall data for a given location (Ven Te Chow, 1988). Figure 5-2 illustrates the distribution of the 100-year 24-hr precipitation depth of 77.6 mm under climate change.

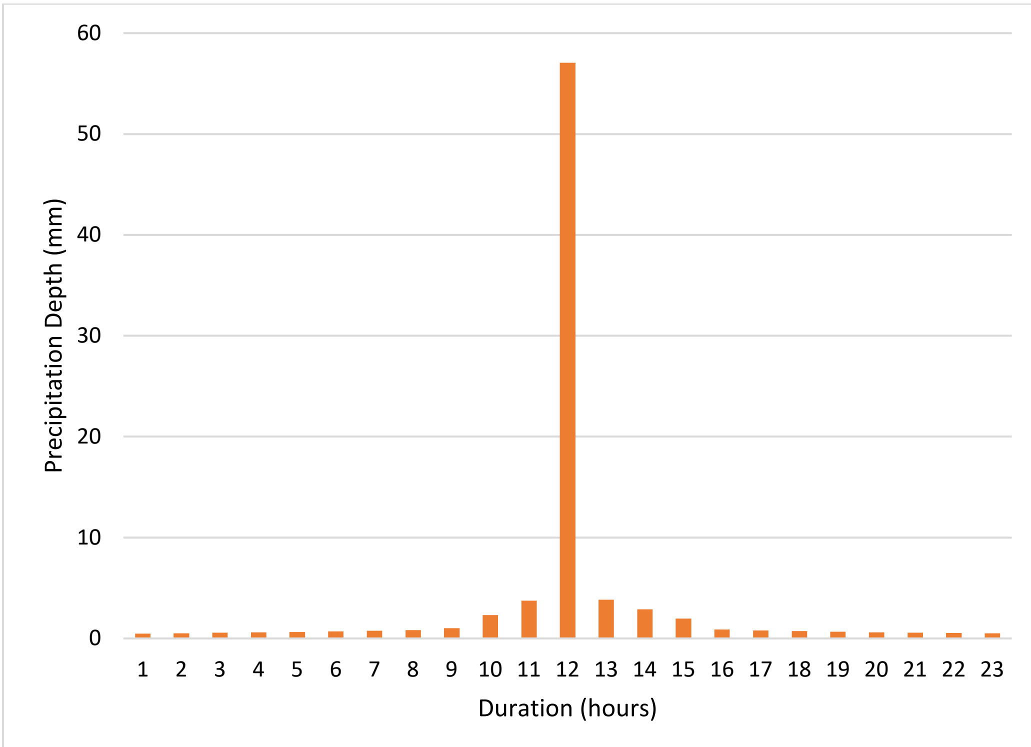

Figure 5-2: 100-year Precipitation Hyetograph

5.3 Curve Number

The SCS Curve Number method was used to estimate runoff and accounts for losses of total precipitation. The Curve Number (CN) is dependent on the SCS hydrologic soil group, land use type, and vegetative cover. The CN for the facility was calibrated using measured peak flows at a nearby hydrometric station.

5.3.1 Curve Number Calibration

Regional hydrometric stations within a 100 km radius from the site and with more than 30 years of flow data were investigated. A total of 28 stations from Water Survey of Canada (WSC) and the USGS were selected for the peak flow analysis. Table 5-2 shows a summary of the metadata and Figure 5-3 illustrates the location of the selected regional stations. Mean annual runoff ranges from 260 mm to 1140 mm and no regional correlations with statistical significance could be established (i.e. elevation, latitude, longitude and MAR). The closest regional station to the Facility is the “Salmo River near Salmo” (08NE074), located approximately 10 km to the south.

Table 5-2: Summary of Regional Hydrometric Station Metadata

Station ID	Station Name	Longitude	Latitude	Area [km^2]	First Year	Last Year
08NE074	Salmo River near Salmo	49.05	-117.29	1240	1949	2015
08NE114	Hidden Creek near the Mouth	49.23	-117.24	56.7	1973	2015
12398000	Sullivan Creek at Metaline Falls	48.86	-117.36	368	1953	2005
12396900	Sullivan Creek at Outlet near Metaline Falls	48.85	-117.29	182	1959	2003
12397100	Outlet Creek near Metaline Falls	48.84	-117.29	133	1959	2015
08NJ130	Anderson Creek near Nelson	49.50	-117.26	9.07	1945	2015
08NJ129	Fell Creek near Nelson	49.50	-117.26	4.4	1945	1996
08NJ162	Smoky Creek above diversions	49.47	-117.52	5.59	1981	1993
08NJ168	Five Mile Creek above City Intake	49.52	-117.21	47.7	1983	2014
08NJ026	Duhamel Creek above Diversions	49.59	-117.24	52.9	1922	2015
12321500	Boundary Creek near Porthill ID	49.00	-116.57	251	1928	2017
08NH032	Boundary Creek near Porthill	49.00	-116.57	242	1928	2013
08NE039	Big Sheep Creek near Rossland	49.01	-117.95	347	1929	2015
08NH016	Duck Creek near Wynndel	49.20	-116.53	57	1921	2015
08NJ061	Redfish Creek near Harrop	49.62	-117.06	27.2	1967	2015
08NH084	Arrow Creek near Erickson	49.16	-116.45	78.3	1945	2015
08NH115	Sullivan Creek near Canyon	49.10	-116.44	6.22	1958	2015
08NJ160	Lemon Creek Above South Lemon Creek	49.70	-117.45	181	1973	2014
08NE087	Deer Creek at Deer Park	49.45	-118.04	81.6	1958	2015
08NH006	Moyie River at Eastport	49.00	-116.18	1480	1915	2015
12306500	Moyie River at Eastport ID	49.00	-116.18	1476	1929	2017

Station ID	Station Name	Longitude	Latitude	Area [km²]	First Year	Last Year
12394000	Priest River near Coolin ID	48.45	-116.90	1582	1948	2006
08NH132	Keen Creek Below Kyawats Creek	49.87	-117.12	92.3	1973	2015
08NH005	Kaslo River below Kemp Creek	49.91	-116.95	442	1914	2015
08NG077	St. Mary River below Morris Creek	49.74	-116.44	208	1973	2016
08NN023	Burrell Creek above Gloucester Creek	49.59	-118.31	221	1974	2015
08NG046	St. Mary River Near Maryville	49.61	-116.17	1480	1945	1995
12392300	Pack River near Colburn ID	48.42	-116.50	321	1958	2017

Source: compiled in text from R code, Z:\01_SITES\HB_Mine\1CR012.004_TSF Closure Design\200_Hydrotechnical\R Code HB Closure\Flow_Rev3_SP_VM.Rmd

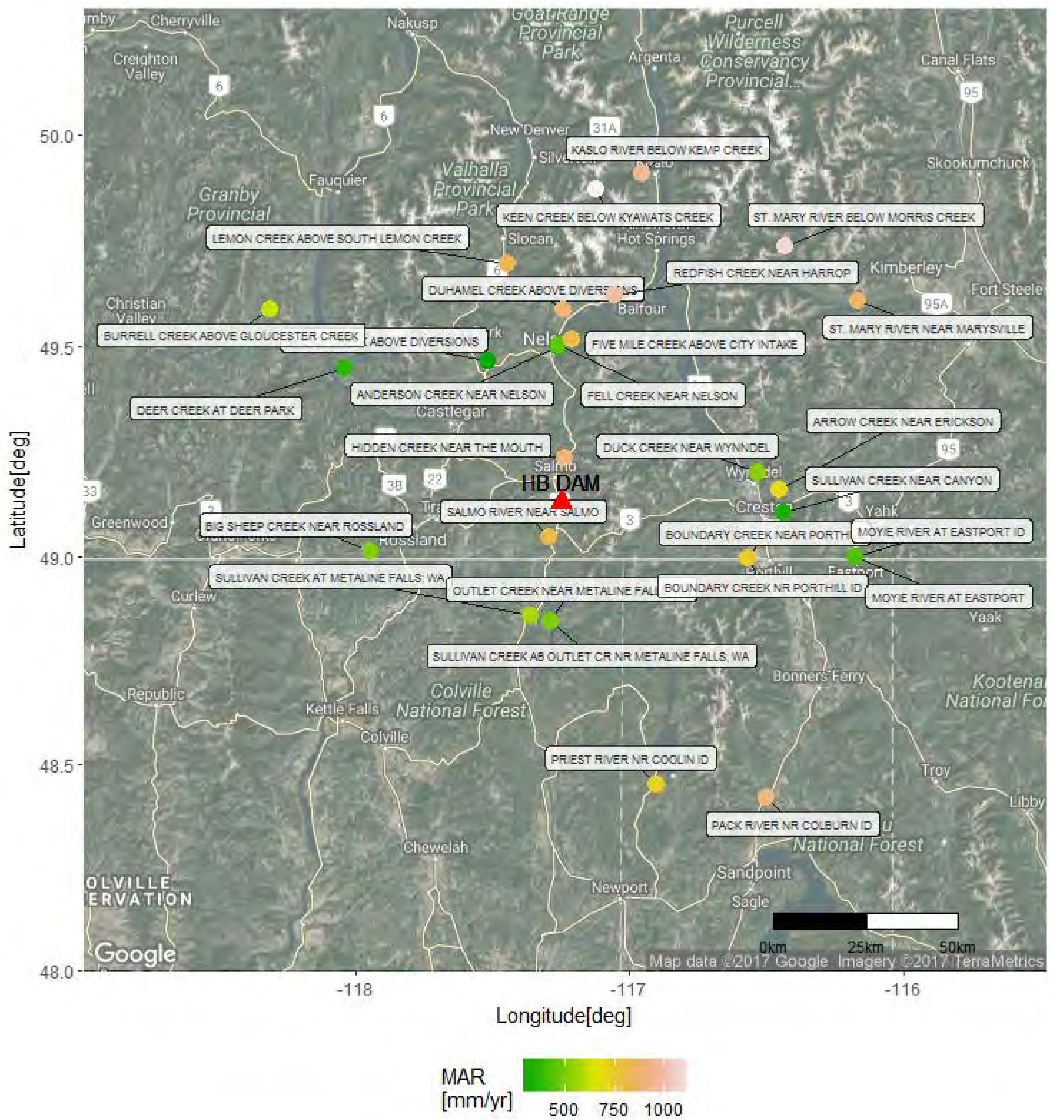

Figure 5-3: Regional Mean Annual Runoff

Figure 5-4 illustrates the 100-year peak flow regional regression analysis where the 100-year peak flow for the Facility catchment (2.18 km2) is estimated to be 1.39 m³/s. A frequency analysis was completed using published instantaneous peak flows for the selected stations presented in Table 5-2. The 100-year peak instantaneous flows for each regional station was plotted against catchment area to highlight the regression analysis to evaluate the 100-year peak flow for an ungauged catchment.

Table 5-3 provides a summary of the catchment input parameters for the calibration of the CN value. It was found that a CN of 54 best represented soil conditions to match the 100-year peak flow. A CN number of 54 is consistent with a natural land use and shallow loess and sandy loam type soils with average antecedent moisture conditions (Singh 1992).

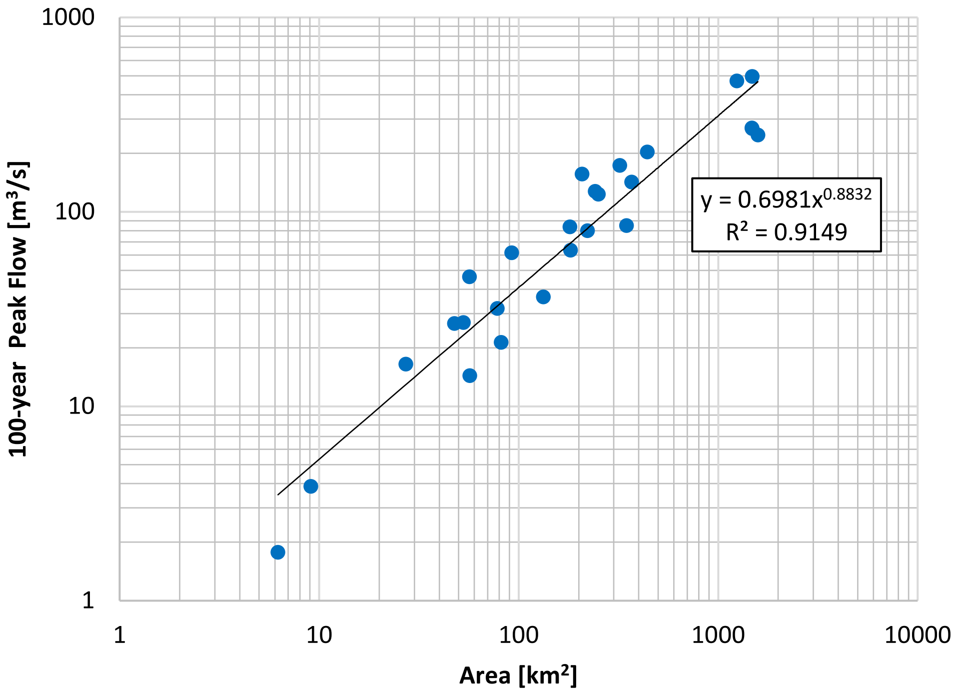

Figure 5-4: 100-year Peak Flow Regression

Table 5-3: Input Parameters for CN Calibration

Parameter	**Value**
Design Return Period	100-year
24-hour Precipitation Depth	71.2 mm
Hyetograph Distribution	Alternating Block Method
Peak Flow	1.39 m^3/s
Catchment Area	2.18 km^2
Loss Method	SCS Curve Number
Transform Method	SCS Unit Hydrograph
Lag Time	11 min

5.4 Hydrologic Scenarios

According to CDA (2014), the inflow design flood (IDF) is the most severe inflow flood (peak, volume, shape, duration, timing) for which a dam and its associated facilities are designed.

There are two PMF cases that must be evaluated:

1. Summer PMF, which is generated by the summer PMP; and
2. Spring PMF, which is defined as the maximum of the following two cases:
   (a) Rainfall dominated event: PMF computed with the spring PMP and snowmelt from a 1 in 100-year snow accumulation; and
   (b) Snowmelt dominated event: PMF computed with the 1 in 100-year rainfall and the snowmelt from the probable maximum snow accumulation.

The reason for computing two separate PMFs for the spring season is that it would not be reasonable to assume that snow accumulation and a spring rainstorm, which are two independent phenomena, occur simultaneously.

Based on Alberta Transportation (2004), the probable maximum snow accumulation (PMSA) can be estimated by multiplying the 100-year snowpack by a factor of 2.0, or another factor based on local site experience. For this study, a factor of 2.0 is applied to evaluate the PMSA.

Table 5-4 summarizes the ten modeled hydrological scenarios for existing conditions and under climate change conditions that were evaluated for the Facility.

Table 5-4: Hydrological Scenarios

Scenario	Condition	Description	Rainfall (mm)	Snowmelt (mm)	Total Water (mm)	Comments
1	Existing	Summer PMF	229	0	229	This value is the same baseline annual PMP value which correspond to summer extreme events.
2		Spring PMF (rainfall dominated)	198	40	238	The spring PMF corresponds the maximum PMF during the months that still have snow on the ground (October to March). As per CDA (2014), the snowmelt value corresponds to the 100-year snowmelt depth (Table 3-8).
3		Spring PMF (snowmelt dominated)	58	80	131	As per CDA (2014), the PMF for a spring snowmelt dominated event is computed using the 24-hour 100-year spring rainfall event and the Probable Maximum Snow accumulation (PMSA). The PMSA was estimated as 2 x the 100-year snowmelt value

Scenario	Condition	Description	Rainfall (mm)	Snowmelt (mm)	Total Water (mm)	Comments
						as suggested by the Alberta Ministry of Transportation (2004).
4		200-year	76	0	76	Corresponds to the value in Table 3-4 .
5		100-year	71	0	71	Corresponds to the value in Table 3-4 .
6	Climate Change	Climate Change - Summer	250	0	250	PMP baseline value increased by 9% as per climate change prediction described in Section 4.3.
7		Climate Change - Spring (rainfall dominated)	215	55	270	Rainfall increased by 9% and snowmelt from Table 4-3.
8		Climate Change - Spring (snow dominated)	63	109	165	Rainfall increased by 9% and snowmelt (PMSA) is 2x100-year snowmelt depth.
9		200-year	83	0	83	Corresponds to a 9% increase to the 24-hour value in Table 3-4.
10		100-year	78	0	78	Corresponds to a 9% increase to the 24-hour value in Table 3-4.

Source: Z:\01_SITES\HB_Mine\1CR012.004_TSF Closure Design\200_Hydrotechnical\ PMP_rev03_spb.xlsb.xlsm

6 Peak Flow Results

The PMF scenarios were modelled in HEC-HMS based on inputs derived in Section 5. In all scenarios, a CN value of 54, lag time of 11 minutes and a total contributing area of 2.18 km^2 was used.

Based on the results in Table 6-1 , the Spring PMF rainfall dominated was determined to be the most critical, where the PMF during climate change conditions (70 m^3/s) is expected to be 40% greater than existing conditions (50 m^3/s).

Table 6-1: Results of Peak Flows

Scenario	Condition	Description	Peak Flow [m^3/s]
1	Existing	Summer PMF	48
2		Spring PMF – Rainfall Dominated	50
3		Spring PMF – Snowmelt Dominated	17
4		200-year	2.2
5		100-year	1.4
6	Climate Change	Summer PMF	62
7		Spring PMF – Rainfall Dominated	70
8		Spring PMF – Snowmelt Dominated	31
9		200-year	4.4
10		100-year	3.2

Source: Z:\01_SITES\HB_Mine\1CR012.004_TSF Closure Design\200_Hydrotechnical\ PMP_rev03_spb.xlsm

6.1 PMF Validation

It is important when estimating the PMF to validate results using regional estimations. The following sections describe two different methods of validating the PMF.

6.1.1 Creager Method

The PMF can be compared worldwide based on the Creager expression. Creager cited by Neill (1985) suggested an overall envelope curve for the maximum flood worldwide based on the watershed area, where the envelope curve is based on one parameter called the Creager coefficient, denoted as “C”. Higher C values suggest higher envelope curves and a higher PMF peak flow. Typically, the Creager coefficient ranges from 30 to 100. (See Figure 6-1). In a national context, Neill (1985) suggested for Canada, C values should be typically within the ranges of 20 to 45.

The existing condition PMF of 50 m^3/s is associated with a C value of 43, which is within the higher range of values suggested by Neill for Canada.

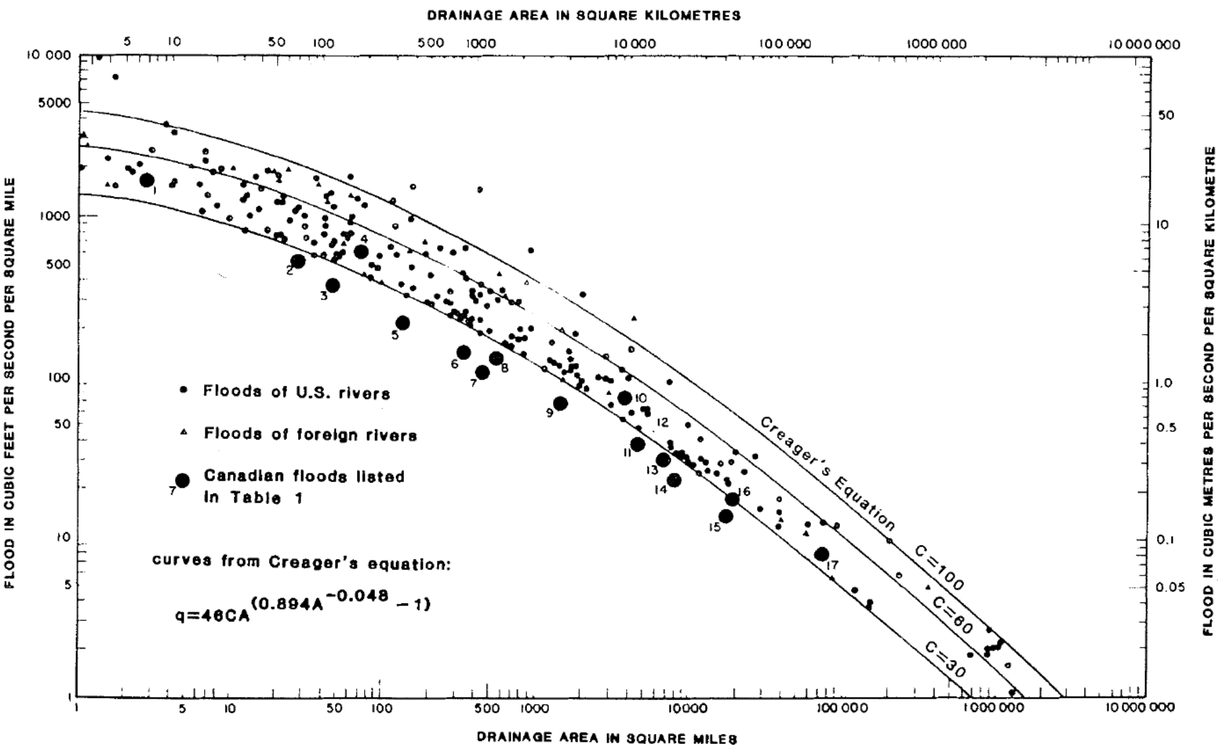

Figure 6-1: Unusual flood peak in Canada superimposed on Creager's plot (Neil 1985)

6.1.2 British Columbia Regional Regressions

Abrahamson (2010) published a report that provides a series of regression indices for high-level estimation of the PMF for British Columbia. The study included regional hydrometric stations and divided the province into zones with similar topography and characteristics. PMF estimations were performed for all suitable hydrometric stations, and results were correlated with catchment area to develop equations that can be applied to other sites.

Based on the location of the project, one equation can be recommended for estimating the PMF:

Columbia Basin: $Q=19.704 \times A^{0.6281}$

The resultant PMF flow rate using the Columbia Basin Equations for a catchment area of 2.18 km^2 is 32 m^3/s.

6.2 Sensitivity Analysis

Table 6-2 shows the sensitivity analysis for the time of concentration on the PMF using two additional empirical compared to the selected method (Watt and Chow, 1985).

Table 6-3 illustrates the sensitivity analysis completed for the curve number. Scenario 1 represents current conditions. Scenario 2 is assuming the CN of 54 for antecedent moisture conditions II and increased to an antecedent moisture condition III. Scenario 3 was developed assuming hydrological conditions are poor for the same type of soil as Scenario 1 under antecedent moisture condition II. Scenario 4 increases scenario 3 to antecedent moisture conditions III.

The sensitivity analyses illustrate that the PMF is most sensible to the curve number. Given that the Creager number for a baseline PMF of 50 m^3/s is approximately 43 and is considered to be on the high end for Canadian watersheds, PMF values greater than this would be abnormally high.

Table 6-2: Time of Concentration Sensitivity Analysis

Catchment ID	USACE (Linsley 1977)	Watt and Chow (1985)	California Highways (1955)
1a	14	27	28
2	9	18	21
1b	10	19	17
3a	8	15	18
3b	6	11	11
PMF (m^3/s)	52	50	47
% Difference	8%	0%	-6%

Source: Z:\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\!080_Deliverables\!DetailedDesignRpt\030_Appendices\E-HydrologicalAssessment\2019 EMPR Comments\HB_Comments.xlsx

Table 6-3: CN Sensitivity Analysis

Scenario	CN Value	Description	Baseline PMF (m^3/s)	% Difference
1	54	Current - good hydrologic conditions Type B AMC II	50	0%
2	73	the above increased to AMC III	72	44%
3	66	Poor hydrologic conditions Type B AMC II	64	28%
4	82	the above increased to AMC III	80	60%

Source: Z:\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\!080_Deliverables\!DetailedDesignRpt\030_Appendices\E-HydrologicalAssessment\2019 EMPR Comments\HB_Comments.xlsx

7 Conclusion

The PMF for the HB Mine Tailings Facility under climate change effects in 2100 was determined to be 70 m^3/s.

The PMF estimate was validated using two regional regression methods. Both the Creager estimate and the British Columbia regression indices present slightly lower PMF estimates than the existing most critical PMF (50 m^3/s) presented in Table 6-1. However, the SRK estimate is within the regional range of estimate which provides sufficient validation for the purpose of the PMF estimation of the Facility.

Table 7-1 provides a summary of the 100 year, 200 year, and PMF flows upstream of the HB Dam under climate change conditions.

Table 7-1: Summary of HB Dam Peak Inflows under Climate Change Impacts

Return Period	Peak Flow [m^3/s]
100	3.2
200	4.4
PMF	70

Source: Z:\01_SITES\HB_Mine\1CR012.004_TSF Closure Design\200_Hydrotechnical\ PMP_rev03_spb.xlsm

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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Appendix C-2 – Probabilistic Seismic Hazard Assessment

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Probabilistic Seismic Hazard Assessment for the HB Mine Tailings Facility

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Probabilistic Seismic Hazard Assessment for the HB Mine Tailings Facility

1 Introduction

The HB Mine Tailings Facility near Salmo, BC has been under the care of the Regional District of Central Kootenay (RDCK) since 1998 when the property was purchased to provide additional buffer and attenuation zones for groundwater from the Central Landfill located northeast of the facility. The HB Dam is located at the south end of the facility across a natural valley and retains approximately 6.63 Mt of tailings. The dam has a “very high” dam hazard classification as defined by the Canadian Dam Association (CDA). In the summer of 2012, a sloughing event occurred in the dam embankment, and the facility has required significant monitoring, maintenance, upgrades, and investigations.

The RDCK has elected to transition the dam to passive closure as defined by the CDA technical bulletin “Application of Dam Safety Guidelines to Mining Dams” [1]. Passive closure reduces the risk of a release of tailings to the environment and minimizes maintenance requirements for the dam, with no management of pond water levels required.

1.1 Purpose

The purpose of the present report is to define the Maximum Design Earthquake (MDE) at the site for assessing the HB Mine Tailings Facility under seismic loading conditions in support of the Closure-Passive Care phase. The seismic parameters employed to define the MDE will be obtained from a site-specific probabilistic seismic hazard assessment (PSHA). The MDE is an upper level earthquake for which the dam should perform without catastrophic failure such as uncontrolled release of a reservoir, although severe damage or economic may be tolerated, and can be considered here as an equivalent to the Safety Evaluation Earthquake (SEE) as defined by ICOLD and the Earthquake Design Ground Motion (EDGM) as defined from CDA

1.2 Scope and Organization

The scope of the present report covers:

- Review of the regional and local seismicity for Western Canada
- Implementation of a spatial model (Earthquake Sources)
- Implementation of a recurrence model (Earthquake Occurrence Rates)
- Implementation of regional Ground Motion Prediction Equations
- Assessment of Annual Exceedance Probabilities for PGA, PGV and Sa
- Definition of Scenario Events
- Estimation of Site Amplification Effects
- Results validation

Amplification effects by time-history analysis (site-response analysis) or frequency-dependent analysis (response spectrum) are beyond the scope. Site amplification effects of the actual site conditions, will be estimated in a simplified way by affecting peak values for PGA and Sa from correction factors [2]. Scaling, selection and generation of design ground motions that meet the specified characteristic, are beyond the scope of this work. Selection of Horizontal Seismic Coefficient (ky) for pseudo-static calculations are also beyond of scope.

1.3 Background Information

- Dam Safety review of HB Mine tailings storage facility (K13103109-01) developed by Tetra Tech EBA Inc.
- Updated Stability Analysis for HB Mine tailings storage facility (704-K13103109-07) developed by Tetra Tech EBA Inc.

1.4 Standards and Codes

This Report has been prepared under the guidelines of the following recommendations

- Application of Dam Safety Guidelines to Mining Dams, Canadian Dam Association: (CDA), 2014
- Dam Safety Guidelines 2007, Canadian Dam Association: (CDA), 2013 Edition
- Technical Bulletin: Seismic Hazard Considerations for Dam Safety, Canadian Dam Association (CDA), 2007
- Bulletin 72 - Selecting seismic parameters for large dams Guidelines, International Commission on Large Dams (ICOLD),2010
- Bulletin 98: Tailings Dams and Seismicity - Review and Recommendations, International Commission on Large Dams (ICOLD), 1995
- ASCE 7-10: Minimum Design Loads for Buildings and other Structures, American Society of Civil Engineers (ASCE), 2010

1.5 Project Team

Gathering of the regional sources and survey of the available hazard information was performed by P. Barbieri. The probabilistic seismic hazard model was developed by Alejandro Verri and implemented in MATLAB by P. Barbieri, M. Balbi and A. Verri. Final computations were performed by P. Barbieri and the final report was written by A. Verri

2 Seismic Hazard Assessment

2.1 Definitions

2.1.1 Passive Care Phase

The HB Mine Tailings Facility, located near Salmo, British Columbia, has been approved to transition to the Closure-Passive Care phase, in which there is no active operation of the mining dam and no changes to the mining dam are expected to occur. The dam is in a steady-state condition that does not require operating personnel on site to manage water levels in the pond upstream of the dam, and no further intervention is required by the owner [1]

2.1.2 Dam Classification

The Dam classification assumes the highest potential consequences, whether loss of life or environmental, cultural or economic losses [1]. According to the CDA Dam Safety Guidelines [3], the Dam Class for the HB Mine Tailings Facility should be considered as a *Very High* (permanent population at risk, significant loss or deterioration of critical fish or wildlife habitat, restoration or compensation in kind possible but impractical and very high economic losses affecting important infrastructure or services).

2.1.3 Probability Levels

Probability levels appropriate for dam design need to be established considering the expected consequences of failure in case it occurs. According to [1], [4] a *Very High* Dam class specifies design ground motions as the maximum Credible Earthquake MCE (if available) or from an annual exceedance probability (AEP) of 1/10.000

2.1.4 Performance Levels

The consequence classification system outlined in the CDA Dam Safety Guidelines [1] is used with the prescribed performance levels in selecting the required seismic loading criteria. Usually, an upper level earthquake related with the ultimate limit state is used to address safety while a lower level earthquake is used to address serviceability (dual-level approach). In a Closure-Passive Care phase, serviceability requirement is not a governing factor and performance levels will be focused only in ultimate limit states [4].

For the design and risk management of dams under seismic excitations, the performance requirement for ultimate limit states is that the dam structures subjected to the upper level earthquake should perform without catastrophic failure such as uncontrolled release of a reservoir, although severe damage or economic may be tolerated. Safety is related to the ultimate limit state. On the other hand, the performance requirements for serviceability limit states is that the dam as well as appurtenant structures and equipment should remain functional (operative) and damage, if any, could be easily reparable after the seismic event [5] [4].

2.1.5 Service Levels: MDE, MCE, SEE and EDGM

There is no consistency in terminology for designating the upper level of earthquakes in the international bibliography ([6], [4], [7], [8], [5] [2]). Terms such as MDE (Maximum Design Earthquake), Maximum Credible Earthquake (MCE), SEE (Safety Evaluation Earthquake) and EDGM (Earthquake Design Ground-Motion) are usually employed for designating upper level earthquakes.

The Canadian Dam Association (CDA) [4] defines the Earthquake Design Ground-Motion (EDGM) which is the level or earthquake ground motions at the location of the dam for which a dam structure is designated and evaluated. To be considered safe, it should be demonstrated that the dam can withstand this level of earthquake shaking without release of water from the reservoir.

The International Commission on Large Dams (ICOLD) [5], [9], [6] defines a similar level for the Safety Evaluation Earthquake (SEE) which is the earthquake ground motion a dam must be able to resist without uncontrolled release of the reservoir. The SEE is the governing earthquake ground motion for the safety assessment and the seismic design of the dam and safety-relevant components, which should be operative after the SEE.

The Maximum Credible Earthquake (MCE) is the largest hypothetical earthquake that may be reasonably expected to occur along a given fault or another seismic source. It is a believable event which can be supported by all known geologic and seismologic data. Is the most severe earthquake that can be expected to occur at a given site based on geologic and seismological evidence.

In this report, the upper level earthquake will be defined as the Maximum Design Earthquake (MDE) and the lower level earthquake as the Operative Basis Earthquake (OBE). When geological and seismological evidence is available for one or more sources, the MCE which would be expected to generate the most severe ground motions would be the maximum design earthquake MDE. Otherwise, the MDE will be a ground motion with prescribed characteristics selected based on a probabilistic level (AEP) of the ground motions that may occur near the dam. According to the Dam Class prescribed for the HB Mine Tailings Facility, the MDE will be the ground motion level with an annual exceedance probability (AEP) of 1/10.000

Table 1 Earthquake hazards standards-based assessments [10].

Dam Class	Annual Exceedance Probability for Earthquakes
Low	1/100
Significant	Between 1/100 and 1/1000
High	1/2500 (*)
Very High	½ between 1/2475 (*) and 1/10,000 of MCE (**)
Extreme	1:10,000 or MCE

(*) This level has been selected for consistency with seismic design levels given in the National Building Code of Canada
(**) MCE have no associated AEP.

2.2 Regional Seismicity for Western Canada

2.2.1 Definitions

According to the Geological Survey of Canada, more than 1,500 earthquakes occur each year in Canadian territory, and only a small percentage of these are of magnitude greater than 3. Approximately 1,000 of these earthquakes occur in Western Canada, the most earthquake-prone region in Canada, and one of the few areas in the world where all three types of plate movements in a fault take place: the plates can either slide past one another, they can collide, or they can move apart. Earthquakes in this region occur along the faults in the Off-Shore region; within the subduction oceanic plate; and within the continental crust. Several seismic regions are identified for Western Canada [11]:

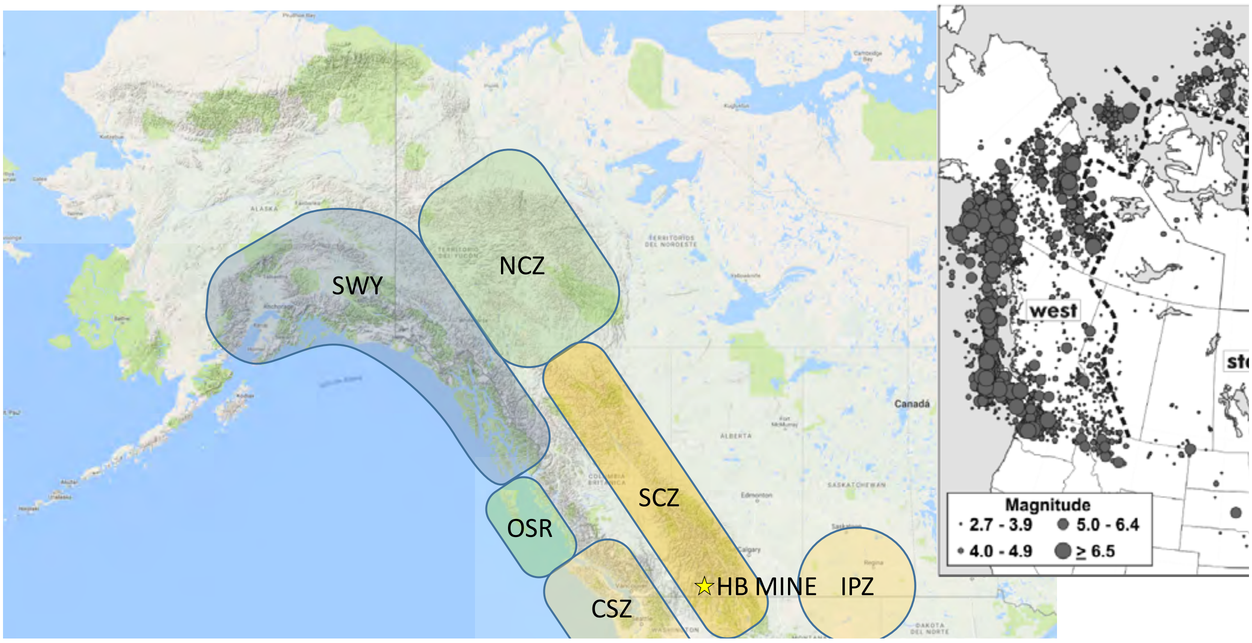

Fig. 1 Seismic zones in Western Canada

2.2.2 Off-Shore Region (OSR)

From northern Vancouver Island, to the Queen Charlotte Islands seismicity is confined to “Queen Charlotte Fault”, that is the boundary between the oceanic pacific plate and North American plate. Canada's largest historical earthquake- a magnitude 8.1, occurred along this fault on August 22, 1949, causing nearly a 500-km-long segment of the Queen Charlotte fault to break. The off-shore region is shown as OSR in Fig. 1.

2.2.3 Cascadia Subduction Zone (CSZ)

West of Vancouver Island, and extending from the north tip of the Island to northern California, the oceanic Juan de Fuca plate is moving towards North America at about 2-5 cm/year. This region is called the Cascadia subduction zone. Here, the much smaller Juan de Fuca plate is sub ducting beneath the continent (about 45 km beneath Victoria, and about 70 km beneath Vancouver). However, there is good evidence that the Juan de Fuca and North America plates are currently locked together, causing strain to build up in the earth's crust. It is this squeezing of the crust that causes the 300 or so small earthquakes located in southwestern British Columbia each year, and the less-frequent (once per decade, on average, damaging crustal earthquakes (e.g., a magnitude 7.3 earthquake on central Vancouver Island in 1946).

Current crustal deformation measurements and geological evidence indicates that at some time in the future, these plates may generate a large subduction earthquake, of similar magnitude to the 1964 M=9.2 Alaska earthquake, or the 1960 M=9.5 Chile earthquake. The available geological evidence also indicates that this subduction earthquakes struck this area every 300-800 years. The Cascadia subduction zone is shown as CSZ in Fig. 1.

2.2.4 St. Elias Region and the South-Western Yukon Territory (SWY)

The St. Elias region of the southwest Yukon Territory, northwest British Columbia, and southeast Alaska is one of the most seismically active areas in Canada. Here, the plate boundary between the giant Pacific and North American plates is changing from one of transform, to subduction. This results in very rapid uplift rates of up to 30 mm/year. The area of the plate margin has experienced many large earthquakes, including a sequence of three earthquakes of magnitude 7.4 to 8.0 in the year 1899. In 1958, a magnitude 7.9 earthquake occurred along the Fair-weather fault (the northern extension of the Queen Charlotte transform fault). The most significant inland zone of seismicity follows the Dalton and Duke River segments of the Denali fault zone through the southwest Yukon. Farther inland, there is minor seismicity between the Denali and Tintina fault systems. The rate of seismic activity increases at the eastern edge of the cordillera. These regions are shown as SWY in Fig. 1.

2.2.5 Northern Cordillera (NCZ)

The northern Rocky Mountain region is one of the most seismically active areas of Canada. The largest earthquake recorded in this area, to date, is the magnitude 6.9 earthquake of December 23, 1985 in the Mackenzie mountains of the Northwest Territories. Magnitude 6-plus earthquakes have occurred in the Richardson Mountains of the Yukon Territory (M=6.2 in May, 1940; M=6.5 in June, 1940, and M=6.6 in March, 1955). The northern cordillera zone is shown as NCZ in Fig. 1.

2.2.6 Southern Cordillera (SCZ)

South of 60 N, seismicity in the interior and Rocky Mountain areas drops off rapidly. The largest earthquake recorded in the southern Cordillera was a magnitude 6.0 in 1918 that struck the Valemount area of the Rocky Mountain trench. In 1986 a magnitude 5.5 earthquake occurred near Prince George, causing some minor damage. The southern cordillera zone is shown as SCZ in Fig. 1.

2.2.7 Interior platform (IPZ)

Seismic activity in the prairie region south of 60 N is predominantly confined to southern Saskatchewan in a zone that continues into Montana. The largest earthquake ever recorded in this area was a magnitude 5.5 event on May 15, 1909 near the Canada - United States border. Small, induced earthquakes associated with potash mining in southern Saskatchewan are sometimes recorded. The interior platform zone is shown as IPZ in Fig. 1.

2.3 Local seismicity

Local Seismicity at the site of HB Mine Tailings Facility has been reviewed from references [12] [13] [14] [15] [16] [17] [18] As a summary, the site of the HB Dam is in the Southern Cordillera where the major “ductile-brittle” faults reported for the area were the southern Purcell Trench fault (Priest River complex); the Kettle River and Granby faults (Kettle-Grand Forks complex); Okanagan Valley and Eagle River faults (Okanagan complex); Slocan Lake fault (Valhala complex); and Columbia

River fault /Shuswap complex). Local faulting has not been considered in the sources model; it can be shown that these sources will have a marginal influence over the overall hazard of the site.

2.4 Earthquake Sources

The earthquake sources capable of producing significant ground motion at the site are identified and characterized from available models. Source characterization includes definition of each source’s geometry and the probability distribution of potential rupture locations within the source. Background sources are employed in areas of diffuse seismicity, where earthquakes are occurring on a poorly understood network of buried faults, and are represented as areal source zones [19].

The sources employed in this report are based in the latest 5th generation model (for the National Building Code of Canada NBCC 2015) developed for the GSC 2015 fifth generation model. The conceptual basis of the definition of these background zones can be found in [20] and can be downloaded from [11]. The GSC has modelled two different seismic source zones, the H (historical seismicity-based) model and the R (regional tectonic-based) model, which reflect geological and seismological features of the considered seismic regions. A subset of 30 sources located within a radius of 1000 km from the site, were considered in the analysis, since the contribution of more distant earthquakes have a negligible contribution to the hazard. The full list of sources employed in the hazard model are shown in Fig. 2 A detailed list of the sources is provided in Appendix A2.

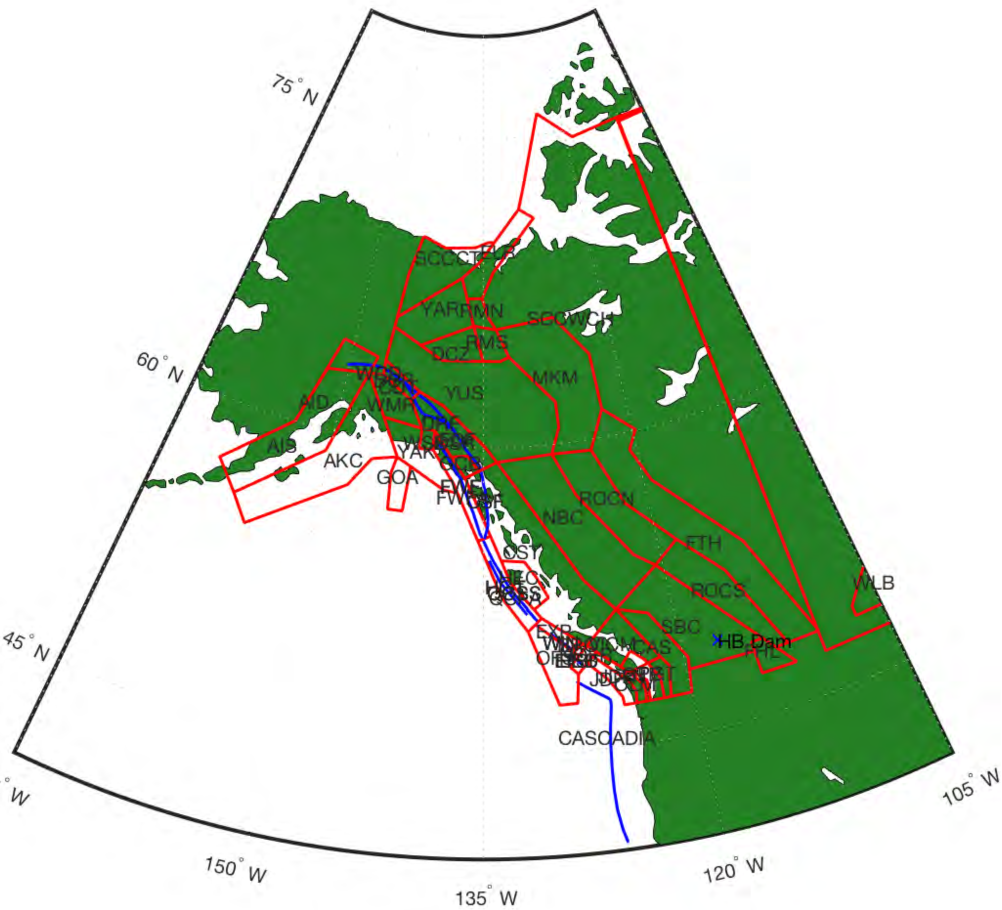

Fig. 2: Seismic sources implemented in the hazard model

2.5 Earthquake Epicenters

A random spatial distribution of the epicenters is assumed inside the boundaries of each source, which is equivalent to assuming a uniform probability density of occurrence of events. This assumption generally results in conservative estimates of seismic hazard, but it reflects the uncertainty that exists in identifying the precise geological features and locations where future earthquakes can occur. The earthquake depths are obtained from a logic tree for three scenarios (best, min, max). For a given source and scenario, a full set of random hypocenters co-ordinates are finally generated by a meshing algorithm based in Montecarlo simulation.

For the HB dam, a mesh grid with 540.000 points separated at 7.5km was employed for the analysis. The 90% of epicenters belongs to the source SCC. Appendix B1 presents the Cumulative Distribution Functions $P\left[R < r^*\right]$ for CASCADIA and SBF sources.

2.6 Earthquake Magnitudes and occurrence Rates

The seismicity or temporal distribution of earthquake occurrence for a given source can be characterized with a recurrence relationship that specifies the average rate at which an earthquake of some magnitude will be exceeded. The recurrence relationship may accommodate the maximum size earthquake, but it does not limit consideration to that earthquake. In general, a given source will produce earthquakes of different sizes up to a maximum earthquake defined empirically or physically. The limits of each source are defined based on the seismologic information available for the area. Each source represents a unique type of mechanism and encompass an area which has a relatively uniform rate of seismic production. The magnitude-recurrence relationship for a given seismic zone is developed by mathematical fit of the historic earthquake data. The annual rate of earthquakes with magnitude greater than m* can be expressed in terms of an asymptotically-truncated Gutenberg-Richter magnitude-frequency distribution.

$$\lambda_M(m^*) = \nu_o \cdot P\left[M > m^*\right] \approx \nu_o \cdot \frac{e^{-\beta\cdot\left(m^* - M_o\right)}}{1 - e^{-\beta\cdot\left(M_{\max} - M_o\right)}} \quad (1)$$

Herein, m is assumed to be equivalent to moment magnitude Mw. Appendix B1 presents the Cumulative Distribution Functions $P\left[M < m^*\right]$ for CASCADIA and SBF sources. Recurrence parameters ν_o β M_o and $M_{\max}$ for the NBCC 2015 sources model are shown in Appendix A1.

2.7 Regional Ground Motion Prediction Equations

The Ground Motion Prediction Equations are regional relations that specify earthquake ground motion parameters, their attenuation with distance, their scaling with magnitude and random variability for all frequencies relevant to the design [21].

The GMPE is an empirical model that express the random variable IM (intensity Measure) in terms of their conditional mean $\eta_{IM/M,R} = \exp\left[\mu_{IM/M,R}\right]$ and their aleatory uncertainty Σ in the form $IM \approx \eta_{IM/M,R} \cdot \Sigma$ [22]. If we assume that the random variable Σ is log-normally distributed with parameters $\eta_{\Sigma} = e^{\mu_{\ln\Sigma}} = 1$ and $\sigma_{\ln\Sigma} = \sigma_{\ln IM/M,R}$, then IM is log-normally distributed and can be expressed in terms of the conditional mean and conditional variance of ln(IM) in the form:

$$\ln IM \approx \mu_{\ln IM/M,R} + \varepsilon \cdot \sigma_{\ln IM/M,R} = f\left(M, R, \{\theta\}\right) \qquad (2)$$

Where $\mu_{\ln IM/M,R}$ and $\sigma_{\ln IM/M,R}$ are deterministic function of magnitude, distance and site conditions and ε is the number of standard deviations

The hazard model for HB dam has implemented numerically the full set of GMPE models specified by the GSC OF. 7576 [23]: The GMPEs are defined for a reference site condition class C ($V_{s30} = 450\,m/s$) according to NBCC 2010 and ASCE 7-10 [2]

2.8 Annual Exceedance Probability (AEP)

2.8.1 Methodology

A probabilistic seismic hazard assessment (PSHA) quantifies numerically the contributions to the intensity measures at the dam site, of all sources for all possible magnitudes within the affected area [24]. In a probabilistic framework, Intensity measures (IM) like peak ground accelerations (PGA) or pseudo-spectral accelerations (PSA), are expressed in terms of an annual exceedance probability (AEP). The methodology employed for estimating the Annual exceedance probability is based on the Cornell-McGuire method initially drafted in [25]. The Cornell-McGuire method combines earthquake occurrence models, seismic source zone models, magnitude-recurrence relationships, and GMPEs through the total probability theorem to assess seismic hazard at a site of interest. The hazard of a given source can be expressed in terms the annual frequency of exceedance for specific levels of seismic intensity due to the potential occurrence of earthquakes from that source. If we assume that the occurrence of earthquakes in that source follows a Poisson process, the probability that a certain seismic intensity parameter, IM, exceeds a certain value im^* during a time interval T_e is given by (3) where of the event defined by IM exceeding a value im^* in the site of interest as a consequence of the earthquakes produced by all the source in the region

$$P_{T_E}\left[IM > im^*\right] = 1 - e^{-\nu_o \cdot P\left[IM > im^*\right] T_e} = 1 - e^{-\lambda_{IM}\left(im^*\right) T_e} \qquad (3)$$

where $\lambda_{IM}(im^*) = \nu_o\, P\left[IM > im^*\right]$ is the annual rate of exceedance during an exposure time T_E and ν_o is the annual frequency of occurrence of earthquakes with magnitude greater than a minimum value M_o. For a given source, the annual rate of exceedance $\lambda_{IM}(im^*) = \nu_o P\left[IM > im^*\right]$ can be expressed by the Total Probability Theorem (TPT) as:

$$\lambda_{IM}\left(im^*\right) = \sum_{i=1}^{NS} \nu_o^{(i)} \sum_{j}^{NM^{(i)}} \sum_{k}^{NR^{(i)}} P\left[IM > im^* / M = m_j, R = r_k\right] P\left[R = r_k\right] P\left[M = m_j\right] \quad (4)$$

The discrete mass probability for magnitudes $P\left[m = m_j\right]^{(i)} \approx f_M^{(i)}\left(m_j\right) dM$ can be obtained from the probability density function (PDF) of Magnitudes, given by the recurrence relationships for $\lambda_M(m^*)$ with source parameters given in Appendix A1.

The discrete mass probability function for distances $P\left[R = r_k\right]^{(i)} \approx f_R^{(i)}\left(r_k\right) dR$ can be obtained numerically from the histogram of an array of hypocenters inside the boundaries of each sources which can be generated by Monte Carlo simulation.

The conditional probability that the seismic intensity IM exceeds a certain value im^* for a given magnitude m_j and hypocentral distance r_k can be obtained from the cumulative density function CDF of the conditional probability $G(im^* / m_j, r_k)$ from

$$P\left[IM > im^* / M = m_j, R = r_k\right] \approx 1 - \Phi\left(\frac{\ln\left(im^*\right) - \mu^{(i)}_{\ln IM/m_j, r_k}}{\sigma^{(i)}_{\ln IM/m_j, r_k}}\right) \quad (5)$$

2.8.2 Results

The mean annual exceedance probability (AEP) for PGA and PGV are shown in Fig. 3 and Fig. 4. AEP curves are defined for a reference site condition class C ($V_{s30} = 760\, m/s$) according to NBCC 2010 and ASCE 7-10 [2]

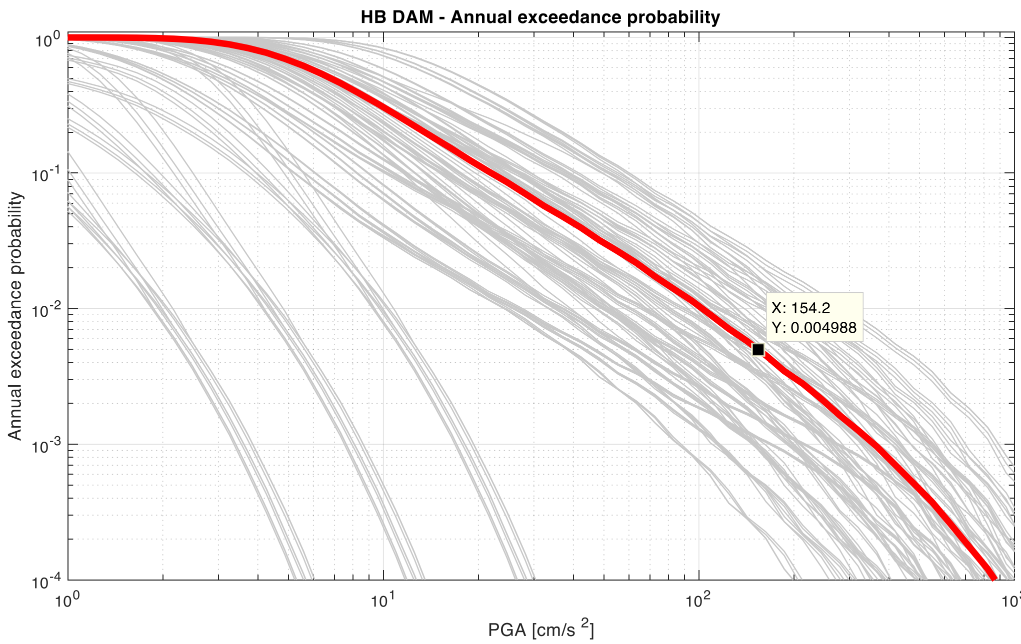

Fig. 3: Mean Annual Exceedance Probabilities for PGA.

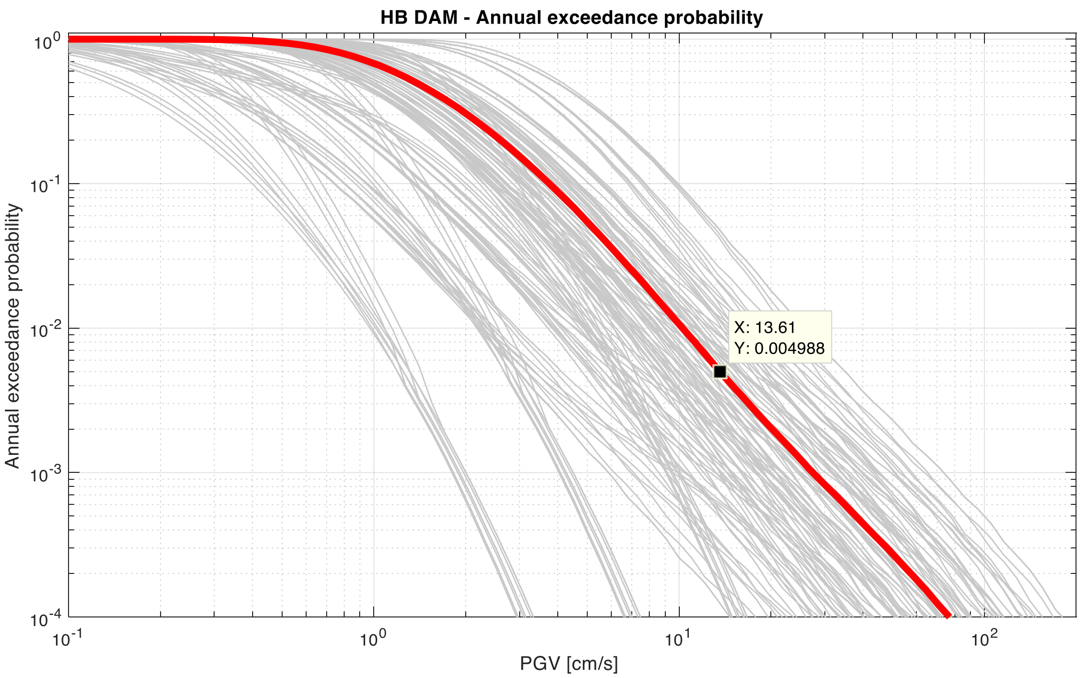

Fig. 4 Mean Annual Exceedance Probabilities for PGV.

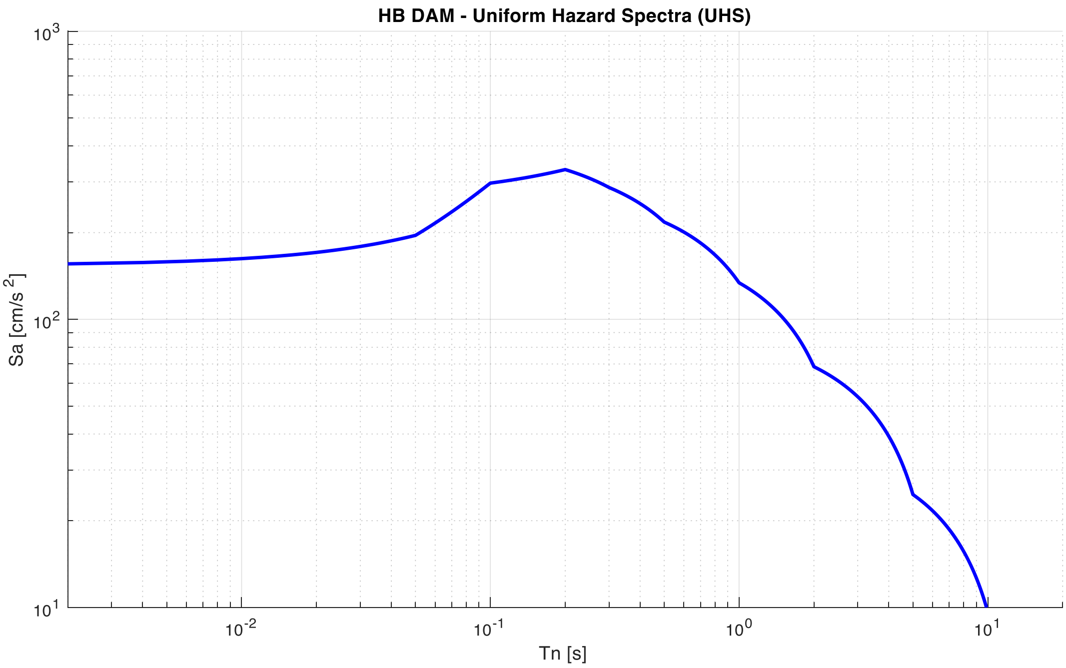

Fig. 5 Mean Uniform Hazard Spectra.

2.9 Treatment of Uncertainty

2.9.1 Methodology

The annual exceedance probabilities obtained from a site-specific seismic hazard evaluation must be defined with appropriate uncertainty factors for low-probability design [4, 9]. The hazard model considers two types of uncertainty; aleatory uncertainty and epistemic uncertainty [7]. Aleatory uncertainty is the physical variability that is inherent to the unpredictable nature of future events. This type of uncertainty is included by the traditional Cornell-McGuire method by incorporating a standard deviation of the ground motion attenuation relationship that reflects the scatter of the data about the median ground motion value. The epistemic uncertainty arises from incomplete knowledge of the physical mechanism, differences in expert specification of modeling assumptions and extrapolation beyond observed range of data. Epistemic uncertainty can be reduced by collection and analysis of additional information or data [8] by implementing a “logic tree” approach to include different attenuation models, values of depths or any other parameter that involves experimental data adjustment [26] [27].

The uncertainty factors can be obtained from the n-th percentile of an array of scenarios derived from a Logic Tree. Logic trees are implemented at sources-level to quantify the epistemic uncertainty in hypocenter locations, fault geometry, recurrence parameters, limiting magnitudes and attenuation models (GMPE). For the HB dam, a logic tree of 2430 different branches was considered by combining 81 branches over 30 sources. The methodology employed in defining the uncertainty factors is summarized in the following paragraphs.

For a given source (i) and a given intensity level $\left\{im^*\right\}_l$, a full set of 81 scenarios of AEP $\left\{\lambda_{IM}^{(i)}(im_l^*)\right\}_b = \lambda_{i,l,b}^*$ can be obtained by combining all different possible scenarios of hypocenter depths, fault geometries, recurrence parameters, limiting magnitudes and attenuation models. For a given intensity level im_l^* there are a set of NB branches $\left\{\lambda_{IM}^{(i)}(im^*)_1, \lambda_{IM}^{(i)}(im^*)_2, \ldots, \lambda_{IM}^{(i)}(im^*)_b, \ldots, \lambda_{IM}^{(i)}(im^*)_{NB}\right\}$ for each source which weights $\left\{w_1, w_2, \ldots, w_b, \ldots, w_{NB}\right\}$. Since the summation of all branch weights are always equal to the unity, a piecewise-linear cumulative density function (CDF) can be readily derived from which a full range of (random) values of AEPs can be obtained by Montecarlo simulation. Integrating over all sources, the array of NSYM values of AEP results in

$$\left\{\lambda_{IM}(im_l^*)\right\} \approx \sum_{i=1}^{NS} \left\{\lambda_{IM}^{(i)}(im_l^*)\right\} \cdot W^{(i)} \qquad (6)$$

For a given intensity level, the array $\left\{\lambda_{IM}(im_l^*)\right\}$ with NSYM elements represents all possible outcomes of AEP for PGA, PGV and PSA, from which mean, 84th 95th and any other percentiles can be readily obtained

2.9.2 Results

The annual exceedance probability (AEP) for PGA and PGV for 84th and 95th percentiles are shown in Fig. 6 and Fig. 7. AEP curves are defined for a reference site condition class C ($V_{s30} = 450\,m/s$) according to NBCC 2010 and ASCE 7-10 [2]

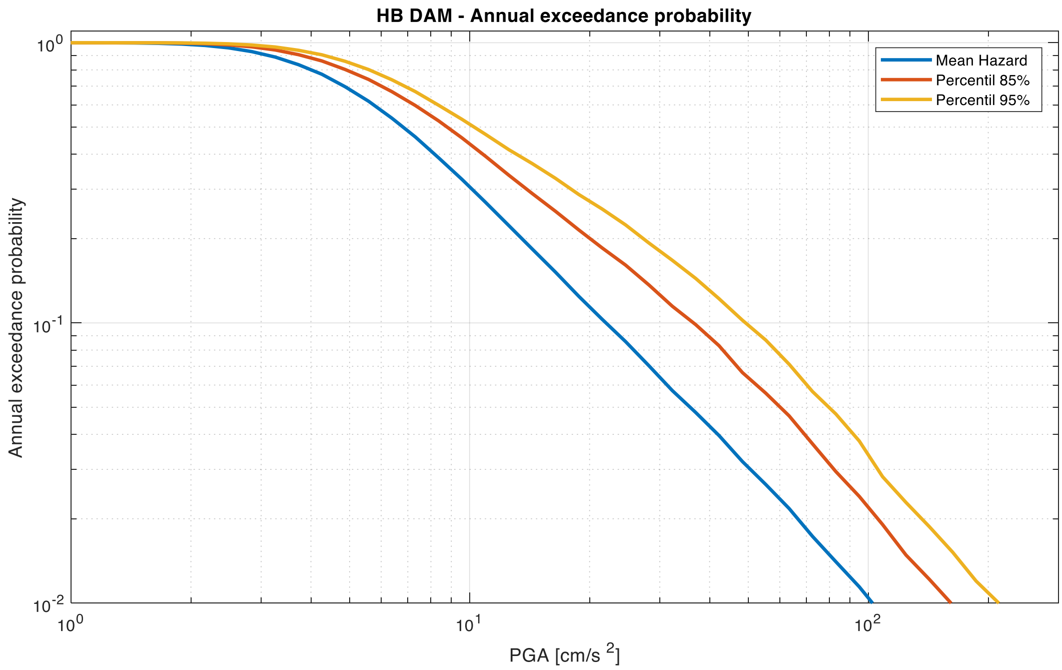

Fig. 6: AEP curves for mean, 84th and 95th percentile for PGA

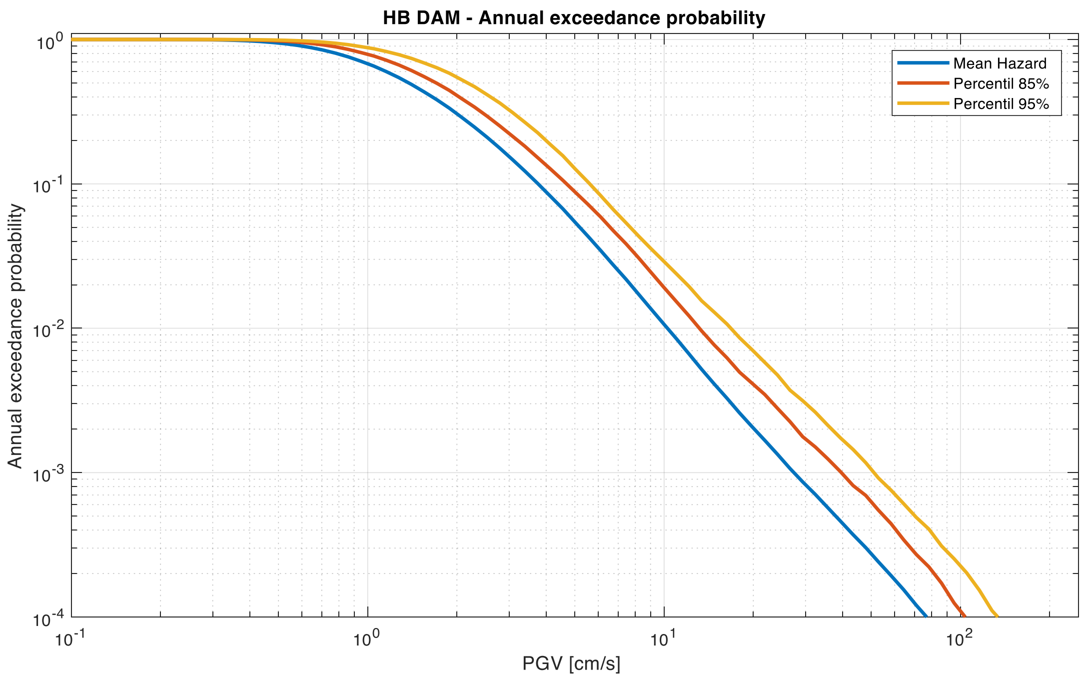

Fig. 7 AEP curves for the mean, 84th and 95th percentile for PGV

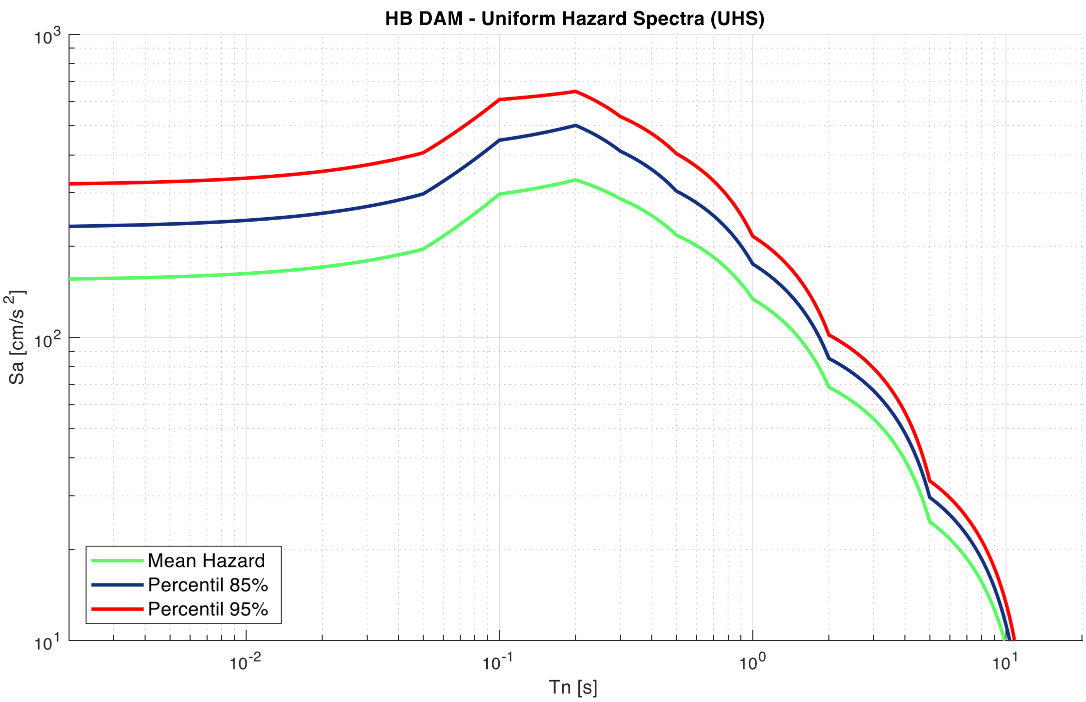

Fig. 8 UHS for MDE. for mean, 84th and 95th percentiles.

Table 2 PSA values for MDE. mean, 5th, 16th 84th and 95th percentiles

Tn [s]	Sa [cm/s²]				
	5th	16th	mean	84th	95th
PGA	51.8	63.68	154.2	229.8	327.6
0.05	63.2	78.9	195.6	297.5	406.7
0.1	94.2	119.1	297.1	447.6	609.7
0.2	114.6	140.6	331.1	501	648.4
0.3	115.6	139.3	285.8	411.7	535.8
0.5	97.6	119.3	217.6	304	404
1	69.8	83.8	134.9	174.8	215.9
2	39	45.4	68.5	85.2	101.9
5	14.1	16.3	24.7	29.7	33.7
10	5.5	6.5	9.6	11.3	13.3

2.10 Site Amplification Effect

Site amplification effects of the ground motions from bedrock to the top layer were considered. The soil class beneath the HB dam is Class "D" ($V_{s30} = 270\, m/s$). The GMPEs (and hazard values) were defined for a reference site condition class C ($V_{s30} = 450\, m/s$). Site amplification effects of the actual site conditions, can be estimated from a correction factors provided by ASCE 7-10 [2] (see Appendix B3) Corrected values for mean, 84th and 95th percentiles of PGA, PGV and PSA are shown in the following tables

Table 3 Corrected PGA values for HB dam site with soil Class D

AEP	MEAN		84th		95th	
	PGA [cm/s^2]	$F_{D/C}$	PGA [cm/s^2]	$F_{D/C}$	PGA [cm/s^2]	$F_{D/C}$
10% (in 50 yr)	30.4	1.33	50.7	1.33	68.4	1.33
4.9% (in 50 yr)	48.5	1.33	81.3	1.33	108.1	1.33
2% (in 50yr)	93.2	1.33	142.7	1.33	182.8	1.33
1% (in 50 yr)	137.1	1.33	214.7	1.33	232.7	1.10
0.5% (in 50 yr)	***205.6***	***1.33***	***250.9***	***1.10***	***349.4***	***1.10***

Table 4 Corrected PGV values for HB dam site with soil Class D

AEP	MEAN		84th		95th	
	PGV [cm/s]	D/C	PGV [cm/s]	$F_{D/C}$	PGV [cm/s]	$F_{D/C}$
10% (in 50 yr)	5.3	1.33	6.4	1.33	7.7	1.33
4.9% (in 50 yr)	7.1	1.33	8.9	1.33	10.4	1.33
2% (in 50yr)	10.5	1.33	13.1	1.33	16.1	1.33
1% (in 50 yr)	13.9	1.33	16.2	1.33	18.3	1.10
0.5% (in 50 yr)	***18.5***	***1.33***	***19.6***	***1.10***	***28.1***	***1.10***

2.11 Results Validation

The 2015 edition of the National Building Code (NBCC 2015) provides hazard values and hazard maps for various Canadian cities including Salmo, BC, near of the BC Mine Tailing Facility. The NBCC hazard model - developed by J. Adams and S. Halchuk [28] [20] reports PGA and PSA for an annual exceedance probability (AEP) of 1/2500 (2% in 50 years). The target AEP from the NBCC model has been selected to achieve uniform reliability across the country for building design. Peak ground accelerations (PGA) and pseudo-spectral accelerations (PSA) were obtained for the 50th percentile (median) values considering Canada-wide reference ground conditions [3].

Although the national hazard values obtained from the NBCC model are not suitable as design hazard values, they can be employed as reference values for validating the SRK site-specific hazard model for the target AEP of 1/2500.

For validation purposes, a PSHA was performed at the Kootenay Canal site with the same parameters that were used for the HB Dam site, and compared to NBCC 2015 values. Hazard Values were corrected to the B Site Class condition. Results are shown in the following table:

Table 5 PGA values at Kootenay Canal

Tr [yr]	SRK 2017 PGA [cm/s2]	NBCC 2015 PGA [cm/s2]	DIFF
475	18.3	16.5	10%
1,000	30.3	26.9	11%
2,000	48.4	41.4	14%
2,475	55.5	47.3	15%

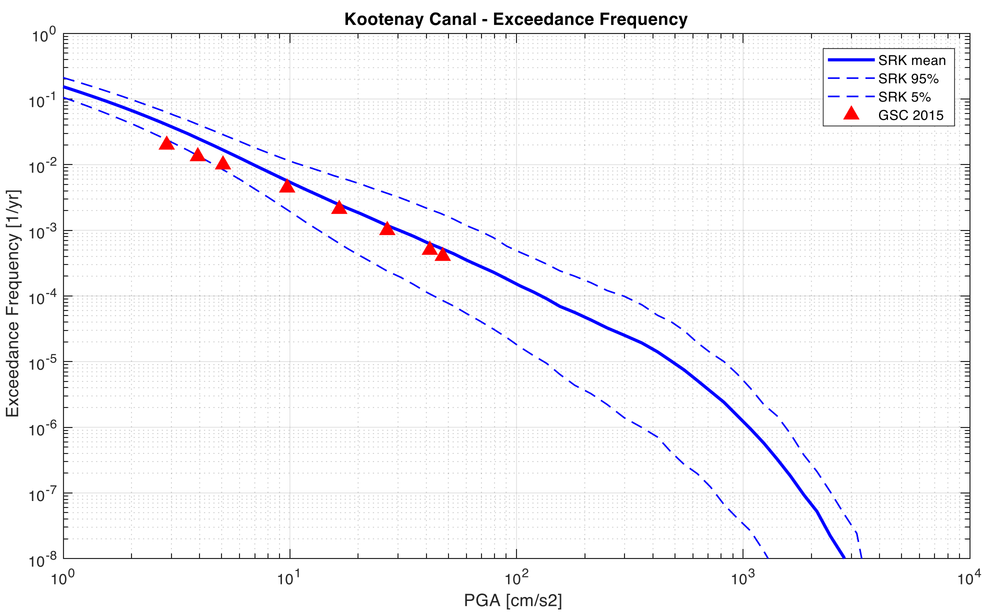

Fig. 9: Mean AEP for PGA at Kootenay Canal. Site Class B

3 Conclusions

In this report, the Maximum Design Earthquake (MDE) for the HB Mine Tailings Facility under seismic loading conditions in support of the Closure-Passive Care phase, has been defined. The Maximum Design Earthquake (MDE) was defined as an event with an Annual Exceedance Probability (AEP) of 0.5% in 50 years (~10,000 years Return Period).

The seismic parameters required to define the MDE were obtained from a site-specific probabilistic seismic hazard assessment (PSHA) The hazard model was implemented in a suite of MATLAB subroutines, with fault geometries, ground-motion prediction equations (GMPEs), and recurrence parameters imported from the Fifth Generation Seismic Hazard Model of the Geological Survey of Canada. The Open File 7576 [29]. employed herein, has been implemented by the GSC to produce the hazard maps for the 2015 National Building Code of Canada (NBCC)

A set of 30 sources located within a radius of 1000 km from the site were considered in the analysis. Risk contributions from sources zones more than 1000 km from site were excluded, as the hazard contributions beyond this cut-off distance are negligible. A full set of 540.000 hypocenters were generated by a meshing algorithm based in Montecarlo simulation.

The Ground Motion Prediction Equations (GMPE) were implemented according reference [23]. The GMPEs were defined for a reference site condition class C ($V_{s30} = 450\, m/s$) and the PGA, PGV and PSA values for the HB Dam site were corrected for a site condition class D ($V_{s30} = 270\, m/s$), according to ASCE 7-10 [2]

For the HB dam site, the MDE has a PGA with a mean value of 0.210 g, a 84th percentile value of 0.256 g and 95th value of 0.356 g.
The MDE defined herein can be considered as an equivalent to the Earthquake Design Ground Motion (EDGM) from reference [4]

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Appendices

Appendix A NBCC 2015 Seismic Sources

A1. Recurrence Parameters

Table 6 Recurrence parameters for NBCC 2015 seismic sources.

SOURCE ID	a			beta			Mo	Mmax		
	MIN	BEST	MAX	MIN	BEST	MAX	BEST	MIN	BEST	MAX
BRO	0.88	1.08	1.30	0.79	1.07	1.36	4.8	6.9	7.2	7.5
CAS	1.71	2.01	2.31	1.42	1.76	2.10	4.8	6.9	7.2	7.5
CASCADIA	-2.70	-2.70	-2.70	-5.00	-3.50	-5.00	8.5	9.02	9.1	9.2
CST	2.20	3.44	4.65	1.54	2.40	3.25	4.8	6.9	7.2	7.5
EISB	-2.52	-2.52	-2.52	-5.00	-5.00	-5.00	7.5	8	8	8
EISI	-3.05	-3.05	-3.05	-5.00	-5.00	-5.00	7.5	8.5	8.5	8.5
EISO	-2.17	-2.17	-2.17	-5.00	-5.00	-5.00	7.5	7.6	7.6	7.6
EXP	2.93	3.12	3.34	1.65	1.84	2.02	4.8	6.9	7	7.3
FHL	1.86	2.24	2.51	1.24	1.54	1.85	4.8	7.2	7.3	7.7
FTH	1.85	2.44	3.03	1.48	2.00	2.52	4.8	6.9	7.0	7.5
GTP	1.72	1.69	2.06	1.06	1.09	1.40	4.8	7.0	7.2	7.5
HEC	2.62	2.84	3.06	1.77	2.02	2.26	4.8	6.9	7.2	7.5
JDFF	1.79	2.20	2.62	1.54	2.00	2.46	4.8	6.9	7.0	7.3
JDFN	1.42	1.72	2.03	1.23	1.59	1.95	4.8	6.9	7.0	7.3
NBC	1.72	2.23	2.83	1.48	2.00	2.52	4.8	6.9	7.2	7.5
NOFR	3.32	3.40	3.50	1.84	1.94	2.05	4.8	6.9	7.0	7.3
OFS	5.19	5.40	5.62	2.17	2.29	2.42	4.8	6.9	7.0	7.3
QCSS	-1.17	-0.97	-0.78	0.00	0.00	0.00	6.5	8.07	8.2	8.4
QCSS	4.03	4.12	4.21	1.84	1.84	1.84	6.5	8.07	8.2	8.4
SCCECH	2.72	3.15	3.53	1.69	2.00	2.26	4.8	6.8	7.0	7.2
SCCECR	2.69	3.13	3.50	1.69	2.00	2.26	4.8	6.8	7.0	7.2
SCCEHYBH	2.72	3.15	3.53	1.69	2.00	2.26	4.8	6.8	7.0	7.2
SCCEHYBR	2.70	3.14	3.51	1.69	2.00	2.26	4.8	6.8	7.0	7.2
SCCWCH	2.19	2.63	3.00	1.69	2.00	2.26	4.8	6.8	7.0	7.2
WIN_A	-1.43	-0.99	-0.26	0.00	0.00	0.00	7.0	7.1	7.4	7.7
WIN_B	3.36	3.66	4.26	1.84	1.84	1.84	7.0	7.1	7.4	7.7
WIN_C	-	-	-	1.84	1.84	1.84	7.0	7.1	7.4	7.7

A2. Geometrical Parameters

Table 7 Aerial and Fault plane parameters for NBCC 2015 seismic sources.

ID	ho [km]			Dip Angle [º]		Dip Depth [km]		
	MIN	BEST	MAX	UPPER	LOWER	LOWER	MIDDLE	UPPER
BRO	10	15	5	-	-	-	-	-
CAS	10	15	5	-	-	-	-	-
CASCADIA	-	-	-	12	8.5	5	15	27
CST	10	15	5	-	-	-	-	-
EISB	-	-	-	18	18	5	10	22
EISI	-	-	-	18	18	5	10	28
EISO	-	-	-	18	18	5	10	16
EXP	10	15	5	-	-	-	-	-
FHL	10	15	5	-	-	-	-	-
FTH	10	15	5	-	-	-	-	-
GTP	50	50	50	-	-	-	-	-
HEC	10	15	5	-	-	-	-	-
JDFF	10	15	5	-	-	-	-	-
JDFN	35	40	30	-	-	-	-	-
NBC	10	15	5	-	-	-	-	-
NOFR	10	15	5	-	-	-	-	-
OFS	7	10	5	-	-	-	-	-
QCSS	-	-	-	90	90	0	10	20
QCSS	-	-	-	90	90	0	10	20
SCCECH	10	20	5	-	-	-	-	-
SCCECR	10	20	5	-	-	-	-	-
SCCEHYBH	10	20	5	-	-	-	-	-
SCCEHYBR	10	20	5	-	-	-	-	-
SCCWCH	10	15	5	-	-	-	-	-
WIN	-	-	-	15	15	2	3.5	5
WIN	-	-	-	15	15	2	3.5	5
WIN	-	-	-	15	15	2	3.5	5

A3. Source Types and Source Mechanisms

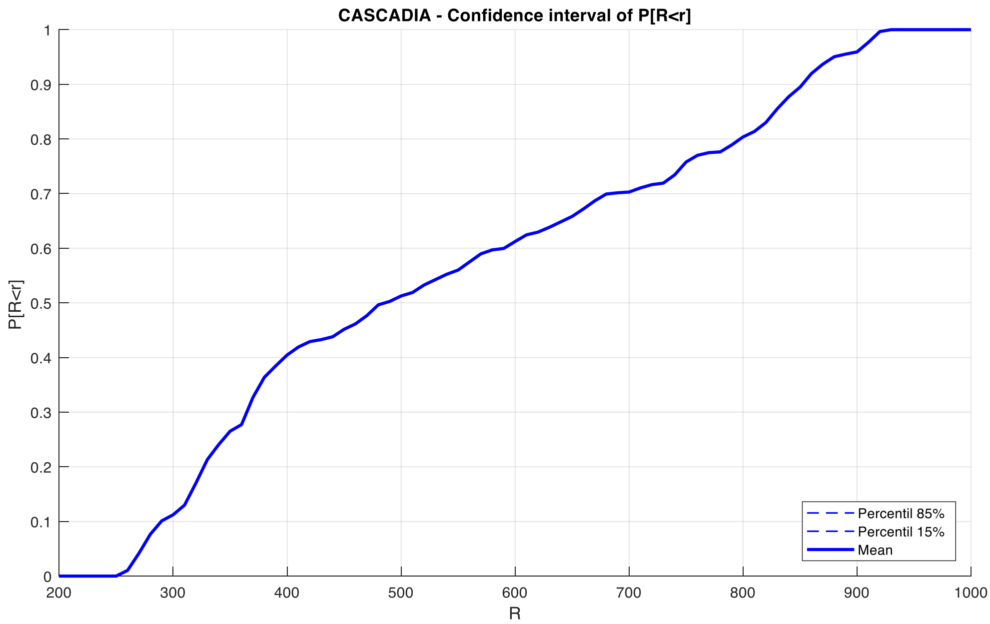
Table 8 Source Types and Source Mechanisms for NBCC 2015 seismic sources.

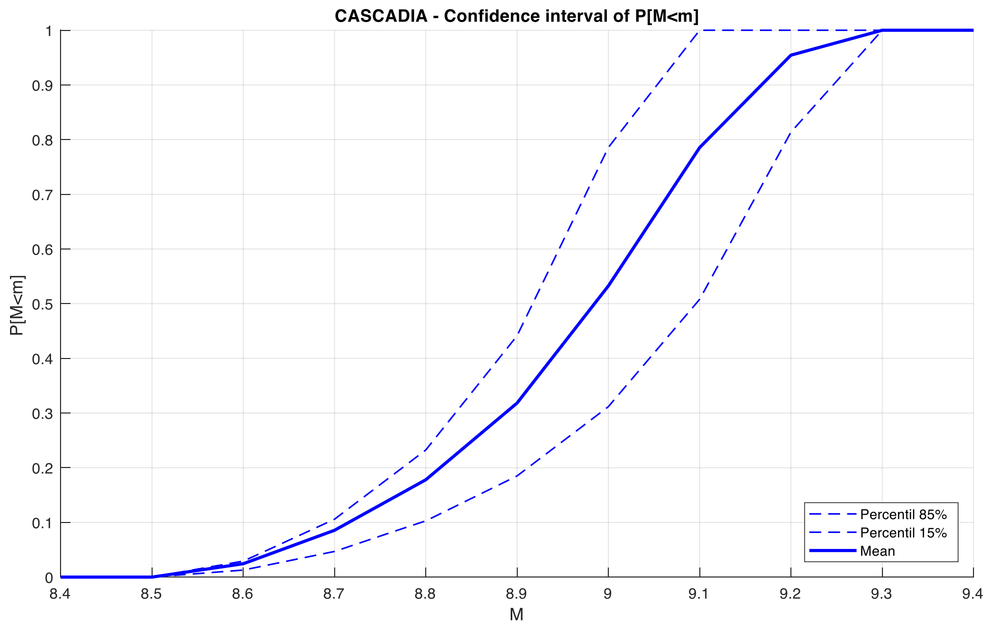
ID	Type	Mechanism	Weight
BRO	aerial	Crustal	1
CAS	aerial	Crustal	1
CASCADIA	fault	Interplate	1
CST	aerial	Crustal	1
EISB	fault	Interplate	0.5
EISI	fault	Interplate	0.25
EISO	fault	Interplate	0.25
EXP	aerial	Crustal	1
FHL	aerial	Crustal	1
FTH	aerial	Crustal	1
GTP	aerial	Intraplate	1
HEC	aerial	Crustal	1
JDFF	aerial	Crustal	1
JDFN	aerial	Intraplate	1
NBC	aerial	Crustal	1
NOFR	aerial	Crustal	1
OFS	aerial	Offshore	1
QCSS	fault	Crustal	0.5
QCSS	fault	Crustal	0.5
SCCECH	fault	Crustal	1
SCCECR	fault	Crustal	1
SCCEHYBH	aerial	Crustal	0.5
SCCEHYBR	aerial	Crustal	0.5
SCCWCH	aerial	Crustal	1
WIN_A	aerial	Crustal	0.25
WIN_B	aerial	Crustal	0.25
WIN_C	fault	Interplate	0.5

Appendix B Seismic Hazard

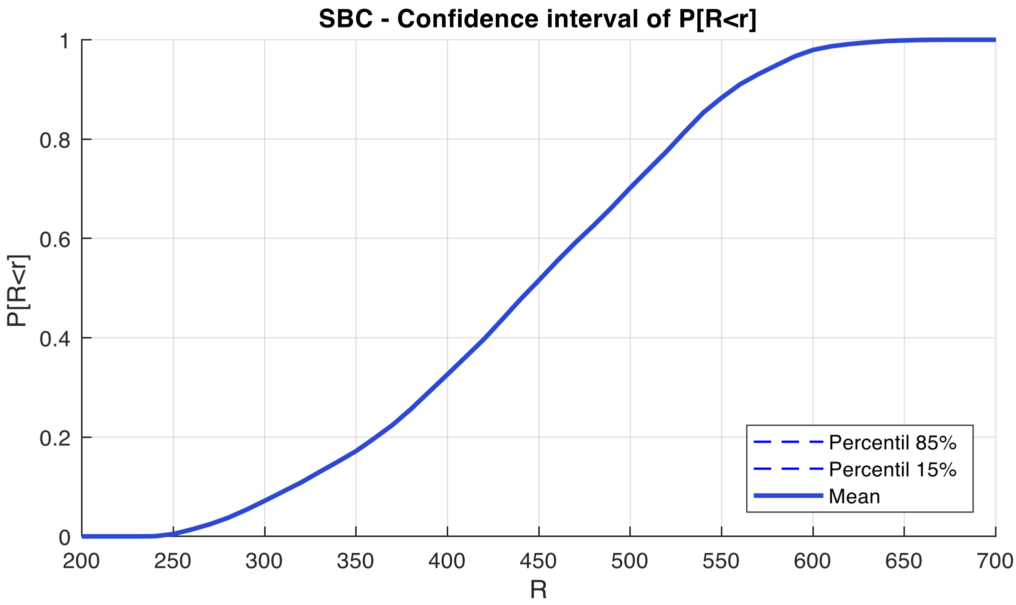
B1. Cumulative Distribution Functions (CDF)

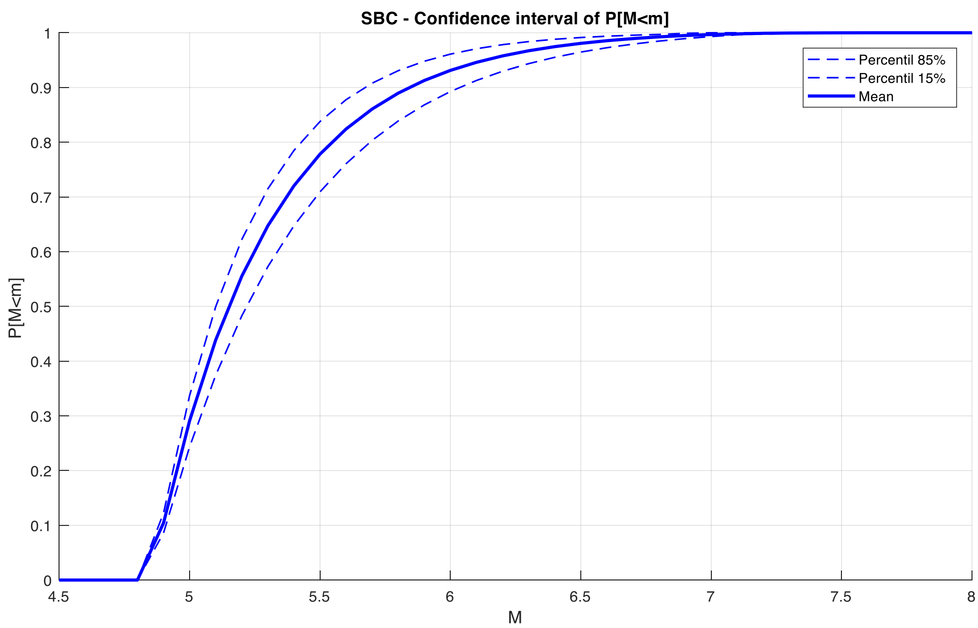
B1-1. CDFs for CASCADIA Source





B1-2. CDFs for SBC Source





B2. Site Class

The National Building Code of Canada (NBCC) code classifies sites based on the Average Shear Wave Velocity (Vs) of the top 30 m of the soil profile (Vs30). The shear wave velocity is defined as the propagation speed of transverse waves in a continuous medium. Sites are divided into six categories presented in the following table. For site classification, V_S^{30} is calculated as the time for a shear wave to travel from a depth of 30 m to the ground surface as follows

$$V_S^{30} \approx \frac{30\,m}{\sum_{NL}(h/V_S)_k} \tag{7}$$

Where $(h/V_S)_k$ is the ratio between layer thickness and the layer velocity

Table 9 CDA NBCC 2010 Site Class and VS30

Site Class	Ground Profile Name	Average Properties in Top 30 m as per Appendix A		
		Average Shear Wave Velocity, $\overline{V}_s$ (m/s)	Average Standard Penetration Resistance, $\overline{N}_{60}$	*Soil* Undrained Shear Strength, s_u
A	Hard Rock	$\overline{V}_s > 1500$	Not applicable	Not applicable
B	Rock	$760 < \overline{V}_s \le 1500$	Not applicable	Not applicable
C	Very Dense Soil and Soft Rock	$360 < \overline{V}_s < 760$	$\overline{N}_{60} > 50$	$s_u > 100$kPa
D	Stiff Soil	$180 < \overline{V}_s < 360$	$15 \le \overline{N}_{60} \le 50$	$50 < s_u \le 100$kPa
E	Soft Soil	$\overline{V}_s < 180$	$\overline{N}_{60} < 15$	$s_u < 50$kPa
		Any profile with more than 3 m of *soil* with the following characteristics: ▪ Plastic index PI > 20 ▪ Moisture content w ≥ 40%, and ▪ Undrained shear strength $s_u < 25$ kPa		
F	Others[1]	Site Specific Evaluation Required		

[1]Other soils include: a) Liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils, and other soils susceptible to failure or collapse under seismic loading, b) Peat and/or highly organic clays greater than

Table 10 ASCE 7-10 Site Class and VS30

Site Class	$\bar{v}_s$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard rock	>5,000 ft/s	NA	NA
B. Rock	2,500 to 5,000 ft/s	NA	NA
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50	>2,000 psf
D. Stiff soil	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/s	<15	<1,000 psf
	Any profile with more than 10 ft of soil having the following characteristics: —Plasticity index $PI > 20$, —Moisture content $w \ge 40\%$, —Undrained shear strength $\bar{s}_u < 500$ psf		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

For SI: 1 ft/s = 0.3048 m/s; 1 lb/ft² = 0.0479 kN/m².

B3. Site Amplification

The ASCE [2] provides conversion factors for different soil conditions for PGA and PSA

Table 11 Conversion factors for PGA

	Mapped Maximum Considered Geometric Mean (MCE_G) Peak Ground Acceleration, PGA				
Site Class	PGA ≤ 0.1	PGA = 0.2	PGA = 0.3	PGA = 0.4	PGA ≥ 0.5
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7				

Note: Use straight-line interpolation for intermediate values of PGA.

Table 12 Conversion factors for Sa(T<1s)

	Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameter at Short Period				
Site Class	$S_S \leq 0.25$	$S_S = 0.5$	$S_S = 0.75$	$S_S = 1.0$	$S_S \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7				

Note: Use straight-line interpolation for intermediate values of S_S.

Table 13 Conversion factors for Sa(T ≥1s)

	Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameter at 1-s Period				
Site Class	$S_1 \leq 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \geq 0.5$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See Section 11.4.7				

Note: Use straight-line interpolation for intermediate values of S_1.

SRK Distribution Record

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Appendix C-3 – HB Dam Zones and Material Properties

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Memo

To:	File	**Client:**	Regional District of Central Kootenay
From:	Peter Mikes, P.Eng.	**Project No:**	1CR012.005
Reviewed By:	Arcesio Lizcano, PhD	**Date:**	December 13, 2019
Subject:	Review of HB Mine Tailings Facility Dam Zones and Geotechnical Properties – **Rev 1**		

1 Introduction

This memo presents a review of the HB Dam material zones and available geotechnical data at the HB Mine Tailings Facility and presents recommended properties for use in stability analyses. This memo has been revised from the version presented in the preliminary design report (SRK 2018b) to incorporate results of the 2017 test pit investigation and review of the native glaciolacustrine properties documented in SRK (2018a).

2 Dam Zoning Review

The following sections provides a brief construction history of the dam, describes the geotechnical aspects of the dam construction and zoning, and summarizes changes made to the dam cross section compared to the previous stability analysis cross section used in BGC (2002) and TTEBA (2016). This section is meant to be read in conjunction with Figures 1 and 2 that provide updated dam cross-sections with the zoning defined based on the dam construction sequence. The location of the dam cross-section is provided in Figure 3.

2.1 Construction History

The tailings facility was operated by Cominco Ltd. between 1955 and 1967, and subsequently between 1974 and 1978.

The foundation soils generally consist of bedrock overlain by 2 to 3 meters of dense silty till (Zone 2) and stiff to very stiff lacustrine deposits (Zone 3) with minor amounts of sand and gravel. The overburden thickness increases at the downstream toe.

During the initial phase of operation (1955 to 1967), Zones 5 and 6 were placed. It is understood that the construction during this period was not under independent geotechnical control. The original dam (Zone 5) was constructed using borrow materials excavated from the east and west abutments and transported into place by dozers, with compaction under the weight of equipment traffic (Golder 1972). An earth filled timber crib retaining wall was constructed at the downstream toe. The crest of the dam and timber crib were raised periodically as required by the downstream construction method (Golder 1972).

Zones 5 consists of silty sand and gravel with scattered cobbles and small boulders (Golder 1972). Golder (1972) describes the material from the eastern abutment as predominately of slightly silty fine to medium sand, and the western abutment material as well graded, heterogeneous mixture of silt, sand, gravel, cobbles and boulders (glacial till). Standard Penetration Tests (Golder 1974a and BGC 2002) indicate these zones are loose to dense, likely as a result of minimal compactive effort during construction. A direct shear test of a representative sample of the fill resulted in a friction angle of 35.5° with zero cohesion.

In 1964, a portion of the timber crib wall failed. The crib wall was reconstructed 3 to 5 m downstream and several concrete and wooden pipe drains were installed prior to the Zone 6 stabilizing fill being placed. The specific nature of the drains is uncertain. Standard penetration Tests through Zone 6 (Golder 1974a) indicates the material is medium dense. Cominco drawings (HB-265 rev 2) dated July 7, 1965 indicate the dam fill was to be 'well compacted in lifts not exceeding 12" in thickness". When mine operations was suspended in 1967, the dam crest elevation was 706 m (2505 feet[1]).

Prior to the restart of operations in 1974, a filter blanket (Zone 7) was added to the downstream slope to reduce the phreatic surface and improve the dam stability (Klohn Leonoff 1981). This material consists of clean sand and gravel that was obtained from a borrow area located approximately 2 km north of the site. The dam was subsequently raised by 10 feet and 5 feet in 1974-75 and 1977, respectively. Each of these dam raises were designed and supervised by Golder Associates (Klohn Leonoff, 1981).

The dam raises included placement of a 'select impervious fill' layer (Zone 9) on the upstream slope and an extension of the filter blanket on the downstream slope. The remainder of the fill was designated as 'common fill' (Zone 8) in the Golder design reports. The 'select impervious fill' was specified in the design specifications to consist of well-graded glacial till with a maximum particle size of 230mm and with a fines content greater than 20% (Cominco 1974). The 'common fill' was specified in the design specifications to consist of a well graded glacial till with a maximum particle size of 230 mm. The fill materials were placed in 0.3 m lifts and were compacted with a compactor.

The 1975 dam raise included placement of additional 'toe protection' where seepage was observed at the toe of the dam and each abutment. Golder (1975) notes the material used for the rock drain consisted of 75 percent gravel from the B.C. Highways Pit (Emerald Pit) and 25 percent waste rock from the Canex Mine. The 1977 dam raise also included the construction of a rock toe drain on the downstream toe (Zone 10). The design specifications (Cominco 1977) specify the material to consist of well graded igneous waste rock from the Canex Mine, with a size range of 19 to 300 mm, and compacted in 450 mm lifts with a minimum of four passes of a

[1] The imperial elevation was the local site datum at the time of operations.

grid roller. BGC (2002) notes sand, gravel, and cobbles were observed on surface at the rock toe drain location.

In 2005, a toe berm was constructed at the downstream toe. The berm consists of a rock drain (Zone 11) that is tied into the 1977 rock drain and filter blanket, and is overlain by layer of geotextile, and compacted glacial till (Zone 12). The rock drain material was produced to specification by a quarry product supplier (BGC 2005). Rip-rap was also placed on the upstream slope of the dam for erosion protection during the 2005 construction works.

In July 2012, a large slough occurred on the downstream slope approximately 40 m from the west abutment, and was subsequently repaired. Details of the slough event and repairs as provided in EBA (2012a and 2012b), and a typical section of the reconstructed dam is provided in Figure 2. Sloughed material was removed, which exposed the continuous filter blanket (Zone 7). The filter blanket was repaired by placing and compacting clean sand and gravel (imported from Trail, BC) to its original elevation and slope. In some areas, the filter blanket was over-built to ensure a proper thickness of material was available to reduce port pressure in the dam (EBA 2012b). Seepage locations were identified, and a French Drain was constructed with 150 mm to 200 mm angular rock to direct the seepage to the dam toe. The till common fill (Zone 8) was reconstructed to its original height and width using locally sourced glacial till. A shear key was constructed at the toe of the sloughed area, with a coarse rock blanket constructed over the shear key on the downstream face of the reconstructed core material.

In 2016, a “weighted filter” was constructed at the toe of the dam between the eastern end of the toe berm to east abutment of the dam at an elevation near the normal pond elevation (Tetra Tech 2017). The purpose of the weighted filter is to reduce the risk of piping and internal erosion due to uncontrolled seepage. Seepage has been evident near the east abutment since operations. The weighted filter consists of a geotextile overlain by a 0.5 m thick layer of 75 mm minus rockfill, overlain by 500 mm minus rockfill to an height of 2 m above the dam toe.

2.2 Dam Cross Section Changes

Figure 1 was created based on a detailed review of design and as-built drawings by Golder Associates (1972 and 1976), Cominco (1975 and 1977), Klohn Leonoff (1981), and BGC (2005). Based on the review the following changes have been made to the dam cross section compared to the sections used in the last stability analyses for the dam (TTEBA 2016).

- The original dam embankment upstream of the timber crib is treated as one zone (Zone 5). Previous stability analyses (BGC 2002 and TTEBA 2016) have separated this zone into two areas, with a weaker zone located immediately upstream of the timber crib. The extent of the weak zone was estimated based on SPT results through borehole BGC-00-BH-01 (BGC 2002). Due to a lack of construction records during the initial phase of mining, and the limited number of boreholes through the dam, the extent of this ‘weaker’ zone is not certain and could be present at other locations within Zone 5. As a result, properties for Zone 5 should be conservatively selected based on the assumption that the low SPT result could occur anywhere within the original dam.

- The timber crib has been moved slightly upstream in the dam section based on the location provided in the Cominco as-built drawings.
- The upstream end of the Zone 7 filter blanket layer has been adjusted to match the Cominco as-built drawings.
- The upstream slope has been adjusted to be 1.5H:1V for the 1955 to 1967 operations, and 2H:1V for the 1974 to 1978 operations.
- Rock toe drain (Zone 10) constructed as part of the 1977 dam raise has been added to the section. This zone was included in the BGC (2002) decommissioning design, but was not included in the TTEBA (2016) stability analyses.

3 Geotechnical Data Review

3.1 Previous Geotechnical Investigations

Table 1 summarizes the previous geotechnical investigations and testing completed at the tailings facility. Borehole and test pit locations from the investigations is provided in Figure 2.

Table 1: Summary of Available Soil Testing Data

Report	Contents
Golder (1972)	Laboratory testing consisted of: • One direct shear test on a representative sample of the embankment fill (Zone 5) that resulted in friction angle of 35.5° with no cohesion. • Particle size distributions of representative samples from Zone 5 and Zone 6.
Golder (1974a)	• Three boreholes through the dam that included standard penetration testing. • Gradation requirements for the Zone 7 filter blanket.
Golder (1974b)	• Five in-situ density tests and a Standard Proctor test on the Zone 7 filter blanket • Four in-situ density tests and a Standard Proctor test on ‘till fill’ (Zone 8 or 9)
Golder (1975)	• Three in-situ density tests and a Standard Proctor test of the ‘impermeable till” (Zone 9) • Three particle size distributions of rock berm material placed in toe area of Zone 3.
Golder (1976)	• Three particle size distributions from the borrow area to the south east of the HB Dam that is assumed to have been used as Zone 5 fill
BGC (2002)	• Two geotechnical boreholes were drilled through the dam with a hollow stem auger with Standard Penetration test completed at 1.5 m intervals with disturbed split spoon samples collected. • Eight test pits were developed within the dam footprint and downstream of the dam. • Laboratory testing was completed on representative soils: – 18 particle size distribution – 5 Atterberg limits – 6 moisture contents • Design gradation specifications are provided for: – Toe berm rock drain and filter – Upstream dam face erosion protection
BGC (2005)	• Three particle size distributions of the toe berm rock drain material

Report	Contents
EBA (2012a)	• Laboratory testing was completed on the sand and till materials used for the 2012 slough repairs, consisting of: – Standard Proctor tests of the sand and till. – Six particle size distributions – One Atterberg limit.
Tetra Tech EBA (2015)	• Rip-rap gradation specifications for the for the HB Dam spillway retrofit in 2015.
Thurber (2016)	• Five test pits within the dam footprint, and two test pits to the south of the dam • Laboratory testing was completed on the following materials: – Zone 3 glaciolacustrine foundation material: two simple direct shear tests, one consolidation test, two Atterberg limit tests. The direct shear tests resulted in tangent friction angles of 34° and 36° with no cohesion. (See note 1). – Zone 8 dam fill: One Standard Proctor test and two particle size distributions – Zone 9 dam fill: One particle size distribution – Zone 7 dam fill (filter): Three particle size distributions
SRK (2017a)	• Six auger holes were drilled within the tailings impoundment. • Laboratory testing was completed on the tailings: – Nine particle size distributions – Two specific gravity tests – Two relative density tests – Two consolidation tests – One consolidated undrained triaxial strength test resulting in a friction angle of 30° with zero cohesion.
SRK (2018a)	• Fifteen test pits excavated at two potential sand and gravel borrow sources, and six test pits excavated near the east abutment of the dam. • Laboratory testing was completed on the following materials: – Sand and Gravel Borrow Source: 21 particle size distributions – Zone 2 till foundation material: Two particle size distributions – Zone 3 glaciolacustrine foundation material: Two simple direct shear tests, one consolidation test, one Atterberg Limit (non-plastic), and one specific gravity test. The direct shear tests resulted in tangent friction angles of 28° and 35° with no cohesion.

Notes:

1. The Thurber (2016) investigation reports a friction angle of 32° for the glaciolacustrine material, however, following a review of the laboratory raw data the Thurber results report the secant friction angle, while the above reports tangent friction angles obtained from the Mohr-Coulomb circles.

3.2 Soil Data Compilation

This section presents a compilation of the available geotechnical data of the dam materials and native soils.

Soil Index Tests

Figure 4 provides a summary of the particle size distributions collected from the geotechnical investigations. The data has been grouped by the dam zoning definitions based on construction sequence provided in Figure 1.

Figure 5 provides a summary of the Atterberg Limit tests completed from all geotechnical investigations. The results show the glacial till samples have low to medium plasticity and generally plot at or above the A-line. The silt glaciolacustrine samples have medium to high plasticity, with the higher plastic samples plotting above the A-line, while the sand glaciolacustrine was found to be non-plastic.

Table 2 provides a summary of the density test results for the dam and tailings materials.

Table 2: Density Test Summary Results

Zone	Number of Tests	Bulk Density (kg/m³)			Source
		Minimum	Maximum	Average	
4 - Tailings	4	1,868	2,235	2,047	Relative Density Testing completed by SRK (2017a).
7 - Filter Blanket	5	2,012	2,211	2,114	In-situ densities completed by Golder during dam construction (Golder 1974b)
9 - Select Impervious Fill	9	2,036	2,306	2,176	In-situ densities completed by Golder during dam construction (Golder 1974b and 1975) and Thurber (2016).

Strength Tests

Figure 6 presents direct shear test results completed on the project. A test completed on a representative glacial till sample (with gravel fraction removed), resulted in a friction angle of 36° (Golder 1972).

Four direct simple shear tests were completed on two samples of undisturbed glaciolacustrine. The friction angles for the four tests range between 28 and 36°. The stress paths for each test indicates that the material is behaving as normally consolidated or lightly overconsolidated soil. This is evident due to the reduction in the effective vertical stress as the material is sheared (and increase in pore pressure) indicating the sample is contracting.

The two glaciolacustrine tests completed at a 150 kPa confining stress resulted in a similar friction angles, while the tests completed at a 300 kPa confining stress resulted in a lower friction angle for SRK17-TP20-1 sample. The difference is suspected to be due to differences in the material consistency and sample variability. The Thurber (2016) sample was described in the test pit log as a “firm to stiff, brown, moist silty clay” with medium plasticity (ML), while the SRK17-TP20-1 sample is a non-plastic, dry, firm to hard, bedded sand with silt (SM).

Figure 7 presents two consolidated-undrained (CU) triaxial strength tests completed on a composite tailings sample (SRK 2017a). The tests resulted in a friction angle of 30° with zero cohesion.

SPT Tests

SPT testing was completed in a total of five boreholes through the dam as part of the Golder (1974a) and BGC (2002) investigations. In addition, SPT testing was completed on six boreholes through the tailings as part of SRK (2017a). The data was reviewed and considered during the selection of the strength parameters presented in Section 4.

A liquefaction assessment was completed based on the SPT data from borehole BGC-BH-00-1, according to the National Center for Earthquake Engineering Research (NCEER) 1998 analysis method. BGC-BH-00-1 was selected for the assessment as the borehole passes through the centerline of the dam and identified a weak layer in the Zone 5 – Original Dam (1955-67) consisting of very loose silty sand. The seismic inputs for the assessment correspond to the Maximum Credible Earthquake (MCE) as determined in SRK (2017b).

The results of the assessment are provided in Attachment 1. The results show that the very loose sand is very likely to liquefy during an MCE. As a result, the stability analysis should consider liquefaction of Zone 5– Original Dam (1955-67), as well as the tailings which were also found to be very loose and susceptible to liquefaction (SRK 2017a).

4 Recommended Stability Analyses Properties

Table 3 provides a summary of the parameters for use in stability analyses for the HB Mine Tailings Facility, and the basis for their selection. In general, the values were selected conservatively where uncertainty is present.

Table 3: Summary of Material Strength Properties for Stability Analysis

Zone/Material	Bulk Density (kN/m^3)	Strength Parameters		Comments/Basis of Parameter Selection
		Cohesion (kPa)	Friction Angle (°)	
1 – Bedrock	26	Infinite Strength		
2 – Native Till	20	0	36	– Density selected as the lowest value of the 9 in-situ density tests completed on the glacial till material. – Friction angle selected based on direct shear test result of glacial till (Golder 1972).
3 – Native glaciolacustrine	18.5	0	32 See note 2	– Parameters selected based direct shear test results on undisturbed glaciolacustrine test results (Thurber 2016 and SRK 2018a) and empirical relationships with SPT blow count data.
4 – Tailings	18.3	0	30 See note 1	– Bulk density selected based on the lowest measured density of the tailings (SRK 2017a). – Friction angle based on CU triaxial test.
5 – Original Dam (1955-67)	19.0	0	28 See note 1	– Density conservatively selected to be lower than the measured in-situ tests completed on the Zone 9 glacial till, while being higher than the minimum bulk density of the tailings. – Friction angle estimated based on SPT data from BGC-BH-00-1 (Bowles 1977) and conservatively

Zone/Material	Bulk Density (kN/m^3)	Strength Parameters		Comments/Basis of Parameter Selection
		Cohesion (kPa)	Friction Angle (°)	
				assumed that the weak area encountered in the borehole is present throughout the zone.
Post 1964 Till fill zones 6 – Stabilizing berm (1964-67) 8 – Common fill 9 – Select Impervious fill 12 – Till Toe Berm	21.3	0	36	– Density selected as the average of nine in-situ density tests completed on the Zone 9 material. – Friction angle selected based direct shear test result of the glacial till material (Golder 1972).
7 – Filter Blanket	20.7	0	38	– Density selected as the average of seven in-situ density tests completed on the Zone 7 material. – Friction angle conservatively estimated based on SPT data according to Bowles (1977).
Zone 10 – Rock Toe Drain	20.7	0	38	– Conservatively estimated to be have the same properties as the Zone 7 filter blanket.
Zone 11 – Rock Drain Zone 13 – Rip-rap	20.7	0	38	– Conservatively estimated to be have the same properties as the Zone 7 filter blanket.

Note(s):

1. Materials are likely to liquefy during the design earthquake (MCE). Liquefied strength ratios ($s_{u\ (liq)}$ / σ'_{vo}) of 0.10 and 0.04 are recommended for the Zone 5 Original Dam and Zone 4 Tailings, respectively.

2. The four direct shear tests resulted in friction angles of 28, 34, 35, and 36 degrees. The 32° is slightly lower than the average based on lab testing (33°); however, because of the one lower friction angle (28°), future stability analyses should consider a sensitivity analysis.

The dam zones consisting of till material placed after the crib failure in 1964 are assumed to have similar properties based on the particle size distributions, and historical reports that indicate all zones received compactive effort. The level of compaction of the Zone 6 Earthfill Berm is uncertain: there is no documentation of the method of compaction, and borehole data (Golder 1974a) indicates the zone has ‘variable density’. However, the single SPT value within this zone is greater than 50, and given the glacial till direct shear test was completed at a low density of approximately 1,700 kg/m^3, the 36° friction angle was deemed to be reasonable.

As noted in Section 3, Zones 4 and 5 are believed to be susceptible to liquefaction, as a result, the stability analysis should consider the loss of strength of these materials. Liquefied strength ratios[2] ($s_{u\ (liq)}$ / σ'_{vo}) of 0.10 and 0.04 are recommended for the Zone 5 Original Dam and Zone 4 Tailings, respectively. These values were estimated based on the average SPT blow count for each zone and using the empirical relationship presented in Olsen and Stark (2002).

[2] Liquefied strength ratio is the ratio of the shear strength of liquefied soil mobilized during a liquefaction flow failure to the vertical effective stress prior to failure.

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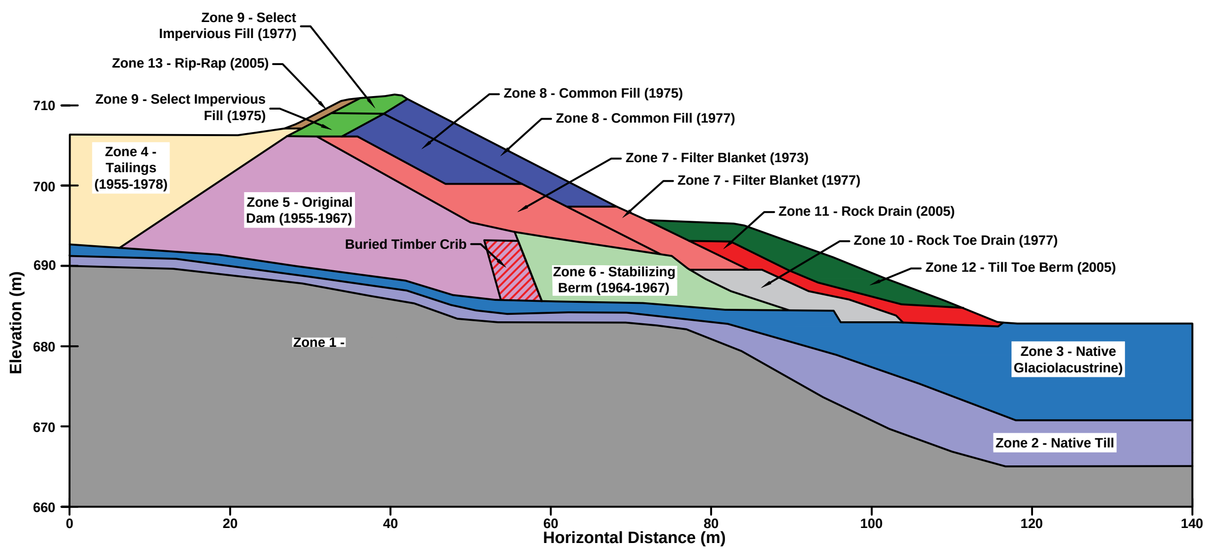
Figures



LEGEND

Colour	Zone	Material Description
	1	Bedrock, granitic and meta-sedimentary
	2	Native Till: Gravelly SAND and SILT with trace clay, dense, grey/brown
	3	Native Glaciolacustrine: Stratified clayey SILT to fine SANDS, dense
	4	Tailings
	5	Original Dam (1955-1967): SAND and SILT with some clays and gravel, very loose to compact
	6	Stabilizing Berm (1964-1967): SILT with sand and gravel, compact to very dense
	7	Filter Blanket (1973 and 1977): SAND and GRAVEL, dense to very dense.
	8	Common Fill [Till] (1975 and 1977): Sandy SILT with gravel, compact
	9	Select Impervious Fill [Till] (1975 and 1977): Sandy SILT with gravel, compact
	10	Rock Toe Drain (1977) - Sand, gravel & cobbles
	11	Rock Drain (2005)
	12	Till Toe Berm (2005): Sandy SILT with some gravel, compacted.
	13	Rip-Rap (2005) upstream erosion protection layer

NOTES

1. Section compiled based on a digitization of historical drawings and borehole logs. The current dam surface obtained from the 2016 aerial site survey provided by RDCK.

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SRK JOB NO.: 1CR012.005

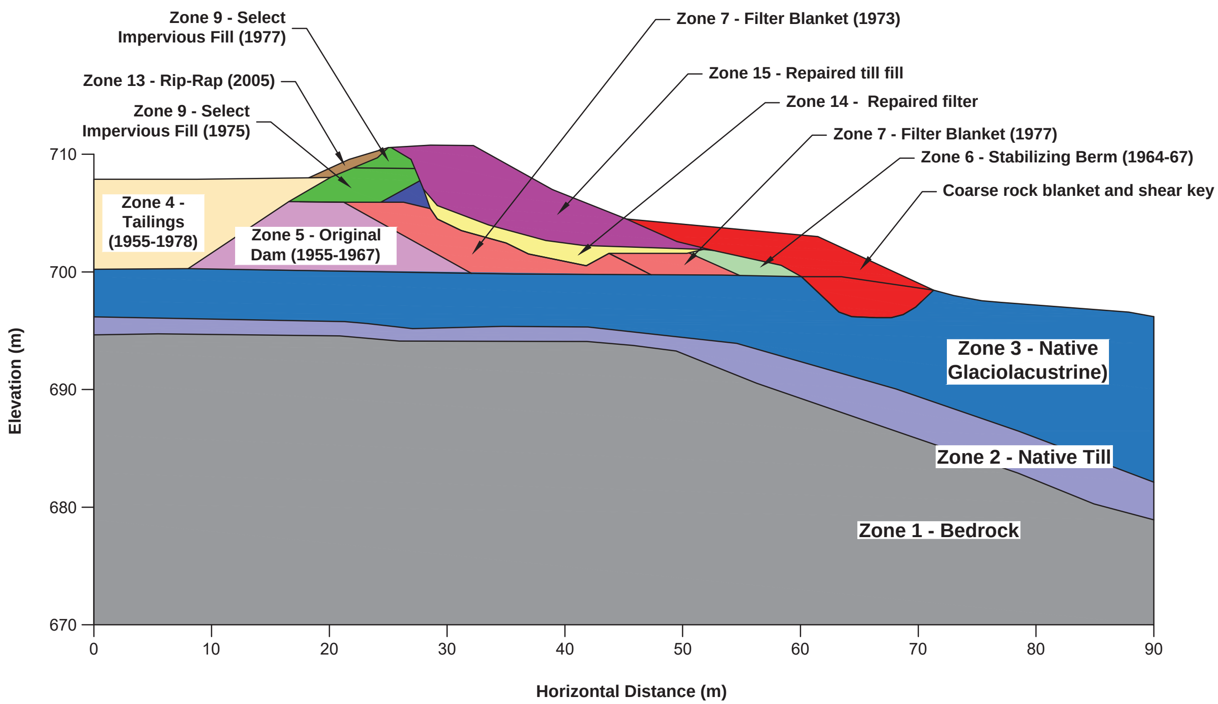
FILE NAME: DamZones_rev01.dwg

HB Mine Tailings Facility

HB Dam Material Property Review

HB Dam Cross Section

DATE:	APPROVED:	FIGURE:
July 2018	phm	01



LEGEND

Colour	Zone	Material Description
	1	Bedrock, granitic and meta-sedimentary
	2	Native Till: Gravelly SAND and SILT with trace clay, dense, grey/brown
	3	Native Glaciolacustrine: Stratified sandy SILT and CLAY
	4	Tailings
	5	Original Dam (1955-1967): SAND and SILT with some clays and gravel, very loose to compact
	6	Stabilizing Berm (1964-1967): SILT with sand and gravel, compact to very dense
	7	Filter Blanket (1973 and 1977): SAND and GRAVEL, dense to very dense.
	8	Common Fill [Till] (1975 and 1977): Sandy SILT with gravel, compact
	9	Select Impervious Fill [Till] (1975 and 1977): Sandy SILT with gravel, compact
	10	Rock Toe Drain (1977): Sand, gravel & cobbles
	11	Rock Drain (2005)
	12	Till Toe Berm (2005): Sandy SILT with some gravel, compacted.
	13	Rip-Rap (2005) upstream erosion protection layer
	14	Repaired filter blanket (2012): Sand and gravel
	15	Repaired Till Fill (2012): Sandy SILT with gravel, compacted

NOTES

1. Section compiled based on a digitization of historical drawings and borehole logs. The current dam surface obtained from the 2016 aerial site survey provided by RDCK.

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HB Mine Tailings Facility

HB Dam Material Property Review

Reconstructed Dam Cross Section

DATE: July 2018 | APPROVED: phm | FIGURE: 02

LEGEND

- Control Point
- Borehole Location
- Monitoring Well Location
- Piezometer Location
- Test Pit Location
- Water Level Measurement Location

0m 10 20 30 40 50 60

Notes
1. Base plan provided by the RDCT
2. Thurber test pit (TEL-TP15-##) and Golder borehole locations are approximate and have be scaled from previous drawings.

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HB Mine Tailings Facility

HB Dam Material Property Review

Borehole and Test Pit Locations

Date:	Approved:	Figure:
July 2018	phm	3

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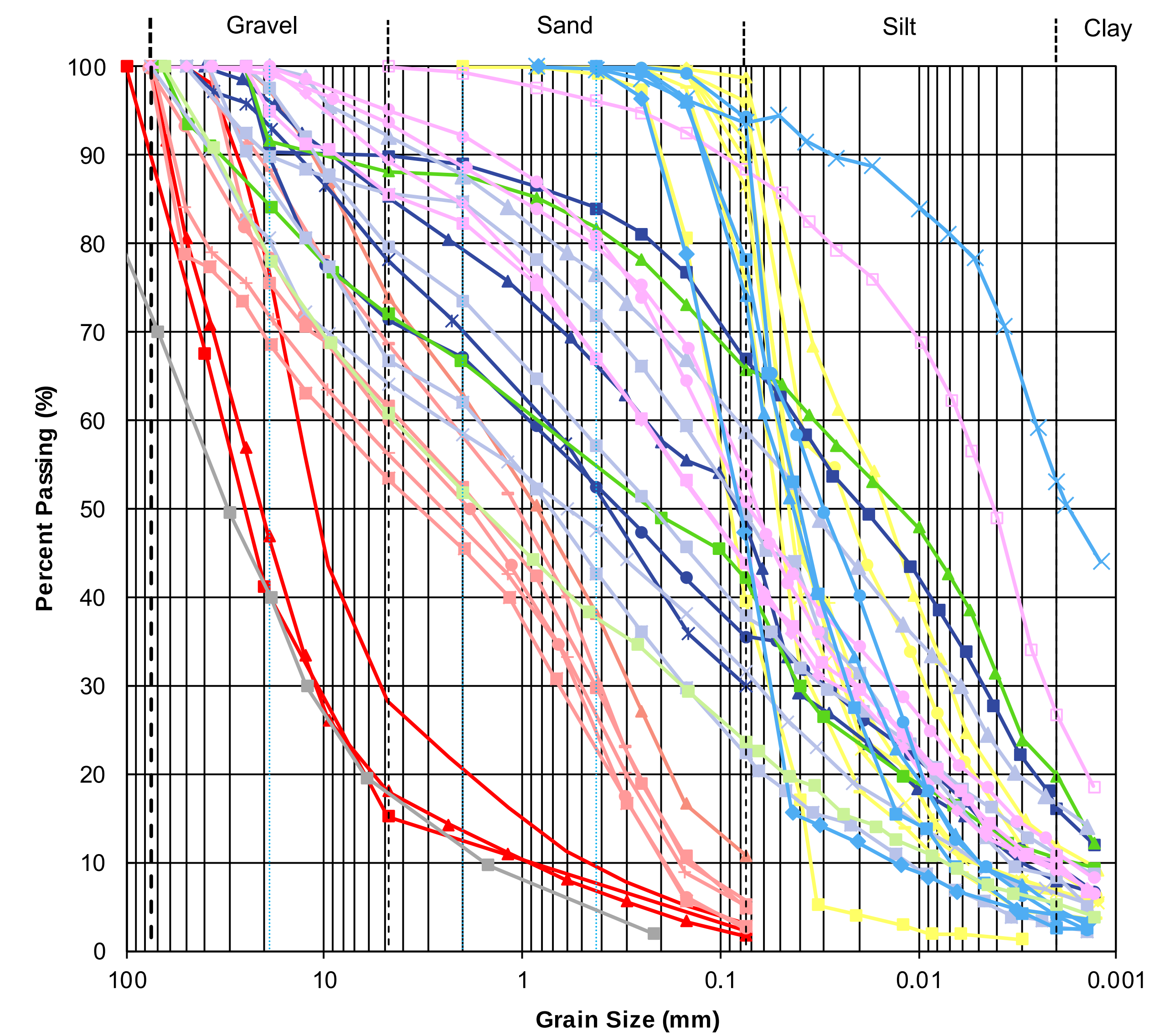
		Particle Size Distribution Summary				
Sample No	Material Description	% Gravel	% Sand	% Fines	% Silt	% Clay
Zone 2 - Native Till						
BH#1 - SPT#15	Gravelly Silty SAND, some clay, moist, olive grey, compact	20	42	38	27	11
BGC-TP3-1	SILT and SAND (Lodgement Till) Borrow area 200m south of abutment	14	36	50	41	8
BGC-TP6-1	Silty SAND, some gravel, dense, moist 75m SE of West abutment.	33	44	22	20	3
SRK17-TP18-1	Silty GRAVEL with sand, brown, moist, some cobbles, non cohesive.	36	33	32	25	7
SRK17-TP18-2	SILT with sand and gravel, some cobbles, grey, firm, low plasticity.	8	33	59	41	18
Zone 3 - Native Glaciolacustrine						
BH#1 - SPT#14	Clayey SILT, some sand, compact, light brown, moist	0	22	78	76	3
BH#2 - SPT#2	Sandy SILT, trace clay, compact, grey, weakly stratified	0	26	74	69	5
BH#2 - SPT#8	Sandy SILT, trace clay, compact, grey, weakly stratified	0	6	94	90	4
BH#2 - SPT#10	CLAY and SILT, moist, compact, contains thin sand layers, olive grey	0	6	94	41	53
SRK17-TP20-1	SILT and SAND, grey cohesive, non-plastic, dry, bedded.	0	53	53	41	6
Zone 4 - Tailings						
SRK-1-G2	Silty SAND, grey, soft, moist, loose, non-plastic	0	60	40	39	1
SRK-3-G3	SILT, grey, very soft, moist, loose, cohesive, non-plastic.	0	1	99	87	12
SRK-3-G5	SILT, grey with orangish brown, very soft, wet to moist, loose, cohesive, non-plastic	0	11	89	83	7
SRK-3-G8	SILT, grey, very soft, wet, loose, cohesive, non-plastic.	0	4	96	87	9
SRK-4-G2	SILT, brownish-grey, very soft, moist, loose, non-plastic.	0	8	92	85	6
SRK-4-G4	SILT, grey, very soft, wet, loose, cohesive, non-plastic.	0	13	87	80	7
SRK-5-G5	SILT with sand, orangish-brown, very soft, moist, non-plastic	0	24	76	72	4
SRK-6-G4	Silty SAND, orangish-brown, soft, moist, loose, non-plastic	0	58	42	41	2
SRK-6-G7	Silty SAND, grey, soft, wet, loose, cohesive, non-plastic	0	58	42	40	2
Zone 5 - Original Dam (1955-67) (mostly till, some zones of glaciolacustrine)						
BH#1 - SPT#8	Silty Sand. Some gravel and trace clay, very loose, wet, medium grey to brown.	11	46	44	34	9
BH#1 - SPT#10	Silty Sand. Some gravel and trace clay, very loose, wet, medium grey to brown.	5	44	51	40	11
BH#1 - SPT#12	SAND and SILT, some gravel and clay, loose to compact, dark grey, moist, contains wood.	14	42	44	34	10
BH#1 - SPT#13	Clayey SILT, some sand, compact, light brown, moist	0	12	88	62	27
Golder-Sa1	n/a	6	40	54	45	9
Zone 6 - Stabilizing Berm (1964-67) (Till)						
Golder-Sa2	n/a	39	37	24	18	5
Zone 7 - Filter Blanket (sand and gravel)						
BGC-TP1-1	SAND and GRAVEL, with trace silt, moist	38	57	5		
BH#1 - SPT#7	SAND and GRAVEL, with trace silt, dense	26	63	11		
TP15-2-1	Sandy GRAVEL, with trace silt, compact brown	40	57	3		
TP15-2-2	Well graded SAND with silt and gravel, compact brown	47	51	3		
TP15-3-1	Well graded SAND with silt and gravel, compact brown	44	51	5		
TP15-3-2	Well graded SAND with silt and gravel, compact brown	31	63	6		
Zone 8 - Common Fill (Till)						
TP15-4-2	Silty SAND with gravel, grey, moist to wet	22	48	30		
BH#1 - SPT#2	Sandy, gravelly SILT, some clay, compact to dense, moist	29	36	36	26	10
BH#1 - SPT#5	Sandy, gravelly SILT, some clay, compact to dense, moist	10	23	67	51	16
TP15-1-4	Well graded SAND with gravel	15	37	48	40	8
Zone 9 - Select Impervious Fill (Till)						
BGC-TP2-1	Sandy SILT, with some clay and gravel, compact, moist (Till)	11.8	22.4	65.8	46	19.8
TP15-1-3	Dense, brown, moist clayey GRAVEL	28	29.8	42.2	31.7	10.5
Zone 10 – Rock Toe Drain						
RockDrain	Approximate gradation of Rock Berm (75% Emerald Pit screened gravel and 25% waste rock)	82	18	0	See note 2	
Zone 11 - Rock Drain						
GMT-4	Sample collected from Korpack Stockpile	85	13	2		
WST-4" #1	Sample collected from Korpack Stockpile (4" Embankment)	82	16	2		
WST-2" #1	Sample collected from Korpack Stockpile (2" Embankment)	72	25	3		

Notes

1. Material descriptions compiled from borehole logs.
2. Zone 10 Rock toe drain estimated to contain 30% cobbles. This total has been included in the % gravel.



LEGEND

Zone 2 – Native Till
- BGC-TP3-1
- BH#1 - SPT#15
- BGC-TP6-1
- SRK17-TP18-1
- SRK17-TP18-2

Zone 3 – Native Glaciolacustrine
- BH#1 - SPT#14
- BH#2 - SPT#2
- BH#2 - SPT#8
- BH#2 - SPT#10
- SRK17-TP20-1

Zone 4 - Tailings
- SRK-1-G2
- SRK-3-G3
- SRK-3-G5
- SRK-3-G8
- SRK-4-G2
- SRK-4-G4
- SRK-5-G5

Zone 11 – Rock Drain
- GMT-4
- WST-4" #1
- WST-2" #1

Zone 5 – Original Dan (1955-67)
- BH#1 - SPT#8
- BH#1 - SPT#10
- BH#1 - SPT#12
- Golder-Sa1
- BH#1 - SPT#13

Zone 8 – Common Fill (Till)
- BH#1 - SPT#2
- BH#1 - SPT#5
- TP15-1-4
- TP15-4-2

Zone 6 –Stabilizing Berm
- Golder-Sa2

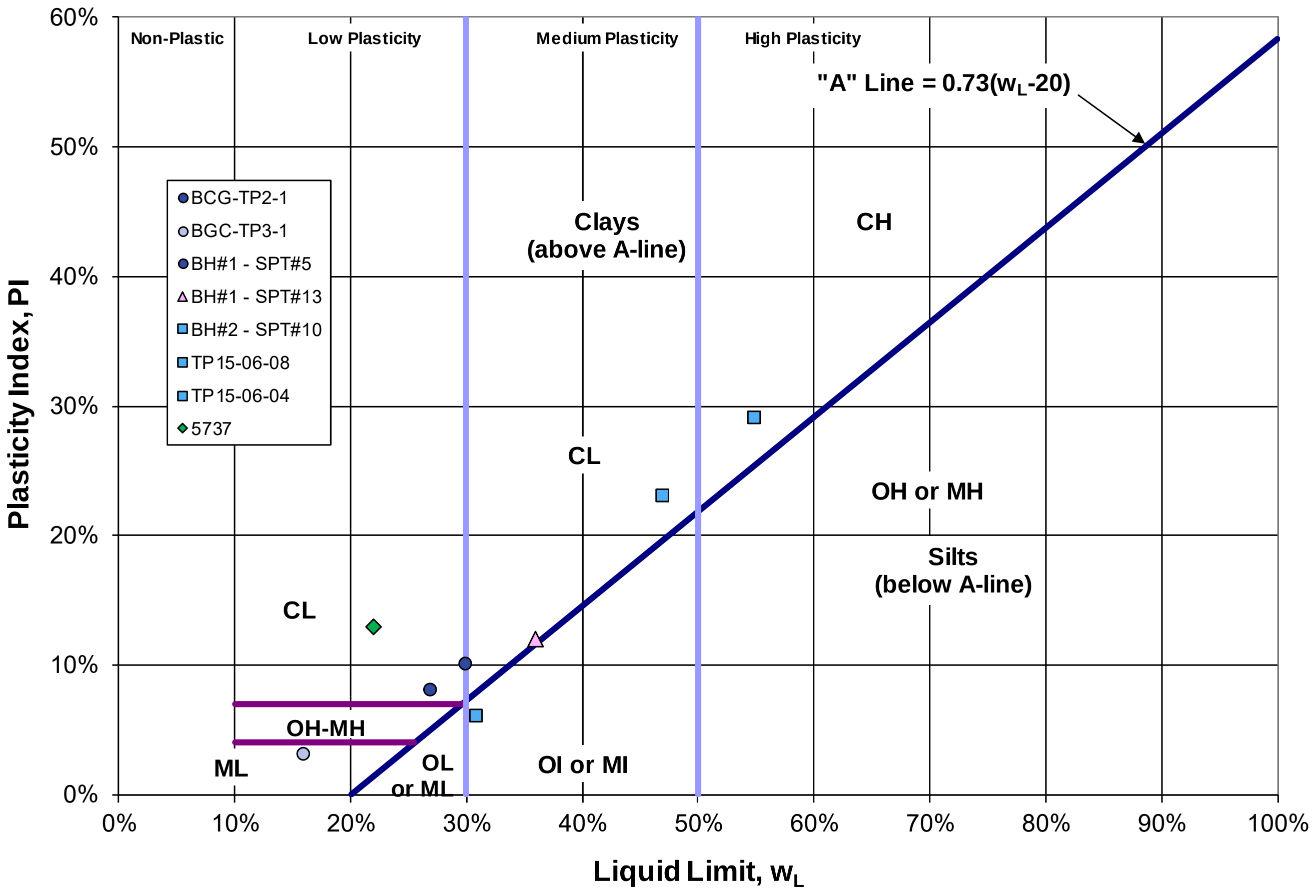
Zone 7 – Filter Blanket
- BH#1 - SPT#7
- TP15-2-1
- BGC-TP1-1
- TP15-2-2
- TP15-3-1
- TP15-3-2

Zone 9 – Select Impervious Fill (Till)
- TP15-1-3
- BGC-TP2-1

Zone 10 – Rock Toe Drain
- RockBerm

srk consulting		HB Dam Material Property Review
		Particle Size Distribution Summary
Job No: 1CR012.005.301 Filename: Figure11x17_MaterialProperties.pptx	HB Mine Tailings Facility	Date: July 2018 · Approved: PHM · Figure: 4

Source: J:\01_SITES\HB_Mine\!020_Site_Wide_Data\Geotechnical Data\HBTailingsFacilitySoilGeotechDB.xlsx



Sample No	Moisture Content	Plastic Limit	Liquid Limit	Plasticity Index
Zone 2 - Native Till				
BGC-TP3-1	11%	13%	16%	3%
Zone 3 – Glaciolacustrine				
BH#2 - SPT#10	33%	24%	47%	23%
TP15-06-08		25%	31%	6%
TP15-06-04		26%	55%	29%
SRK17-TP20-1	23%	Non-plastic		
Zone 5 - Original Dam (1955-67)				
BH#1 - SPT#13	26%	24%	36%	12%
Zone 8 - Common Fill				
BH#1 - SPT#5	20%	19%	27%	8%
BCG-TP2-1	18%	20%	30%	10%
2012 Reconstructed Core (Till)				
5737	9%	13%	22%	9%

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Job No: 1CR012.005

Filename: FigurePortrait_MaterialProperties.pptx

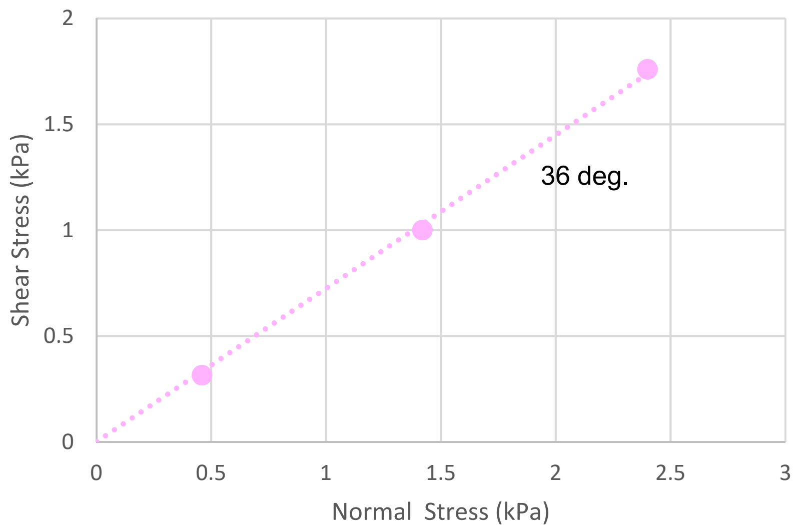
REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

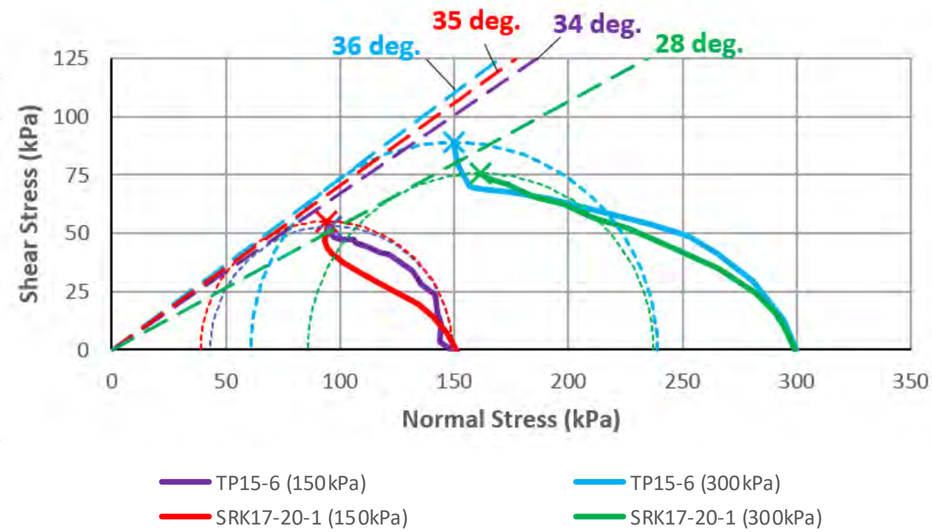
HB Dam Material Property Review

Atterberg Limit Summary

Date: July 2018 | Approved: PHM | Figure: 5



a) Glacial till test results (Golder 1972)



b) Glaciolacustrine sample results

Till Test Result Notes:

1. Sample 'Sa-2' was placed in the shear box at a density of 1,698 kg/m^3 and then saturated. The testing was completed a strain rate of 2.5 mm/min.

Glaciolacustrine Test Result Notes:

1. TP15-6 test results were digitized from laboratory results provided in Thurber (2016).
2. SRK17-20-1 test results are reported in SRK (2018a).
3. The 'X' for each test denotes the point of maximum shear stress.

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Job No: 1CR012.005

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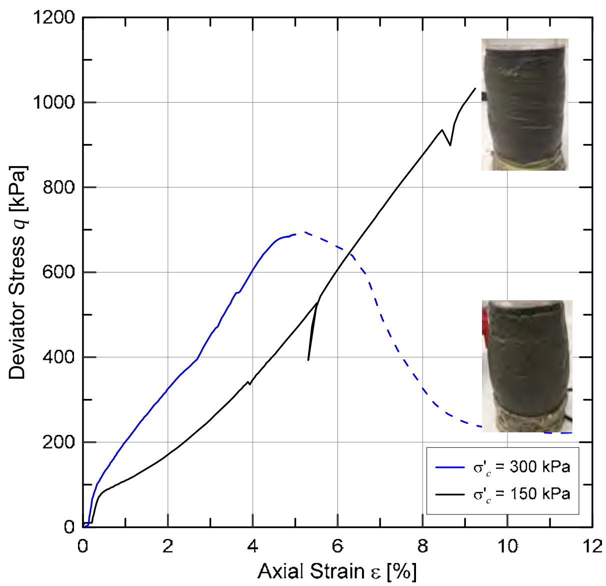
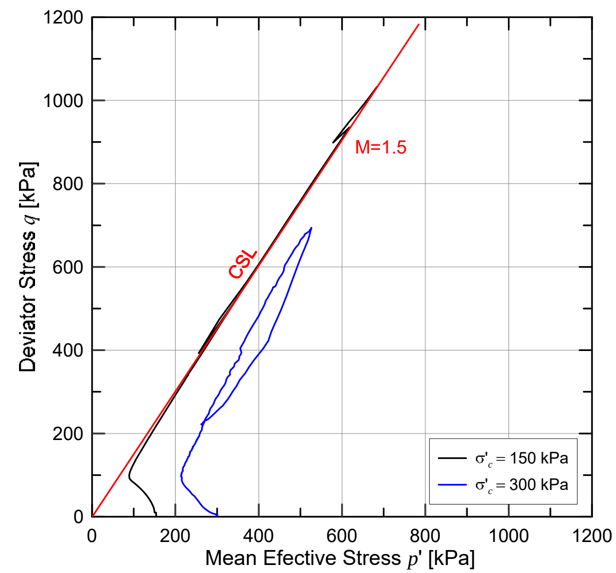
HB Mine Tailings Facility

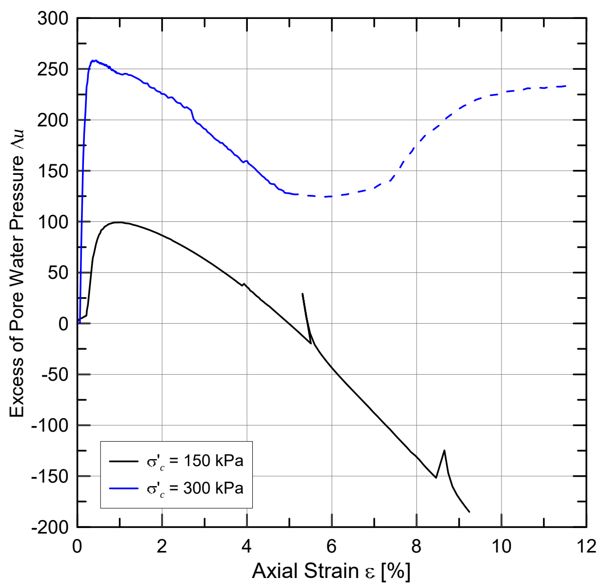
HB Dam Material Property Review

Direct Shear Testing Results

Date:	Approved:	Figure:
July 2018	phm	6







	Confinement Pressure	
	150 kPa	300 kPa
Stress Ratio at failure, σ'_1/σ'_3	2.95	1.59
Deviator Stress at failure, σ_d (kPa):	107.24	106.38
Peak angle at failure, ϕ_m:	29.6	
Axial strain at failure %:	0.95	

Notes:
1. Two consolidated-undrained triaxial strength tests were completed on a composite sample of tailings (SRK 2017).
2. Failure as defined in the table is taken at the point of maximum pore pressure.
3. Strength parameters are for the 300kPa test are unable to determined. It was suspected that an internal collapse of the sample occurred prior to reaching the critical state line (SRK 2017).

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HB Dam Material Property Review

Tailings Triaxial Strength Test Results

Job No: 1CR012.005
Filename: FigureLandscape_MaterialProps.pptx

HB Mine Tailings Facility

Date: July 2018 | Approved: phm | Figure: 7

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Attachment 1 – Liquefaction Assessment

PeterMikes

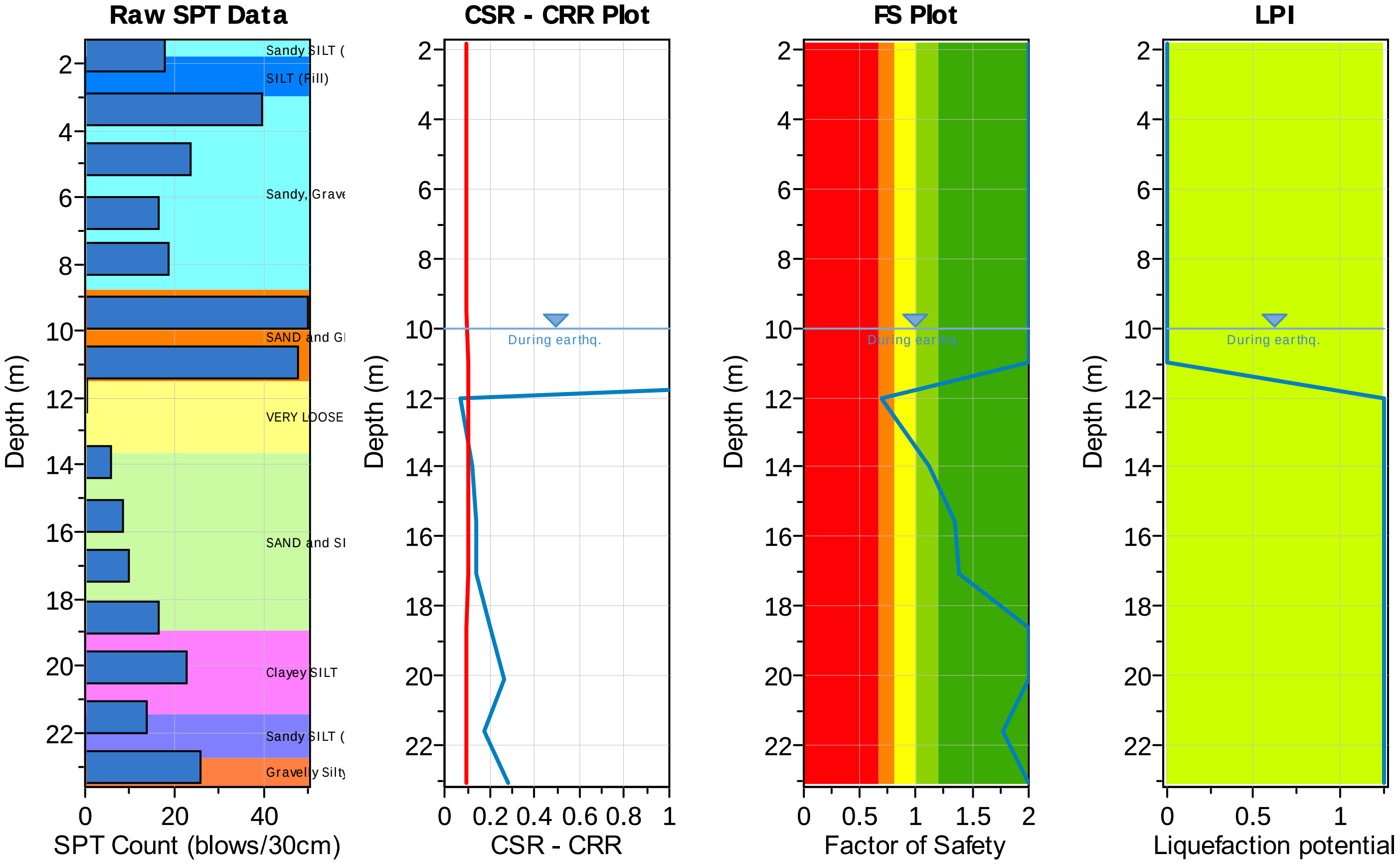
SPT BASED LIQUEFACTION ANALYSIS REPORT

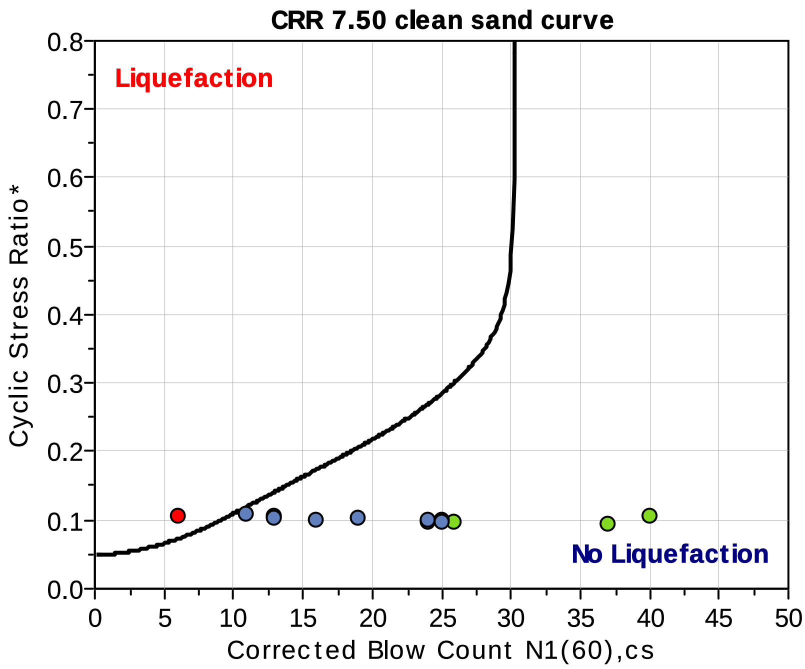
Project title : HB Mine Tailings Facility **SPT Name: BGC-BH-00-1**

Location : Salmo, BC

:: Input parameters and analysis properties ::

Analysis method:	NCEER 1998	G.W.T. (in-situ):	10.00 m
Fines correction method:	NCEER 1998	G.W.T. (earthq.):	10.00 m
Sampling method:	Standard Sampler	Earthquake magnitude M_w:	6.70 m
Borehole diameter:	200mm	Peak ground acceleration:	0.20 g
Rod length:	2.00 m	Eq. external load:	0.00 kPa
Hammer energy ratio:	1.00		

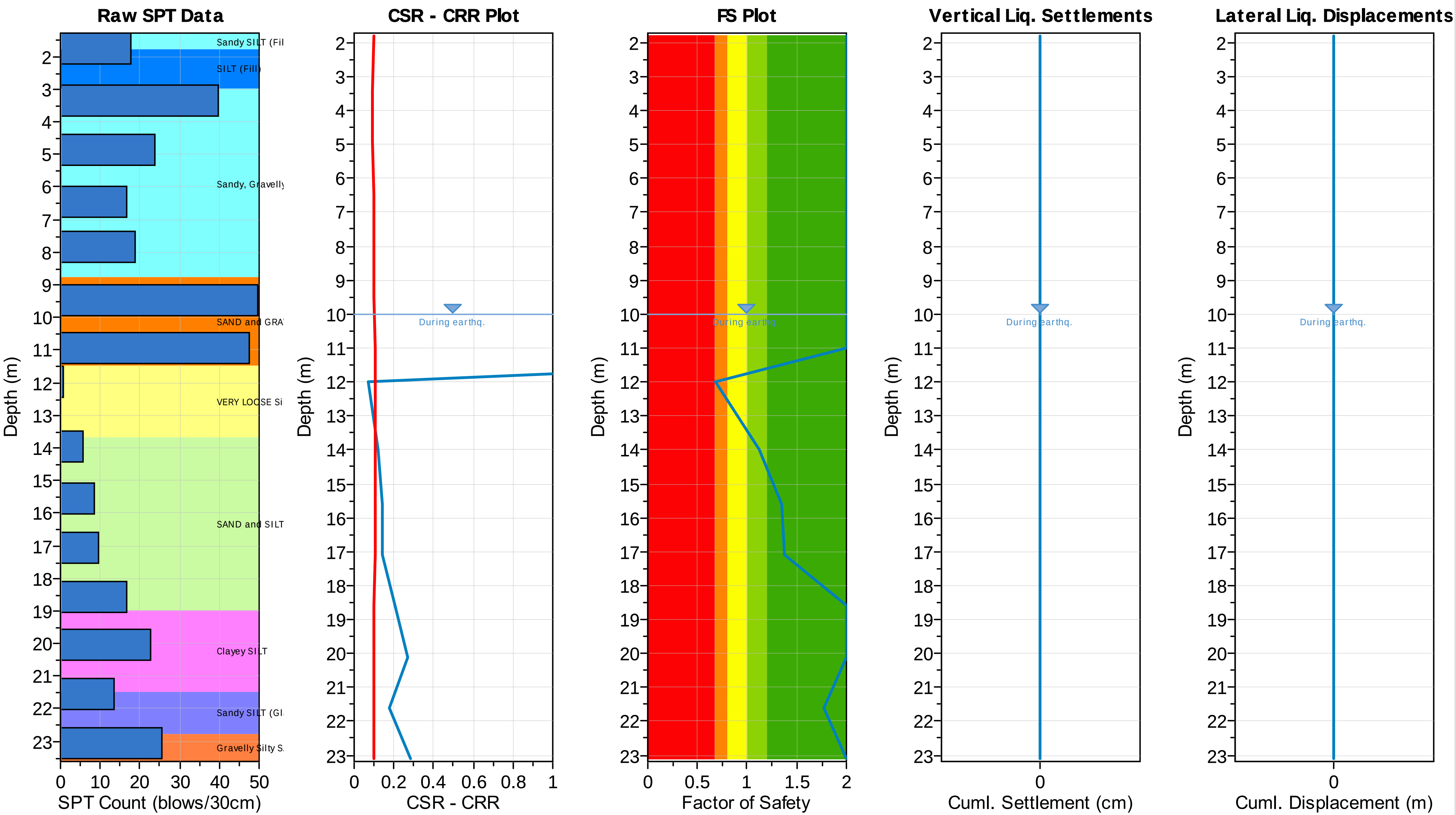




F.S. color scheme
- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme
- Very high risk
- High risk
- Low risk

:: Overall Liquefaction Assessment Analysis Plots ::



:: Field input data ::

Test Depth (m)	SPT Field Value (blows)	Fines Content (%)	Unit Weight (kN/m³)	Infl. Thickness (m)	Can Liquefy
1.80	18	0.00	20.00	0.00	Yes
3.40	40	36.00	20.00	0.00	Yes
4.90	24	36.00	20.00	0.00	Yes
6.50	17	36.00	20.00	0.00	Yes
7.90	19	67.00	20.00	0.00	Yes
9.50	50	67.00	20.00	0.00	Yes
11.00	48	11.00	20.00	0.00	Yes
12.00	1	44.00	19.00	0.00	Yes
14.00	6	44.00	19.00	0.00	Yes
15.60	9	44.00	19.00	0.00	Yes
17.10	10	44.00	19.00	0.00	Yes
18.60	17	44.00	19.00	0.00	Yes
20.10	23	89.00	19.00	0.00	Yes
21.60	14	78.50	19.00	0.00	Yes
23.10	26	38.00	19.00	0.00	Yes

Abbreviations

Depth:	Depth at which test was performed (m)
SPT Field Value:	Number of blows per 30 cm
Fines Content:	Fines content at test depth (%)
Unit Weight:	Unit weight at test depth (kN/m³)
Infl. Thickness:	Thickness of the soil layer to be considered in settlements analysis (m)
Can Liquefy:	User defined switch for excluding/including test depth from the analysis procedure

:: Cyclic Resistance Ratio (CRR) calculation data ::

Depth (m)	SPT Field Value	Unit Weight (kN/m³)	σ_v (kPa)	u_o (kPa)	σ'_{vo} (kPa)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	Fines Content (%)	α	β	$(N_1)_{60cs}$	$CRR_{7.5}$
1.80	18	20.00	36.00	0.00	36.00	1.68	1.00	1.15	0.75	1.00	26	0.00	0.00	1.00	26	4.000
3.40	40	20.00	68.00	0.00	68.00	1.22	1.00	1.15	0.85	1.00	48	36.00	5.00	1.20	63	4.000
4.90	24	20.00	98.00	0.00	98.00	1.02	1.00	1.15	0.95	1.00	27	36.00	5.00	1.20	37	4.000
6.50	17	20.00	130.00	0.00	130.00	0.88	1.00	1.15	0.95	1.00	16	36.00	5.00	1.20	24	4.000
7.90	19	20.00	158.00	0.00	158.00	0.80	1.00	1.15	0.95	1.00	17	67.00	5.00	1.20	25	4.000
9.50	50	20.00	190.00	0.00	190.00	0.73	1.00	1.15	1.00	1.00	42	67.00	5.00	1.20	55	4.000
11.00	48	20.00	220.00	9.81	210.19	0.69	1.00	1.15	1.00	1.00	38	11.00	1.21	1.03	40	4.000
12.00	1	19.00	239.00	19.62	219.38	0.68	1.00	1.15	1.00	1.00	1	44.00	5.00	1.20	6	0.073
14.00	6	19.00	277.00	39.24	237.76	0.65	1.00	1.15	1.00	1.00	5	44.00	5.00	1.20	11	0.120
15.60	9	19.00	307.40	54.94	252.46	0.63	1.00	1.15	1.00	1.00	7	44.00	5.00	1.20	13	0.142
17.10	10	19.00	335.90	69.65	266.25	0.62	1.00	1.15	1.00	1.00	7	44.00	5.00	1.20	13	0.142
18.60	17	19.00	364.40	84.37	280.03	0.60	1.00	1.15	1.00	1.00	12	44.00	5.00	1.20	19	0.206
20.10	23	19.00	392.90	99.08	293.82	0.59	1.00	1.15	1.00	1.00	16	89.00	5.00	1.20	24	0.269
21.60	14	19.00	421.40	113.80	307.60	0.57	1.00	1.15	1.00	1.00	9	78.50	5.00	1.20	16	0.174
23.10	26	19.00	449.90	128.51	321.39	0.56	1.00	1.15	1.00	1.00	17	38.00	5.00	1.20	25	0.285

:: Cyclic Resistance Ratio (CRR) calculation data ::

Depth (m)	SPT Field Value	Unit Weight (kN/m³)	σ_v (kPa)	u_o (kPa)	σ'_{vo} (kPa)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	Fines Content (%)	α	β	$(N_1)_{60cs}$	$CRR_{7.5}$

Abbreviations

σ_v: Total stress during SPT test (kPa)
u_o: Water pore pressure during SPT test (kPa)
σ'_{vo}: Effective overburden pressure during SPT test (kPa)
C_N: Overburden corretion factor
C_E: Energy correction factor
C_B: Borehole diameter correction factor
C_R: Rod length correction factor
C_S: Liner correction factor
$N_{1(60)}$: Corrected N_{SPT} to a 60% energy ratio
α, β: Clean sand equivalent clean sand formula coefficients
$N_{1(60)cs}$: Corected $N_{1(60)}$ value for fines content
$CRR_{7.5}$: Cyclic resistance ratio for M=7.5

:: Cyclic Stress Ratio calculation (CSR fully adjusted and normalized) ::

Depth (m)	Unit Weight (kN/m³)	$\sigma_{v,eq}$ (kPa)	$u_{o,eq}$ (kPa)	$\sigma'_{vo,eq}$ (kPa)	r_d	α	CSR	MSF	$CSR_{eq,M=7.5}$	K_{sigma}	CSR^*	FS
1.80	20.00	36.00	0.00	36.00	0.99	1.00	0.128	1.33	0.096	1.00	0.096	2.000
3.40	20.00	68.00	0.00	68.00	0.98	1.00	0.127	1.33	0.095	1.00	0.095	2.000
4.90	20.00	98.00	0.00	98.00	0.97	1.00	0.126	1.33	0.094	1.00	0.094	2.000
6.50	20.00	130.00	0.00	130.00	0.95	1.00	0.124	1.33	0.093	0.95	0.098	2.000
7.90	20.00	158.00	0.00	158.00	0.94	1.00	0.122	1.33	0.091	0.91	0.100	2.000
9.50	20.00	190.00	0.00	190.00	0.91	1.00	0.119	1.33	0.089	0.88	0.101	2.000
11.00	20.00	220.00	9.81	210.19	0.88	1.00	0.120	1.33	0.090	0.86	0.104	2.000
12.00	19.00	239.00	19.62	219.38	0.86	1.00	0.121	1.33	0.091	0.86	0.106	0.686
14.00	19.00	277.00	39.24	237.76	0.79	1.00	0.120	1.33	0.090	0.84	0.107	1.124
15.60	19.00	307.40	54.94	252.46	0.74	1.00	0.117	1.33	0.088	0.83	0.106	1.344
17.10	19.00	335.90	69.65	266.25	0.69	1.00	0.114	1.33	0.085	0.82	0.103	1.372
18.60	19.00	364.40	84.37	280.03	0.65	1.00	0.110	1.33	0.083	0.82	0.101	2.000
20.10	19.00	392.90	99.08	293.82	0.62	1.00	0.107	1.33	0.080	0.81	0.099	2.000
21.60	19.00	421.40	113.80	307.60	0.59	1.00	0.105	1.33	0.078	0.80	0.098	1.777
23.10	19.00	449.90	128.51	321.39	0.56	1.00	0.103	1.33	0.077	0.79	0.097	2.000

Abbreviations

$\sigma_{v,eq}$: Total overburden pressure at test point, during earthquake (kPa)
$u_{o,eq}$: Water pressure at test point, during earthquake (kPa)
$\sigma'_{vo,eq}$: Effective overburden pressure, during earthquake (kPa)
r_d : Nonlinear shear mass factor
α: Improvement factor due to stone columns
CSR : Cyclic Stress Ratio (adjusted for improvement)
MSF : Magnitude Scaling Factor
$CSR_{eq,M=7.5}$: CSR adjusted for M=7.5
K_{sigma}: Effective overburden stress factor
CSR^*: CSR fully adjusted
FS: Calculated factor of safety against soil liquefaction

:: Liquefaction potential according to Iwasaki ::

Depth (m)	FS	F	wz	Thickness (m)	I_L
1.80	2.000	0.00	9.10	1.60	0.00
3.40	2.000	0.00	8.30	1.60	0.00
4.90	2.000	0.00	7.55	1.50	0.00
6.50	2.000	0.00	6.75	1.60	0.00

:: Liquefaction potential according to Iwasaki ::

Depth (m)	FS	F	wz	Thickness (m)	I_L
7.90	2.000	0.00	6.05	1.40	0.00
9.50	2.000	0.00	5.25	1.60	0.00
11.00	2.000	0.00	4.50	1.50	0.00
12.00	0.686	0.31	4.00	1.00	1.26
14.00	1.124	0.00	3.00	2.00	0.00
15.60	1.344	0.00	2.20	1.60	0.00
17.10	1.372	0.00	1.45	1.50	0.00
18.60	2.000	0.00	0.70	1.50	0.00
20.10	2.000	0.00	0.00	0.00	0.00
21.60	1.777	0.00	0.00	0.00	0.00
23.10	2.000	0.00	0.00	0.00	0.00

Overall potential I_L : 1.26

I_L = 0.00 - No liquefaction
I_L between 0.00 and 5 - Liquefaction not probable
I_L between 5 and 15 - Liquefaction probable
I_L > 15 - Liquefaction certain

:: Vertical settlements estimation for dry sands ::

Depth (m)	$(N_1)_{60}$	τ_{av}	p	G_{max} (MPa)	α	b	γ	ε_{15}	N_c	ε_{Nc} (%)	Δh (m)	ΔS (cm)
1.80	26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
3.40	48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
4.90	27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
6.50	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
7.90	17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
9.50	42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000

Cumulative settlemetns: 0.000

Abbreviations

τ_{av}: Average cyclic shear stress
p: Average stress
G_{max}: Maximum shear modulus (MPa)
α, b: Shear strain formula variables
γ: Average shear strain
ε_{15}: Volumetric strain after 15 cycles
N_c: Number of cycles
ε_{Nc}: Volumetric strain for number of cycles N_c (%)
Δh: Thickness of soil layer (cm)
ΔS: Settlement of soil layer (cm)

:: Vertical settlements estimation for saturated sands ::

Depth (m)	D_{50} (mm)	q_c / N	e_v (%)	Δh (m)	s (cm)
11.00	0.05	3.30	0.00	0.00	0.000
12.00	0.13	4.36	5.80	0.00	0.000
14.00	0.00	5.00	0.81	0.00	0.000
15.60	0.00	5.00	0.39	0.00	0.000
17.10	0.00	5.00	0.00	0.00	0.000
18.60	0.15	4.54	0.00	0.00	0.000

:: Vertical settlements estimation for saturated sands ::

Depth (m)	D_{50} (mm)	q_c / N	e_v (%)	Δh (m)	s (cm)
20.10	0.00	5.00	0.00	0.00	0.000
21.60	0.04	3.10	0.00	0.00	0.000
23.10	0.23	5.15	0.00	0.00	0.000

Cumulative settlements: 0.000

Abbreviations

D_{50}: Median grain size (mm)
q_c/N: Ratio of cone resistance to SPT
e_v: Post liquefaction volumetric strain (%)
Δh: Thickness of soil layer to be considered (m)
s: Estimated settlement (cm)

:: Lateral displacements estimation for saturated sands ::

Depth (m)	$(N_1)_{60}$	D_r (%)	γ_{max} (%)	d_z (m)	LDI	LD (m)
1.80	26	71.39	0.00	0.00	0.000	0.00
3.40	48	100.00	0.00	0.00	0.000	0.00
4.90	27	72.75	0.00	0.00	0.000	0.00
6.50	16	56.00	0.00	0.00	0.000	0.00
7.90	17	57.72	0.00	0.00	0.000	0.00
9.50	42	90.73	0.00	0.00	0.000	0.00
11.00	38	86.30	0.00	0.00	0.000	0.00
12.00	1	14.00	51.20	0.00	0.000	0.00
14.00	5	31.30	0.00	0.00	0.000	0.00
15.60	7	37.04	0.00	0.00	0.000	0.00
17.10	7	37.04	0.00	0.00	0.000	0.00
18.60	12	48.50	0.00	0.00	0.000	0.00
20.10	16	56.00	0.00	0.00	0.000	0.00
21.60	9	42.00	0.00	0.00	0.000	0.00
23.10	17	57.72	0.00	0.00	0.000	0.00

Cumulative lateral displacements: 0.00

Abbreviations

D_r: Relative density (%)
γ_{max}: Maximum amplitude of cyclic shear strain (%)
d_z: Soil layer thickness (m)
LDI: Lateral displacement index (m)
LD: Actual estimated displacement (m)

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Appendix C-4 – HB Dam Stability Analysis

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Memo

To:	File	**Client:**	Regional District of Central Kootenay
From:	Peter Mikes, P.Eng.	**Project No:**	1CR012.005
Reviewed By:	Arcesio Lizcano, PhD.	**Date:**	January 9, 2020
Subject:	HB Dam Stability Analysis Update		

1 Introduction

The HB Mine Tailings Facility near Salmo, BC has been under the care of the Regional District of Central Kootenay (RDCK) since 1998 when the property was purchased to provide additional buffer and attenuation zones for groundwater from the Central Landfill located northeast of the facility. The HB Dam is located at the south end of the facility across a natural valley and retains approximately 6.4 million tonnes of lead-zinc tailings processed from 1955 to 1966 and from 1974 to 1978 (Figure 1). The dam has a “very high” dam hazard classification as defined by the Canadian Dam Association (CDA).

In the summer of 2012, a sloughing event occurred in the dam embankment, and the facility has required significant monitoring, maintenance, upgrades, and investigations. In 2016, the RDCK has elected to transition the dam to passive closure as defined by the CDA Technical Bulletin on the Application of Dam Safety Guidelines to Mining Dams” (CDA 2014).

A history of the dam construction and geotechnical characterization is provided in SRK (2018). The dam is approximately 27 m high, 220 m long with a crest width between 6 and 7 m. The original dam (1955-1967) was constructed with an upstream slope of 1.5H:1V and a downstream slope of 2H:1V. During the second phase of operations (1974-1978), the dam was constructed with upstream and downstream slopes of 2H:1V. The 2005 toe berm has a height of 12 m, a width of 10 m, and a downstream slope of 2.5H:1V, resulting in an overall downstream slope of approximately 2.5 H:1V.

This memo presents the stability analysis for the HB Dam in support of the passive closure design for the HB Mine Tailings Facility. The analyses were completed in accordance with the Canadian Dam Safety Guidelines (CDA 2013) and the Canadian Dam Associations Technical Bulletin on the Application of Dam Safety Guidelines to Mining Dams (CDA 2014).

This memo is an update to the previous stability analysis dated December 18, 2018. The major changes consist of the following:

1. *The post-seismic loading target FOS criterion was increased from 1.3 to 1.5;*
2. *Additional screening-level seismic deformation analyses were completed according to Newmark sliding block method (1965), Makdisi and Seed (1987), and Rathje and Saygili (2009).*
3. *An additional sensitivity analysis was added to assess the variability in the assumed thickness of the glaciolacustrine foundation layer.*
4. *The toe berm was expanded as a result of the increase to the post-seismic loading target FOS criterion.*

2 Methodology

2.1 Assessment Methods

Stability modeling was completed using Slide 8.0 limit equilibrium slope stability modeling software (Rocscience 2019). Factor of safety (FOS) values were used to assess results. All analyses were conducted using the Spencer method, which is a rigorous method that satisfies all three conditions of equilibrium (force equilibrium in the horizontal and vertical directions, and the moment equilibrium condition). Multiple circular and non-circular search methods were used for all cases, with the block search method focused on the inferred ‘weak zone’ identified in BGC-BH-00-1 (BGC 2002).

Seismic embankment deformation was assessed using Swaisgood (2003), Newmark sliding block method (1965) and critical seismic coefficient analyses, with permanent deformations obtained from Makdisi and Seed (1978) charts, and Rathje and Saygili (2009) probabilistic displacement curves.

2.2 Design Criteria

The geotechnical stability design criteria for the dam are in accordance with requirements stipulated in CDA (2014) with the minimum FOS for static and seismic assessments provide in Table 1.

Table 1: Factors of Safety for Dam Stability – (Table 6-2 and 6-3, CDA (2014))

Loading Conditions	Minimum FOS (CDA 2014)	Design FOS
Long-term, drained	1.5	1.5
Pseudo-static (see Note 1)	1.0	1.0 (see Note 1)
Post-seismic	1.2	1.5 (see Note 2)

Note(s):

1. As the original dam fill (Zone 4) is expected to liquefy and undergo a significant loss of strength, pseudo-static results should be used with caution. As per ANCOLD (2012) guidance, post-liquefaction shear strengths should be used to assessed stability under post-earthquake conditions.
2. Under post-earthquake conditions, the tailings and original dam fill (Zone 4) were assumed to have liquefied, and a target FOS criterion of 1.5 was adopted. This value is higher than the guidance provided in USACE (2015) that states for FOS values in the 1.2 to 1.3 range, it is likely that the embankment will not develop significant displacement. The higher value was adopted as Perlea and Beaty (2010) indicate that a FOS in excess of 1.2 to 1.5 may be required to achieve tolerable displacements.

Based on the dam hazard classification of VERY HIGH assigned to the dam, the annual exceedance probability earthquake design ground motion will be the 1 in 10,000-year return period event or the maximum credible earthquake event as per CDA (2014) requirements for passive closure.

2.3 Seismicity

A site specific probabilistic seismic hazard assessment (PSHA) was completed for the HB Mine Tailings Facility to determine the design earthquake parameters corresponding to the 1 in 10,000-year return period event (SRK 2017a). Table 2 provides a summary of the peak ground accelerations (PGA) determined by the assessment. The 84th percentile values for the 1 in 10,000-year event have been adopted for the design earthquake.

Table 2: Peak Ground Acceleration Summary from PSHA

Site Class	Mean 10,000-year return period event	84th percentile 10,000-year return period event
Site Class C	0.157 g	0.234 g
Site Class D	0.210g	**0.256 g**

Site amplification effects of the earthquake ground motions from bedrock to the top layer were considered in the assessment with the soil class beneath the HB dam assigned a Site Class D (stiff soil) as per the National Building Code of Canada (2015) definitions. The soil class was assigned following a review of the five boreholes in the vicinity of the dam (BGC 2002 and Golder 1974) with the average Standard Penetration Resistance (N_{60}) being between 15 and 50. The Site Class D values were used in the liquefaction assessment (SRK 2018b) to determine that the tailings and original dam fill zones were potentially liquefiable.

The pseudo-static analyses were completed using the methodology proposed by Hynes-Griffen and Franklin (1984). The method specifies a horizontal seismic coefficient equal to half of the bedrock peak ground acceleration to be used. A horizontal seismic coefficient of 0.117g (50% of the Site Class C PGA) was used in the analysis.

The Hynes-Griffen and Franklin (1984) methodology also recommends pseudo-static stability analyses include a shear strength reduction factor of 20 percent to account for cyclic loading during an earthquake. A strength reduction factor was not included in this assessment due to the conservative strength parameters adopted for the static analyses, and that reductions in strength due to static loading are probably offset by the effects of a higher loading rate during an earthquake compared to normal loadings rates in static strength tests (Duncan et al. 2014).

2.4 Model Geometry

Seven sections (Section 01 through 07) were analyzed for the HB Dam stability analysis with the locations provided in Figure 1 and the model geometries presented in Figures 2 to 5.

Details of the dam construction history, foundation conditions, and the geotechnical characterization of each of the dam zones is provided in SRK (2018). As foundation information within the dam footprint is limited to boreholes located near the valley bottom (Section 04), near surface test pits near the dam toe, and observations of bedrock at near abutment, conservative interpretations of the foundation's stratigraphy were applied to the remaining sections that likely overestimate the depth to bedrock and thickness of the glaciolacustrine material.

Two dam model geometries were evaluated at Section 04 that considered the current dam geometry, as well as the proposed upgraded dam geometry (with upstream beach and backfilled tailings pond, and expanded toe berm). At each section the toe berm was adjusted as required until the design FOS criteria were achieved. A summary of the resulting expanded toe berm dimensions at each section is provided in Section 4.

2.5 Material Properties

Material properties used in the analyses are presented in Table 2. The properties were selected following a review of all geotechnical investigations at the HB Mine Tailings Facility, the details of the review are provided in SRK (2018b).

Table 2: Material Properties – Dam Stability

Zone	Material Description	Density (kN/m^3)	Apparent Cohesion (kPa)	Friction Angle (°)	Undrained Strength Ratio, S_u/σ'_{vo}
1	Bedrock	26	Infinite Strength		
2	Native Till: Gravelly SAND and SILT with trace clay, (dense).	20	0	36	-
3	Native Glaciolacustrine: Stratified SILT and SANDS, (med. dense/very stiff)	18.5	0	30[1]	0.30[1]
4	Tailings	18.3	0	30	0.04 [2]
5	Original Dam Fill: till and glaciolacustrine	19.0	0	28	0.10 [2]

Zone	Material Description	Density (kN/m^3)	Apparent Cohesion (kPa)	Friction Angle (°)	Undrained Strength Ratio, S_u/σ'_{vo}
6 8 9 12	All other dam till zones: • Stabilizing Berm • Common Fill; • Select Impervious Fill; • Till Toe Berm; • All proposed till fill	21.3	0	36	-
7	Dam filter	20.7	0	38	-
10 11 13	All rock drain layers (existing and proposed)	20.7	0	38	-

Note(s):

1. The 30° friction angle for the native glaciolacustrine material consists of the 33rd percentile value calculated from the four direct simple shear tests completed on the material. Sensitivity analyses considered 26°, and 28°, and fully-softened friction angles estimated according to Gamez and Stark (2014).

2. Liquefied strength ratio is the ratio of the shear strength of liquefied soil mobilized during a liquefaction flow failure to the vertical effective stress prior to failure. Values were estimated based on SPT blow counts according to Olsen and Stark (2002).

Glaciolacustrine Sensitivity Analysis Properties

The native soils along the proposed dam spillway consists primarily of a silty sand glaciolacustrine based on five test pits excavated along the alignment. As a check to the laboratory test results of the glaciolacustrine material, a literature review was completed and estimates of the glaciolacustrine strength was estimated based on the Gamez and Stark (2014) correlations for fully softened shear strength at low stresses for fine-grained soils. The fully-softened shear strength is commonly used to model embankment soil strength as it represents the material after the effects of over-consolidation, compaction, desiccation, have been removed due to wetting, stress relief, swelling, and weathering (Gamez and Stark 2014).

The resulting strength envelop for the glaciolacustrine material is shown in Figure 6. The strength envelope assumes a clay content less than 10%, which is supported by the glaciolacustrine grain size distributions, and a liquid limit of 55%, which is the maximum liquid limit of all soils measured on the HB Mine Tailings Facility property.

The sensitivity analysis of the glaciolacustrine considered friction angles of 30°, 28°, and 26°. As detailed in SRK (2018b), four direct shear tests were completed on undisturbed glaciolacustrine samples that resulted in friction angles of 28°, 34°, 35°, and 36° degrees. The sample with the 28° friction angle result was tested at an applied normal stress of 300kPa and is slightly less than the values predicted by Gamez and Stark (2014).

The base case scenarios adopted a friction angle of 30° for the glaciolacustrine, which believed to be conservative based on the testing completed to date and because the maximum applied stress within the glaciolacustrine layer beneath the dam is approximately 300 kPa beneath the center line of the dam, with normal stresses much less near the toe of the dam where most of the potential critical failure surfaces through the glaciolacustrine could be located.

Scenarios completed using a glaciolacustrine friction angle of 28° represent the reasonable worst-case scenario based on the laboratory testing completed to date and based the Gamez and Stark (2014) empirical correlations presented in the previous section.

Scenarios completed using a glaciolacustrine friction angle of 26° are not believed to be a realistic scenario but are presented for the long-term drained loading to assess the sensitivity of the dam performance to changes in the glaciolacustrine friction angle.

2.6 Piezometric Levels

Pore water pressures for the stability analysis were selected following a review of measured water level in the dam at piezometers. The location of each piezometer is provided in Figures 1 and 2a. Figure 2a also plots the maximum recorded water level at each piezometer since the lowering of the spillway in 2012. Table 3 provides a summary of maximum water levels recorded at each location.

Table 3: Piezometric Level Summary

Piezometer	Location	Maximum Recorded Water Level [1]	Post-Slough[2] Maximum Recorded Water Level
P1	Dam crest, piezometer screened in dam foundation	697.9 m July 6, 2012	696.7 m April 15, 2018
P2	Dam crest, piezometer screened near the top of Zone 5 (Original Dam 1955-67)	702.5 m July 6, 2012	698.6 m Nov. 30, 2016
P3	Near the Dam toe, piezometer screened in native glaciolacustrine	687.2 m May 11, 2011	686.8 m March 17, 2017
P5	Toe berm (2005) crest, screened in Zone 7 Filter Blanket	693.7 m July 6, 2012	693 m April 29, 2014
P6	Toe berm (2005) crest, screened in Zone 6 Stabilizing berm (1964-67)	694.9 July 6, 2012	693.8 m April 15, 2018
Reservoir	Water level gauge located near east abutment	709.0 m June 30, 2011	707.9 m March 15, 2017

Note(s):

1. Monitoring data collected annually 2007 and 2009, month during non-winter months between 2010 and 2012, and at least monthly since July 2012.

2. A large embankment slough occurred at the HB Dam some time between June 25, 2012 and July 2012. During the repairs to the dam, the spillway invert was lowered by 0.95m to the current invert elevation of 707.2 m.

The proposed closure design will lower the current spillway by approximately 1.5 m to an approximate elevation of 705.8 m. Under the design in flood event corresponding to the probable maximum flood (PMF), the maximum water elevation through the spillway is approximately 708.5 m.

The piezometric levels through the dam were conservatively assumed to correspond to the spillway invert elevation (705.8 m) upstream of the dam, and to follow the base of the filter and drainage layers through the dam. The resulting water table is higher than that measured through the dam since the spillway was last lowered in 2012 and higher than that predicted in the seepage analysis of the design configuration (SRK 2017b).

The pore water pressure sensitivity analyses considered a worst-case scenario that assumed a water elevation of 708.5 m within the tailings impoundment corresponding to a PMF, saturated overburden conditions downstream of the dam, and nearly saturated conditions in the dam sand and gravel filter zone at its narrowest width in Zone 7.

2.7 Cases Considered

The stability analysis considered the following conditions under the proposed dam geometry, as well as the existing dam geometry (Section 04 only) with pore water pressures as described in Section 2.6:

1. Long-term drained
2. Short-term construction (undrained foundation beneath the toe berm expansion)
3. Pseudo-static conditions (Zones 4 and 5 liquefied)
4. Post-earthquake (Zones 4 and 5 liquefied)

Sensitivity analyses were completed on each condition listed above that varied (i) the pore water pressures, (ii) the friction angle of the glaciolacustrine material, and (iii) the glaciolacustrine material thickness. The variable ranges considered for each parameter is described in Section 2.5 and 2.6.

3 Results

3.1 Dam Stability Analysis

3.1.1 Current Dam Geometry – Section 04 Only

Table 4 presents stability analysis results along Section 04 for the current dam geometry. Pore water pressures were determined by importing the results of the steady-state finite element seepage assessment with an upstream pond elevation of 707.9 m. Model geometries and critical slip surfaces for the downstream analyses are presented in Figure 7.

Table 4: Stability analysis results along Section 04 with current dam geometry

Condition	Water Conditions	Minimum CDA FOS	Calculated FOS
Long-term, drained	PMF	1.5	1.74
Pseudo-static conditions	PMF	1.0	0.90
Post-seismic conditions	PMF	1.2	1.12

Source: Z:\01_SITES\HB_Mine\1CR012.006_TSF 2019 Design Support\Task_202_FinalDesign\StabilityAnalysisUpdate\HBDam2019StabilityResults.xlsx

Note(s):

1. Values in red are equal to or below minimum FOS values specified by CDA (2014) for passive closure.
2. The maximum water elevation in the tailings impoundment during a PMF is expected to be 708.5 m following lowering of the spillway to the design invert elevation of 705.8 m. The normal water level in the tailings impoundment was conservatively assumed to correspond to the design spillway elevation.

The results show that the existing dam does not meet target FOS values under pseudo-static and post-earthquake loading conditions assuming the tailings and original dam fill (Zones 4 and 5) liquefy. As a result, expansion of the toe berm is required.

3.1.2 Upgraded Dam Geometry

Table 5 presents the stability analysis results for the upgraded dam geometry. The table lists the minimum FOS for failure surfaces that pass through the crest of the dam. Model geometries and critical slip surfaces for each case are provided in Figures 8 to 11 for select sections (shaded green in Table 5).

Table 5: Dam stability analysis results

Condition	Target FOS	Calculated Factors of Safety						
		Section 01	Section 02	Section 03	Section 04	Section 05	Section 06	Section 07
Long-term, drained	1.5	2.07	2.01	2.05	2.01	1.97	2.01	1.81
Short-term, construction	1.3	-	-	1.49	1.57	1.48	-	-
Pseudo-static	1.0	1.17	1.13	0.99	1.09	1.05	1.04	1.00
Post-earthquake	1.5	1.85	1.68	1.66	1.54	1.59	1.54	1.47

Source: Z:\01_SITES\HB_Mine\1CR012.006_TSF 2019 Design Support\Task_202_FinalDesign\StabilityAnalysisUpdate\HBDam2019StabilityResults.xlsx

Note(s):

1. Values in red are below the target design FOS.
2. Critical slope surfaces of cells shaded green are provided in the report figures.

Long-term, drained loading condition results are provided in Figure 8. The Typically, failure surfaces that pass through the dam crest have a FOS values of 2.0 with a low of 1.8 at Section 7. The FOS of the expanded toe berm is greater than 1.8.

The short-term interim construction results are provided in Figure 9. The case assumes undrained conditions within the native glaciolacustrine layer beneath the expanded toe berm. The minimum FOS through the berm is 1.2 at Section 3, with the minimum FOS through the crest is 1.5. This case is considered to be conservative as the glaciolacustrine unit was assumed to be saturated and the case does not allow for pore water pressure dissipation during construction.

Pseudo-static loading condition results are provided in Figure 10. FOS values ranged from 0.99 to 1.17. As noted in Section 2.2, pseudo-static analysis results should be used with caution in cases where materials may undergo a significant loss of strength due to liquefaction.

Post-seismic loading conditions results are provided in Figure 11. The FOS values are generally greater than 1.5 and at values where no significant deformations would be expected as a result of liquefaction during a seismic event. The minimum FOS value of 1.47 reported in Table 5 at Section 07 corresponds to the critical failure surface that passes through the full dam crest. Although the Section 07 result is slightly below the target FOS criterion, the result was deemed to be acceptable as this failure surface would not result in a loss of tailings as the remaining upstream portion of the dam has sufficient freeboard to provide containment.

Although no significant deformation is expected due to the high post-seismic FOS, SRK performed a seismic deformation assessment to validate the results, with results presented in Section 3.2.

3.1.3 Pore Pressure Sensitivity

Table 6 presents the pore pressure sensitivity analyses results for the worst-case scenario as described in Section 2.6. Model geometries and critical slip surfaces for select sections and conditions (shaded green in Table 6) is provided in Figure 12.

Table 6: Pore pressure sensitivity analysis results

Condition	Target FOS	Calculated Factors of Safety						
		Section 01	Section 02	Section 03	Section 04	Section 05	Section 06	Section 07
Long-term, drained	1.5	2.03	2.00	2.04	1.99	2.00	1.96	1.81
Post-seismic	1.5	1.81	1.67	1.60	1.51	1.57	1.54	1.46

Source: J:\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\301_GeotechDesign\StabilityAnalysis\HBDamDetailedStability SectionResults.xlsx

Notes:

1. Values in red are below the target design FOS for base case conditions.
2. Critical slip surfaces of cells shaded green are provided in the report figures.
3. FOS values listed are the minimum failure surfaces that pass through the dam crest and foundation.

All long-term (drained) analyses resulted in FOS values that exceeded the target FOS. The post-seismic analyses resulted in FOS values that ranged from 1.46 to 1.81 for failure surfaces that passed through the dam crest and foundation. The failure surface for the low FOS of 1.46 at Section 7 would not result in a loss of tailings. As the post-earthquake FOS values are generally 1.5 or greater, no significant dam deformation is expected due to seismic activity under the worst-case pore pressure scenario.

3.1.4 Glaciolacustrine Sensitivity

Table 7 presents the glaciolacustrine friction angle sensitivity analysis results. Model geometries and critical slip surfaces for select sections and conditions (shaded green in Table 7) are provided in Figure 13. As noted in Section 2.4:

- A friction angle of 30° was used for the base case stability analysis which is believed to be reasonably conservative based on laboratory test results.
- Fully-softened glaciolacustrine shear strength (Figure 6).
- A friction angle of 28° was selected to represent the worst-case conditions.

Table 7: Glaciolacustrine strength sensitivity analysis results

Condition	Calculated Factors of Safety						
	Section 01	Section 02	Section 03	Section 04	Section 05	Section 06	Section 07
Long-term, drained, glaciolacustrine 28°	1.97	1.89	1.97	1.95	1.93	1.84	1.71
Post-Seismic, glaciolacustrine 28°	1.75	1.58	1.52	1.46	1.59	1.46	1.40
Post-Seismic, fully-softened glaciolacustrine shear strength	2.03	1.75	1.68	1.58	1.63	1.61	1.53

Source: J:\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\301_GeotechDesign\StabilityAnalysis\HBDamDetailedStability SectionResults.xlsx

Note(s):

1. Values in red are below the target design FOS for base case conditions.
2. Critical slip surfaces of cells shaded green are provided in the report figures.
3. FOS values listed are the minimum failure surfaces that pass through the dam crest and foundation and may not result in a loss of tailings.

The results show a slight reduction in FOS values using the worst-case glaciolacustrine friction angle, with all sections meeting, or close to the target FOS of 1.5 under drained and post-earthquake conditions. Use of the fully-softened shear strength resulted in higher FOS values compared to the base case strength of 30°.

3.1.5 Glaciolacustrine Thickness Sensitivity

Two additional stability analyses were completed at Section 04 and 05 to assess the sensitivity of the FOS results to an increase to the thickness of the native glaciolacustrine unit. For both sections, the entire foundation was conservatively assumed to consist of glaciolacustrine. The geometries of Sections 6 and 7 to the east already conservatively assumed the foundation consists entirely of glaciolacustrine. Similarly, Sections 1 and 2 located to the west conservatively assumed thick glaciolacustrine units and the FOS results are not expected to be sensitive to additional increases to the unit.

Table 8 presents the sensitivity analysis results. Model geometries and critical slip surfaces for select sections and conditions (shaded green in Table 8) is provided in Figure 15.

Table 8: Glaciolacustrine thickness sensitivity analysis results

Condition	Section 04		Section 05	
	Base Case	Glaciolacustrine Foundation	Base Case	Glaciolacustrine Foundation
Long-term, drained	2.01	1.71	1.97	1.95
Post-seismic	1.54	1.33	1.59	1.56

Source: J:\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\301_GeotechDesign\StabilityAnalysis\HBDamDetailedStability SectionResults.xlsx

Notes:

1. Values in red are below the target design FOS for base case conditions.
2. Critical slope surfaces of cells shaded green are provided in the report figures.
3. FOS values listed are the minimum failure surfaces that pass through the dam crest and foundation and may not result in a loss of tailings.

Section 4 shows a significant reduction in FOS values for the all glaciolacustrine foundation, however, this scenario is not realistic as there is a high degree of confidence in the base case foundation conditions at this location due to the presence of four boreholes along this alignment. Section 5 shows a slight reduction in FOS values, with both drained and post seismic FOS values exceeding the FOS target criteria of 1.5.

3.2 Seismic Deformation Analysis

A higher target FOS criterion of 1.5 were adopted for the post-seismic condition to mitigate deformations during the design earthquake. USACE (2015) states that for FOS values in the 1.2 to 1.3 range, it is likely that the embankment will not develop significant displacement. ANCOLD Guidelines for the Design of Dams and Appurtenant Structures for Earthquakes (ANCOLD 2019) notes that for post-seismic FOS values marginally less than 1.0 or marginally above 1.0, deformations could be significant but would not be so large as to lose freeboard between the dam crest and the reservoir level. Perlea and Beaty (2010) indicate that a FOS in excess of 1.2 to 1.5 may be required to achieve tolerable displacements.

Simplified seismic deformation analyses were completed according to the Swaisgood (2003) method, Newmark (1965) method, and using seismic yield coefficients with the Rathje and Saygili method (2009), and Makdisi and Seed (1978) permanent displacement curves. Each of these methods are only appropriate if no liquefaction occurs and is likely not applicable to the HB Dam as liquefication is predicated to occur within the original dam fill (Zone 5) during the design earthquake event.

Table 9 provides a summary of the predicted displacement results at Section 4, where the maximum displacement would be expected. The values presented in Table 10 are based on the 84th percentile, 1 in 10,000-year seismic event for Site Class D (0.256g). Additional details for each method are provided in the following subsections.

Table 9: Seismic deformation analysis summary

Method	Result
Swaisgood (2003)	Best estimate of settlement 2 cm with a range between 0 cm and 16 cm.
Newmark (1965)	Predicted displacement of 2 cm.
Rathje and Saygili (2009)	Predicted displacement of 21 cm.
Makdisi and Seed (1978)	Displacement range between 4 cm and 22 cm.

Source: J:\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\301_GeotechDesign\SeismicDeformaiton\SiesmicDeformationCalcs.xlsx

Swaisgood (2003) Method)

This is a method of simplified seismic stability assessment recommended by ANCOLD (2012). The percentage settlement predicted by Swaisgood (2003) is a function of the dam height plus the thickness of any underlying alluvium overlying bedrock. The input parameters and results are presented in Table 10.

Table 10: Seismic embankment deformation estimate (Swaisgood 2003)

Input	Value	Source/Comment
Dam height (m)	24	Maximum height below the crest of the dam.
Earthquake magnitude, M	6.7	SRK (2017a)
Peak ground acceleration, PGA (g)	0.256	84^{th} percentile PGA of the 1 in 10,000 year event (SRK 2017a)
Overburden thickness (m)	3	Overburden thickness beneath the maximum height of the dam.
Results		
Settlement – best estimate	2 cm (0.07%)	
Settlement – minimum	0.3 cm (0.01%)	
Settlement – maximum	16 cm (0.6%)	

Source: J:\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\301_GeotechDesign\SeismicDeformaiton\SiesmicDeformationCalcs.xlsx

Newmark (1965) Sliding Block Analysis

A Newmark sliding block analysis was completed using software Slide 8.0 by Rocscience. For each slip surface in the stability analysis, the potential failure mass is treated as a rigid body with a yielding base. Permanent seismic deformations occur when the average acceleration of the failure mass is larger than the yield acceleration (i.e. the seismic coefficient that results in a FOS of 1.0).

The analysis used an example seismic record provided by the Slide software with a similar PGA and magnitudes to the site seismic design criteria and an additional record with a PGA 22% higher than the design seismic event. The material properties are the same as those used during pseudo-static loading.

Table 11 provides a summary of the displacement results for the two example earthquake records, with the results provided in Figure 16.

Table 11: Newmark Displacement Result Summary

Earthquake Record	Magnitude	PGA (g)	Maximum Calculated Displacement (cm)
Duzce, Turkey, 1999, Record 1060-090	7.1	0.257	2
Imperial Valley, 1940, Record ECL-180	7.0	.313	5

Seismic Yield Coefficient

A seismic yield coefficient analysis was completed using Slide that calculates the horizontal seismic coefficient required to lower the slip surface FOS to 1.0. Figure 17 provides the analysis results plotting the critical slip surface for Section 4.

Table 12 provides the seismic yield coefficients for each section. The calculated yield coefficients were normalized to the design seismic coefficient. Permanent displacements were then estimated using displacement curves provided by Makdisi and Seed (1978), and Rathje and Saygili (2009) The Makdisi and Seed (1978) displacements for a magnitude 6.5 earthquake are provided in Table 6. Figure 18 provides a summary of the predicted displacements according to the Rathje and Saygili (2009) methodology for the mean 1 in 10,000-year seismic event (0.21 g) and the 84th percentile 1 in 10,000-year seismic event (0.21 g).

Table 12: Maksisi and Seed (1978) Displacement Charts

Section	Seismic Yield Coefficient, k_y (g)	Design Seismic Coefficient, k_{max} (g)	k_y/k_{max}	Estimated Permanent Displacement, (cm)	
				Minimum	Maximum
Section 1	0.15	0.256	0.57	1	9
Section 2	0.14	0.256	0.55	1	9
Section 3	0.11	0.256	0.43	3	18
Section 4	0.09	0.256	0.36	4	22
Section 5	0.10	0.256	0.38	3	20
Section 6	0.11	0.256	0.44	2	18
Section 7	0.11	0.256	0.43	3	19

Source: Z:\01_SITES\HB_Mine\1CR012.006_TSF 2019 Design Support\Task_202_FinalDesign\StabilityAnalysisUpdate\HBDam2019StabilityResults_rev00.xlsx

4 Conclusions

The stability analysis determined that expansion of the toe berm originally constructed in 2005 is required. The critical failure surfaces for the downstream pseudo-static and post-earthquake conditions under the current dam geometry sows the toe berm is required to be both raised to increase post-earthquake stability and widened down-valley to increase seismic stability.

A summary of the expanded toe berm requirements is provided in Table 13. Dam stability analysis results for the seven cross-sections show that the lateral extent of the toe berm expansion is appropriate to ensure adequate FOS across the dam.

Table 13: Summary of minimum expanded toe berm dimensions

Section	Crest Elevation (m)	Width (m)	Side-Slope (H:1V)
1	Not required		
2	702	12	3.3
3	702	15	2.8
4	702	12	2.8
5	702	12	2.8
6	702	12	2.8
7	Not required		

All calculated FOS values for the proposed upgraded HB dam meet the requirements prescribed by the CDA guidelines. The pseudo-static loading results are slightly below the minimum FOS values (0.99); however, the seismic deformations during the design earthquake are expected to be insignificant as the post-earthquake stability analysis resulted in FOS values of 1.5 or greater. The dam sensitivity analysis shows that adequate FOS values are generally maintained for the worst-case pore pressures and glaciolacustrine material strengths.

SRK Consulting (Canada) Inc.

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P. H. MIKES
33319
BRITISH COLUMBIA
Jan 9/2020
ENGINEER

Peter Mikes, MEng, PEng
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Reviewed by

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Principal Consultant

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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Figures

LEGEND

- Borehole Location
- Monitoring Well Location
- Piezometer Location
- Test Pit Location
- Water Level Measurement Location
- Blast Rock Repair Area
- Rip Rap

0m 10 20 30 40 50 60

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REGIONAL DISTRICT CENTRAL KOOTENAY

SRK JOB NO.: 1CR012.006	HB Mine Tailings Facility	HB Dam Stabilty Analysis	
FILE NAME: Fig1_StabilityAnalysis_rev01.dwg		Site Plan and Section Locations	
		DATE: December 2019	APPROVED: PHM
		FIGURE: 1	

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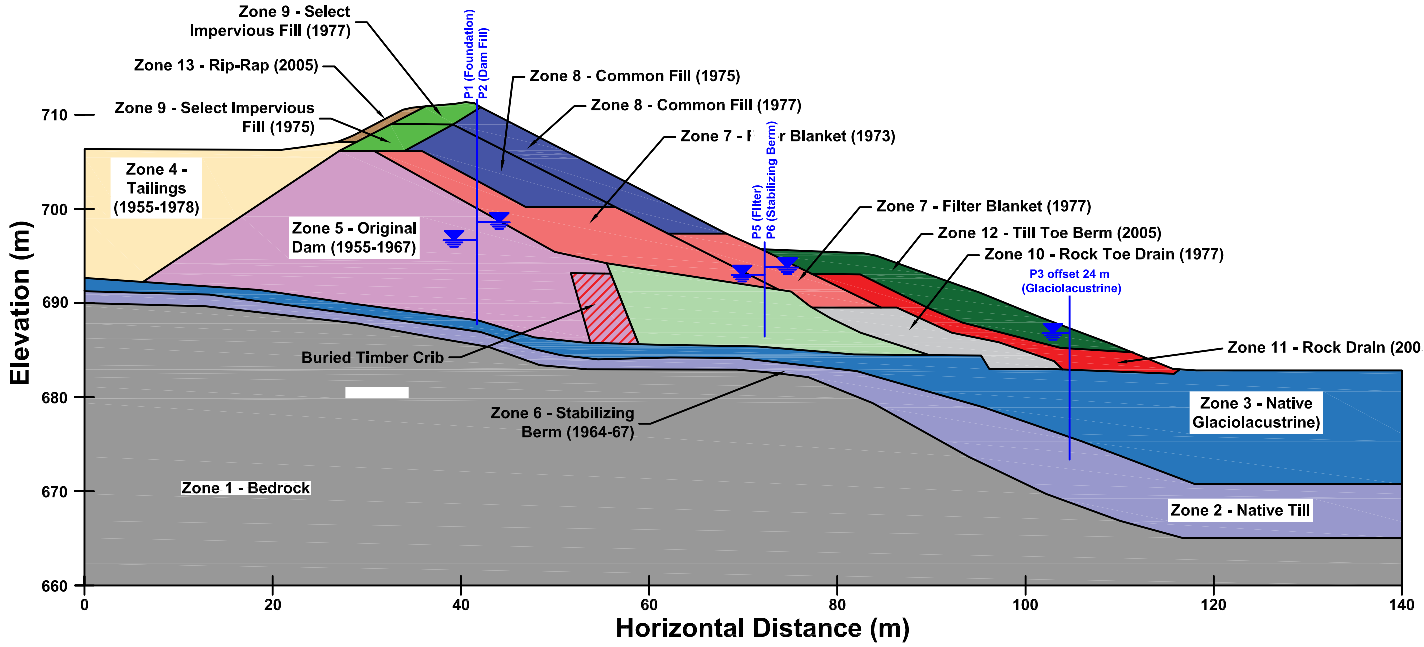
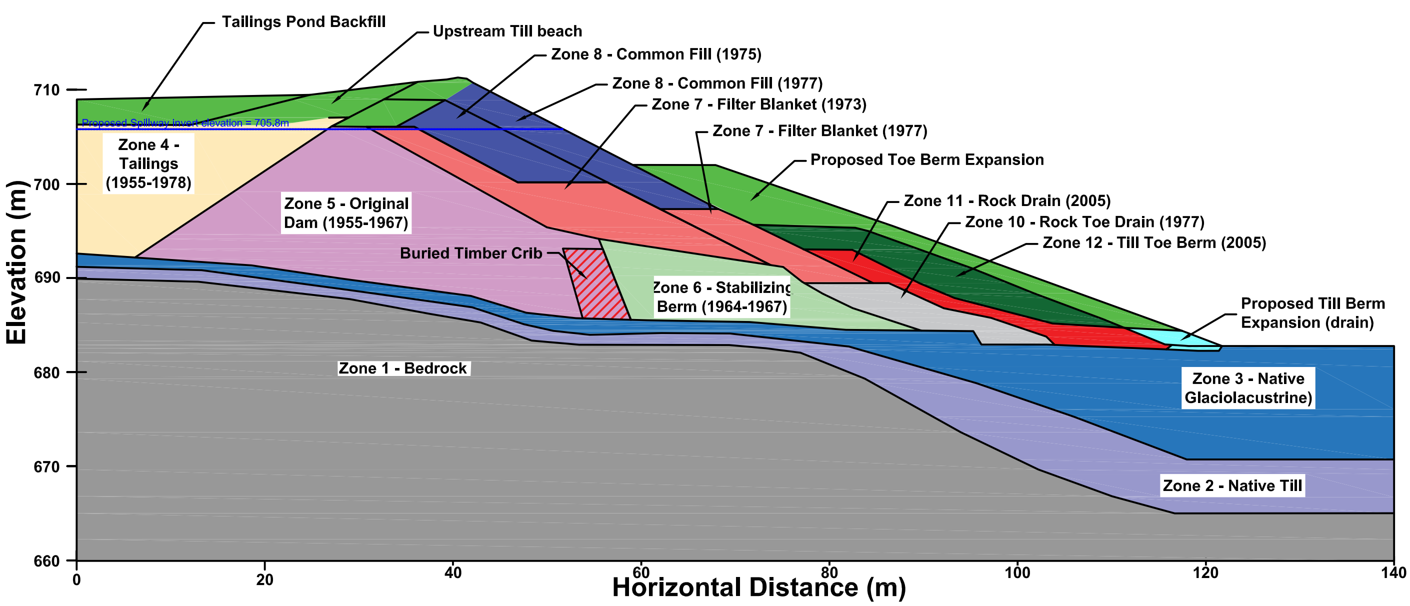


a) Current Dam Geometry

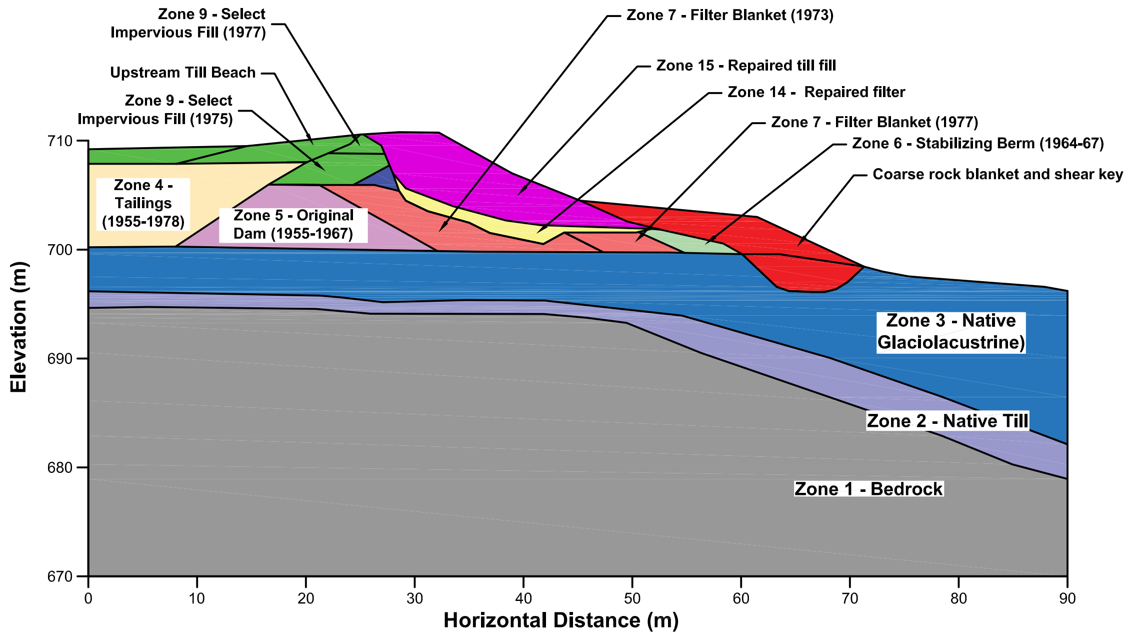


b) Upgraded Dam Geometry

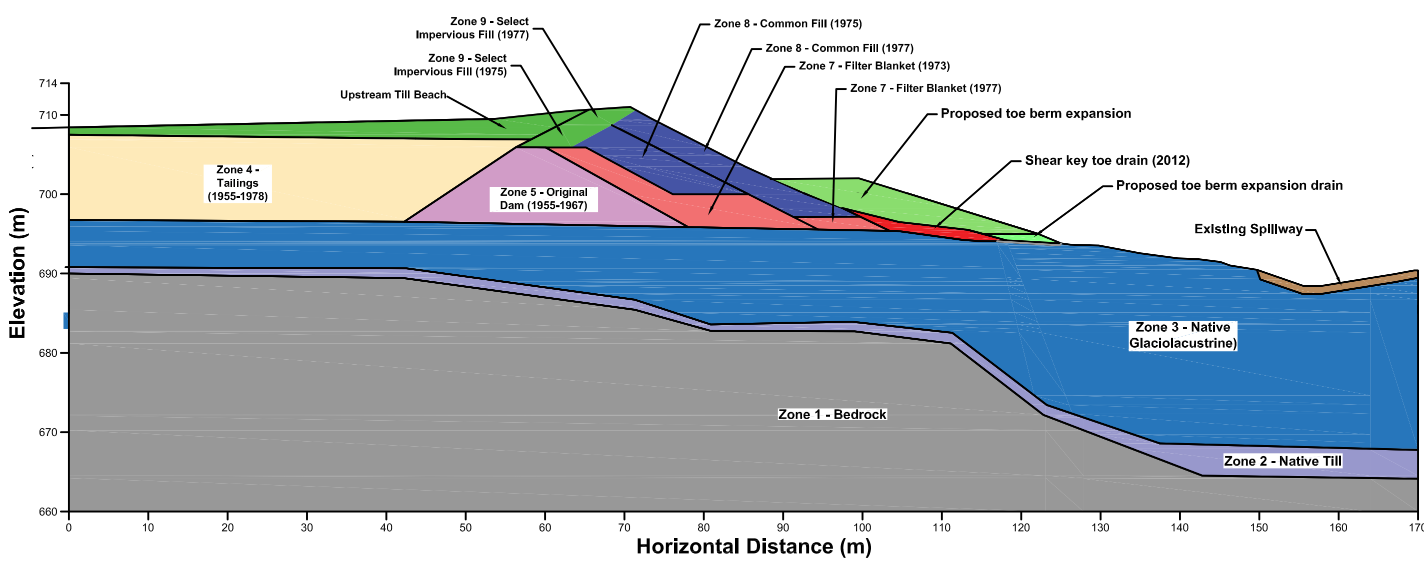
NOTES

1. Section compiled based on a digitization of historical drawings and borehole logs. The current dam surface obtained from the 2016 aerial site survey provided by RDCK.
2. Further details of the dam construction zones is provided in the SRK memo "Review of HB Mine Tailings Facility Dam Zones and Material Properties" dated Sept. 2017.

srk consulting		HB Dam Stability Analysis
		Model Geometry - Section 4
SRK JOB NO.: 1CR012.006	HB Mine Tailings Facility	DATE: December 2019
FILE NAME: Figures_DamModelGeometry.dwg		APPROVED: PHM
		FIGURE: 2



Section 1



Section 2

NOTES

1. Section compiled based on a digitization of historical drawings and borehole logs. The current dam surface obtained from the 2016 aerial site survey provided by RDCK.
2. Further details of the dam construction zones is provided in the SRK memo "Review of HB Mine Tailings Facility Dam Zones and Material Properties" dated July 2018.

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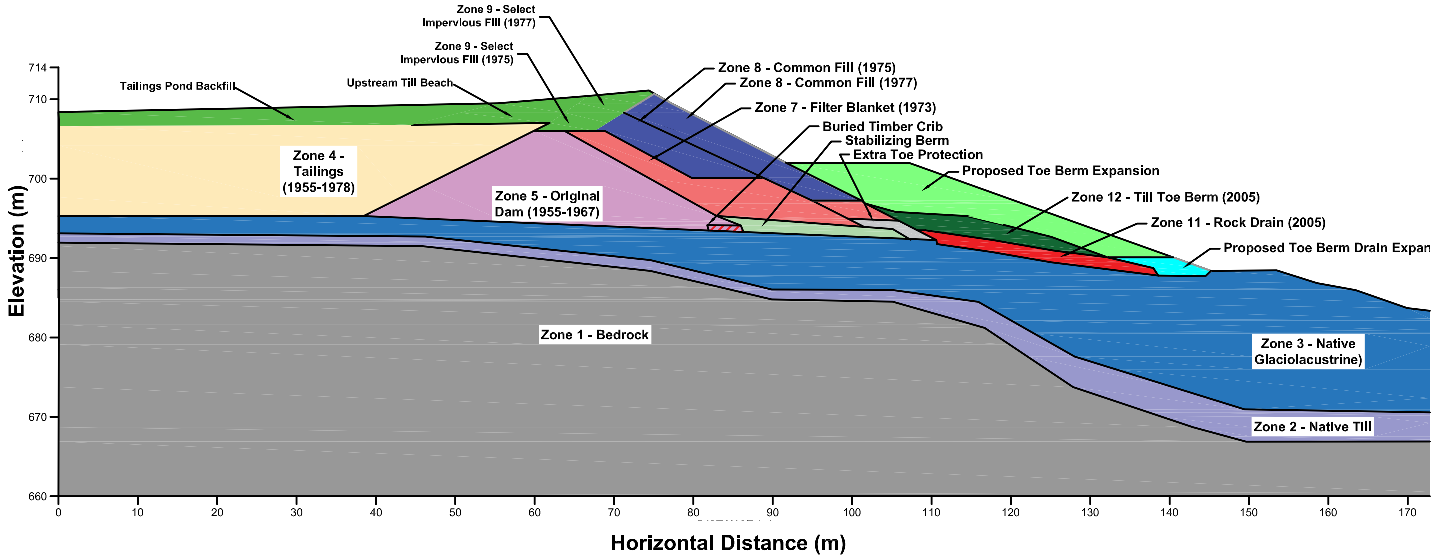
HB Dam Stability Analysis

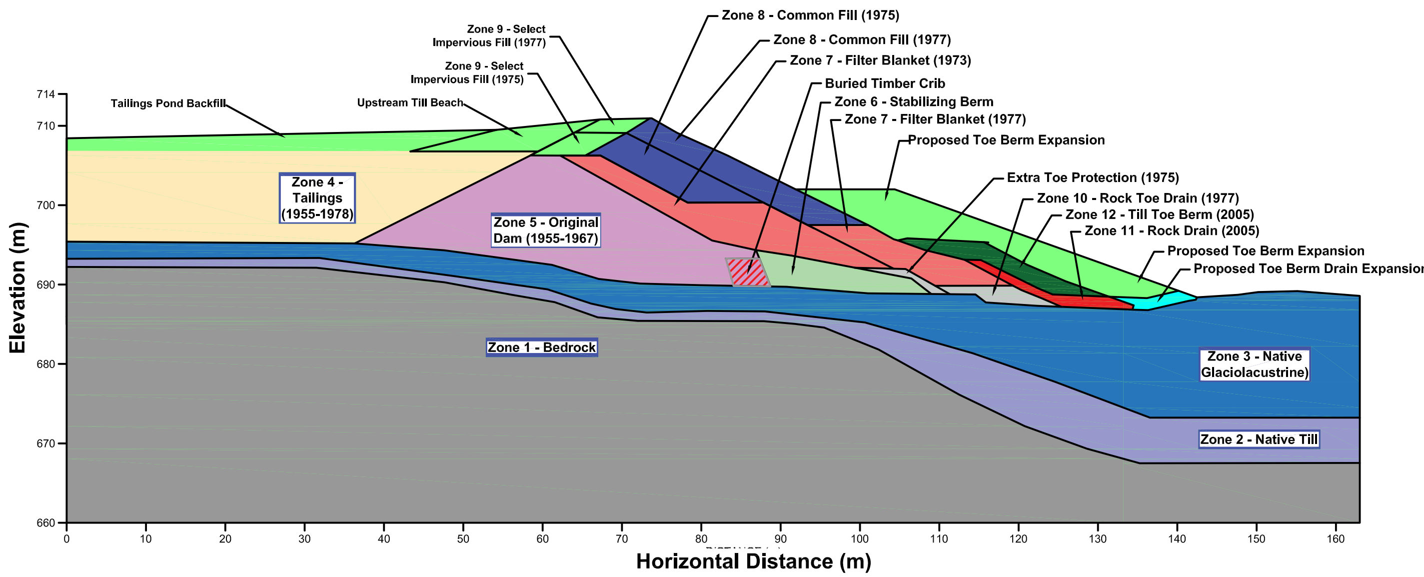
Model Geometry - Sections 1 and 2

HB Mine Tailings Facility

SRK JOB NO.: 1CR012.006		DATE: December 2019	APPROVED: phm	FIGURE: 3
FILE NAME: Figures_DamModelGeometry.dwg				



Section 3



Section 5

NOTES

1. Section compiled based on a digitization of historical drawings and borehole logs. The current dam surface obtained from the 2016 aerial site survey provided by RDCK.
2. Further details of the dam construction zones is provided in the SRK memo "Review of HB Mine Tailings Facility Dam Zones and Material Properties" dated July 2018.

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REGIONAL DISTRICT CENTRAL KOOTENAY

HB Dam Stability Analysis

Model Geometry - Sections 3 and 5

SRK JOB NO.: 1CR012.006

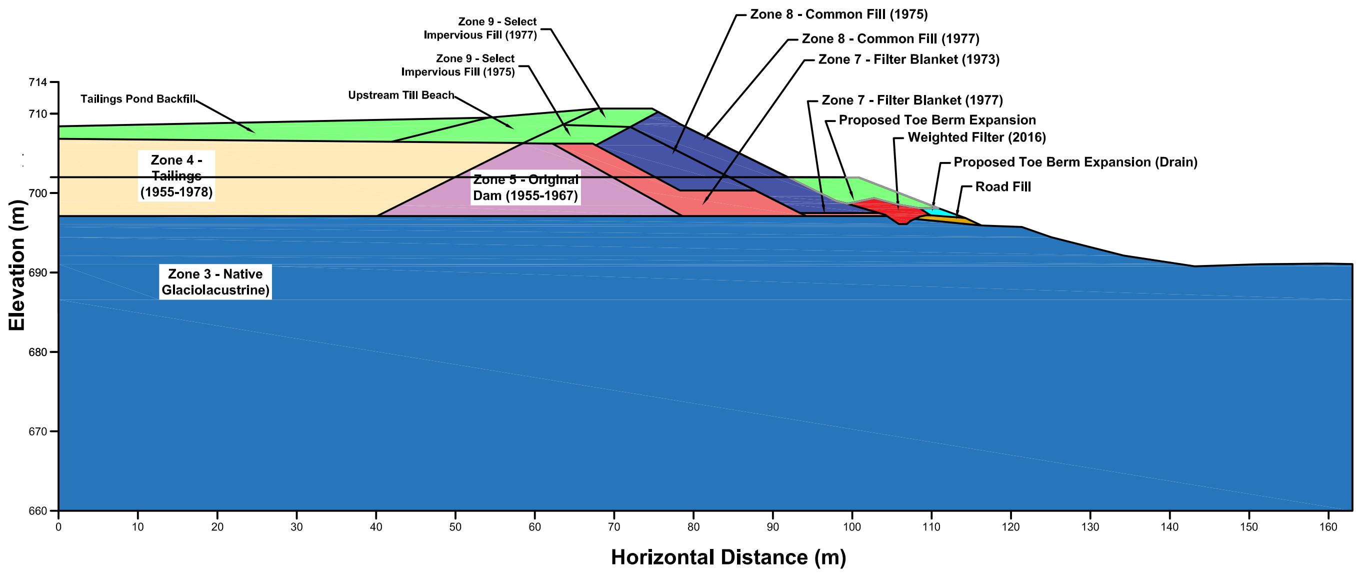
FILE NAME: Figures_DamModelGeometry.dwg

HB Mine Tailings Facility

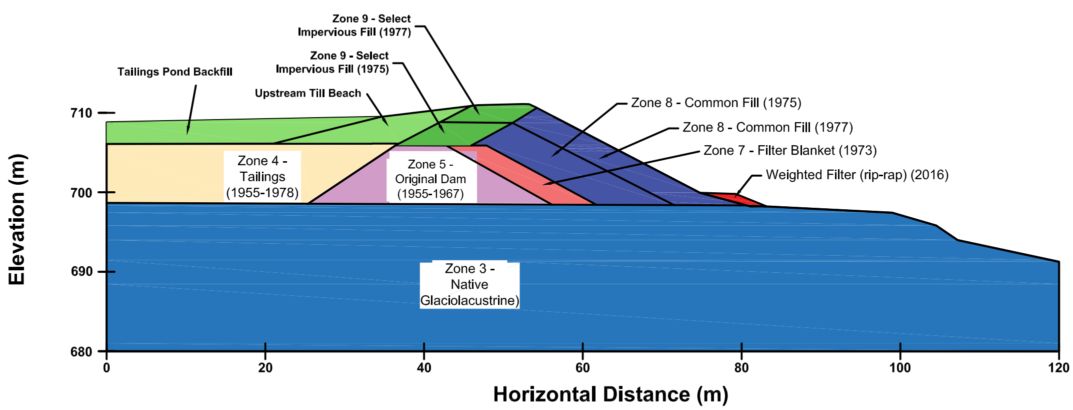
DATE: December 2019

APPROVED: phm

FIGURE: 4



Section 6

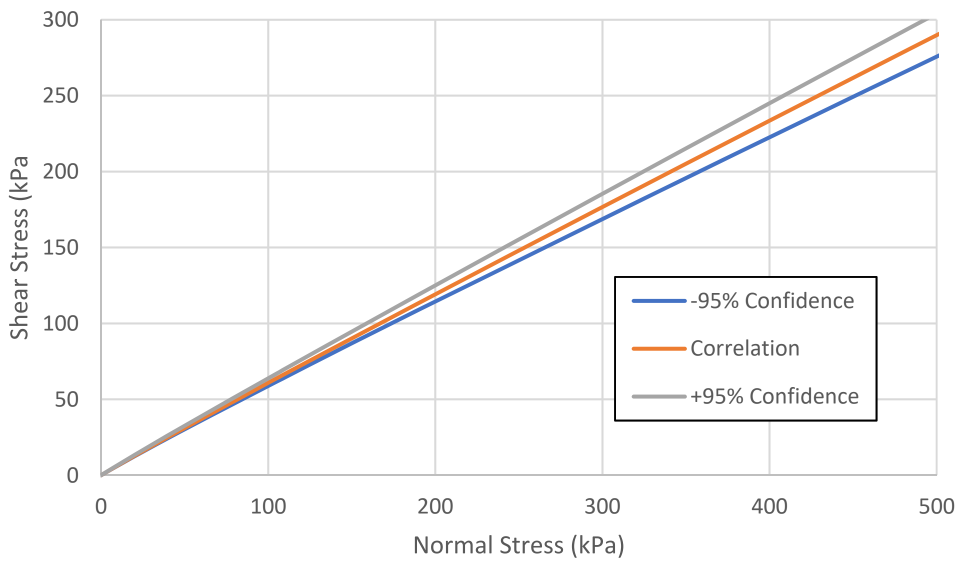


Section 7

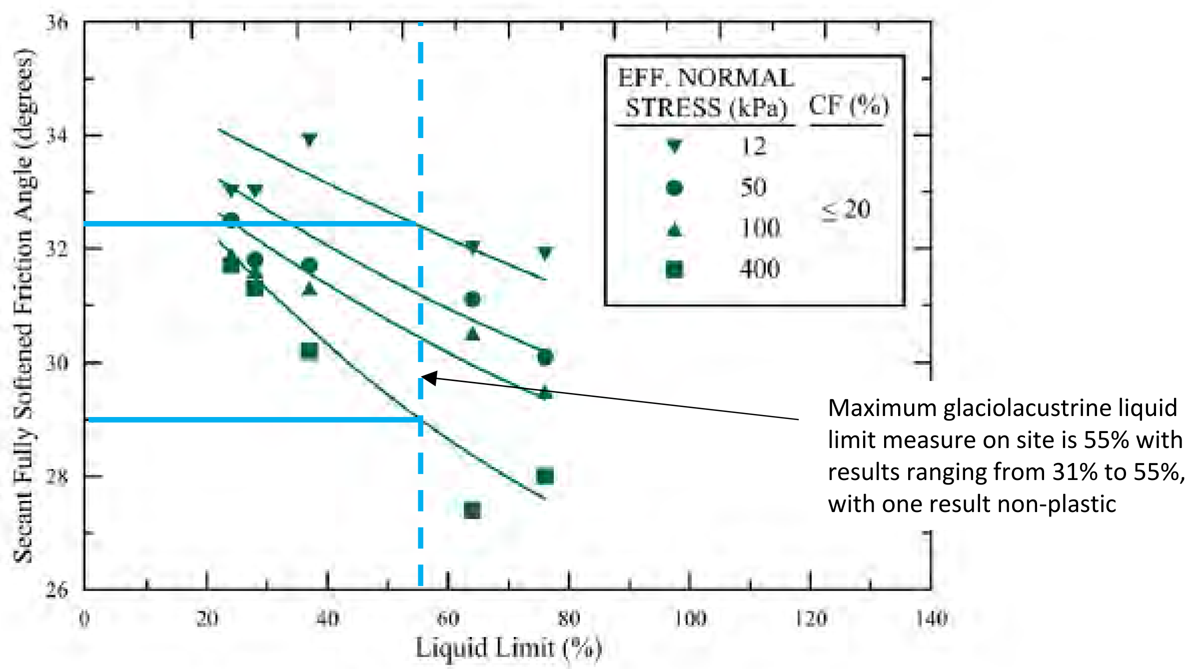
NOTES

1. Section compiled based on a digitization of historical drawings and borehole logs. The current dam surface obtained from the 2016 aerial site survey provided by RDCK.
2. Further details of the dam construction zones is provided in the SRK memo "Review of HB Mine Tailings Facility Dam Zones and Material Properties" dated July 2018.

srk consulting		HB Dam Stability Analysis
		Model Geometry - Sections 6 and 7
SRK JOB NO.: 1CR012.006	HB Mine Tailings Facility	DATE: December 2019
FILE NAME: Figures_DamModelGeometry.dwg		APPROVED: phm
		FIGURE: 5

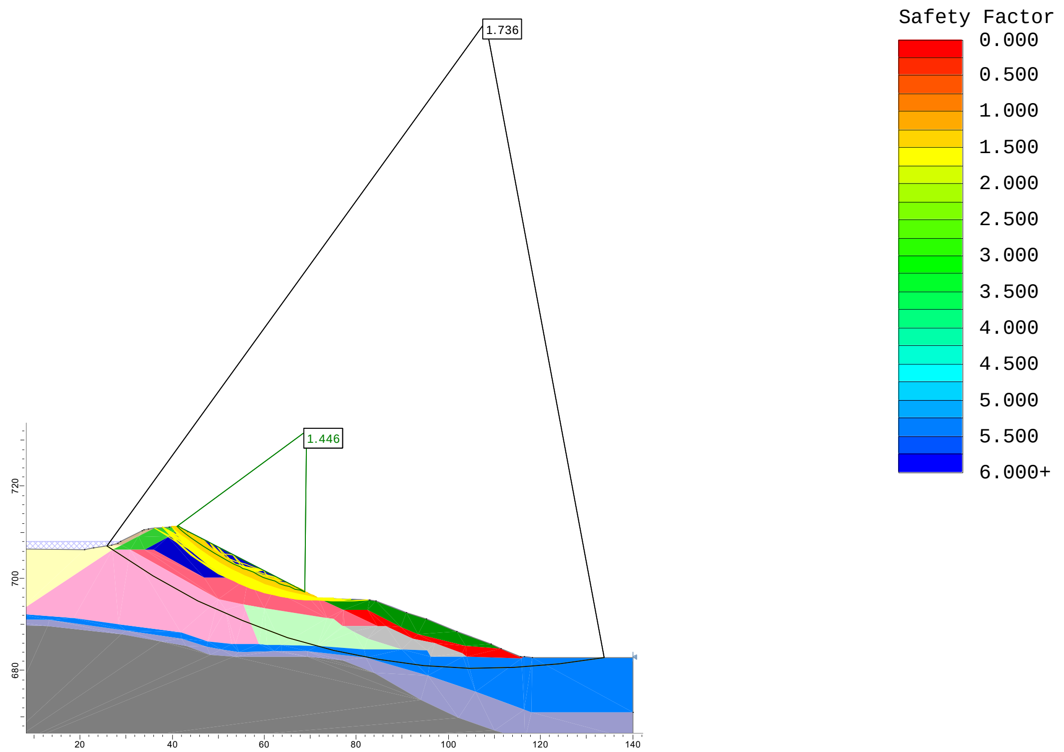


a) Graph above plots the stress dependent fully softened strength envelope for fine grained samples with a clay fraction less than 20% as presented in Equation 4 of Gamez and Stark (2014). The lower 95% confidence band was used in the stability analysis, and result in secant friction angles between 32.6 degrees at a normal stress of 12 kPA and 29 degrees at a normal stress of 400 kPa.



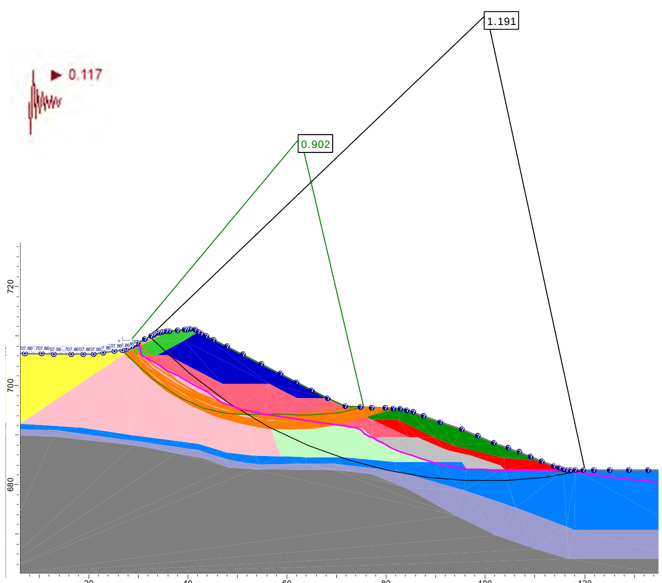
Augmented drained fully softened friction angle correlation for CF ≤ 20%

b) Graph above is from Figure 3 of Gamez and Stark (2014) and shows augmented drained friction angles for fine-grained samples with clay fractions less than 20%. Assuming a liquid limit of 55% for the glaciolacustrine, the secant friction angle varies between 29 and 32.5 degrees between normal stresses of 12 and 400 kPa.



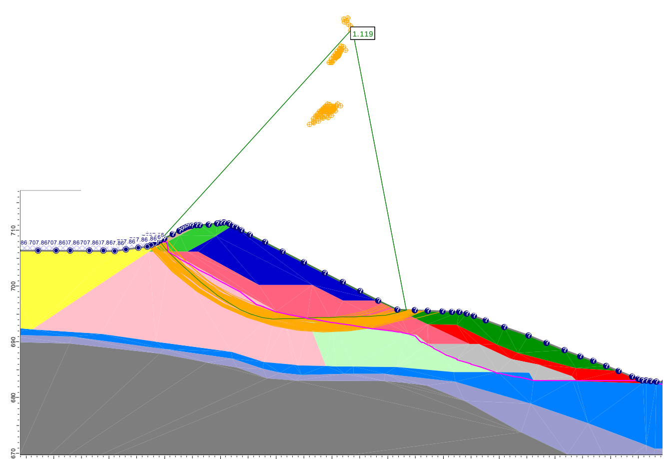
Material Name	Color
1-Bedrock	
2-Native Till	
3-Native Glaciolacustrine	
4-Tailings	
5-Original Dam	
6-Stabilizing Berm	
7-Filter Blanket	
8-Common Fill	
9-Select Imp Fill	
10-Rock Toe Drain	
11-Rock Drain (2005)	
12-Till Toe Berm (2005)	
13-Rip-Rap	
Toe Berm Expansion-Drain	
Toe Berm Expansion-Till	

a) Long-term Drained



b) Pseudo-static

- Figure plots all failure surfaces less than 1.0.

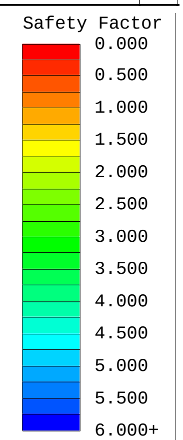


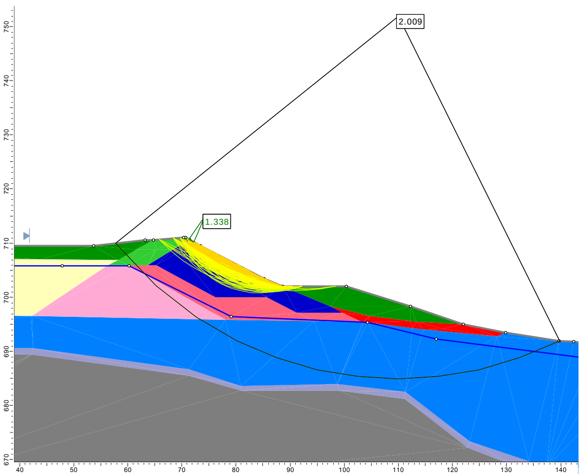
c) Post-Earthquake

- Figure plots all failure surfaces less than 1.2.

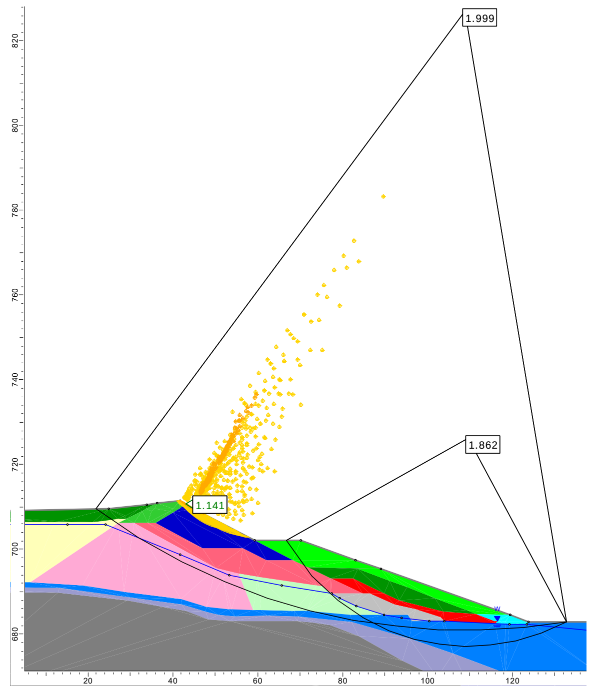
srk consulting	Regional District Central Kootenay	HB Dam Stability Analysis
		Results – Existing Dam Geometry Section 04
Job No: 1CR012.006 Filename: FigurePortrait_StabilityAnalysis.pptx	HB Mine Tailings Facility	Date: December 2019 / Approved: PHM / Figure: 7

Material Name	Color
1-Bedrock	
2-Native Till	
3-Native Glaciolacustrine	
4-Tailings	
5-Original Dam	
6-Stabilizing Berm	
7-Filter Blanket	
8-Common Fill	
9-Select Imp Fill	
10-Rock Toe Drain	
11-Rock Drain (2005)	
12-Till Toe Berm (2005)	
13-Rip-Rap	
Toe Berm Expansion-Drain	
Toe Berm Expansion-Till	

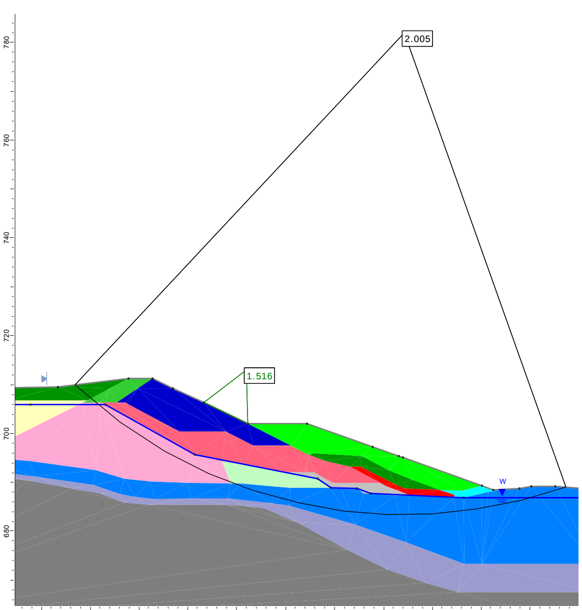




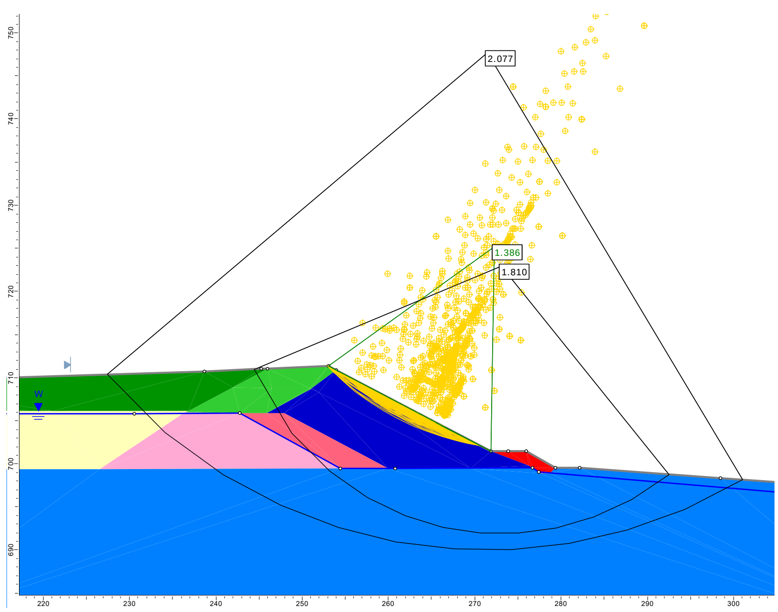
a) Section 02



b) Section 04



c) Section 05



d) Section 07

Notes:

1. Figures plot all failure surface below a factor of safety of 1.5.

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Job No: 1CR012.006

Filename: FigurePortrait_StabilityAnalysis.pptx

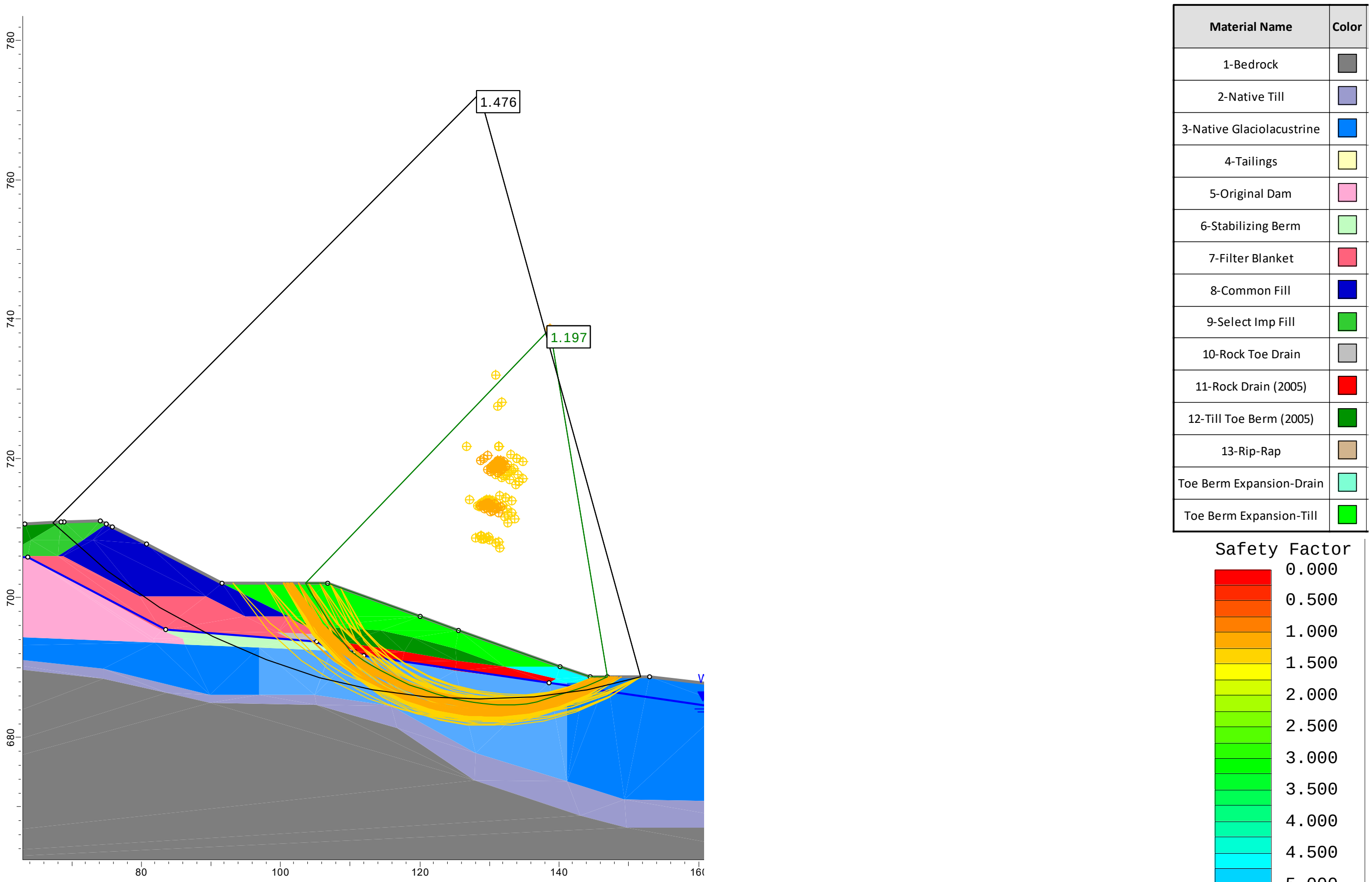
REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

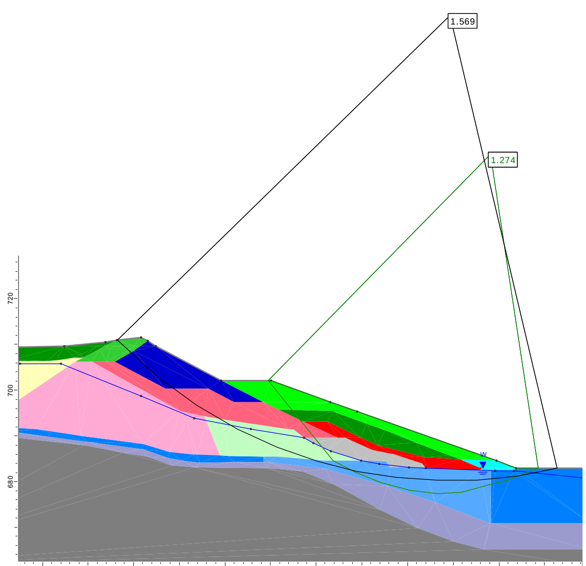
HB Dam Stability Analysis

Upgraded Dam - Long-Term Drained Conditions

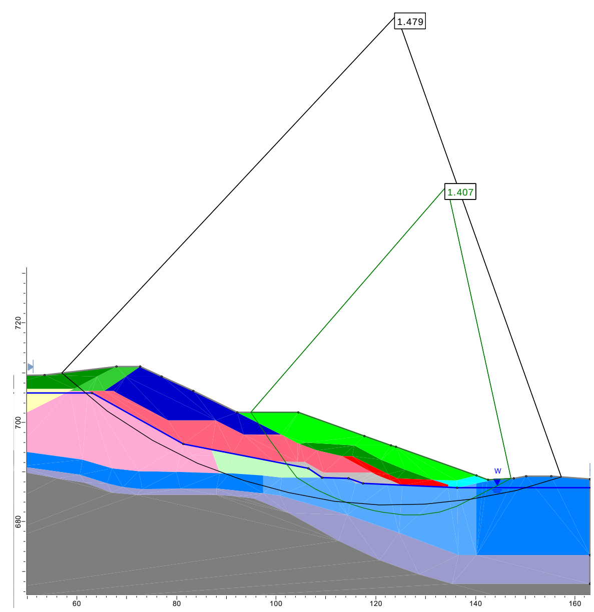
Date:	Approved:	Figure:
December 2019	PHM	8



a) Section 03



b) Section 04



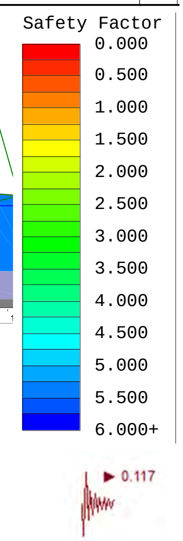
c) Section 05

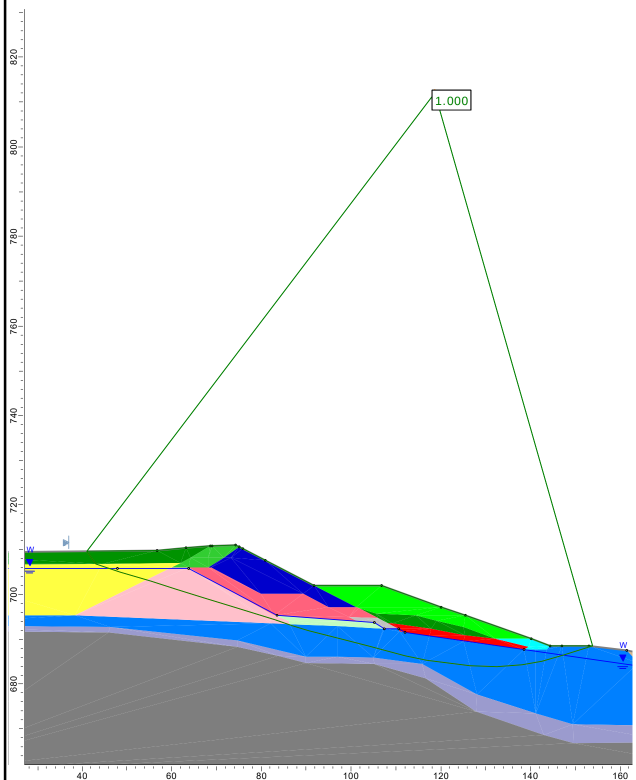
Notes:

1. Figures plot all failure surface below a factor of safety of 1.3.

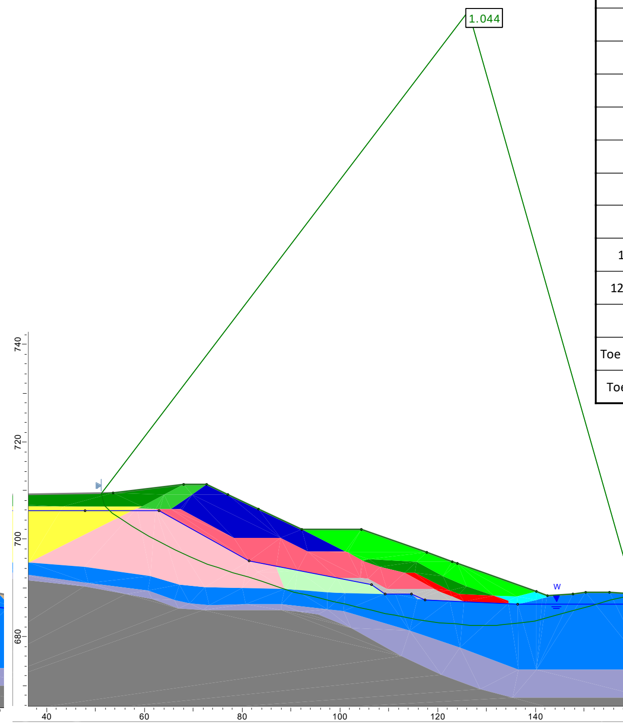
srk consulting	REGIONAL DISTRICT CENTRAL KOOTENAY	HB Dam Stability Analysis
		Upgraded Dam – Interim Construction Conditions
Job No: 1CR012.006 Filename: FigurePortrait_StabilityAnalysis.pptx	HB Mine Tailings Facility	Date: December 2019 · Approved: PHM · Figure: 9

Material Name	Color
1-Bedrock	
2-Native Till	
3-Native Glaciolacustrine	
4-Tailings	
5-Original Dam	
6-Stabilizing Berm	
7-Filter Blanket	
8-Common Fill	
9-Select Imp Fill	
10-Rock Toe Drain	
11-Rock Drain (2005)	
12-Till Toe Berm (2005)	
13-Rip-Rap	
Toe Berm Expansion-Drain	
Toe Berm Expansion-Till	

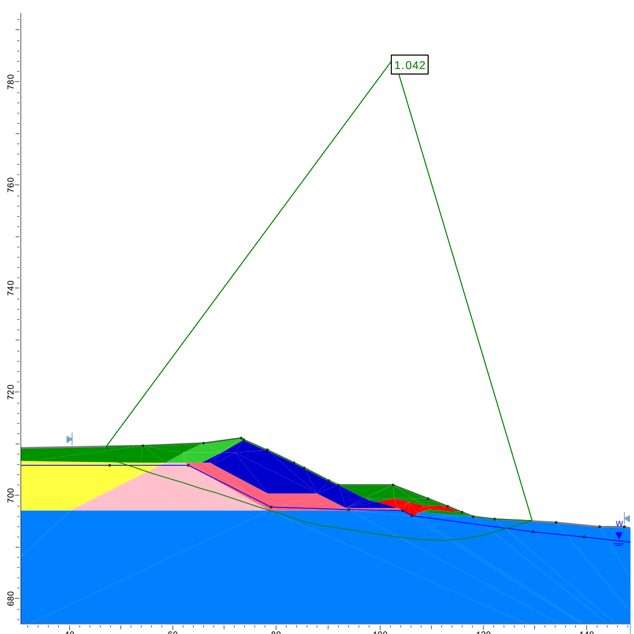




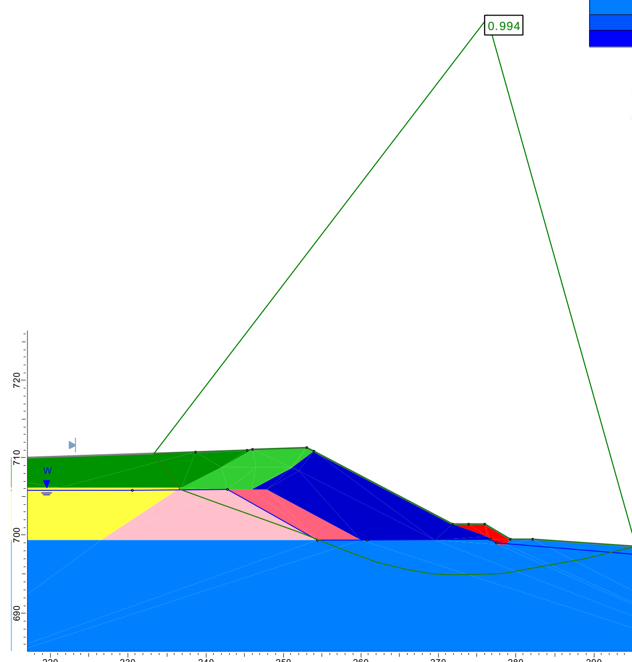
a) Section 03



b) Section 05



c) Section 06

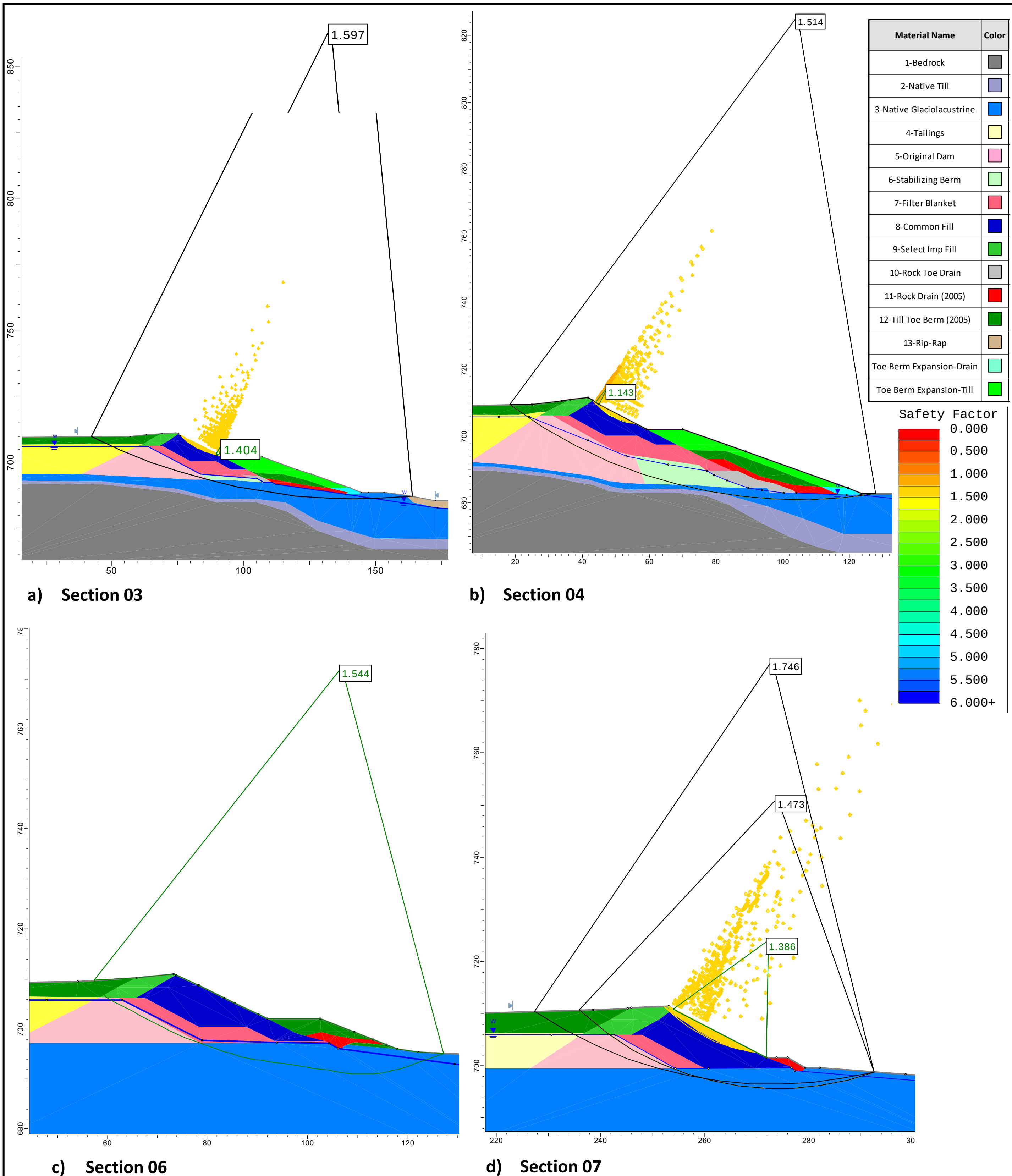


d) Section 07

Notes:

1. Figures plot all failure surface below a factor of safety of 1.1.

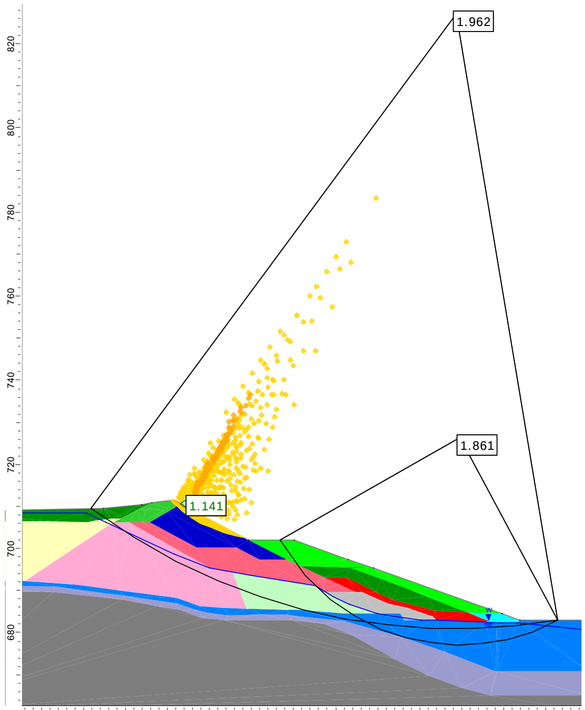
srk consulting		HB Dam Stability Analysis		
		Upgraded Dam - Pseudo-static Conditions		
Filename: FigurePortrait_StabilityAnalysis.pptx	HB Mine Tailings Facility	Date:	Approved: PHM	Figure: 10



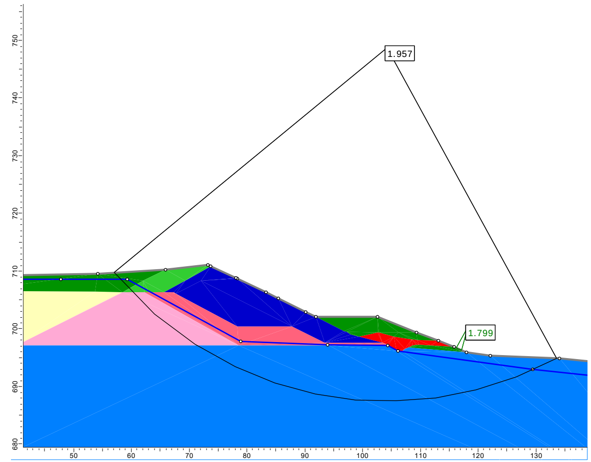
Notes:

1. Figures plot all failure surface below a factor of safety of 1.5.

srk consulting		HB Dam Stability Analysis
		Upgraded Dam – Post-Seismic Conditions
Job No: 1CR012.006 Filename: FigurePortrait_StabilityAnalysis.pptx	HB Mine Tailings Facility	Date: December 2019 | Approved: PHM | Figure: **11**

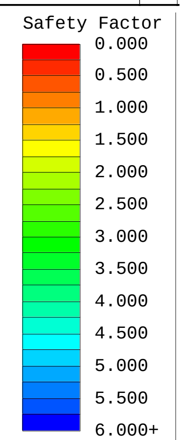


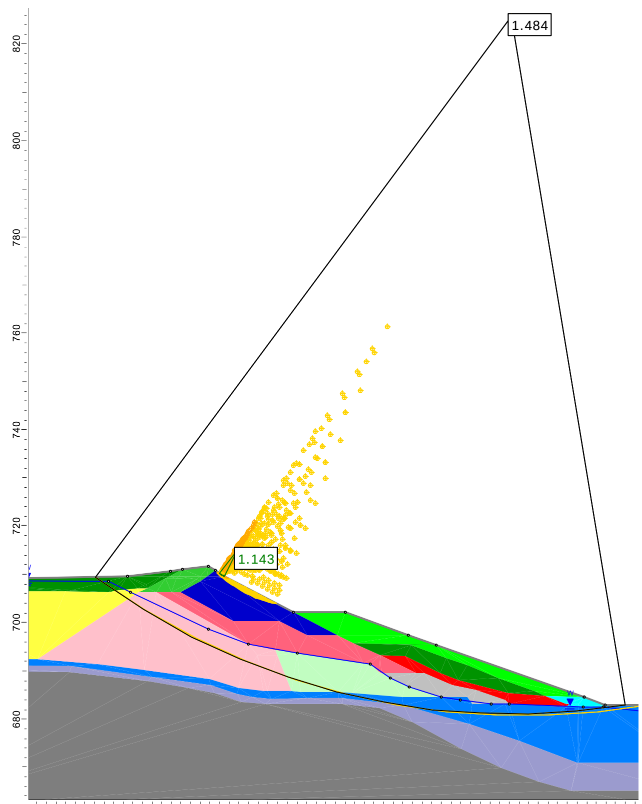
a) **Section 04, drained conditions**



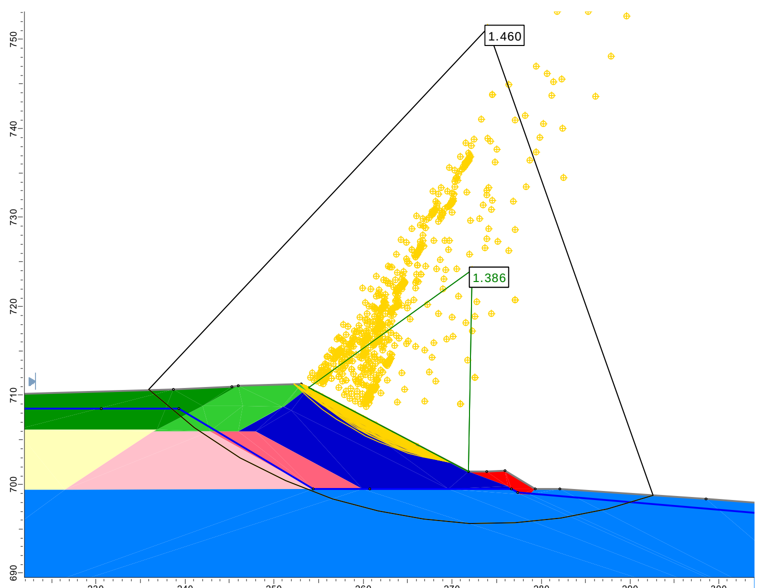
b) **Section 06, drained conditions**

Material Name	Color
1-Bedrock	
2-Native Till	
3-Native Glaciolacustrine	
4-Tailings	
5-Original Dam	
6-Stabilizing Berm	
7-Filter Blanket	
8-Common Fill	
9-Select Imp Fill	
10-Rock Toe Drain	
11-Rock Drain (2005)	
12-Till Toe Berm (2005)	
13-Rip-Rap	
Toe Berm Expansion-Drain	
Toe Berm Expansion-Till	





c) **Section 04, post-seismic conditions**

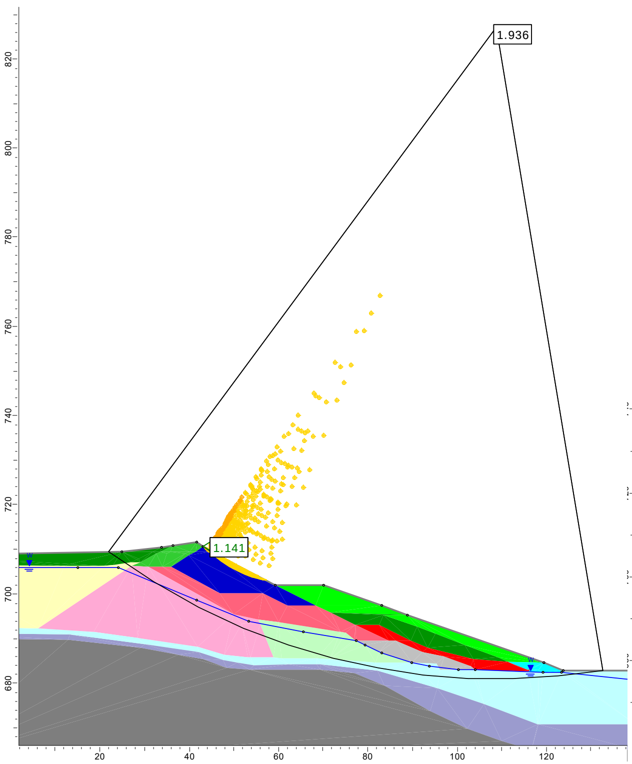


d) **Section 07, post-seismic conditions**

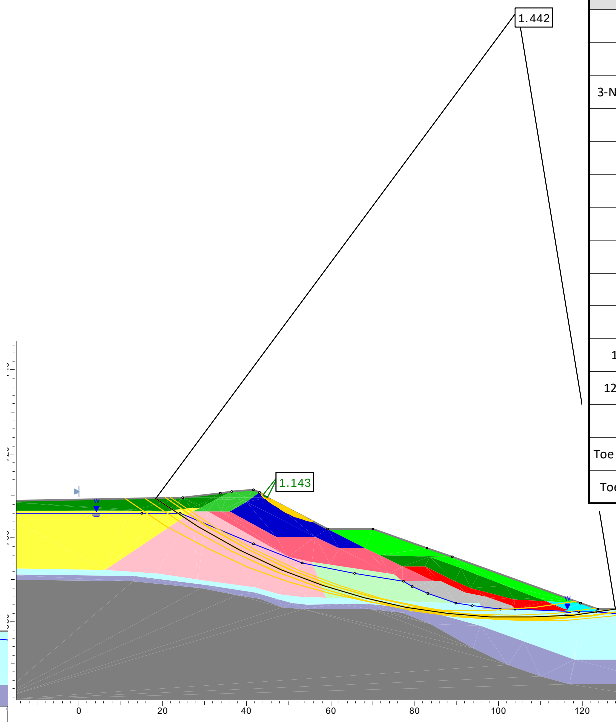
Notes:

1. Figures plot all failure surfaces below a the target factor of safety of 1.1 (pseudo-static) and 1.3 (post-earthquake).

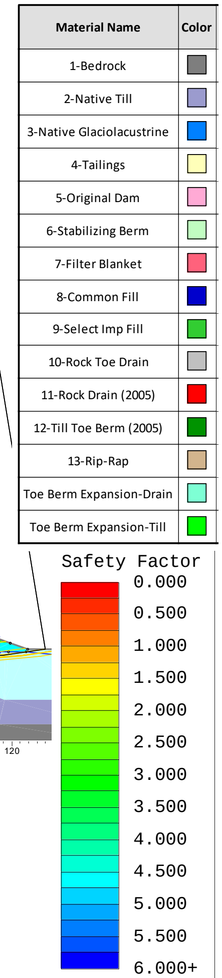
srk consulting		HB Dam Stability Analysis **Pore Pressure Sensitivity Analysis Results**
Job No: 1CR012.006 Filename: FigurePortrait_StabilityAnalysis.pptx	HB Mine Tailings Facility	Date: December 2019 | Approved: PHM | Figure: 12

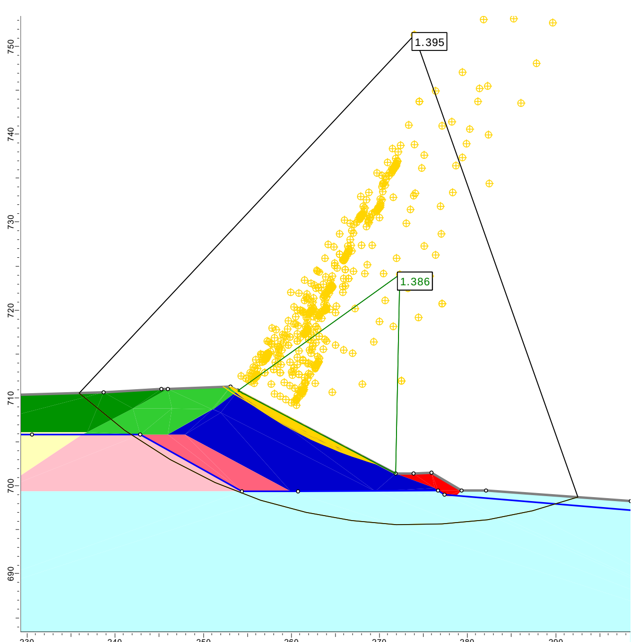


a) **Section 04, drained conditions with a glaciolacustrine friction angle of 28°**

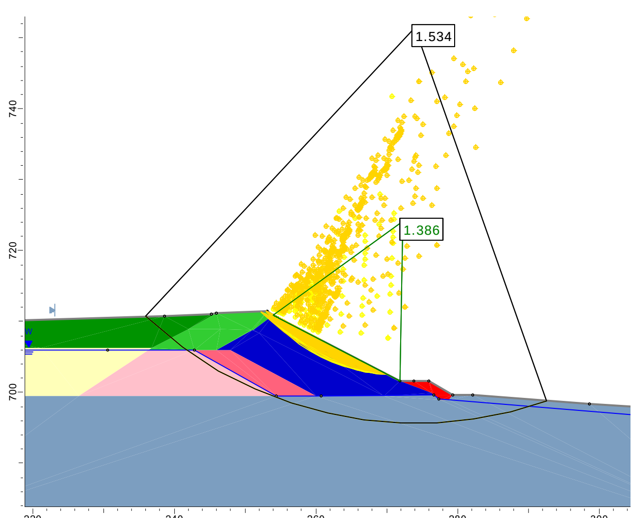


b) **Section 04, post-seismic conditions with a glaciolacustrine friction angle of 28°**





c) **Section 07, post-seismic conditions with a glaciolacustrine friction angle of 28°**



d) **Section 07, post-seismic conditions with fully-softened glaciolacustrine shear strength**

Notes:

1. Figures plot all failure surfaces below a the target factor of safety of 1.5.

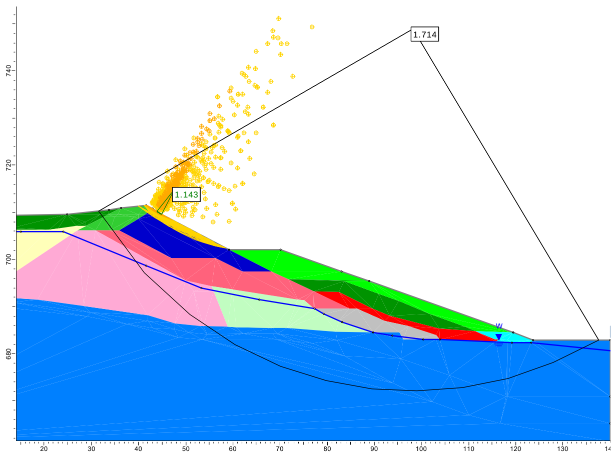
srk consulting

REGIONAL DISTRICT CENTRAL KOOTENAY

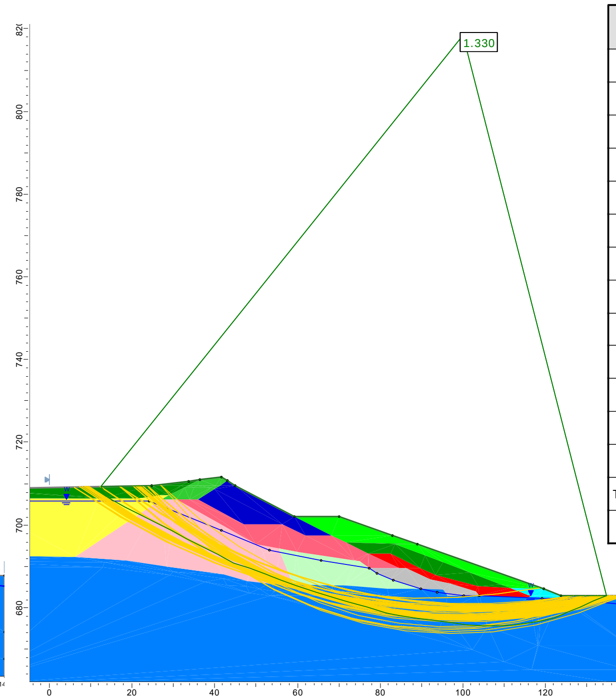
HB Dam Stability Analysis

Glaciolacustrine Sensitivity Analysis Results

Job No: 1CR012.006	HB Mine Tailings Facility	Date: December 2019	Approved: PHM	Figure: 13
Filename: FigurePortrait_StabilityAnalysis.pptx				

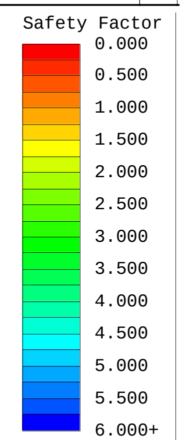


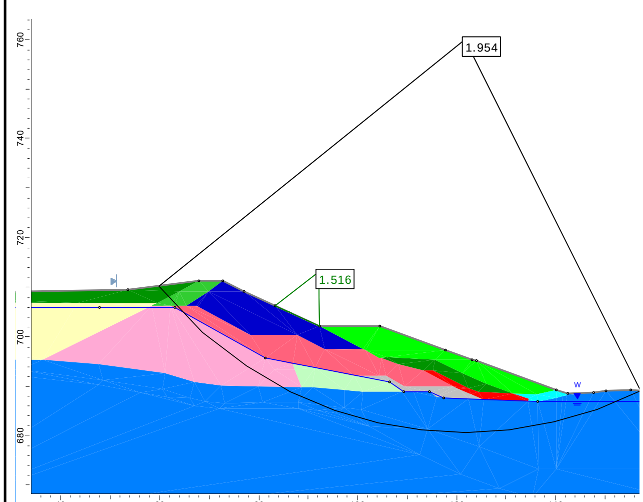
a) Section 04, drained conditions with a glaciolacustrine foundation



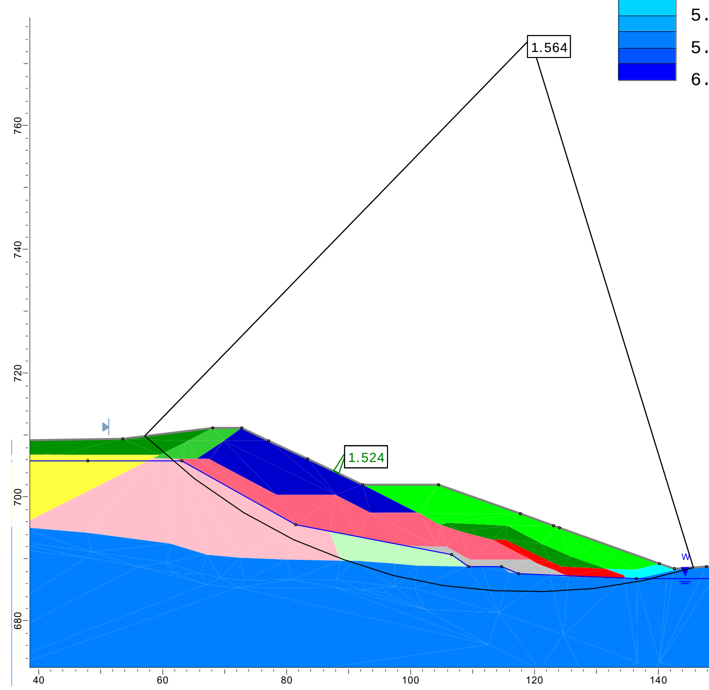
b) Section 04, post-seismic conditions with a glaciolacustrine foundation

Material Name	Color
1-Bedrock	
2-Native Till	
3-Native Glaciolacustrine	
4-Tailings	
5-Original Dam	
6-Stabilizing Berm	
7-Filter Blanket	
8-Common Fill	
9-Select Imp Fill	
10-Rock Toe Drain	
11-Rock Drain (2005)	
12-Till Toe Berm (2005)	
13-Rip-Rap	
Toe Berm Expansion-Drain	
Toe Berm Expansion-Till	





c) Section 05, drained conditions with a glaciolacustrine foundation



d) Section 05, post-seismic conditions with a glaciolacustrine foundation

Notes:

1. Figures plot all failure surfaces below a the target factor of safety of 1.5.

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HB Dam Stability Analysis

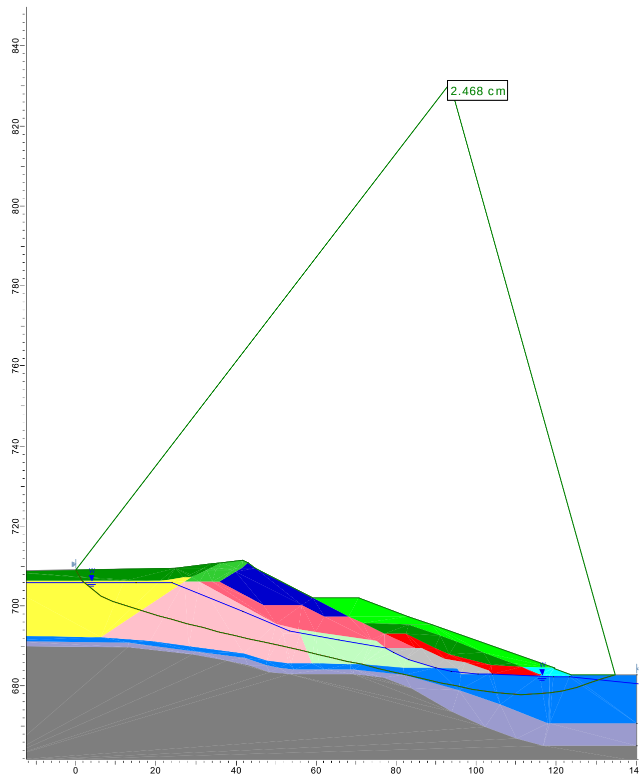
Glaciolacustrine Thickness Sensitivity Analysis Results

Job No: 1CR012.006

Filename: FigurePortrait_StabilityAnalysis.pptx

HB Mine Tailings Facility

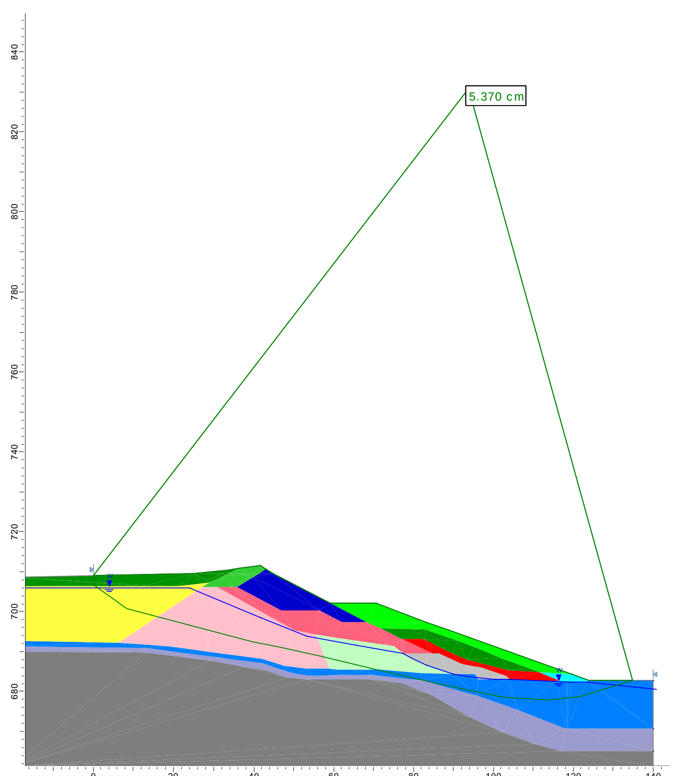
Date:	Approved:	Figure:
December 2019	PHM	15



a) **PGA = 0.256 g**

Material Name	Color
1-Bedrock	
2-Native Till	
3-Native Glaciolacustrine	
4-Tailings	
5-Original Dam	
6-Stabilizing Berm	
7-Filter Blanket	
8-Common Fill	
9-Select Imp Fill	
10-Rock Toe Drain	
11-Rock Drain (2005)	
12-Till Toe Berm (2005)	
13-Rip-Rap	
Toe Berm Expansion-Drain	
Toe Berm Expansion-Till	

Newmark Displacement (cm)
0.000
0.208
0.417
0.625
0.833
1.042
1.250
1.458
1.667
1.875
2.083
2.292
2.500+



b) **PGA = 0.313 g**

HB Dam Stability Analysis

Seismic Deformation – Newmark Analysis

Job No: 1CR012.006

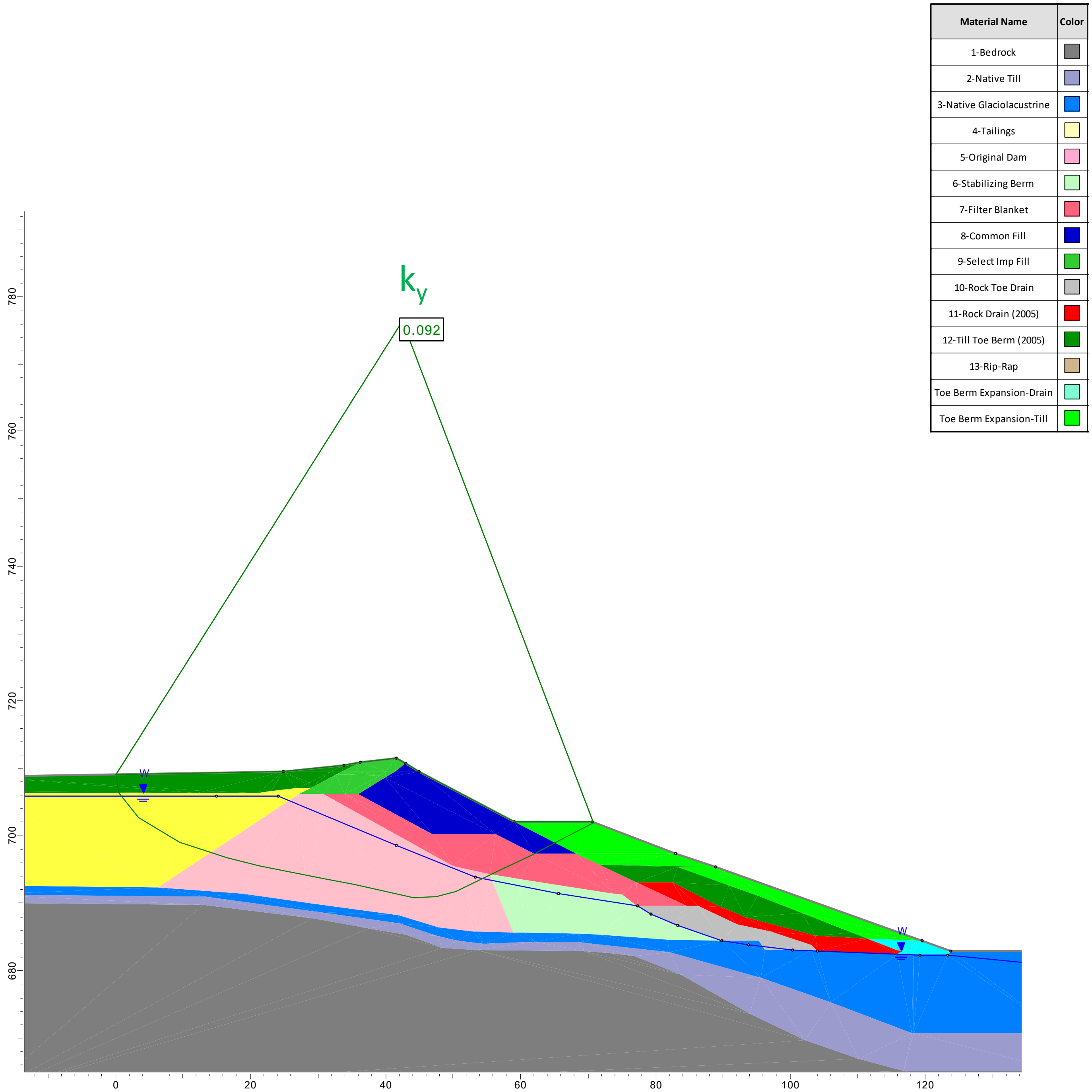
Filename: FigurePortrait_StabilityAnalysis.pptx

HB Mine Tailings Facility

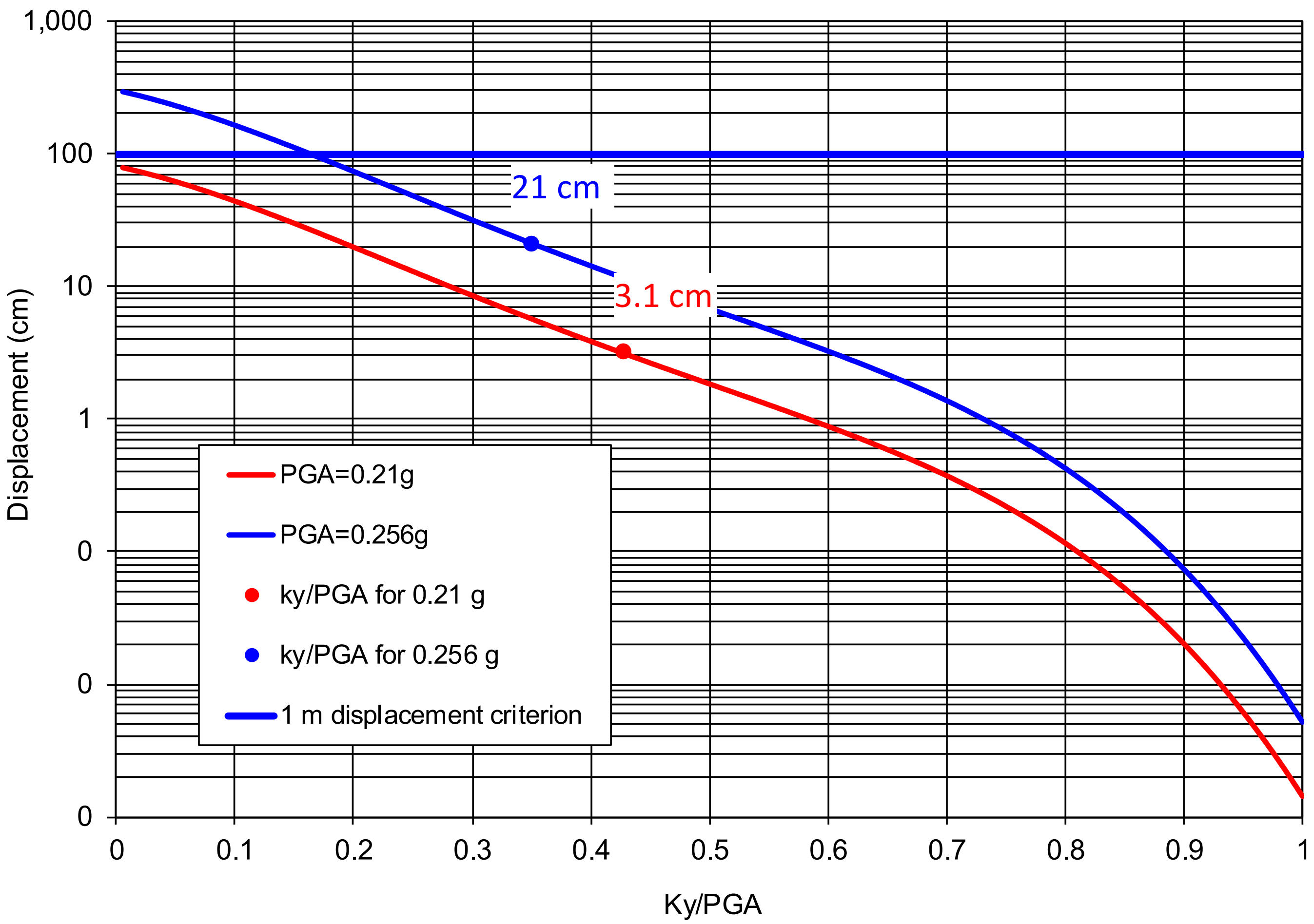
Date: December 2019

Approved: PHM

Figure: 16



srk consulting		HB Dam Stability Analysis
		Seismic Deformation – Seismic Yield Coefficient
Job No: 1CR012.006 Filename: FigurePortrait_StabilityAnalysis.pptx	HB Mine Tailings Facility	Date: December 2019 | Approved: PHM | Figure: 17



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Job No: 1CR012.006

Filename: FigurePortrait_StabilityAnalysis.pptx

HB Mine Tailings Facility

HB Dam Stability Analysis

Seismic Deformation – Rathje and Saygili (2009) Predicted Displacements

Date:	Approved:	Figure:
December 2019	PHM	18

Appendix C-5 – Spillway Design

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Memo

To:	File	**Client:**	Regional District of Central Kootenay
From:	Sarah Portelance, P.Eng.	**Project No:**	1CR012.004
Reviewed by:	Victor Munoz, P.Eng.	**Date:**	December 13, 2019
Subject:	HB Mine Tailings Facility Spillway Design		

1 Introduction

As part of HB Mine Tailings Facility closure and remediation, the spillway at the western abutment of the HB Dam is to be upgraded to convey the probable maximum flood (PMF). This memo documents the design details of the upgraded spillway.

2 Hydrology

The inflow design flood hydrograph to the HB Dam was determined using HEC-HMS hydrologic software, developed by the United States Army Corps of Engineers. The SCS curve number and unit hydrograph method was used. Table 1 provides a summary of the input parameters used in the hydrology assessment. The PMF with climate change effects was determined to be 68 m^3/s. Additional details of the derivation and calibration of the PMF is further described in Appendix E of the Design Report.

Table 1: Hydrologic Runoff Parameters

Parameter	Value
Inflow Design Flood (IDF) Criteria	PMF under climate change effects
Catchment area	2.18 km^2
PMP (spring rainfall dominated)	Rainfall = 215 mm Snowmelt = 55 mm
Hyetograph Distribution	Alternating Block Method
Loss Transformation	SCS Curve Number
Transform Method	SCS Unit Hydrograph
SCS curve number	54
Lag time	11 min
PMF – with climate change	68 m^3/s

3 HB Dam and Spillway Configuration

The HB Dam has a current crest and spillway invert elevation of 711.0 m and 707.5 m respectively.

The spillway invert will be lowered to an elevation to 705.8 m, which is 0.5 m lower than the top of the dam filter layer[1]. Fill is to be placed within the tailings pond to prevent pooling of water in the facility and convey flows to the spillway at the western abutment of the dam. The remainder of the tailings will be covered with a 0.3 m thick soil cover. Channels constructed over the tailings cover will convey surface runoff to the spillway and will be sized to convey the 1:200 year event. As a result, water will only be stored within the impoundment during flood events greater than the 1:200 year event. Additional details of the drainage channels are further described in Appendix G of the Design Report.

Table 2 shows the storage-elevation details for the remediated tailings facility after closure (tailings pond backfill, tailings cover, and upgraded spillway).

Table 2: HB Dam upstream stage-storage

Elevation [m]	Depth above spillway invert [m]	Storage Volume [m^3]
705.8 (spillway invert)	0.0	0
706.0	0.2	10
707.0	1.2	643
708.0	2.2	4,331
709.0	3.2	43,174
710.0	4.2	123,568
711.0 (dam crest)	5.2	250,000

Source: Z:\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\302_HydrotechDesign\West_Final_Spillway_Design_11142018_Rev00_spb.xlsm

Figure 1 shows the spillway design. The spillway channel consists of two distinct sections:

- The upper section (Station 0+000 to 0+085) curves around the west abutment of the dam and has a relatively flat longitudinal slope of 2.2% through bedrock.
- The lower section (Station 0+085 to 0+200) is a straight chute down the western side of the valley at a steep 20% slope in till.

The riprap erosion protection for the lower section was sized for the 1000-year peak flow. In the event of the PMF, there is a risk of movement of the riprap and erosion of the underlying soil section of the spillway. The design spillway has been realigned further away from the dam and aligned to exit from the bedrock perpendicularly to reduce the risk of the potential erosion of the soil portion of the spillway undercutting the toe of the dam, and to prevent a full dam breach. Further details of the risk of erosion and benefits of the bedrock outcrop are provided in Section 4.3.

[1] Additional details regarding the dam construction history and material zones can be found in Appendix A of the Design Report.

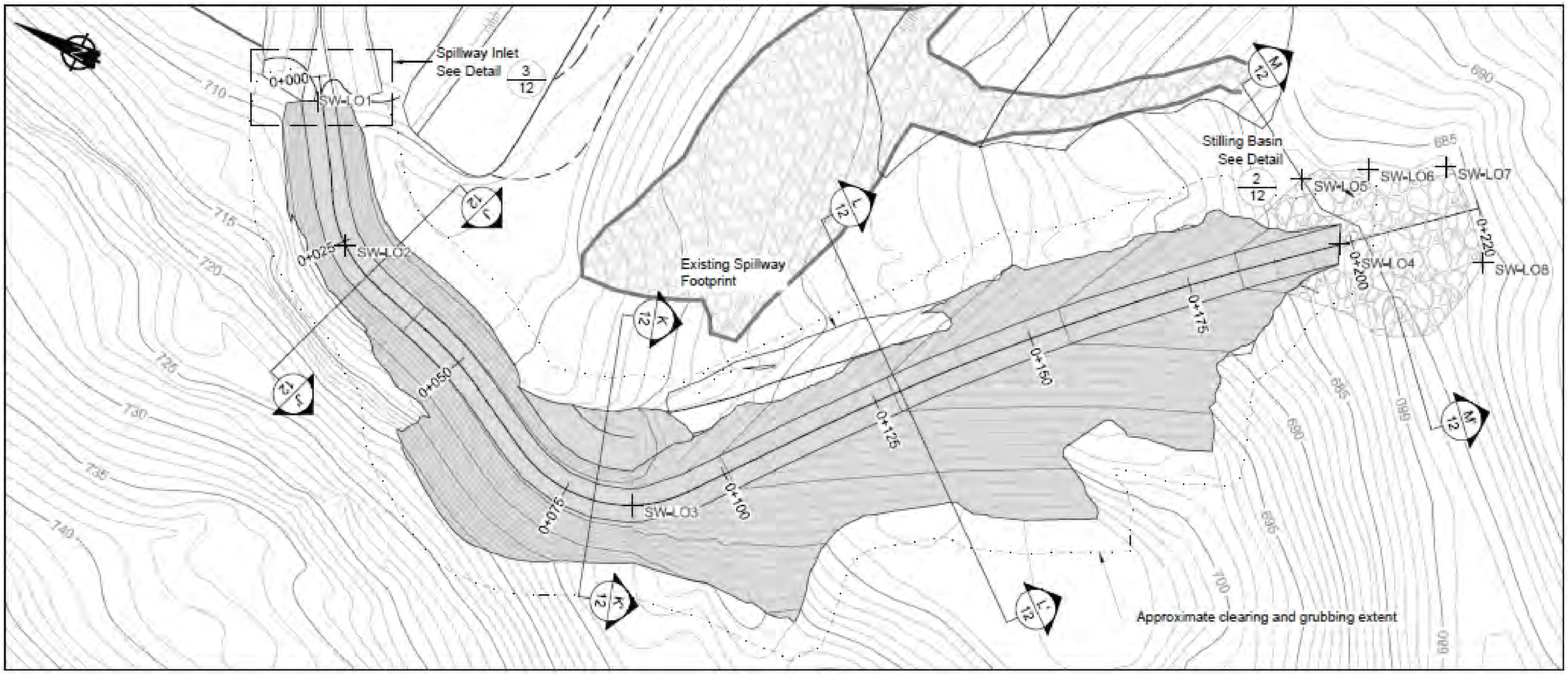
The stilling basin at the outlet of the spillway channel is designed to ensure energy is properly dissipated into the existing creek. Table 3 summarizes key design parameters for the HB Dam spillway.

Table 3: HB Dam and Spillway Design Parameters

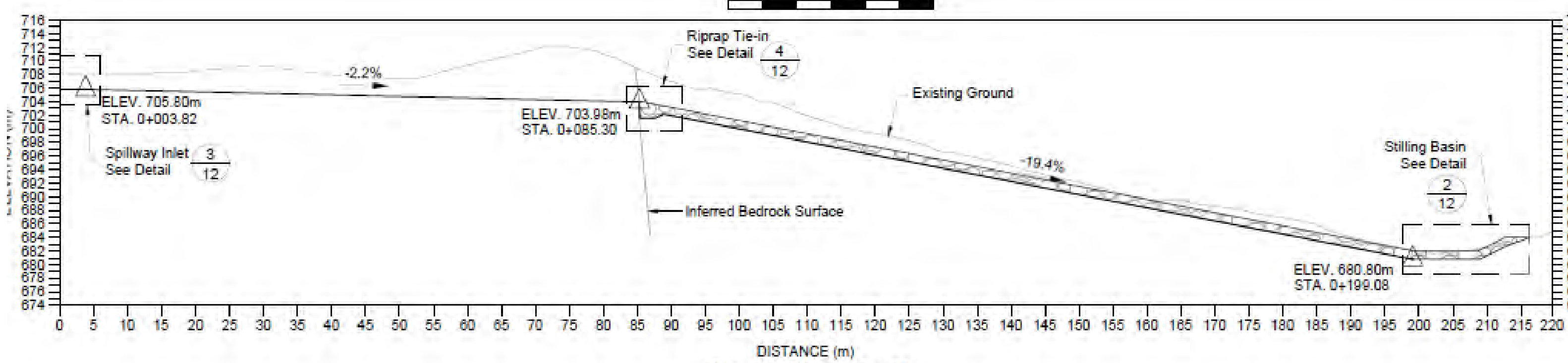
Parameter		Value
Dam crest elevation [m]		711.0 m
Upstream till beach side slope [H:V]		4:1
Spillway invert elevation [m]		705.8 m
Spillway bottom width [m]		5 m
Spillway channel side slope [H:V]	in bedrock	0.75:1
	in till	2:1
Spillway channel longitudinal slopes	Upper	2%
	Lower	20%
Minimum channel depth[1]	Upper	2.3
	Lower	1.4
Riprap median size (D_{50})[2]	Upper	n/a, in bedrock
	Lower	600 mm
	Stilling Basin	600 mm

Note:

1. Calculated based on channel hydraulics, peak flow routing (Section 4.1) and spillway channel slopes.
2. Erosion protection for the PMF requires riprap with a median diameter size of 1.3 m. Due to the impracticality of producing and placement such large riprap, a decision was made to adopt a riprap size with a D50 of 600mm corresponding to an IDF event design criteria greater than the 1 in 1,000-year event. See Section 4.3 for further details.



West Spillway Plan



West Spillway Profile

srk consulting	Regional District Central Kootenay	Tailings Spillway Channel Design
		Spillway Design
Job No: 1CR012.005 Filename: Figure1_SpillwayDesign.pptx	HB Mine Tailings Facility	Date: Jan 2019 / Approved: phm / Figure: 1

4 Hydraulic Analysis

4.1 Flood Routing

The flood routing of the PMF through the spillway was estimated using the available storage capacity upstream of the spillway inlet (i.e. stage-storage curve) and the following trapezoidal spillway equation (Smith 1985):

$$Q = 1.70\ BH^{3/2} + 1.27\ H^{5/2}\ tan(\phi/2)$$

Where B is the width of the spillway, H is the height of water over the spillway invert and $\phi/2$ is the angle of the side slope relative to the vertical, for which a channel with side slopes of 2:1, tan($\phi/2$) will have a value of 2.

Figure 2 shows the inflow and outflow hydrographs for the PMF. The peak inflow of 68 m^3/s is attenuated by the spillway inlet and reduced to 57.5 m^3/s. Figure 3 shows the maximum water level during the passage of the IDF in the spillway inlet is 708.63 m resulting in a maximum water depth of 2.83 m above the spillway invert.

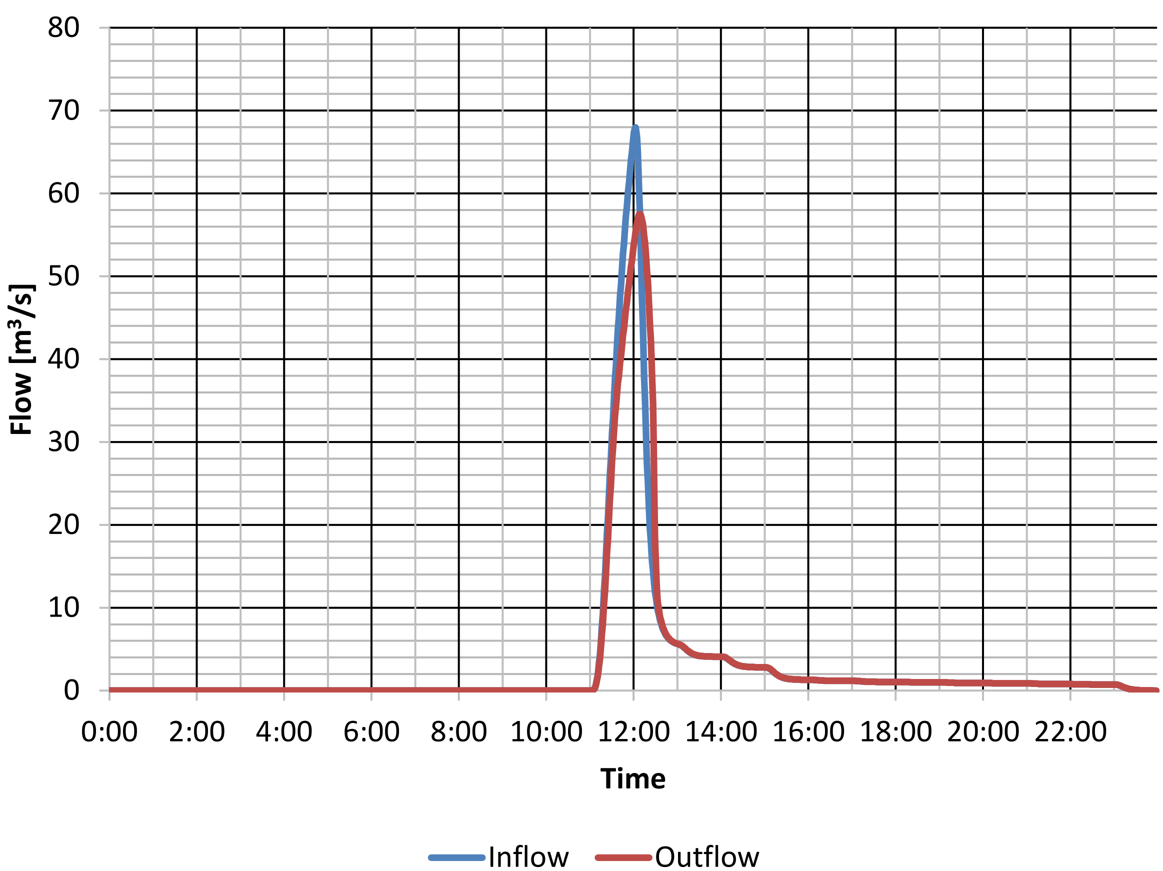


Figure 2: Routed PMF Hydrograph

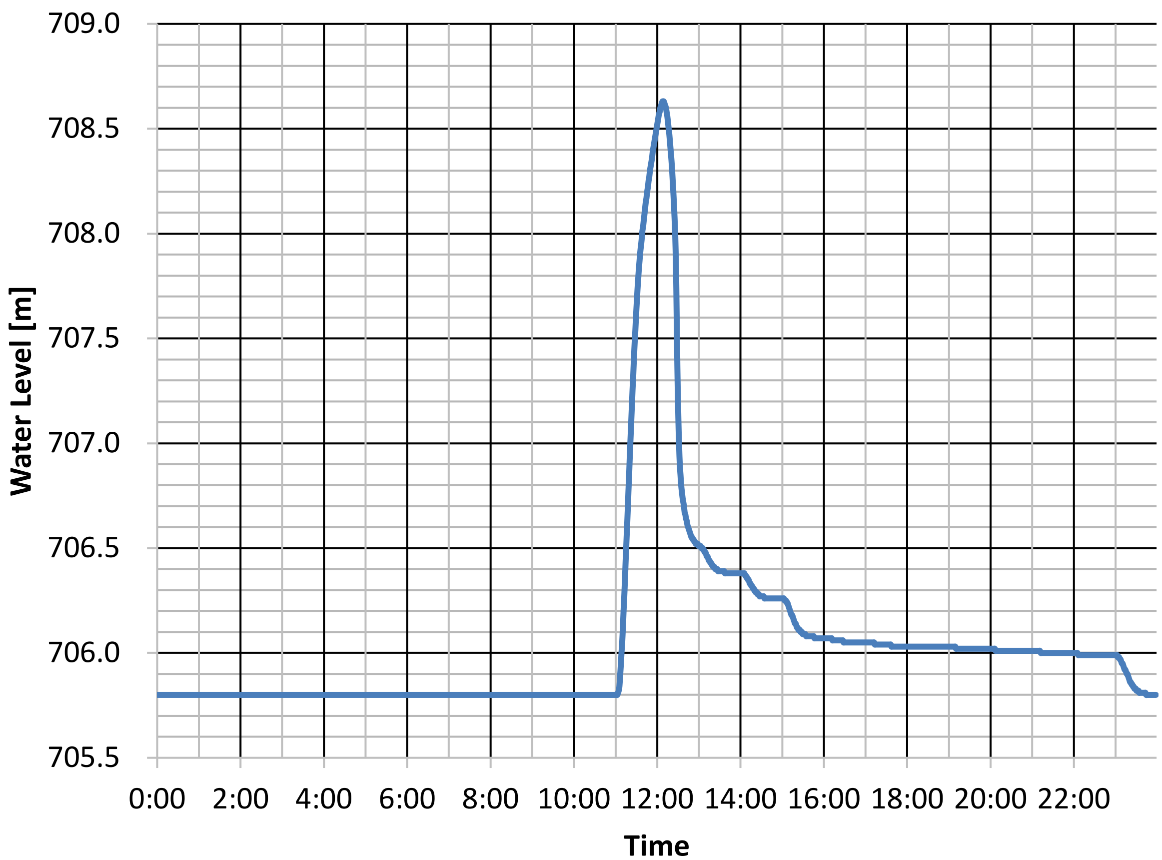


Figure 3: PMF Water Level

4.2 Freeboard Analysis

A wind set-up and wave run-up analysis was performed to ensure that the crest of the dam is protected from overtopping during the passage of the inflow design flood (IDF) (CDA 2013).

The CDA guidance require calculation of freeboard requirements under two conditions:

- The normal freeboard is defined as the vertical distance between the crest of the dam and the maximum reservoir operating water level.
- The minimum freeboard is defined as the vertical distance between the IDF and the crest of the dam.

As there will be no more permanent pond following lowering of the spillway and construction of the till beach, only the minimum freeboard needs to be evaluated.

4.2.1 Freeboard Calculations

Minimum freeboard is described as no overtopping by 95% of the waves caused by the most critical wind associated with the annual exceedance probability (AEP) event when the reservoir is at its maximum extreme level during the occurrence of the IDF (CDA 2013). Figure 4 illustrates the minimum freeboard estimate during the IDF with a wind storm event with a frequency of 1 in 2 year. The design freeboard is the minimum freeboard plus a safety factor allowance.

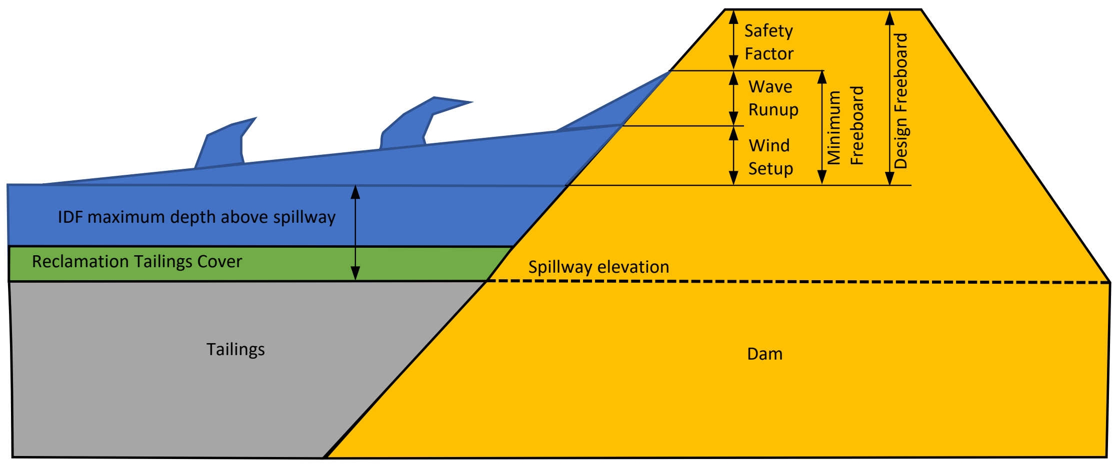


Figure 4: Freeboard Schematic

Inputs for calculating the minimum freeboard for the HB Dam (Table 4) includes wind speed, water level during the passage of the IDF, average pond depth during the IDF event and fetch length.

Table 4: Minimum Freeboard Calculation Inputs

Parameter	Value	Comment/Reference
IDF (m^3/s)	68	Probable maximum flood (PMF). Details of the derivation in Appendix E of the Design Report.
Peak spillway flow (m^3/s)	57.5	IDF spillway routing (see Section 4.1)
Maximum depth above spillway (m)	3.28	IDF spillway routing (see Section 4.1)
Proposed spillway elevation (m)	705.80	HB Dam Spillway Configuration (see Section 3)
Maximum water elevation during IDF (m)	708.63	Maximum depth during IDF passage (see Section 4.1)
Average water depth in reservoir (m)	1.6	Based on tailings surface plus 0.3 m cover
Fetch length (km)	0.36	Based on flood extent during routing IDF
Wind Gust (km/hr)	133	Design criteria is the 1:2 return period event. Details of the derivation is provided in Appendix E of the Design Report.
1-hr wind speed (km/hr)	86	Correction from 1s (i.e. gust) to 1-hr. (USACE 1984)
Upstream Embankment Slope	4H:1V	Vegetated with grass

Source: Z:\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\302_HydrotechDesign\West_Final_Spillway_Design_11142018_Rev00_spb.xlsm

4.2.2 Wind Setup

When the wind blows over a water surface, it creates horizontal stress on the water resulting in an accumulation of the water at the downwind end of the enclosed water body. This accumulation of water is referred to as wind setup. As defined in the CDA guidelines (2014), wind setup can be determined by:

$$S = \frac{U^2 F}{Kd} \quad \text{(Eq. 1)}$$

Where:

S is the wind setup relative to the still water level (m);
U is the wind speed over water (m/s);
F is the effective fetch length (km);
d is the average water depth over the fetch (m); and
K is a constant set at 4850 (USBR 1992).

Based on the input parameters presented in Table 1 the wind setup was determined to be 0.03 m.

4.2.3 Wave Run-up

Wave run-up is defined as the maximum vertical extent of a wave uprush on a beach or structure. The wave run-up is governed by the slope of the structure, the water depth at the structure toe, the roughness and permeability of the embankment and wave characteristics such as the significant wave height.

As described in the CDA guidelines, wave heights and period were determined using the following equations, which are valid only for fetch-limited conditions:

$$H_S = 1.616 \times 10^{-2} U_A F^{1/2} \quad \text{(Eq. 2)}$$

$$T = 6.238 \times 10^{-1} (U_A F)^{1/3} \quad \text{(Eq. 3)}$$

$$U_A = 0.71\, U^{1.23} \quad \text{(Eq. 4)}$$

Where:

H_s is the significant wave height (m);
F is the effective fetch length (km);
T is the wave period (s);
U is the wind speed (m/s); and
U_a is the wind stress factor.

The deepwater wavelength can be determined from the following expression:

$$L = \frac{T^2 g}{2\pi} \quad \text{(Eq. 5)}$$

Where:

L is the wavelength (m);
G is the gravitational acceleration (m/s²); and
T is the wave period as defined above (s).

Table 5 presents the results of the significant wave height and run-up distances. The relative depth (d/L) was determined to be greater than 0.5 indicating that the deep-water equations described above are applicable.

The significant wave height equation (Eq. 2) represents the average of the highest one-third of waves. Given that CDA guidelines (2014) state that the structure needs to be protected by 95% of waves, the calculated significant wave heights were corrected using a factor of 1.37.

Based on the above equations and corrections, a run-up height of 0.90 m was estimated.

Table 5: Wave Run-up Calculation Inputs

Parameter	Value	Source
Significant Wave Height (m)	0.51	Calculated
Correction factor for average of highest 5% of all waves	1.37	CDA 2014
Corrected Significant Wave Height (m)	0.69	Calculated
Wavelength	3.84	Calculated
Relative Depth	0.52	Calculated
Non-dimensional Wave Runoff (R/H)	1.3	Sancold 1990
Wave Runup (m)	0.90	Calculated

4.2.4 Minimum Freeboard

Table 6 summarizes the results of the minimum freeboard requirements for the HB Dam during the passage of the IDF under climate change conditions. The assessment determined a minimum freeboard depth to be 0.94 m, which is less than the currently available freeboard of 2.4 m.

Table 6: Minimum Freeboard Calculation Results

Parameter	Value
Maximum water elevation during IDF (m)	708.63
Wind setup (m)	0.04
Wave run-up (m)	0.90
Minimum freeboard depth (m)	0.94
Minimum freeboard elevation (m)	709.57
Current available freeboard based on a dam crest elevation[1] (m)	2.4

Note(s):

1. Available freeboard was calculated based on the dam crest elevation at 711 m less the maximum water level during the IDF passage.

4.3 Riprap Sizing

The channel riprap size was estimated using a range of empirical expressions. As summarized in the National Engineering Handbook for Stone Sizing Criteria Handbook (USDA 2007), some expressions are better suited for steep slopes and others for flatter slopes. Table 7 provides a summary of empirical relationships applied to evaluate the required riprap size of the HB Dam spillway channel. The Manning's n roughness coefficient was calculated using an iterative process based on the chosen riprap size using two empirical expressions (Strickler (1923) and Anderson et al. (1970)).

Table 7: Summary of Riprap Sizing Expressions

Method	Application
Robinson (1998)	High energy rock chutes.
Isbash	High and low energy, no slopes specified.
NCHRP 108	High and low energy, slopes less than 10%
USACE - Maynord Method	Low energy, slopes less than 2%
USBR Method	High energy, 0.3 to 6.1 m/s and slopes not specified
Tillatoba Model Study	High and low energy, no slopes specified.
USACE steep slope riprap design	High energy, slopes between 2% to 20%
Abt and Johnson	High energy, slopes between 2% to 20%
ARS Rock Chutes	High energy, slopes between 2% to 40%
Khan and Ahmad (2011)	High energy overtopping flows for steep slopes.

Figure 5 illustrates the median riprap size (D_{50}) for a flow rate of 57.5 m^3/s and a spillway channel with a bottom width of 5 m. For a 20% slope, it is recommended that the D_{50} be 1,300 mm. Riprap this large will be difficult to produce and place. A screening assessment to assess riprap alternatives in the steep section of the spillway was completed as part of the preliminary design which included variations of the spillway configuration to reduce flows and grades, use of concrete, check dams, and step-pools. The assessment concluded that use of smaller diameter riprap is the most practical option.

The riprap should still be sized as large as possible and based on observations at site, 600 mm is feasible. With a D_{50} of 600 mm, Figure 6 illustrates the steep section of the spillway channel with a longitudinal slope of 0.20 should be able to withstand a flood event greater than the 1,000 year, while the upper section of the spillway near the dam abutment founded in bedrock will be able to withstand a flood event corresponding to the PMF. A summary of the riprap particle size distribution with a D_{50} of 600 mm is provided in Table 8.

Table 8: Spillway Rip-Rap Particle Size Requirements

Characteristic Diameter (% Passing)	Diameter (mm)
D_{100}	900
D_{85}	650
D_{50}	600
D_{30}	400
D_{15}	200

Flood events in excess of the 1 in 1,000 year event could result in erosion and damage to the lower section of the spillway and potentially require repairs. In addition, there is a risk of backwards erosion of the native soils beneath the riprap. The following section provides additional details of the risk of head cutting and maximum erosion extent.

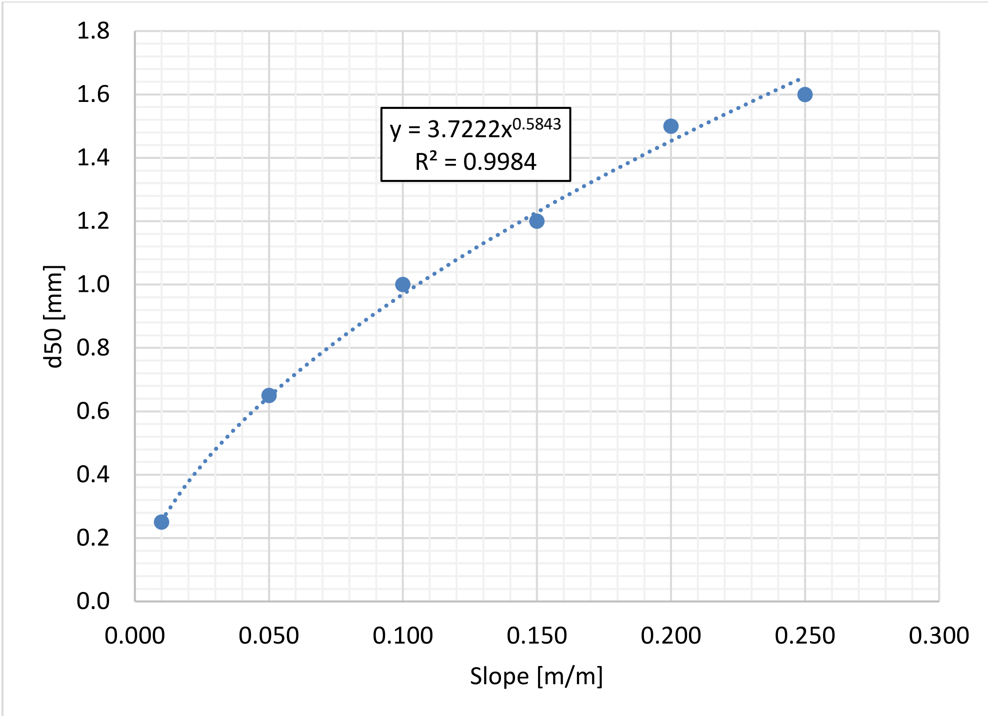


Figure 5: Median Riprap Size for Range of Different Slopes (Q = 54 m^3/s)

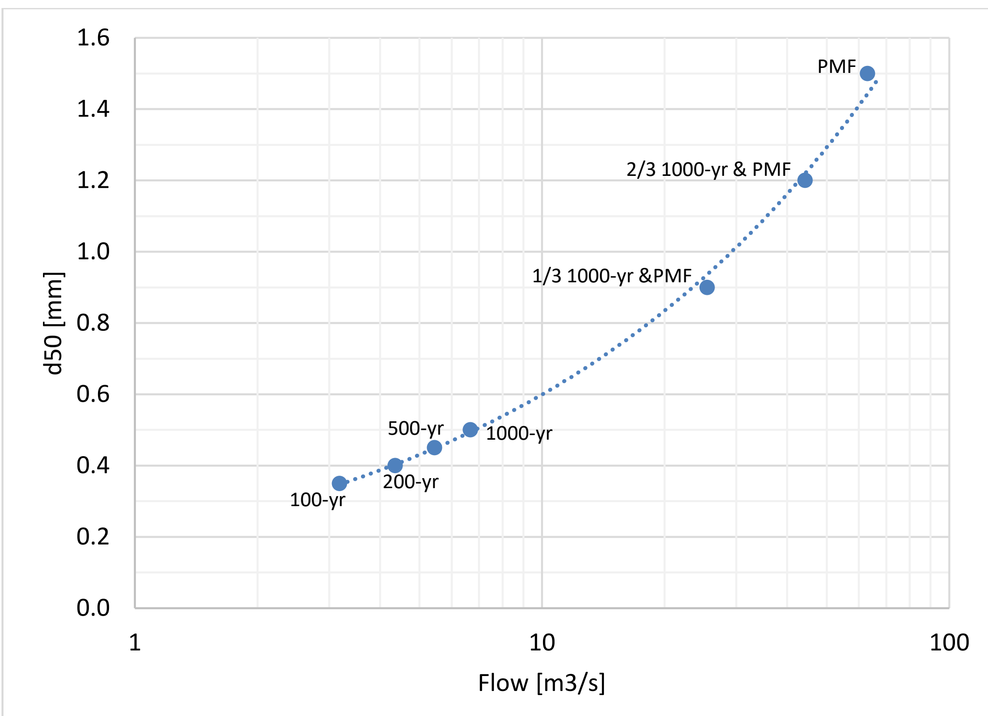


Figure 6: Median Riprap Size for Range of Flows (slope of 20%)

4.4 Erosion Extent

The spillway channel was aligned to be as far as practical away from the dam mitigating the risk of eroding the dam and to prevent a tailings breach. Maintaining the spillway in bedrock further to the south is not practical without significantly deepening the spillway and increasing the rock excavation volume as the bedrock is observed to dip down to the south.

In the event of backwards erosion during large storm events greater than the 1000-year, till in the lower section of the spillway channel may erode down to natural observed grades (i.e. 2- 10%). The extent of backward erosion is limited to the contact of bedrock. The erosion extent and potential plunge pool development at the bedrock surface (Figure 7) was conservatively evaluated as a function of discharge, height of potential head cut, upstream slope and relevant soil properties using the following equations (Floreso-Cervantes, 2004):

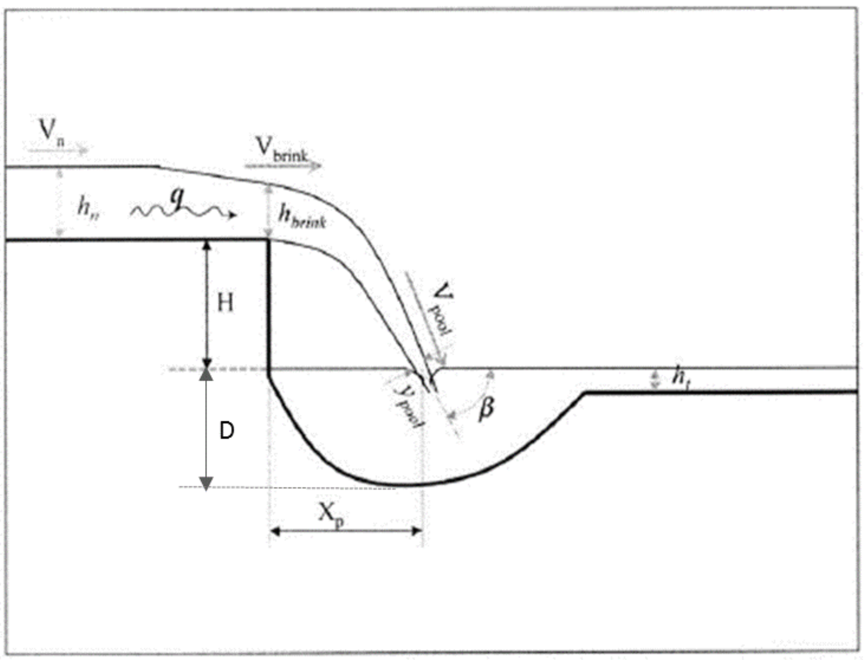


Figure 7: Flow Characteristics and Plunge Pool Development (Floreso-Cervantes, 2004)

$$V_{brink} = \frac{\sqrt[3]{qg}}{0.715}, Fr < 1$$

$$V_{brink} = V_n \frac{Fr^2 + 0.4}{Fr^2}, Fr > 1$$

$$X_p = V_{brink}\sqrt{2H/g}$$

$$\beta = arctan\sqrt{2gH/V_{brink}}$$

$$y_{pool} = h_{brink} cos\beta$$

$$D = \frac{X_p}{2}$$

Where:

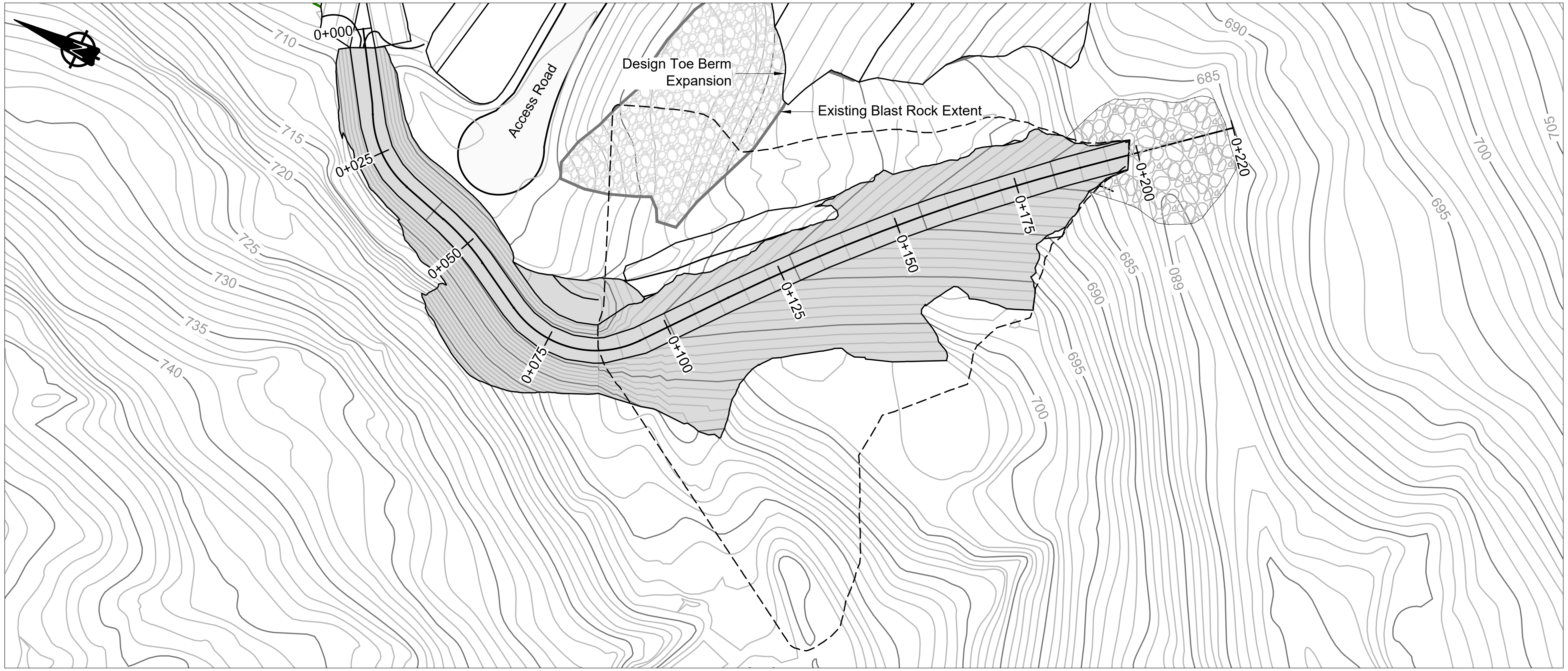
V_{brink} is velocity at the brink;
Fr is Froude's number;
V_n is the upstream channel velocity (m/s);
H is the maximum drop height (m);
β is the angle of the jet impinging the plunge (rad);
X_p is the jet's impinging distance (m) and;
D is the depth of pool (m).

Table 9 presents the erosion model inputs and results of the erosion and plunge pool development. For a maximum drop height of 21 m and an assumed angle of repose of 1.5H:1V for the till, the maximum erosion extent at the bedrock face was conservatively determined to be approximately 42 m. Figure 8 illustrates the alignment of the spillway channel and maximum extent of erosion. The figure shows that undercutting of the 2012 rock buttress is possible, however, a breach of the dam and loss of tailings is unlikely to occur.

Table 9: Erosion and Plunge Pool Development

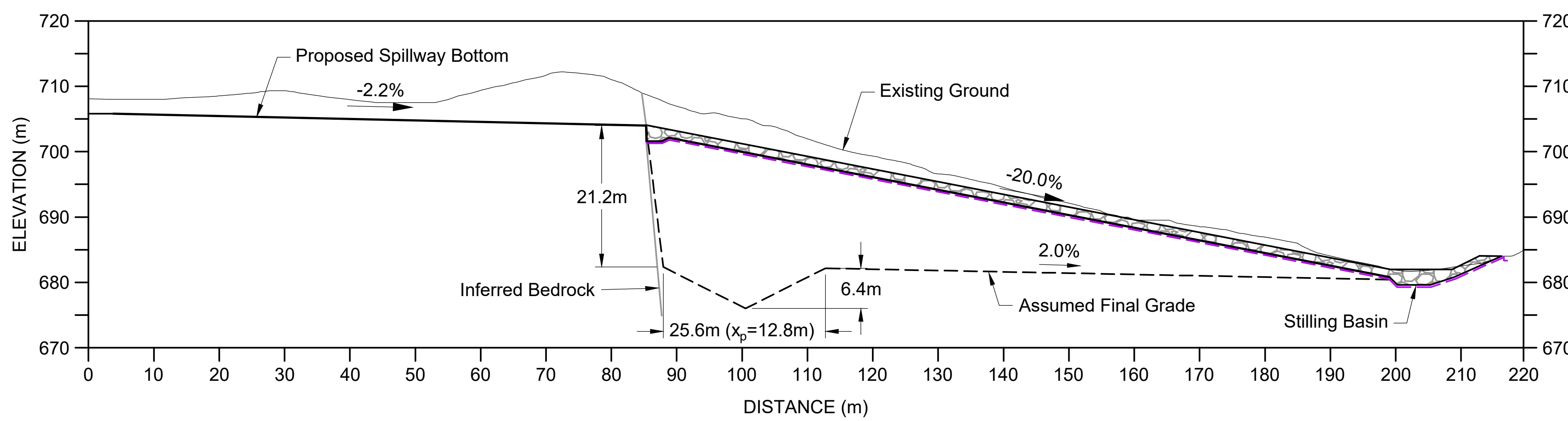
Parameter	Value	Source
Channel Hydraulics		
Maximum channel flow	57.5 m^3/s	Calculated, Table 4
Spillway channel width	5.0 m	Table 3
Spillway channel side slopes	0.75H:1V	in bedrock, Table 3
Spillway channel longitudinal slope	2%	Table 3
Manning's n coefficient, n	0.04	Manning's in in bedrock (Chow 1959)
Normal depth, y_n	2.06 m	calculated using Manning's equation
Flow area	13.5 m^2	calculated
Average velocity, V_n	4.27 m/s	calculated using Manning's equation
Froude number, Fr	0.95	Calculated
Plunge pool development and erosion extents		
Velocity at brink, V_{brink}	6.2 m/s	Calculated
Maximum drop height, H	21.2 m	Measured based on channel profile (Figure 8)
Jet impinging distance, X_p	12.8 m	Calculated
Depth of pool, D	6.4 m	Calculated
Angle of repose	1.5	Engineering judgement for native soil
Maximum erosion distance (m)	41.5 m	Calculated

Source: \\VAN-SVR0\Projects\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\302_HydrotechDesign\Spillway_Headcut\Spillway_Headcut_Calculation_West_Alignment.xlsm



West Spillway Plan

0m 10 20 30 40



West Spillway Profile

0m 5 10 15 20 25 30

LEGEND

- Geotextile
- Rip Rap
- Erosion Extent

NOTES

1. Contours shown at 2.0 m intervals.
2. All dimensions in meters unless stated otherwise.
3. Excavation boundaries are approximate and may vary depending on the depth of bedrock.
4. Depth to bedrock shall be confirmed prior to excavation between 0+070 and 0+100.

srk consulting

1CR012.005

1CR012.005 - Spillway.dwg

HB Dam

Tailings Spillway Channel Design

West Spillway Erosion Extent

DATE:	APPROVED:	FIGURE:
December 5, 2018		8

4.5 Hydraulic Model

The U.S Army Corps of Engineers HEC-RAS 2D software was used to model maximum velocities and flood depths in the spillway channel and downstream stilling basin. HEC-RAS 2D is a software program that simulates both one-dimensional and two-dimensional unsteady channel flow. The HB spillway model was prepared as a 2D unsteady state model using the design spillway surface (Figure 1) and outflow hydrograph (Figure 2).

A stilling basin lined with riprap was designed to ensure energy is properly dissipated at the downstream end of the spillway channel Figure 10 illustrates the 1000-year peak flow velocities downstream of the spillway channel. For the 1000-year peak flow, based on Isbach's expression for riprap sizing (Equation 1), a minimum D50 of 600 mm was determined to be sufficient for the 1000-year flood where the maximum velocity in the stilling basin is 5 m/s.

$$D_{50} = \frac{V^2}{C^2 2g(\frac{\gamma_s - \gamma_w}{\gamma_w})} \quad \text{Eq. [6]}$$

Where V is the average velocity (ft/s), g is gravitational acceleration (ft/s²), γ_s is the unit weight of riprap (lb/ft³), γ_w is the unit weight of water (lb/ft³), D_{50} is the median rip rap size (ft), and C is the Isbach coefficient. The Isbach coefficient was set to 1.2 for low turbulence and/or bank protection.

The extent of the stilling basin erosion protection shown in Figure 1 is based on the maximum water level during the 1000-year event with an additional minimum freeboard of 0.3 m. For the confluence of the spillway channel and stilling basin, the super elevation on the opposite bank was evaluated to be 0.6 m using the following two equations (Chow, 1959).

$$\Delta h = \frac{C^2}{2g{r_o}^2{r_i}^2}({r_o}^2 - {r_i}^2) \quad \text{Eq. [7]}$$

Where h is the super elevation of the water surface, r_o and r_i are respectively the outer and inner radii of the confluence curve, g is the gravitational acceleration and the constant C can be determined from equation 8.

$$Q = V_z y_m (r_o - r_i) = C\left(E - \frac{C^2}{2g r_o r_i}\right) ln\frac{r_o}{r_i} \quad \text{Eq. [8]}$$

Figure 9 and Figure 10 illustrate the extent of the stilling basin design and peak flow velocities during the 1000-year and PMF respectively. As expected, maximum velocities in the spillway channel occur in the lower section of the channel. In the upper section of the channel, a maximum velocity of 5.9 m/s occurs immediately upstream of the change in channel slope at the bedrock outcrop. As shown in Figure 1, the riprap in the lower section of the channel is keyed into the bedrock surface with a minimum depth of 2.4 m (2x min. riprap thickness) to provide additional erosion protection. A similar concept is applied at the outlet of the spillway channel in the stilling basin. A thickness of 2.4 m is recommended at the outlet of the spillway channel to provide additional erosion protection.

Table 10: HEC-RAS 2D Model Results

Spillway Channel	Maximum Velocity [m/s]		Maximum Channel Depth [m]	
	PMF	1000-year	PMF	1000-year
Upper Section	5.9	2.5	1.81	0.51
Lower Section	10	4.4	0.98	0.3
Stilling Basin	9.3	5.0	2.18	0.84

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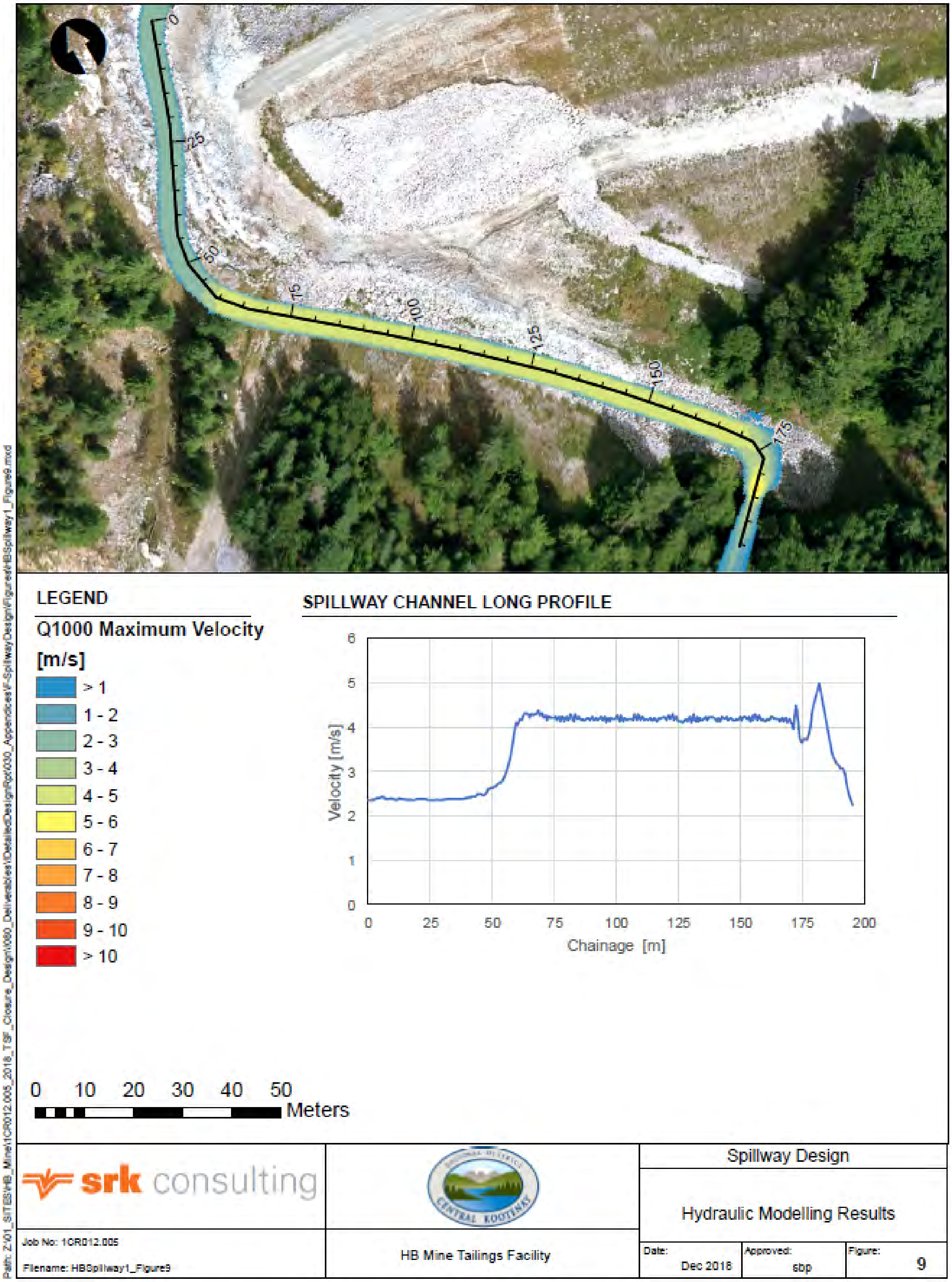

Figure 9: Spillway Channel - 1000 Maximum Velocity

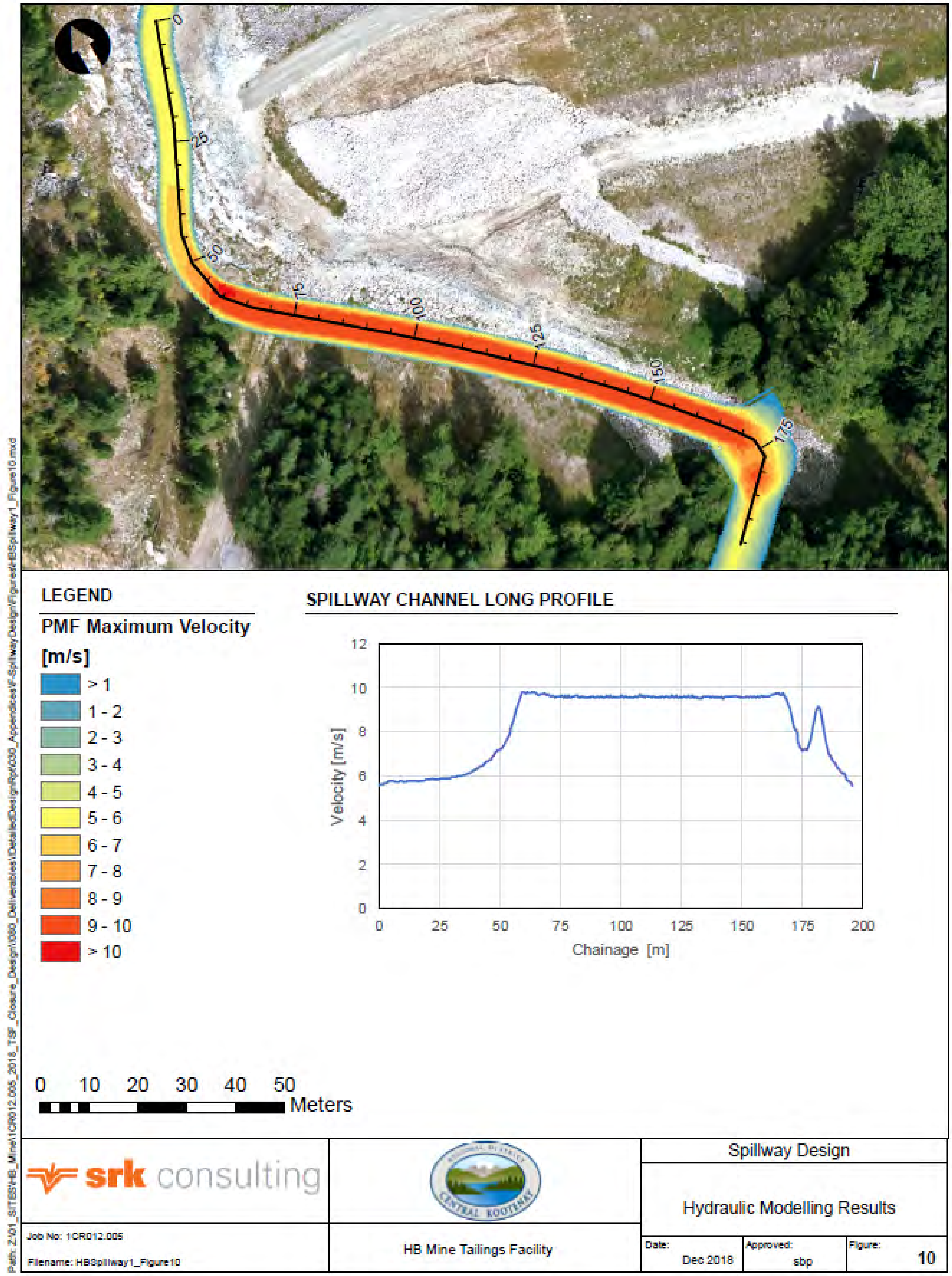

Figure 10: Spillway Channel - PMF Maximum Velocity

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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Appendix C-6 – Tailings Surface Drainage Channels

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Memo

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Reviewed by:	Victor Munoz , P.Eng.	**Date:**	December 13, 2019
Subject:	HB Mine Tailings Facility - Tailings Surface Drainage Channels		

1 Introduction

As part of the HB Mine Tailings Facility closure and remediation, lined channels are required to convey surface runoff from the tailings cover and surface inflows to the tailings facility to the spillway at the west abutment of the HB Dam in a manner that prevents erosion and migration of tailings from the facility.

This memo documents the design of the tailings surface drainage channels. Figure 1 shows the alignment of the channels that capture water from the landfill wetland area (Main Channel) and two streams on the east side of the impoundment (North and South Spur Channels).

2 Design Criteria

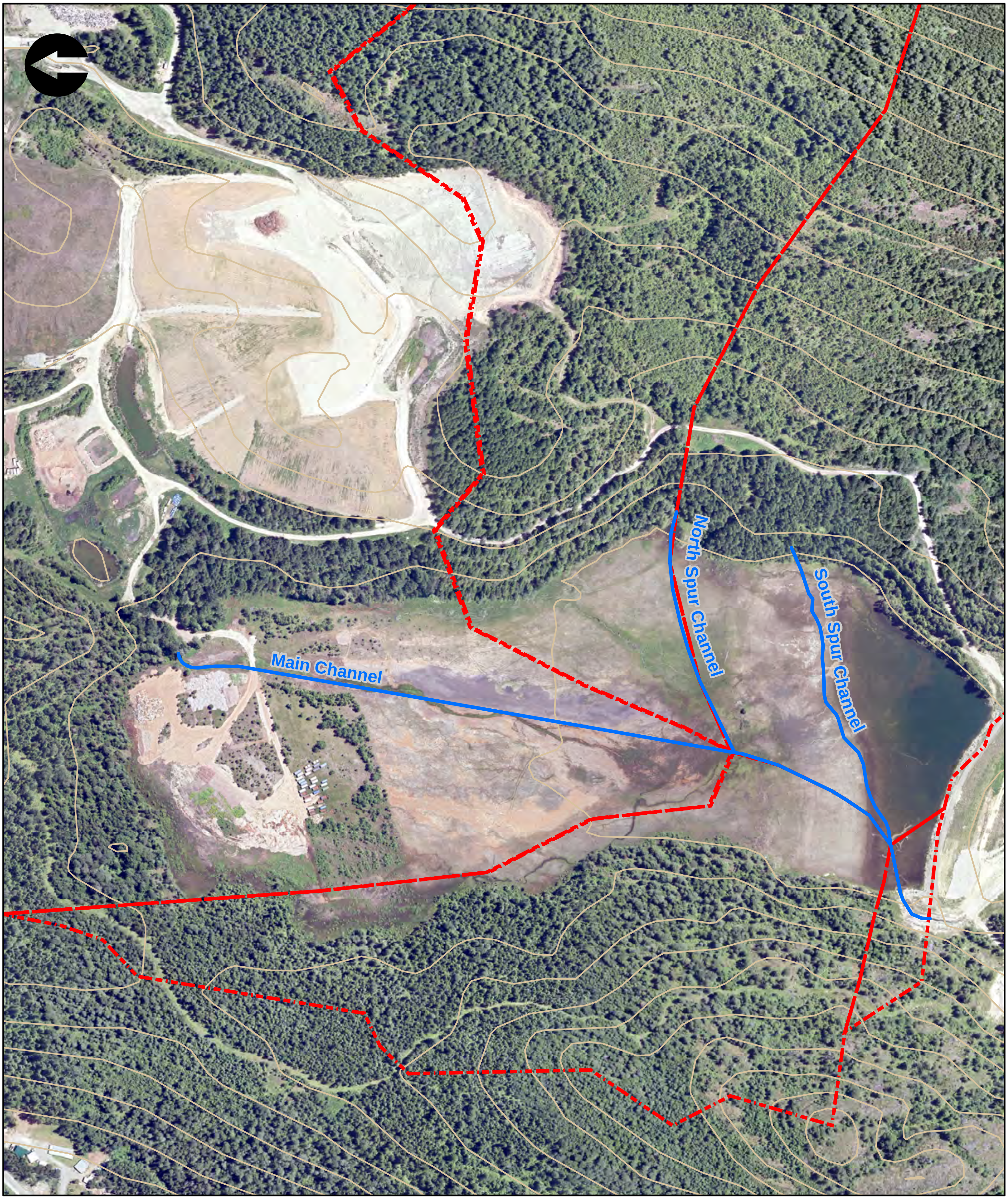
The following design criteria were used in the design:

- The channels must convey the 200-year peak flows under climate change effects with typical geometry that reflects size and capability on common construction equipment.
- The channels are to promote vegetation growth as a stand-along erosion protection measure to minimize long-term maintenance requirements.
- Immediate protection must be provided to the short-term to prevent erosion until vegetation is established.
- Water that overtops the channel during extreme events are to have velocities less than 1 m/s to prevent significant erosion of the tailings cover.

3 Design Overview

Figure 1 illustrates the alignment of the surface drainage channels and catchment delineations. The channel alignments were selected based on current drainage patterns on site. All channels were designed to have a minimum base width of 0.5 m, side slopes of 3H:1V and lined with a geosynthetic liner to reduce infiltration into the tailings, and prevent erosion of the tailings A 0.2 m thick liner protection layer is placed over the geosynthetic liner that is overlain by a turf reinforcement mats (TRM) to provide immediate erosion protection and promote vegetation growth as a stand-alone protection.

TRMs were selected as part of the design because it was determined that long-term grass vegetation was sufficient to provide long-term erosion protection, and because the alternative of lining with riprap would have required a median size of 100 mm, which would be more costly to produce, and require larger tailings excavation volumes.



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	Job No:		HB Dam Catchment Delineation
	Filename: HBDamCatchment_Delineation_westAlignment	HB Tailings Storage Facility	Date: November 2018
			Approved:
			Figure: 1

4 Hydraulic Design

4.1 Peak Flow Analysis

The design peak flows were evaluated using a rainfall-runoff approach using HEC-HMS hydrologic software. Catchment areas for each surface drainage channel was delineated using the software Arc GIS and LiDAR topography. A HEC-HMS model was developed using the SCS curve number and unit hydrograph method. Additional details of the methodology used to evaluate peak flows for the project is described in Appendix E of the Design Report. Table 1 presents the 200-year 24-hr precipitation-duration-frequency (PDF) curve under climate change conditions.

Table 1: HB Mine Tailings Facility 200-yr PDF Under Climate Change Effects

Duration [min]	Precipitation [mm]
5	21.5
10	27.5
15	30.8
30	40.0
60	56.6
120	60.3
360	71.3
720	75.9
1440	83.2

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Note: The 100-year PDF distribution was applied for the 200-year return period

As described in the hydrology analysis of the site (SRK 2017) included as Appendix E in the Design Report, it was found that a CN of 54 best represented soil conditions during extreme flood events. Table 2 summarizes the design peak flows for the upstream and downstream Main Channel and North Spur and South Spur Channels.

Table 2: Surface Drainage Channel Design Peak Flows

Surface Drainage Channel	200-year Peak Flow (m^3/s)
Main Channel (Segment 1)	1.40
North Spur Channel	0.95
Main Channel (Segment 2)	2.62
South Spur Channel	1.33
Main Channel (Segment 3)	3.83

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4.2 Channel Sizing

The hydraulic analysis and sizing of channels was determined using Manning's equation assuming steady state normal depth conditions. As summarized in Section 2, the option of lining the surface drainage channels with reinforced turf mats was chosen instead of conventional riprap protection to promote vegetation. Based on an average channel grade of 0.5% across the tailings surface, the maximum velocity expected in the channels for a 200-year peak flow in the channels with turf reinforcement matting is 2.0 m/s (Table 3). These velocities are lower that the maximum permissible velocity of 2.9 m/s for unvegetated turf matting (Nilex, 2018).

The minimum design channel depths of the surface drainage channels were designed to convey the 200-year peak flow once vegetation is established. This is more conservative given that a Manning's roughness coefficient of 0.04 (Chow, 1976) is greater than a Manning's n of 0.026 for turf reinforced matting (Catchments & Creeks, 2018).

Channel depths were designed to have a minimum freeboard of 0.3 m above the design peak flow water level to allow for sediment accumulation in the channels and unforeseen climatic events.

Table 3 summarizes the hydraulic design parameters of the surface drainage channels.

Table 3: Design Summary for Surface Drainage Channels

Surface Drainage Channel	Design Peak Flow (m^3/s)	Design Channel Base Width (m)	200-year Velocity[1] (m/s)	200-year Water Level[2] (m)	Design Channel Depth (m)
Main Channel (Segment 1)	1.40	0.5	1.11	0.68	1.0
North Spur Channel	0.95	0.5	1.00	0.58	1.0
Main Channel (Segment 2)	2.62	0.5	2.07	0.68	1.0
South Spur Channel	1.33	0.5	1.09	0.67	1.0
Main Channel (Segment 3)	3.83	2.0	1.40	1.03	1.1

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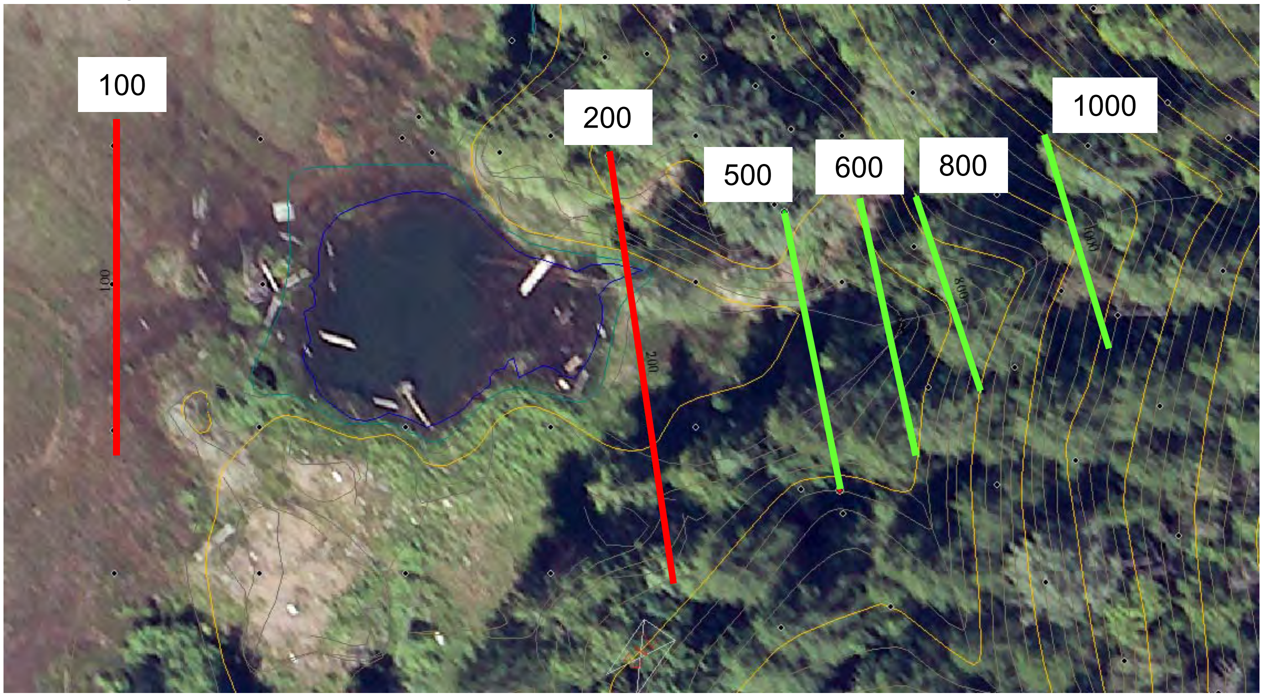
Note: [1] Manning's n of 0.026 for turf reinforced mat.

[2] Manning's n of 0.04 for vegetated channel.

4.3 Energy Dissipators

To protect the inlets of the North and South Spur surface drainage channels from erosion, two energy dissipaters were designed to protect the tailings surface area from erosion by reducing the velocity of flows to acceptable limits. A HEC-RAS hydraulic model (1D, version 5.0.5) was developed based on available LIDAR data to design the required erosion protection at the inlet of the North and South Spur channels. Figure 2 presents a plan view illustrating the cross-sections used in the HEC-RAS model. Cross-sections labelled "natural" highlight existing natural cross-sections. Trapezoidal sections apply a typical 0.5 m wide, 3H:1V side slope trapezoidal section as described in Section 3.

North Spur Channel Inlet



South Spur Channel Inlet

Trapezoidal Section
Natural Section

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Tailings Drainage Channel Design

HEC-RAS Energy Dissipators Cross-Section Locations

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HB Tailings Storage Facility

Date: 09/26/2018
Approved: SPB
Figure: 2

For the 200-year peak flow, it was determined that riprap erosion protection is required given that channel velocities at the inlets were determined to be greater than the permissible velocity of 2.9 m/s for turf reinforce matting.

Riprap was sized using the Isbachs expression

$$D_{50} = \frac{V^2}{C^2 2g(\frac{\gamma_s - \gamma_w}{\gamma_w})} \quad \text{Eq. [1]}$$

Where *V* is the average velocity (ft/s), *g* is gravitational acceleration (ft/s²), γ_s is the unit weight of riprap (lb/ft³), γ_w is the unit weight of water (lb/ft³), D_{50} is the median rip rap size (ft), and C is the Isbach coefficient. The Isbach coefficient was set to 1.2 for low turbulence or bank protection.

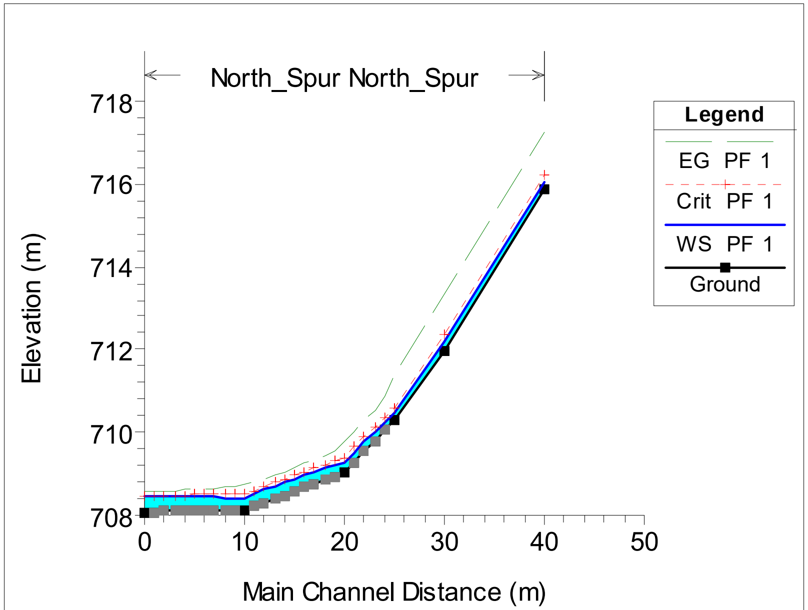
Riprap sizing is an iterative process given that rip rap size affects Manning's *n* and Manning's *n* in turn affects channel velocities and depths.

Based on the Isbach expression and Manning's equation, it was determined that a riprap size with a median riprap size (D_{50}) of 400 mm is required to provide the required erosion protection for the 200-year design peak flows.

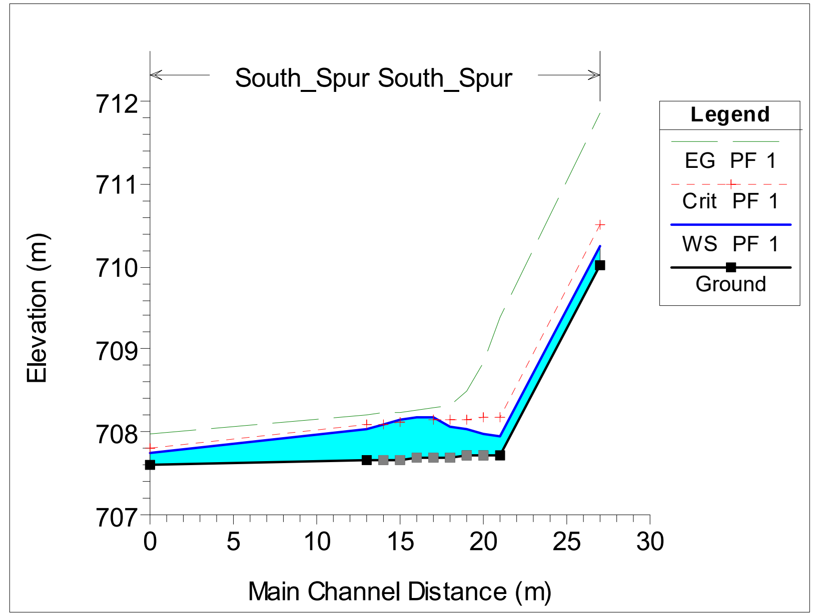
Figure 3 presents the surface water profile and maximum channel velocities respectively for the North and South Spur inlet energy dissipators. For both inlets, riprap protection is required for a minimum length of 15 m before flow velocities are lower than 2.9 m/s.

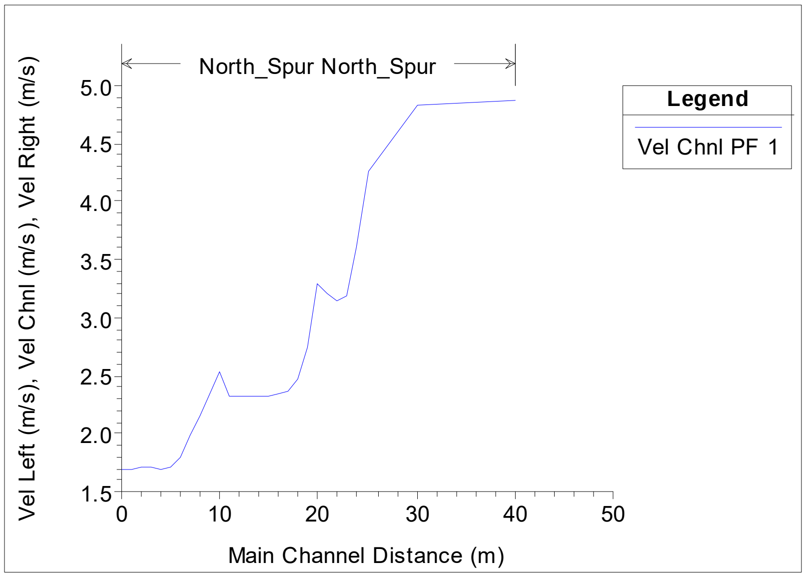
Detailed drawings of the inlet energy dissipators and surface drainage channel designs are provided in SRK's detailed design report (SRK, 2018).

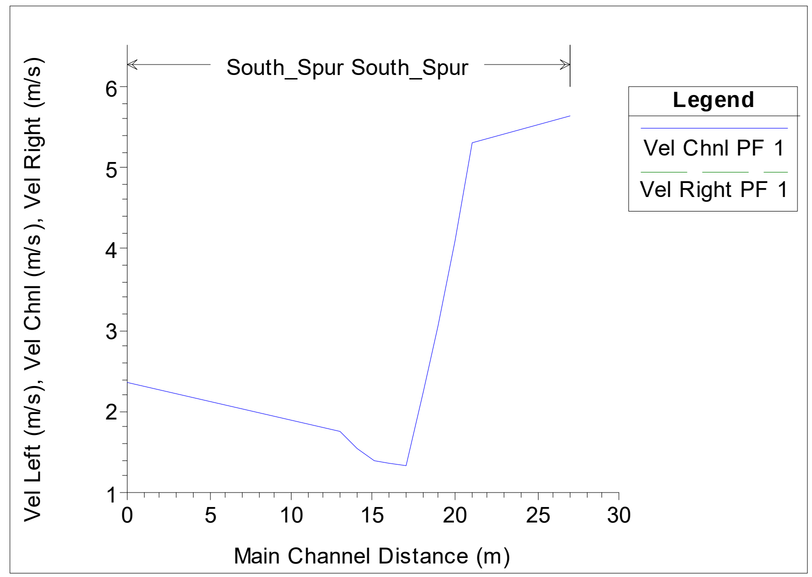
North Spur



South Spur







srk consulting	Regional District Central Kootenay	Tailings Drainage Channel Design
		HEC-RAS Results
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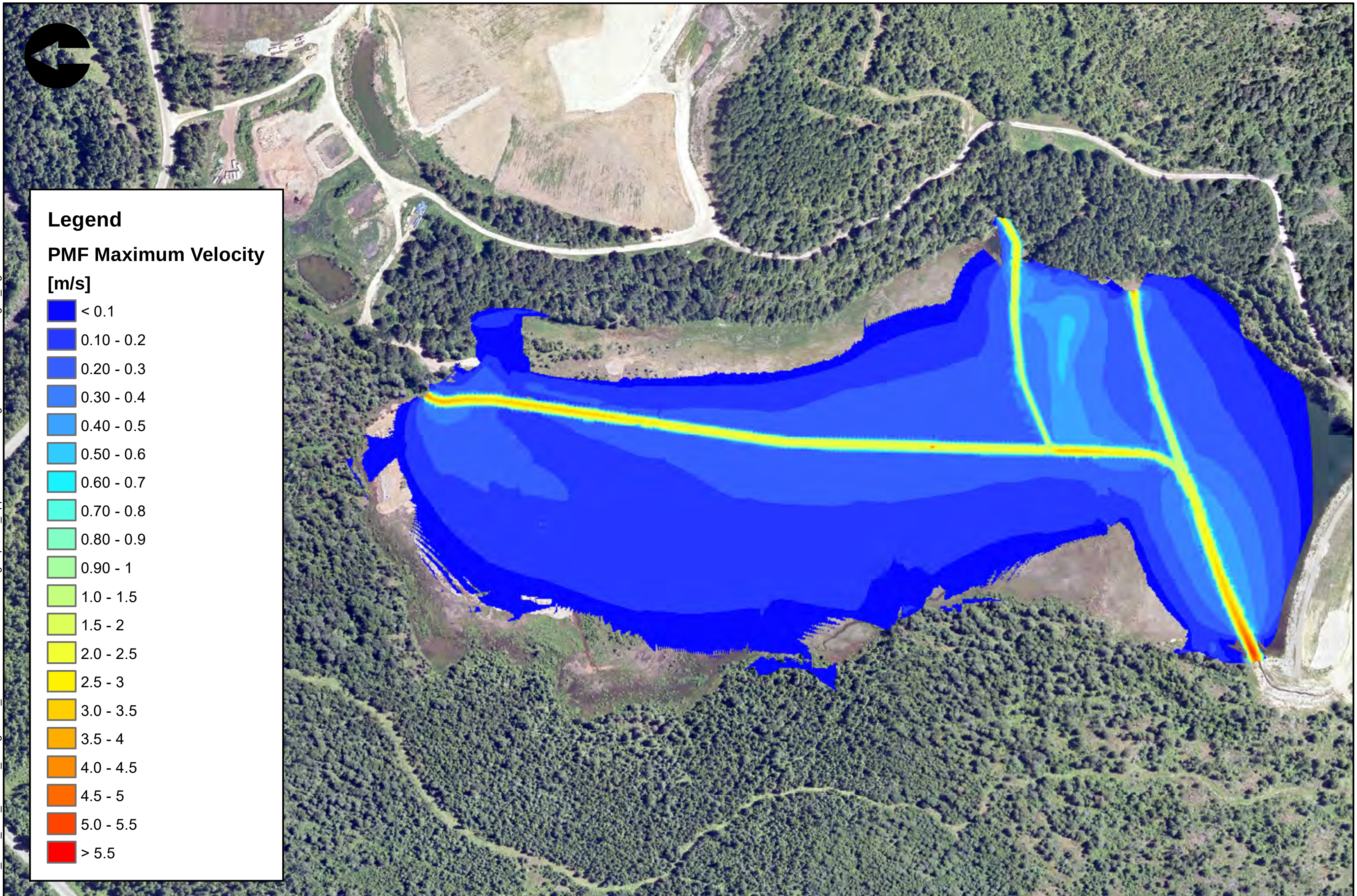
5 Overland Flow Assessment

The surface drainage channel capacity and erosion protection were sized for the 200-year peak flow. For storm events greater than the 200-year peak flows such as the probable maximum flood (PMF), flows will overtop the channels but will still report to the spillway channel at the west abutment of HB Dam.

A HEC-RAS 2D hydraulic model was developed to evaluate overland flow velocities. The model was prepared as a 2D unsteady state model to evaluate overland flow velocities on the tailings cover surface. The PMF inflow hydrographs were applied in the model to the three surface drainage channels. A Manning's *n* value of 0.04 was used in the drainage channel and 0.12 on the tailings cover surface assuming vegetation is established. Manning's *n* value for overland flow is generally larger that that of a channel.

Maximum permissible velocities for flat slopes (0 – 5%) with vegetative protection typically ranges from 0.9 to 1.2 m/s (RTAC Drainage Manual 1987). Figure 4 illustrates maximum overland flow velocities during the PMF event. It was determined that the maximum overland velocities would be less than 1.0 m/s for the tailings cover surface. Any high velocities result from minor surface features on the cover are neglectable as it is expected that during construction, features will be smoothed and ultimately reduce overland velocities.



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Regional District Central Kootenay

HB Mine Tailings Facility

Tailings Drainage Channel Design

Overland and Channel Flow Velocities
PMF Event

Date:	Approved:	Figure:
Nov 2018	spb	4

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Appendix C-7 – Deformation Assessment

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Reviewed by:	Arcesio Lizcano, PhD	**Date:**	December 13, 2019
Subject:	HB Mine Tailings Dam Deformation Analysis		

1 Introduction

1.1 Background

The HB Mine Tailings Facility near Salmo, BC has been under the care of the Regional District of Central Kootenay (RDCK) since 1998 when the property was purchased to provide additional buffer and attenuation zones for groundwater from the Central Landfill located northeast of the facility. The HB Dam is located at the south end of the facility across a natural valley and retains approximately 6.6 million tonnes of lead-zinc tailings processed from 1955 to 1966 and from 1974 to 1978. The dam has a “very high” dam hazard classification as defined by the Canadian Dam Association (CDA).

In the summer of 2012, a sloughing event occurred in the dam embankment, and the facility has required significant monitoring, maintenance, upgrades, and investigations. In 2016, the RDCK has elected to transition the dam to passive closure as defined by the CDA Technical Bulletin on the Application of Dam Safety Guidelines to Mining Dams” (CDA 2014).

SRK has already performed a series of analysis for the dam that includes:

- Review of dam construction and geotechnical characterization (SRK 2017a).
- Dam seepage assessment (SRK 2017b).
- Dam stability assessment in support of the mine passive closure design (SRK 2017c).

The dam is approximately 27 m high, 220 m long with a crest width between 6 and 7 m. The original dam (1955-1967) was constructed with an upstream slope of 1.5H:1V and a downstream slope of 2H:1V.

During the initial phase of operations, an earth-filled timber crib retaining wall was constructed at the downstream toe. The crest of the dam and timber crib were raised periodically as required by the downstream construction method (Golder 1972).

In 1964, a portion of the timber crib wall failed. The crib wall was reconstructed 3 to 5m downstream and several concrete and wooden pipe drains were installed. The specific nature of the crib wall is uncertain.

During the second phase of operations (1974-1978), the dam was constructed with upstream and downstream slopes of 2H:1V. The 2005 toe berm has a height of 12 m, a width of 10 m, and a downstream slope of 2.5H:1V, resulting in an overall downstream slope of approximately 2.5 H:1V.

The current cross-section of the dam, as well as the upgraded dam geometry proposed by SRK, are shown in SRK (2017a).

1.2 Objective

A numerical analysis was completed to estimate the potential settlements of the dam crest due to rot of wood from the crib wall. The analysis was conducted using the preliminary design dam geometry presented in SRK (2017a). This technical memo summarizes the results of the analysis.

2 Methodology

2.1 General

There is little information available regarding the construction of the timber crib. It is estimated to be 7.5 m high and 5.0 m wide for the whole length of the dam.

Technical literature was reviewed to infer the likely timber crib configuration in the HB Dam. The objective being to estimate the volume of the crib occupied by wood. This information was used to evaluate the maximum expected volumetric change of the timber crib under the conservative assumption that all the timber will rot and reduce its volume to zero.

Expected settlements at the dam crest were calculated using the finite element software Plaxis 2D-2018 for the target volumetric strain of the timber crib zone.

2.2 Timber Crib Dams

In timber crib dams, cribs of timbers are drift-bolted together and filled with rock fragments or boulders (Creager, 1945). The timbers are usually spaced about 8 ft centers both ways. A picture of this type of dam is shown in Figure 1.

Considering a timber crib made of 25 cm x 25 cm timbers, spaced 2.5 m between centers, the expected timber volume is between 10% to 15% of the total volume of the crib.

2.3 Finite Element Model

A finite element model was developed using the software Plaxis 2D-2018. The outcome of the model is the vertical displacements along the crest of the dam due to the volume reduction in the timber crib zone within the dam. The volume reduction was assumed equal to the expected timber volume (Section 2.2).

2.4 Geotechnical Parameters

All materials were modeled with the Mohr-Coulomb (MC) elastic-perfectly plastic constitutive model included in Plaxis. Strength parameters and soil unit weight are as depicted in SRK (2017c).

Stiffness parameters for the MC model are the Young's modulus E_s and the Poisson ratio ν. These were selected from empirical correlations with the void ratio, as explained in Appendix A. A sensitivity analysis was performed on the Young modulus with all granular materials having the same value ranging from 50MPa to 100MPa.

The selected geotechnical parameters are summarized in Table 2-1.

Table 2-1. Summary of Geotechnical Parameters

Zone/Material	Bulk Density(1) (kN/m³)	Strength Parameters(1)		Stiffness Parameters(2)	
		Cohesion (kPa)	Friction Angle (º)	Young Modulus (MPa)	Poisson Ratio
1 – Bedrock	26	Infinite Strength		1000	0.2
2 – Native Till	20	0	36	50 - 100	0.2
3 – Native glacio-lacustrine	18.5	0	32	50 - 100	0.2
4 – Tailings	18.3	0	30	50	0.2
5 – Original Dam	19.0	0	28	50 - 100	0.2
6 – Stabilizing berm 8 – Common fill 12 – Till Toe Berm Toe Berm Expansion	21.3	0	36	50 - 100	0.2
7 – Filter Blanket	20.7	0	38	50 - 100	0.2
Zone 10 – Rock Toe Drain Toe Berm Expansion Drain	20.7	0	38	50 - 100	0.2
Zone 11 – Rock Drain	20.7	0	38	50 - 100	0.2

Note(s):

1. SRK (2017c)
2. Appendix A

2.5 Geometry and Mesh

Figure 2 shows the finite element mesh used for the analysis. The model is 225 m wide and 48 m high. The mesh has 3852 16-nodes elements with an average element size of 1.8 m.

The modeled geometry is the “upgraded dam geometry” from SRK (2017a), which includes the following proposed dam upgrades as part of passive closure:

- Expanded toe berm: The existing toe berm was widened by 5 m further downstream, with a second 5 m-high, 8 m-wide lift constructed on top of the existing toe berm.
- Lower crest elevation: The dam crest was lowered by approximately 1.5 m to 709.5 m. This elevation results in a freeboard of 1.0 m above the maximum water level in the tailings impoundment during the probable maximum flood (PMF).
- Filter blanket raise: The filter blanket sand and gravel layer was raised to the crest of the dam. The filter raise is constructed with a 5 m width.
- Upstream Till Beach: The upstream rip-rap was removed and an upstream till beach constructed that widens the dam crest by 7 m then slopes down at a 4H:1V slope.

2.6 Seepage Conditions

The water table was defined according to SRK (2017b) for the passive closure design (upgraded dam geometry, Stage 2). Pore pressures were modeled as hydrostatic by imposing the position of the water table (Figure 3).

2.7 Cases Considered

Settlements were calculated under long-term drained conditions, for the maximum and minimum young modulus shown in Table 2-1 (E_s = 50 MPa to 100MPa).

2.8 Calculation Phases

The following phases were modeled:

1. Initial stress field: gravity loading and hydrostatic pore pressure for the final configuration of the dam. No intermediate stages were modeled.
2. Imposed volumetric contraction of 1% in the timber crib zone.
3. Repeats Phase 2 until the accumulated imposed volumetric contraction is 20%.

The phases are illustrated in Figure 4.

3 Results

Figure 5 shows the vertical displacement field contours for different volumetric strains and for both stiffness scenarios (i.e., E_s = 50MPa and E_s = 100MPa). There is a marked subsidence zone that includes the crest of the dam, and that starts to form at imposed volumetric strains as low as 5%.

Vertical displacements plots along the surface of the dam are shown in Figures 6 and 7. Stiffness parameters have little influence on the response of the model for volumetric strains in the target range (from 10% to 15%) because the shear strength is fully mobilized on certain surfaces for low values of volumetric strains of the timber crib; i.e., plastic displacements are independent of the stiffness parameters. Figure 8 shows the sliding surfaces.

Table 3-1 summarises the vertical displacements along the dam crest. The crest is approximately 20 m wide. Displacements are referred to the downstream side of the dam crest. The average crest settlement ranges from 0.11 m to 0.16 m.

Table 3-1. Summary of Vertical Settlement at the Crest

Distance to the Downstream Side of the Crest (m)	Vertical Settlement (mm) Volumetric Strain of 10%		Vertical Settlement (mm) Volumetric Strain of 15%	
	E_s = 100 MPa	E_s = 50 MPa	E_s = 100 MPa	E_s = 50 MPa
0	4	9	4	9
6	45	43	61	64
13	186	179	278	270
20	202	186	306	291

4 Conclusions

The widening of the dam crest by the construction of the Upstream Till Beach proved to be an important element to reduce the settlement of the upstream side of the dam crest in contact with the supernatant water of the tailings. The calculated settlements at the upstream side of the crest are lower than 1 cm. The highest average settlement along the crest is 0.16 m.

The freeboard should consider the potential settlement of the dam crest due to rot of the timber crib. SRK recommends the highest average crest settlement in the specification of the freeboard.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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Appendix A – Stiffness Parameters

Small-Strain Shear Stiffness

The small strain shear stiffness G_0 can be roughly estimated using the following equation from Hardin & Black (1969) for undisturbed clayey soils and crushed sands.

$$G_0 = G_0^{ref} \left(\frac{p}{p_{ref}} \right)^{0.5}$$

$$G_0^{ref} = 330 \cdot p_{ref} \cdot \frac{(2.97 - e)^2}{2.97 - e}$$

where $p_{ref} = 100\ kPa$ is the atmospheric pressure, e is the void ratio, and p is the effective pressure on the soil.

Secant Shear Stiffness

The secant shear stiffness can be calculated through a modified version of the degradation modulus curve by Harding-Drnevich (Santos & Correia, 2001)

$$G_s = \frac{G_0}{1 + 0.385 \frac{\gamma_{ur}}{\gamma_{0.7}}}$$

where $\gamma_{0.7}$ is the shear strain at which the secant shear modulus has reduced to 0.7 times G_0, and γ is the shear strain.

The value of $\gamma_{0.7}$ typically ranges between 1×10^{-4} to 2×10^{-4} (Brinkgreve 2007). The expected shear strain depends on the type of structure (Figure 1), but a value of $\gamma_{ur} = 10^{-3}$ is in the typical range. For the selected value, the secant shear stiffness will be $G_s \approx 0.20 \cdot G_0$.

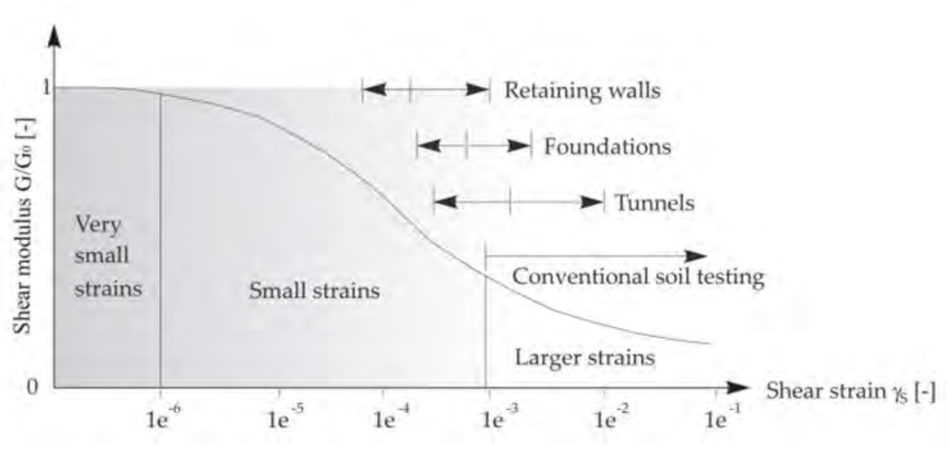

Figure 1. Characteristic stiffness-strain behavior with typical ranges of structures (after Atkinson & Sallfors (1991)).

Secant Young Modulus

Young modulus is computed using through linear elasticity theory as

$$E_s = G_s \cdot 2(1 + \nu)$$

where ν is the Poisson ratio.

For a Poisson ratio of $\nu = 0.2$, the Secant Young Modulus is $E_s = 2.4 \cdot G_s$.

Selected Stiffness Parameters

From the available geotechnical information (SRK 2017a) and selected bulk modulus, the void ratio of the granular materials is in the range from 0.45 to 0.85.

For a 27m-height dam, the average vertical stress is $\sigma_v = 270\ kPa$. Considering a horizontal to vertical stress ratio $K_0 = 0.6$, the average mean stress will be $p \approx 200\ kPa$.

Calculated values for the stiffness parameters are summarized in Table 5-1, for the mentioned range of void ratio.

The proposed range for the Young Modulus to be used in the calculations is from 50 MPa to 100 MPa.

Table 5-1: Calculated Stiffness Parameters

Void Ratio	ν	G_0^{ref} (MPa)	p (kPa)	G_0 (MPa)	G_s (MPa)	E_s (MPa)
0.45	0.20	144	200	204	42	101
0.85	0.20	80	200	113	23	56

Appendix C-8 – Seepage Assessment

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Memo

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From:	Ignacio García, CPEng	**Project No:**	1CR012.004
Reviewed by:	Peter Mikes, PEng	**Date:**	December 13, 2019
Subject:	HB Mine Tailings Dam Seepage Assessment		

1 Introduction

SRK is assisting the Regional District of Central Kootenay in their objective to transition the HB Mine Tailings Facility to passive closure as defined by the Canadian Dam Association (CDA 2014) to reduce the overall liability and resources required to maintain the facility. This memo presents the seepage analysis completed in support of the proposed upgrades to the HB Dam.

The sinkholes observed during the 2012 slough event are believed to be attributable to undocumented instrumentation and an armouring gravel/cobble layer placed on the upstream slope of the dam that was subsequently buried (EBA 2012). This armour layer was believed to lead to a granular foundation soil near the west abutment that is a preferential pathway through the dam. It is believed there is a potential for additional sinkholes to develop on the upstream slope of the dam. To mitigate this risk, the proposed closure measures include:

- Construction of a new spillway to remove the tailings pond immediately upstream, and sized to convey the probable maximum flood.
- Construction of lined surface water conveyance channels over the tailings such that no ponding occurs within the impoundment for design storms less than the 1 in 200 year flood event; and,
- Construction of an upstream till beach such that when the tailings facility stores water during extreme flood events, the flood water is not directly impounded against the dam.

The seepage assessment described in this document consisted of two stages:

1. Developed a model that represents current conditions, and evaluated its sensitivity to various parameters – e.g. permeability of the different materials, boundary conditions, and the presence of “sinkholes” and/or granular foundation conditions.

2. Prediction of the seepage rate and water table location under the proposed design dam geometry.

2 Methodology

2.1 Assessment Method

The seepage assessment was modelled using 2-D finite element groundwater analysis with the software Slide 7.027 (Rocscience 2017). The focus is to study the long-term steady-state conditions, and as a result, the assessment did not account for seasonal changes or transient flood events, nor did it consider variations along the axis of the dam.

2.2 Material Characterization

SRK defined the cross section using its interpretation of the as-built dam geometry and materials conditions as described in SRK (2017). The resulting cross section is presented in Figure 1.

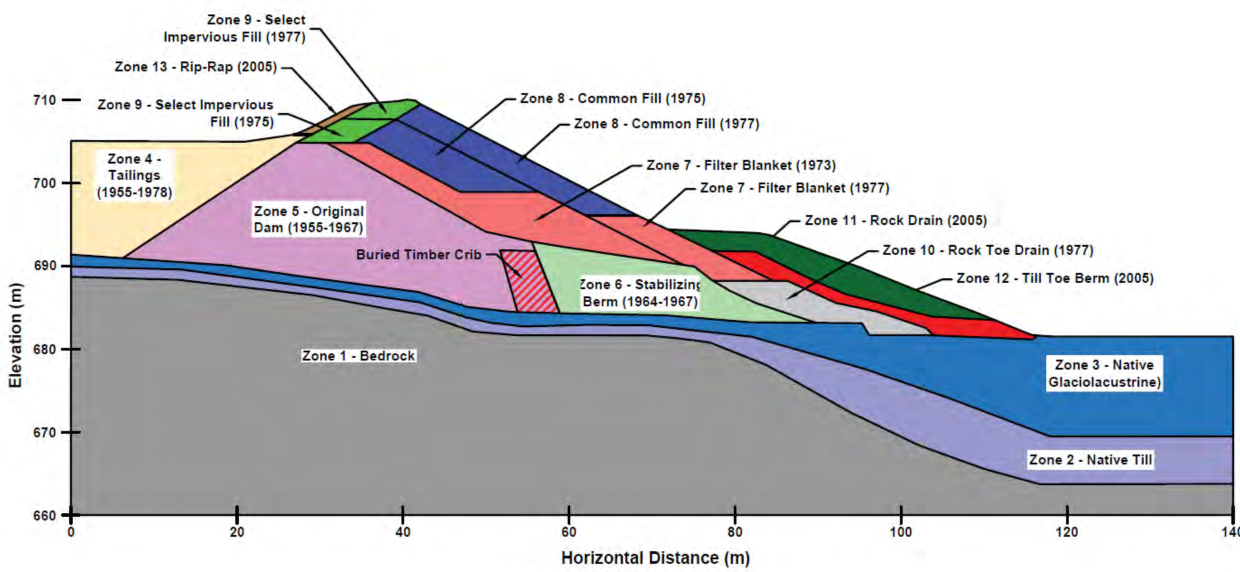

Figure 1 – Dam Cross Section

The main parameter required for the seepage assessment is the materials' saturated permeability. SRK defined the base values from the information available from previous reports by BGC (2002) and Tetra Tech EBA (2014), from particle size distribution tests available and from typical values expected. Table 1 presents the coefficient of permeability defined for the materials.

Table 1 – Coefficient of Permeability of the Materials

Zone	Material	Description	Best Estimate Saturated Permeability (m/s)	Calibrated Model Saturated Permeability (m/s)	Comments
1	Bedrock		1×10^{-11}	1×10^{-11}	Assumed to be practically impermeable in comparison to the permeability of the overburden and dam materials.
2	Native Till	Gravelly, silty sand. 20-50% fines	1×10^{-7}	1×10^{-7}	These units were assigned the same permeability in previous studies, but they have updated based on a review of particle size distributions.
3	Glaciolacustrine	Clayey silt. Fines generally between 70-90%	1×10^{-9}	1×10^{-9}	
4	Tailings	Mostly fine silt with between 75 and 100% fines. Some samples (at north end of the impoundment) have more sand than silt (in the order of 60% sand)	1×10^{-7}	1×10^{-7}	Due to the coarser samples, there could be preferential paths in areas. A more permeable coefficient was used to check sensibility.
5	Original Dam	The borrow source of these dam materials are generally believed to be the same. There is more variance in the particle size distributions compared to the other materials, but most samples have between 50 and 60% fines.	1×10^{-7}	1×10^{-7}	This parameter has been considered somewhat less permeable in previous studies. However, in such case, the total seepage through the dam does not align with the evidence on site
6	Stabilizing Berm				
8	Select Fill				
9	Common Fill				
12	2005 Till Toe Berm				
7	Filter Blanket	Sand and gravel. D_{10} = 0.1-0.2 mm	1×10^{-4}	**1×10^{-5}**	Clean sand and gravel material
10	Rock Toe Drain	Sand, gravel and cobbles. D_{10} = 0.5-2 mm	1×10^{-2}	**1×10^{-5}**	Coarser than the filter blanket
11	Rock Drain 2005			1×10^{-2}	
12	Rip Rap	Upstream erosion protection layer	1×10^{0}	1×10^{0}	
-	Granular sandy foundation	Suspected superficial layer that may have not been thoroughly removed during construction	1×10^{-5}		Typical value chosen
-	"Sinkhole"	It was assumed that a potential sinkhole would behave as clean gravel	1×10^{-2}		Value assumed

2.3 Boundary Conditions

2.3.1 Stage 1 – Current Conditions

Upstream, a fixed pond elevation of 707.86 m was assumed. This value is on the high range of measured pond levels in the last 5 years.

Downstream, a fixed water table elevation of 680.00 m was assumed. This level corresponds to a water table depth of approximately 2.8 m, which is the condition encountered in boreholes downstream of the dam (MW-04-2004). The sensitivity analysis was completed on this parameter to determine its influence on seepage through the dam. An alternative value of 675.00 m was assigned to the downstream boundary conditions and found that the shape and location of the water table did not vary greatly, and resulted in a minor decrease of seepage through the dam toe of 2-3%.

An ‘unknown’ boundary condition (either no flow or no pressure) was assigned to the downstream slopes of the dam and the downstream ground. The seepage was calculated through these areas.

2.3.2 Stage 2 – Passive Closure Design Conditions

The proposed design changes to the dam, namely lowering the spillway elevation and constructing a beach on the upstream face, will eventually dry the pond and distance the water table from the dam. A conservative scenario has been modelled assuming that the water table will be close to the elevation of the spillway at 705.8 m upstream, and at the same depth as it is currently downstream. It is believed that in the long term the water table will drop further. Its elevation will be set by the phreatic conditions of the broader area.

The same condition as in stage 1 was applied to the downstream faces of the embankment and open surface, where there is either no flow or no pressure, and the seepage is calculated.

3 Results

3.1 Stage 1 and Model Calibration

The objective of stage 1 was to develop a suitable model that represents the current conditions, and evaluate its sensitivity to variations in the various parameters.

The model was calibrated by comparing the modeled water table to measured water levels at piezometers P1, P2, P5, and P6. The calibration also considered the modeled seepage rate compared to the measured flow in the weir downstream of the dam, which is typically 0.5 L/s and typically ranges between 0.3 and 1.0 L/s. Using the best estimate of the material permeability, it was found that the water table through the dam was significantly lower in the model compared to measured values, while the seepage rate was within the correct range. To correct the water table location, it was assumed that the Zone 10 rock drain had a lesser difference in permeability as compared to the dam fill and a value of $1x10^{-5}$ m/s was assigned. The resulting water table location after this change better reflects the current conditions, as showed in Figure 2.

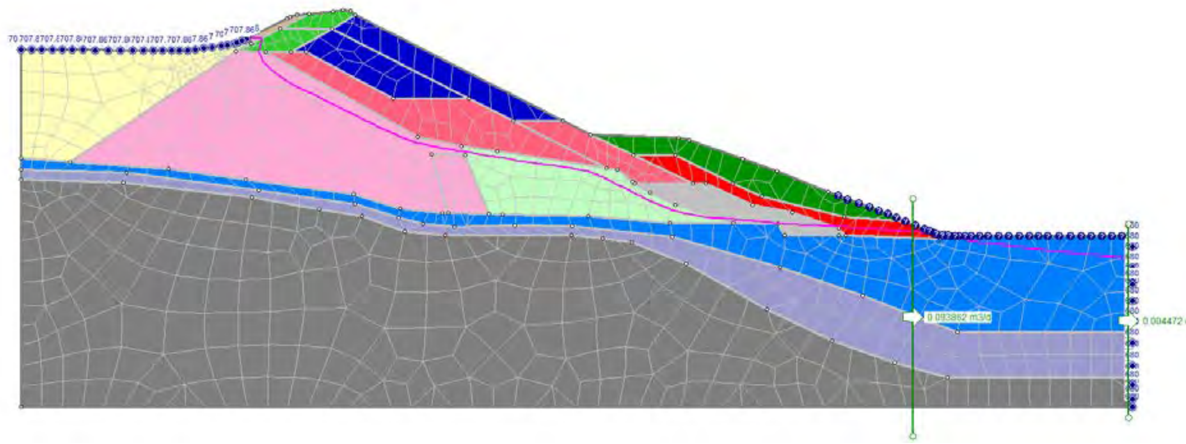

Figure 2 **– Calibrated Model under Current Dam Conditions**

Table 2 presents the base case and sensitivity analysis results under current dam conditions. The seepage rates listed assume a 200 m long homogeneous dam as an approximation. The sensitivity analysis include variation of the permeability of the tailings, the foundation and a possible “sinkhole” to test the sensibility of the system to those parameters.

The base case calculated seepage rate is 0.21 L/s, which is in the low end of the typical seepage rates measured at the downstream weir. The result is considered to be reasonable as the difference in flow may be attributed to the known seepage zones near the east and west abutments.

The sensitivity analysis on the various material permeability (Table 2, model #3 to #6) indicates the most sensitive material to be the dam till. The dam till permeability is estimated to be on the order of $1x10^{-7}$ to $1x10^{-8}$ m/s mainly due to its grain size characteristics. In order to provide better calibration to the measured seepage rates, the more permeable value was selected.

Two hypothetical scenarios were also modeled. The first (Table 2, model #7) assumes a 0.5 m thick granular foundation layer is present at the base of the dam. This model results in a 65% increase in the seepage rate. The second hypothetical scenario (Table 2, model #8) includes the granular foundation, as well as a thin highly-pervious layer (“sinkhole”) on the upstream slope of the dam. The results of the second scenario are the same as the first, as the seepage rate is controlled by the permeability of the granular foundation.

Table 2 – Seepage Rates for the Defined Base Case and Sensitivity Analyses

Model No.	Model Description	Seepage Rate (L/s)	Comments
1	Base case	0.21	After calibration.
2	Downstream water table boundary condition lowered by 5 m (H = 675 m)	0.20	No significant influence in model behaviour and seepage rate.
3	Tailings less permeable than fill – k=1x10^{-8} m/s	0.16	Water table changes slightly and seepage rate decreases in 23% compared to the base case.
4	Glaciolacustrine unit is more permeable – k=1x10^{-8} m/s	0.21	Change does not have a noticeable effect in the model output.
5	Dam till less permeable – k=1x10^{-8} m/s	0.04	Seepage rate reduced to 18% of the base case. This parameter is one of the most sensitive ones.
6	Native till more permeable k=1x10^{-6} m/s	0.18	Change does not carry a large effect in the behaviour of the model with a reduction of 13% in the seepage rate.
7	Sandy granular foundation – 0.5 m thick – k=1x10^{-5} m/s	0.34	If a sandy granular layer had been left at the surface before constructing the dam as is suspected, there would be an additional 65% of seepage rate.
8	Existence of 0.5 m x 0.5 m upstream coarse layer with k=1x10^{-2} m/s	0.34	The effect of a single sinkhole approximately 0.5 square meter connected to the granular foundation with a permeability of 1x10^{-2} m/s (clean gravel) would only impact marginally

Note(s):

1. Seepage rates assume a dam width of 200 m.

3.2 Stage 2

In stage 2, the seepage rate and water table under the proposed design dam geometry was predicted. The objective of the Stage 2 modeling was to assess how the seepage behaviour through the dam is affected.

As noted in Section 2.3.2, the long-term water table is expected to lower. This assessment presents a medium term scenario that represents a conservative approximation.

The passive closure design involves lowering the spillway elevation, and constructing a beach on the upstream face of the dam and a buttress on the toe, amongst other works. Figure 3 shows the results of the base case parameters with the closure design conditions.

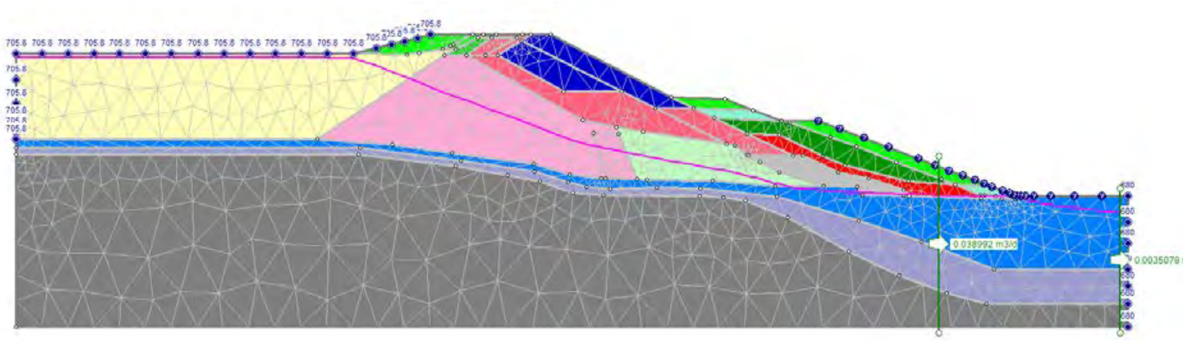

Figure 3 – Passive Closure Design Resulting Water Table

Table 3 presents a comparison of the Stage 1 and Stage 2 seepage analysis results for the base case and two hypothetical scenarios. The results show a reduction in the seepage rates between 30 to 60 %, mainly due to the removal of the high pond and the upstream beach pushing the potential water further away from the dam. The Stage 2 results also resulted in a significant decrease internal hydraulic gradients through the foundation of the dam reducing the risk of internal erosion.

The seepage rates are also believed to be conservatively high as the long-term water level within the facility is likely to be lower as a result of the lined surface water conveyance channels removing the majority of the surface run-on into the facility.

Table 3 – Comparison of Stage 1 and Stage 2 Seepage Rates

Model Description	Stage 1 - Current Condition Seepage Rate (L/s)	Stage 2 – Proposed Design Seepage Rate (L/s)
Base case	0.21	0.08
Hypothetical granular foundation	0.34	0.25
Hypothetical granular foundation and pervious layer on the upstream slope.	0.34	0.25

4 Summary

The seepage through the HB Mine dam was modelled. The parameters of the model were chosen based on previous information and engineering judgement, and the model was tested for its variability in different scenarios.

The modelled seepage rates are in the same order of magnitude with the measured seepage rate on-site for the base case, as well as the hypothetical scenarios where preferential flow paths are present through the foundation and upstream slope. The modeling results are not able to confirm nor rule out the presence of such preferential pathways, but the effect these features have in terms of total seepage rate are minor compared to the whole dam. It also appears that water levels within the dam are higher than would be predicted based on the best estimate material properties. It is believed that the main reason for this is that the contrast in permeability between the dam fill and the drains is not as high as initially assumed and a less permeable Zone 10 rock drain has been modelled.

The seepage model results under the proposed design dam geometry and using conservative boundary conditions resulted in a significantly lowered water table and reduced seepage rates. These results confirm that lowering the spillway and constructing the beach upstream to push the water away from the dam have a positive effect in relation to seepage.

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5 References

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Appendix C-9 – Erosion Assessment

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Reviewed by:	Peter Mikes, P.Eng.	**Date:**	December 13, 2019
Subject:	HB Dam Erosion Protection Analysis		

1 Introduction

The RDCK has decided to transition the HB Mine Tailings Facility to passive closure as defined by the Canadian Dam Association (CDA 2014) to reduce the overall liability and resources required to maintain the facility.

The downstream slope of the HB Dam consists primarily of silts and sands (till). A review of previous inspection reports indicates there is a history of slumping of the downstream slope. The downstream slope was hydroseeded in 2012, and good vegetation growth and coverage has since developed. No evidence of erosion on the downstream has been observed in sine 2014 where a minor slough occurred during the 2014 freshet above the right abutment toe berm. Vegetation growth on the downstream slope was minimal at the time.

An erosion protection assessment was completed on the downstream slope of the HB Dam to gauge the sensitivity of the downstream slope to erosion and to determine if additional erosion protection is required as part of closure. A soil loss estimation analysis was completed to estimate the potential soil losses due to sheet and rill water erosion that could occur over short-term and long-term periods at the site and compare those losses to commonly accepted soil loss values.

Only sheet and rill erosion were considered in this assessment. Sheet and rill erosion occur as a result of flows that are not concentrated into a particular flow path. Erosion that may occur within channel flow was not assessed as part of this memo. All calculated erosion estimates are presented as “soil loss”. Soil loss is a mass of eroded material that leaves the slope entirely.

2 Soil Loss Estimation Methods

There are several methods available for estimating water erosion including the Universal Soil Loss Equation (USLE), the Revised Universal Soil Loss Equation (RUSLE) Versions 1 and 2, the Revised Universal Soil Loss Equation for Application in Canada (RUSLEFAC), the Water Erosion Prediction Project (WEPP), Community Surface Dynamics Modeling System’s SIBERIA, and many others. Most of these programs take several factors into account to compute soil loss such as climate, topography, soil type, vegetation, and land management practices. The key difference between these methods is that some are based on empirical data while others are based on a mathematical approach using soil physics.

2.1 RUSLEFAC

The soil loss analysis described within this analysis uses only the RUSLEFAC method (Wall et al. 2002). The RUSLEFAC is a method based on empirical data, and uses metric units and input parameters that apply to Canadian conditions. The RUSLEFAC has an advantage over other current methods in that it is relatively simple to calculate manually and the effects of each of the input parameters can easily manipulated to a variety of scenarios.

2.1.1 The Equation

The RUSLEFAC equation is calculated manually by first determining several inputs. The RUSLEFAC equation is:

$$A = RKLSCP$$

Where,

A is the potential long term average annual soil loss in tonnes per hectare. *A* can be converted to depth per year if the density of the soil is known. *A* can also be represented as a short term loss, in which case would be tonnes per hectare per event, as opposed to per year.

R is the rainfall factor, which is expressed in energy multiplied by depth over area times duration (MJ mm ha^{-1} hr^{-1}), is calculated using the equation:

$$R = EI$$

Where *E* is the volume of rainfall and runoff (mm/ha) and *I* is the prolonged peak rate of detachment that occurs with runoff (MJ/hr).

- R value contours (isoerodent maps) have been developed by the Government of Canada and are included in the RUSLEFAC document (Wall et al., 2002). To determine the R value in a particular area, interpolation between contours is often required.
- R can be calculated for a single storm event using the R equation if the storm distribution is known or can be estimated.

K is the soil erodibility factor, which is expressed in the units [t hr MJ^{-1} mm^{-1}].

- *K* is dependent on the sand content, fine sand content, silt content, organic matter content, soil structure, and permeability of the soil.

- *K* is determined by applying the appropriate parameters to the soil erodibility nomograph included in the RUSLEFAC.

L is the length of slope factor (dimensionless)

S is the slope steepness factor (dimensionless)

- *L and S* are typically presented as a single value.
- The *LS* factor represents a ratio of soil loss in comparison to a “standard plot”, which is an experimental plot that has a steepness of 9% and a slope length of 22.13 m. Charts based on experimental data are included in the RUSLEFAC document (Wall et al., 2002), which is used to determine the *LS* factor.
- The *LS* factors presented in the RUSLEFAC are representative of straight slopes, but can be manipulated to represent complex slopes (i.e. convex, concave, slopes with benches).

C: the cover factor (dimensionless)

- *C* is *dependent* on the vegetative cover and the land use.
- This factor is based on tables available in the RUSLEFAC document (Wall et al., 2002).

P: the support practice factor (dimensionless)

- The support practice factor accounts for the effects of practices that may reduce the volume or rate of runoff water by altering the flow pattern, surface grade, or direction of surface runoff.

2.1.2 Limitations of the RUSLEFAC Method

The RUSLEFAC (Wall et al., 2002) is a tool for calculating sheet flow erosion and rill erosion, and as stated in Section 2, is based on empirical data. The experimental soil plots used to develop the equations were subjected to conditions that generally reflected average annual climatic conditions. Therefore, the intent of the RUSLEFAC is to produce a numerical representation of an average annual quantity of soil loss in the units of tonnes per hectare per year, which can be converted to depth per year given an understanding of the soil’s in-situ density. The equation is a useful tool for long term predictions, and can also be used for short term losses; however, due to the nature of the experimental data that was collected to develop the equations, short term estimates are likely associated with a greater degree of error.

The RUSLEFAC has the following limitations:

- It does not estimate soil loss from a single rainfall event with a great deal of accuracy. However, the erosivity of a single storm can be estimated using the method described in the RUSLE, which can be used to determine soil loss from a single rainfall event;

- It does not account for erosional losses within gullies or streams;
- Although there can be some account for erosional losses due to snow melt, the equation does not account for this loss with great accuracy; and
- Freeze/thaw can cause ice lenses in soil that will affect the rate of soil loss: the RUSLEFAC does not take this into account.

2.2 Soil Loss Guidelines

Based on the RUSLEFAC, acceptable rates of erosion for the site have been preliminarily estimated at approximately 6 Tonnes per hectare per year. Table 1 presents the soil erosion classes included in the RUSLEFAC.

Table 1: Soil Erosion Classes

Soil Erosion Class	Potential Soil Loss (T/ha/year)
1. Very Low (i.e. tolerable)	< 6
2. Low	6-11
3. Moderate	11-22
4. High	22-33
5. Severe	> 33

The RUSLEFAC considers Class 1 soils to have:

> “Slight to no erosion potential. Minimal erosion problems should occur if good soil conservation management methods are used... A tolerable soil loss (<6 T/ha/year) is the maximum annual amount of soil which can be removed before the long term natural soil productivity of a hillslope is adversely affected.” (Wall et al., 2002).

Although 6 Tonnes per hectare per year is considered an acceptable annual rate of erosion, acceptable rates for single events should not be included in the acceptable annual total. Since a design event occurs so infrequently, the annual acceptable total is considered acceptable for a single event as well (i.e. in a year that a design event occurs, the total acceptable soil loss would be twice the annual acceptable rate).

3 Calculation Inputs

3.1.1 Erosivity/Rainfall Factor (R)

Annual erosivity represents the precipitation energy that causes soil loss over the course of an average year. The annual erositivity value should be used to determine the cumulative soil loss over a long period of time.

Storm event erosivity should be used to determine short term soil loss. As discussed in Section 2.1.2, the degree of accuracy of soil loss predictions for single storm events is low relative to that of annual soil loss predictions.

Annual Erosivity

Annual R values near the Site are shown on the Canadian Isoerodent Maps (Figure R-4 of the RUSLEFAC). An annual R value of 850 MJ mm ha^{-1} hr^{-1} was used for the Site.

Storm Event Erosivity

Erosivity was calculated for single storm events using the method described in Wischmeier and Smith (1978). The storm events were determined using intensity-duration-frequency curves for Environment Canada's Castlegar A station. Single storm distributions are not available from Environment Canada and were estimated using the Alternating Block Method (Chow, Maidment & Mays, 1988). The storm event erosivity values are presented in Table 2.

Table 2: Storm Event Erosivity Values

Storm Event	Total Precipitation (mm)	Erosivity (MJ mm ha^{-1} hr^{-1})
1 in 200 year, 24 hour	83	951

3.1.2 Soil Erodibility Factor (K)

The soil erodibility factor (K) is the rate of soil loss per unit area and is a quantitative value that was derived using the method described in Wischmeier and Smith (1978). Grain size distributions of four till samples collected from the downstream slope of the dam (BGC-BH01-SPT02BGC-BH01-SPT05, TEL-TP15-1-4, and TEL-TP15-4-2) (SRK 2017a) were used to obtain the following inputs:

- Soil texture: Loam
- Average percent silt and very fine sand: 54%
- Average percent sand (between 0.1 and 2 mm): 29%
- Organic matter content estimated at 1%
- Fine granular soil structure
- Slow to moderate permeability.

Based on the above inputs, the K value was estimated to be 0.045 t hr MJ^{-1} mm^{-1}.

3.1.3 Length and Slope Steepness Factor (LS)

The RUSLEFAC was developed using square plots of uniform length and grade. As the HB Dam geometry is not uniform, it the dam was divided into several segments of more uniform geometry.

A weighted average LS factor for the entire dam was calculated to determine soil loss, using the different LS factors from the individual segments (for each of the different cases assessed as discussed in Section 4).

The extent of the non-uniform geometry of HB Dam includes the percent grade: the top portion of the dam (Original Dam) is steeper than the bottom portion of the dam (Toe Berm). This adds a level of complexity to the LS calculation that requires the application of an LS "convex" slope adjustment factor (Table LS-6 of the RUSLEFAC). This factor does not account for truly convex slopes, but for straight slopes that contain a break point where the grade transitions into another straight slope.

The LS factor is also affected by the degree of compaction of the soil. Soil that has been compacted or has settled over time has a lower LS factor and less soil loss, while disturbed soils have greater LS factors and a higher degree of soil loss.

Two slopes conditions were assessed: the current dam geometry and the dam geometry following expansion of the toe berm. Details of the toe berm design are provided in SRK (2017b). Table 3 and Table 4 present the details of the slope segments for the two slope conditions.

Table 3: Current Dam Slope Segments

Slope Segment Number	Relative Position (looking upstream)	Slope (H:V)	Slope Type	Length (m)	Approximate Area (m²) (percentage of total slope)
1	Original Dam, Left	1.9	Straight	15	975 (14%)
2	Original Dam, Middle	1.9	Convex	32	3,200 (45%)
3	Original Dam, Right	1.9	Straight	22	880 (12%)
4	Toe Berm, Middle	2.9	Convex	34	850 (12%)
5	Toe Berm, Right	2.9	Straight	17	1,275 (17%)

Table 4: Expanded Toe Berm Dam Slope Segments

Slope Segment Number	Relative Position on Dam (facing dam)	Slope (H:V)	Slope Type	Length (m)	Approximate Area (m²) (percentage of total slope)
1	Original Dam, Left	1.9	Straight	15	975 (14%)
2	Original Dam, Middle	1.9	Convex	22	2200 (33%)
3	Original Dam, Right	1.9	Straight	11	440 (6%)
4	Upper Expanded Toe Berm, Middle	2.5	Convex	11	825 (12%)
5	Upper Expanded Toe Berm, Right	2.5	Straight	7	175 (3%)
6	Lower Expanded Toe Berm, Middle	2.8	Convex	33	825 (12%)
7	Lower Expanded Toe Berm, Right	2.8	Straight	17	1275 (20%)

3.1.4 Cover Factor (C)

The *C* factor was estimated using Table C-5 in the RUSLEFAC (Wall et al. 2002). Values decrease with lesser cover (yielding lesser soil loss). The value for bare, undisturbed soil with no vegetative canopy (canopy is considered having plants/weeds/shrubs of 0.5 m height or greater) or surface cover is 0.45. The value for 80% or greater grass coverage is 0.01. The current state of vegetation on HB Dam appears to be greater than 80% grass coverage.

3.1.5 Support Practice Factor (P)

The support practice factor (P) accounts for effects of farming on erosion and is not applicable to the HB Dam and was set equal to one.

4 Results

Table 5 presents the cases assessed along with the estimated soil losses. The K and P factors are not shown in the table as they were constant for all cases (0.045 t hr MJ^{-1} mm^{-1} and 1, respectively).

Table 5: Soil Loss Result Summary

Case	**LS Factor**	**Cover Factor**	**Estimated Soil Loss**
Annual (R = 850)			**t/ha/yr**
1 – Current dam geometry with a compacted soil surface and >80% grass coverage	9.36	0.01	2.7
2 – Immediately following toe berm expansion construction with loose disturbed soil and no grass coverage	9.97	0.45	130
3 – Long-term following toe berm expansion with a compacted soil surface and >80% grass coverage	e	0.01	2.4
1 in 200 year Storm (R = 951)			**t/ha/event**
1 – Current dam geometry with a compacted soil surface and >80% grass coverage	9.36	0.01	3.0
2 – Immediately following toe berm expansion construction with loose disturbed soil and no grass coverage	9.97	0.45	145
3 – Long-term following toe berm expansion with a compacted soil surface and >80% grass coverage	8.14	0.01	2.6

5 Conclusions

The results indicate the downstream slope of the HB dam has a “very low” soil erosion classification if adequate grass coverage is present. The annual estimated potential soil loss of 2.7 and 3.0 tonnes/ha/year is less than the guidance value of 6 tonnes/ha/yr, which is the maximum annual amount of soil that can be removed before the long-term natural soil productivity of a hill slope is adversely affected. No additional erosion protection measures are recommended.

The construction of the expanded toe berm will result in slightly lower potential soil loss values as the expended berm will shorten the slope length on the top portion of the dam.

The results indicate that vegetative cover is the most important consideration in limiting erosion. In the short-term following construction and prior to the establishment of vegetation, erosion protection methods (Hydroseeding, silt fencing, mulch, wood chips, coconut matting, etc.) should be implemented to protect the slope, as the analysis shows that bare, loose soil post construction is susceptible to a high degree of erosion.

SRK Consulting (Canada) Inc.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

6 References

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Appendix D – Existing Environmental Monitoring Program Specifications

Environmental Monitoring Program

HB Dam Sampling Schedule									
EMS Number	Well Depth (m BTOR)	Ground Water	Surface Water	Field Designation	Unit	Purpose	April or May	October or November	Comment
HB Mines Southern CAZ									
E275563	17.15	1		MW99-1(S)	OB	Downgradient along Southern Flowpath	1		
E240501	29.71	1		MW99-1(D)	BR	Downgradient along Southern Flowpath	1		
E275543	4.32	1		MW99-2(S)	BR	West Side of Tailing	1		
E240502	24	1		MW99-2(D)	BR - Artesian	West Side of Tailing	1		
E252593	4.71	1		MW-05-01	OB	Background east of Tailings Pond	1		Sample in spring every other year
---	5.99	1		MW-01-2004(S)	OB	Downgradient along Southern Flowpath	1		
---	16	1		MW-01-2004(D)	BR	Downgradient along Southern Flowpath	1		
---	10.55	1		MW-02-2004(S)	OB	Downgradient along Southern Flowpath	1		
---	53.6	1		MW-02-2004(D)	BR	Downgradient along Southern Flowpath	1		
E242841		1		Ross Residence		due diligence	1		
HB Mines Surface Water							Spring	Fall	
---			1	SW1-07	Surface Water		1	1	
---			1	SW2-07	Surface Water		1	1	
---			1	SW3-07	Surface Water		1	1	
---			1	SW4-07	Surface Water		1	1	
E252602			1	Tailings Pond Outlet	Surface Water		1	1	
E252603			1	Outlet Ditch	Surface Water		1	1	

Summary of Analytical Program	Spring	Fall
Total Number of Locations Sampled	55	8
Duplicates (specified at 1 duplicate for every 10 samples)	5	1
Total Number of Analyses per Year	60	9

Duplicates **Specified at 1 duplicate for every 10 samples.**

HB Summary of Specified Sampling Requirements				
Parameters		Surface Water	Ground Water	Comments
Field Measured				
Temperature		1	1	
Conductivity		1	1	
Dissolved Oxygen		1	1	
pH		1	1	
Turbidity		1		Not necessary for groundwater.
Sulphide - Field Measured		1	1	Field test is preferred for sulphide.
Lab Measured				
Total Alkalinity		1	1	Anions can be measured in a single
Chloride		1	1	
Bromide		1	1	
Sulphate		1	1	
Hardness		Calculated	Calculated	Calculated from calcium and magnesiu
TOC		1	1	
TIC		1	1	Compare values with Total Alkalinity
Total Metals - Standard		1		
Dissolved Metals - Standard			1	
Phosphate		1	1	Total phosphate from metals analysis.
Ammonia		1	1	
TKN		1	1	Measures ammonia and organic nitrog
Nitrate		1	1	From anion chromatography.
Nitrite		1	1	

Anion chromatography package

From Metals Package

Note: Water depth is measured and recorded at each well during each Site's sampling events.

Appendix E – Prospective Human Health and Ecological Risk Assessment

global environmental solutions

HB Mine Tailings Management Facility
Prospective Human Health and Ecological Risk Assessment
Salmo, BC

Regional District of Central Kootenay
Box 590, 202 Lakeside Drive, Nelson, BC

July 2019
SLR Project No.: 204.03242.00000

HB MINE TAILINGS MANAGEMENT FACILITY
PROSPECTIVE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT
SALMO, BC

SLR Project No.: 204.03242.00000

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EXECUTIVE SUMMARY

SLR Consulting (Canada) Ltd. (SLR) was retained by the Regional District of Central Kootenay (RDCK) to conduct a prospective human health and ecological risk assessment (HHERA) for chemical contamination anticipated to reside within the HB Tailings Management Facility.

This HHERA has been prepared to identify whether contamination may adversely affect the health of site biota and the public, to make recommendations for risk management and future site monitoring and to assess potential “passive” closure of the site and reduce liability and resources required to maintain the facility.

The site is located southwest of Salmo, British Columbia and has been under the care of the RDCK since 1998. The site consists of the tailings deposition area (or tailings area) as well as the drainage channel. The drainage channel starts at the base of the tailing ponds and seasonally flows west towards the Salmo River. The section of the channel included in this assessment is located between the end of the tailings pond’s spillway and the culvert north of Highway 3.

Numerous environmental investigations have been conducted at the site and adjacent landfill area to characterize soil, groundwater, surface water and sediment impacts related to tailings area and landfill leachate. Based on these previous investigations, metals (including aluminum, arsenic, barium, beryllium, cadmium, chromium (total), cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, selenium, tungsten, uranium and zinc) and select organic parameters (ammonia-N, chloride, nitrite (as N), nitrate (as N) and phosphorus) have historically been identified as potential contaminants of concern in soil, groundwater, sediment and/or surface water at the site. The groundwater plume beneath the site has been reported to consist of impacts related to the tailings area as well as a landfill located hydraulically upgradient of the site (AMEC 2014).

SRK has prepared a report detailing the design for the closure, reclamation, and the remediation of the HB Mine Tailings Facility (SRK, 2018). Currently, a tailings pond is located in the southern extremity of the tailings deposition area and is retained by an earthen dam. The tailings pond will be drained and backfilled during closure to prevent pooling of water in the tailings. A tailings cover will be placed over the tailings facility. Under post-closure conditions, the entire tailings deposition area will be covered with 0.3 m of fill sourced from the borrow pit area located east of the Landfill to the northeast of the Site. The SRK Report also includes the design of three lined surface water drainage channels lined surface water drainage channels, constructed over the tailings cover to convey surface runoff to the spillway. Vegetation will be re-established across the entire tailings deposition area using species pre-approved by relevant stakeholders.

The HHERA is “prospective” in nature in that it is based on anticipated future post-closure site configuration and assumed environmental quality. Specifically, the HHERA is quantifying risks to human and ecological receptors once the proposed TMF cap (thickness of 30 cm) and surficial drainage channels as well as other proposed upgrades to the spillway and outlet ditch are implemented.

Human Health Risks

Based on the results of the HHERA problem formulation, no complete or significant exposure pathways were identified for human health. Exposure to on-site contaminants is expected to be negligible for on-site trespassers and maintenance workers and off-site residents and farmers under post-closure conditions.

No complete exposure pathways were identified between groundwater COPCs on-site and potable water use to the north and west of the site. Based on the direction of groundwater flow, exposure to off-Site receptors south of the site is a potentially complete exposure pathway. However, based on the results of the historical sampling, exposure via potable water use is considered an insignificant pathway based on current land uses south of the site.

A potentially complete and significant exposure pathway was identified for potential future groundwater users immediately south of the site for lithium in groundwater. The source of the lithium in groundwater has not been confirmed. RDCK indicated that the lithium concentrations appeared to be stable downgradient, and were likely not related to groundwater quality concerns at the site (SLR 2019b). The concentration of lithium in the downgradient wells indicated that concentrations have historically been higher than groundwater concentrations measured within the Tailings Area and lithium has been below detection limits in all soil samples collected within the tailings area, (RDCK 2019b), supporting this assessment.

Ecological Risks

The risks to wildlife associated with soil to plant bioaccumulation, and ingestion of site food items and soil are expected to be negligible for all ROCs for arsenic and lead (i.e. HQ<1). Risks are also expected to be negligible for cadmium and zinc for all ROCs with the exception of the song sparrow (HQ of 1.4 and 2.1, respectively) and American robin (zinc, HQ = 1.6), where the risk estimates were marginally above the target risk level (HQ = 1).

Based on the results of the quantitative evaluation combined with site observations, risks to plant communities at the site was concluded to be negligible. A summary of the results of the vegetation assessment is provided below:

- Although risk estimates above the risk target level (i.e. HQ=1) were identified for plant root contact with arsenic, lead and zinc in subsurface soil (i.e. tailings material) and manganese, fluoride, uranium and zinc in groundwater, based on the frequency of exceedances across the site, the site wide risk at the site as a whole is likely to be negligible.
- Based on the review of historical information related to vegetation at the site, historical planting of grasses and fescue occurred at the site prior to 1982 as documented in the Stage 1 Submission for reactivation of the HB Mill report (IEC Ltd., 1982). Based on a review of historical planting activities at the site risks to the vegetation species expected to be planted during closure (i.e. grasses, alfalfa etc.) are expected to be negligible.

Risks for wildlife due to bioaccumulation in the food chain are expected to be negligible for arsenic, and lead (i.e. HQ<1). Risks are also expected to be negligible for cadmium and zinc for all ROCs with the exception of the song sparrow (cadmium and zinc) and American robin (zinc only), where the risk estimate was marginally above the target risk level (HQ = 1). Risks to burrowing mammals are also expected to be negligible (i.e. HQ<1).

Due to the size of the available dataset, risk estimates for wildlife were calculated based on maximum plant tissue concentrations collected from the site. This may result in an overestimate of risks to plant-consuming ROCs such as the song sparrow and American robin. Risks for these receptors were recalculated based on the 95th percentile and geometric mean of the plant tissue concentrations for cadmium and zinc. The HQs calculated using geometric mean plant tissue concentrations risks to song birds are expected to be low, however uncertainty with risks to these receptors are expected to be high due to the limited dataset, and limited on-site receptor information.

The results of the HQ step of risk characterization for aquatic life indicated that potential risks to most receptor groups were negligible or low, however the results of the risk characterization for surface water indicated potential risks for the following COPCs-ecological receptor group combinations in the downstream channel post closure:

- Aquatic plants exposed to aluminum, copper and nitrite;
- Aquatic invertebrates exposed to aluminum, copper, zinc and nitrite;
- Fish exposed to zinc; and
- Amphibians exposed to aluminum, copper and nitrite.

In addition, exposure to sediment were associated with potential risks to aquatic life from exposure to cadmium, lead and zinc.

Based on the low magnitude of the HQs obtained for surface water and sediment, the ephemeral nature of the habitat provided by the channels and the conservative assumptions made in the risk assessment (e.g. use of total metal in the exposure assessment), the potential risks are considered to be low.

ACRONYMS

ADD	Average Daily Dose
AMSL	Above mean sea level
AW	Aquatic Life, Water Use
AWF	Aquatic Life Water Use, Freshwater
BC	British Columbia
BTF	Biotransfer factor
CDC	Conservation data centre
CKRD	Kootenay and Central Kootenay
cm	centimetre
COPC	Contaminant of potential concern
COSWIC	Committee on the Status of Endangered Wildlife in Canada
CSAP	Contaminated Sites Approved Professional Society
CSM	Conceptual Site Model
CSR	Contaminated Sites Regulation (BC)
DERA	Detailed Ecological Risk Assessment
DEQ	Department of Environmental Quality
DKL	Kootenay Lake Forest District
$DQRA_{CHEM}$	Detailed Quantitative Risk Assessment for Chemicals
DW	Drinking Water Use
EC	Environment Canada
EMA	Environmental Management Act
EMPR	The Ministry of Energy Mines and Petroleum Resources
ENV	BC Ministry of Environment and Climate Change Strategy
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
FCSAP	Federal Contaminated Sites Action Plan
ha	hectare
HHERA	Human Health Ecological Risk Assessment
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
ILCR	Incremental Lifetime Cancer Risk
IEC	International Environmental Consultants Ltd.
IW	Irrigation Water Use
LW	Livestock Water Use
m	meter
mbg	meters below grade
mg/kg	milligram per kilogram
mg/kg	milligram per liter

NOAEL	No observed Adverse Effect Level
PEL	Probable Effect Level
PQRA	Preliminary Quantitative Risk Assessment
RDCK	Regional District of Central Kootenay
ROC	Receptor of Concern
SAR	Species at Risk
SARA	Species at Risk Act
SedFS	Sediment Standards, Freshwater Sensitive use
SedFT	Sediment Standards, Freshwater Typical use
SLR	SLR Consulting
SRK	SRK Consulting
Eco-SSL	Ecological Soil Screening Level
TCEQ	Texas Commission on Environmental Quality
TRG	Tissue Residue Guideline
TRV	Toxicity Reference Value
TRM	Turf-reinforcement matting
TSF	Tailings Storage Facility
UCLM	Upper confidence level of the mean
µg/L	micrograms per litre
US EPA	United States Environmental Protection Agency
WL	Wildlands land use
WQG	BC Water Quality Guideline

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DRAWINGS

PHOTOGRAPHS

APPENDICES

1.0 INTRODUCTION

SLR was retained by the Regional District of Central Kootenay (RDCK) to complete a Conceptual Site Model (CSM) and prospective Human Health and Ecological Risk Assessment (HHERA) for the HB Mine Tailings Management Facility (the site) under a planned future post-closure configuration.

1.1 Background

The site is located southwest of Salmo, British Columbia and has been under the care of the RDCK since 1998. The property was originally purchased to provide a buffer and attenuation zone for groundwater from the Central Landfill located northeast of the site. The site location is indicated on Drawing 1.

In 2012 a sloughing event occurred along the dam embankment of the tailings storage facility (TSF) resulting in significant monitoring, maintenance, upgrades, and investigations. As a result of this, the RDCK has elected to transition the Property to a state of "passive closure" with the intent to ensure the containment, and long-term stability of the tailings and to reduce liability and the resources required to maintain the facility.

The Ministry of Energy and Mines and Petroleum Resources (EMPR) completed a Memorandum dated December 20, 2018 summarizing the HB Tailings Reclamation and Closure Plan – Pre-Application Review. EMPR recommended completion of a CSM and HHERA to evaluate the effects of metals uptake and leaching on groundwater, surface water, soil and vegetation following installation of tailings cover and to evaluate human health and ecological risks associated with site contamination.

1.2 Scope and Objectives

SLR Consulting (Canada) Ltd. (SLR) was retained by the Regional District of Central Kootenay (RDCK) to conduct a prospective human health and ecological risk assessment (HHERA) for chemical contamination within the HB Tailings Management Facility.

This HHERA has been prepared to address the following RDCK and BC Mines management goals:

1. To identify whether contamination may adversely affect the health of site biota and the public under the proposed “passive closure” site configuration;
2. To guide site reclamation planning, in particular with respect to any recommendations towards risk management and future site monitoring; and
3. To reduce liability and resources required to maintain the facility.

1.2.1 Spatial Scope

The HHERA was confined to the area within the tailings storage facility (TSF) boundary and the drainage ditch that leaves the facility to the point it intersects Crowsnest Highway 3 (Drawing 2). Migration of TSF groundwater and surface water to surrounding properties was also considered.

1.2.2 Temporal Scope

The HHERA is “prospective” in nature, in that it is based on anticipated future post-closure site configuration and assumed environmental quality. Specifically, the HHERA has evaluated risks to human and ecological receptors for a time period of a few years in the future, assuming the tailings pond has been drained, infilled, and the entire TSF has been capped with 30 cm of native borrow pit soils (RDCK’s chosen cap thickness) and replanted with native vegetation, largely grasses.

1.2.3 Environmental Media Considered in the Risk Assessment

The environmental media assessed in the HHERA include groundwater, surface water, soil and vegetation following installation of the tailings cover.

The HHERA also includes sediment in the downstream channel to provide an understanding of potential risk associated with sediment quality at baseline conditions prior to remediation activities at the TSF. Predicted sediment quality following installation of the tailings cover is not available. The results of the sediment evaluation will form the basis for a before-after comparison approach and/or inform the design of future monitoring programs.

1.3 General Approach

1.3.1 General Approach

The methods used to conduct this HHERA were based on risk assessment procedures recommended by the BC Ministry of Environment and Climate Change Strategy (ENV). Specifically, the HHERA was conducted in general accordance[1] with the risk assessment guidance listed below.

- BC ENV. 2017a. Technical Guidance 7: Supplemental Guidance for Risk Assessments. Version 5, November 2017.
- BC MOE. 2013. Protocol 20: Detailed Ecological Risk Assessment Requirements. Version 1.0. April 1, 2013.
- Golder Associated Inc. 2006. Guidance for Detailed Risk Assessment (DERA) in British Columbia.
- Environment Canada. 2012. Federal Contaminated Sites Action Plan (FCSAP) Ecological Risk Assessment Guidance. March 2012.
- Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA)(Health Canada, 2012).
- Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals (DQRACHEM)(Health Canada, 2010).

[1] Deviations from these protocols based on risk assessor professional judgement, or remedial design by SRK or RDCK have been noted.

The first part of HHERA is the problem formulation. For there to be any possibility of a risk to ecological health, the receptors must be exposed to a chemical. This question was addressed systematically by identifying the contaminant of potential concern (COPC), the receptors of concern (ROCs) that might be exposed to the COPCs, and the specific pathways through which the ROCs might be exposed. The information was summarized in a conceptual site model (CSM)[2] to determine the ROC-COPC combinations arising from complete exposure pathways that were carried forward for risk characterization. Only complete and significant exposure pathways are carried forward into the subsequent sections for risk characterization.

Subsequent steps of HHERA are calculation of the degree to which the ROCs are exposed to the COPCs (i.e., Exposure Assessment) and determination of the toxicity of the COPCs (i.e., Toxicity or Effects Assessment). Using these two factors, a calculation of risk can be completed. Risk estimates are compared to the acceptable regulatory risk criteria for a quantitative assessment and also can be interpreted and allow for a qualitative description of risk, i.e. negligible, low, moderate, or high.

Resulting human health hazard quotients (HQ) or total hazard indices (HI) can be compared to the BC CSR risk-based standard of HI≤1 and estimates of potential for developing cancer can be compared to the BC CSR risk-based standard of Incremental Lifetime Cancer Risk (ILCR) ≤ $1X10^{-5}$ or 1 in 100,000 chance of developing cancer through site exposure.

For ecological receptors, BC ENV identify an HQ ≤ 1.0 as the level below which risks to ecological receptors are considered negligible (i.e., acceptable). HQs above the identified risk levels do not indicate that adverse effects are certain, but rather that adverse effects are possible.

1.3.1.1 *CSR Professional Statement*

The primary authors of this report were Kathryn Matheson and Celine Totman. Contributions to the report text, tables, and appendices were also made by Erica Moran, Michael McLeay, and Cindy Ott.

1.3.1.2 *Report Organization*

This report is organized into the sections described in Table 1-1.

[2]A CSM combines information on COPCs, potential receptors, and potential exposure pathways to provide an overall picture of interactions on a site and identifies complete exposure pathways which are carried forward for risk characterization (refer to Appendix B).

Table 1-1: Report Organization

Report Section	Description
Section 1 - Introduction	Identifies site location, contracting agencies, assumed management goals, and authors and contributors.
Section 2 – Problem Formulation	Provides a general site description and summarizes historic environmental investigations; determines receptor- and media-specific contaminants of potential concern (COPC); identifies potential human and ecological receptors; discusses fate and transport of COPCs and evaluates receptors potential exposure pathways to COPCs; presents conceptual site models identifying complete exposure pathways to be further quantitatively evaluated in the HHERA.
Section 3 – Quantitative Ecological Risk Assessment	Quantitatively estimates exposures and risks from COPCs to the site-wide communities for plants, soil invertebrates, trees, and freshwater aquatic life. Utilizes hazard quotient (HQ) approach for terrestrial and aquatic biota.
Section 4 – Uncertainty Evaluation	Discusses general uncertainties common to HHERA and lists more site-specific investigation and HHERA uncertainties (human and ecological).
Section 5 – Conclusions and Recommendations	Provides the high-level findings of the HHERA, indicates how these findings correlate with the assumed management goals, and provides general recommendations with respect to addressing HHERA uncertainties and risk-management.
Section 6 – Statement of Limitations	Discusses obligations and responsibility of SLR regarding this report.
Section 7– References	Lists references used in the HHERA.

2.0 PROBLEM FORMULATION

2.1 Applicable Regulatory Guidelines and Standards

The site is municipally owned land presently under permit (Permit M-218) by BC Mines. Since the HHERA is intended to be prospective in nature, guidelines and standards were selected based on post-closure conditions.

The *Contaminated Sites Regulation* (CSR) under the *Environmental Management Act* (EMA) is the principal regulatory document defining requirements for contaminated sites management in British Columbia. The CSR came into effect on April 1, 1997 and was amended most recently on January 24, 2019 via the Stage 12 amendments.

The EMA and CSR have provisions for both numerical standards and risk-based approaches to managing site contamination. The legislation outlines the procedures for site assessment, risk assessment, remediation and application for environmental closure for a property. Numerical standards are a key component of the requirements in the CSR, as they define whether a site is contaminated or has been satisfactorily remediated when the numerical standards approach has been used.

The following subsections present the standards specifically used in the HHERA to identify the site contaminants and COPCs requiring risk characterization. The COPC identification process (or COPC screening) is further discussed in Section 2.7. The applicable standards/guidelines are listed by division of media below.

2.1.1.1 *Soil*

The CSR soil standards for wildlands (reverted) land use (WL) are applicable to all soil and subsurface tailings material at the site based on the expected post-closure conditions at the site. Standards applied to all soil data at the site include:

- Matrix Numerical Soil Standards for the mandatory site-specific factors: human intake of contaminated soil; and, toxicity to soil invertebrates and plants (CSR Schedule 3.1, Part 1);
- Matrix Numerical Soil Standards for the site-specific factors: groundwater used for drinking water and groundwater flow to surface water used by freshwater aquatic life (CSR Schedule 3.1 Part 1); and
- Generic Numerical Soil Standards (CSR Schedule 3.1) to protect human health (Part 2) and ecological health (Part 3).

In addition, the BC CSR Protocol 4 Table 1: Regional estimates for background concentrations in soil for inorganic substances (Region 4 Kootenay) were compared to soil results at the site.

2.1.1.2 *Groundwater*

Numerical standards for substances in water in the CSR are presented in Schedule 3.2. The numerical standards are referenced to four classes of water use: Aquatic Life (AW), Irrigation (IW), Livestock (LW), and Drinking Water (DW).

Four aspects of the site in relation to surface water and groundwater are important for determining potentially applicable standards.

- Ephemeral surface waterbodies including surficial drainage channels on the tailings area, the spillway and the natural drainage ditch are expected to be present on-site post closure. In addition, a constructed pond is located approximately 80 m northeast of the Site and is used for landfill surface water management. In this case, the aquatic life (freshwater) standards apply.
- The ENV groundwater database well search and other information indicates two water supply wells are located within 500 m of the subject site. In this case, DW standards apply.
- ENV considers DW standards to be applicable at the site in relation to future groundwater use unless:
  - site conditions meet all the DW exemption requirements outlined in Protocol 21; or
  - ENV has approved a site-specific exemption from the DW standards.
- Irrigation and livestock watering use may occur downgradient of the site as agricultural land is located 700 m southwest of the tailings area.
- All requirements outlined in Protocol 21 are not met, therefore DW standards are considered to apply. Groundwater analytical results have been compared to the CSR AW (freshwater), DW, IW and LW standards.

2.1.1.3 *Surface Water*

The following guidelines or standards have been applied to surface water at the site based on identified water uses.

- The BC Water Quality Guidelines (WQGs) for drinking water were used to identify COPCs for human health.
- The Approved BC Water Quality Guidelines (WQGs) were applied for the protection of freshwater aquatic life (AWF) (long-term value). Where BC Approved WQGs were unavailable, the BC Working WGQs, CSR Generic Numerical Water Standards (Schedule 3) Aquatic Life (freshwater) (AWF) divided by 10 or the Canadian Water Quality Guidelines for the Protection of Aquatic Life were used.

The BC Approved and Working WQGs for the protection of wildlife was applied for the protection of wildlife receptors using the surface water in channels as a source of drinking water. In the absence of guidelines specific to wildlife, the BC WQG and the BC CSR, Schedule 3.2, Generic Numerical Water Standards for the protection of livestock (LW) were used to identify contaminants. Where wildlife or livestock values were not available, the BC WQGs for drinking water were conservatively selected to identify COPCs for wildlife.

2.1.1.4 *Sediment*

Due to the presence of waterbodies on-site, CSR Schedule 3.4 Generic Numerical Sediment Standards for the protection of freshwater environments are considered to apply to the site. The sediment standards for freshwater sensitive use (SedFS) were conservatively used to identify contaminants and COPCs (Section 3.7).

2.2 General Site Description

The site is located southeast of Salmo, British Columbia and is situated in the Columbia Mountain System. The site consists of the tailings deposition area (or tailings area) as well as the downstream channel. The Tailings area covers an approximate area of 26 ha. The downstream channel starts at the base of the tailing pond beneath the spillway and seasonally flows west towards the Salmo River. As indicated in the Introduction, the section of the channel included in this assessment is located between the end of the tailings pond's spillway and the culvert north of Highway 3. Photos of the tailings facility and downstream channel are presented following the text.

Currently, approximately 90 percent (~ 26 ha) of the tailings area is dry and the remaining 10 percent (~2.6 ha) is submerged within the tailings pond. The tailings pond is located in the southern extremity of the tailings deposition area and is retained by an earthen dam. The pond occupies an approximate area of 2 ha with the spillway inlet in the southwest corner. The tailings pond is currently fed by groundwater as well as surficial drainage channels which flow southward across the tailings area.

SRK has prepared a report detailing the design for the closure, reclamation, and the remediation of the HB Mine Tailings Facility (SRK, 2018a). The tailings pond will be drained and backfilled during closure to prevent pooling of water in the tailings. A soil cover will be placed over the tailings deposition area. SRK indicated that the main objective of the tailings cover was to provide dust and erosion control to prevent migration of the tailings due to wind and water. Under post-closure conditions, the entire tailings deposition area will be covered with 0.3 m of fill sourced from the borrow pit area located east of the Landfill to the northeast of the Site. The SRK Report includes the design of lined surface water drainage channels, constructed over the tailings cover to convey surface runoff to the spillway. The design includes three lined surface water drainage channels: Main Channel and the North and South Spur Channels. The Main Channel will direct surface water to the spillway from the landfill wetland area, the North and South Spur Channels will direct surface water from two ephemeral streams on the east side of the impoundment (Drawing 4). The surficial drainage channels will be lined with geosynthetic and geotextile liners. Vegetation will be re-established across the entire tailings deposition area using species pre-approved by relevant stakeholders. SRK indicated that "*the channels are to be lined with an geosynthetic liner and covered with a 0.20 m protection layer overlain by a layer of turf-reinforcement matting (TRM*). *The objective of the TRM is to provide short term erosion protection until vegetation is established in the channel".* The spillway will also be excavated and lined with a geotextile layer. The outlet ditch is expected to remain in its current condition and continue to convey water on a seasonal basis.

2.2.1 Regional Topography and Surface Drainage

The tailings deposition area is relatively flat with elevations ranging from 715 (northeast corner) to 712 m (southeast corner) AMSL. The spillway inlet of the tailing pond is 1.7 m below the crest elevation of the dam (BGC, 2002). North of the site is Sheep Creek that flows westward to the Salmo River and is located in a steeply incised bank.

Regionally, the site is located within the Pend-d'Oreille watershed. The major drainage in the area of the site is the southward flowing Salmo River, which occupies a floodplain to the west of the site. The majority of surface water from the surrounding area, including the southern portion of the adjacent landfill operation, currently drains towards the tailing area to the pond. As mentioned above, during post-closure conditions, water is expected to continue to drain southward through the lined drainage channels, on an ephemeral basis, toward Highway 3. Drainage water will then follow its current path through a culvert under the highway and through a man-made ditch system to the Salmo River.

2.2.2 Geology and Hydrogeology

Geological and hydrogeological information from previous investigations was reviewed for the purpose of creating a conceptual site model (CSM) for the site. A detailed summary of the information reviewed is provided within the CSM in Appendix B. A brief summary of the geological and hydrogeological features of the site is provided below.

2.2.2.1 *Geology*

On a regional scale, the site geology is composed mainly of metamorphic rocks including highly metamorphosed schist, gneiss, amphilbolite, and quartzite as well as unaltered siltstone, sandstone, conglomerate, limestone, and dolomite (Groundwater Resources of BC). Bedrock in the vicinity of the site belongs to the North America – basinal strata terrane, Lower Cambrian Laib Formation and consists mainly of phyllite, argillite, schist, quartzite, and minor limestone (RDCK 2019a). The majority of the site is underlain by phyllite bedrock. Granite from the Cretaceous Anstey Pluton formation is also located within the southwestern portion of the site property boundary and is exposed in the west spillway cut (AMEC 2014).

The depth to bedrock varies across the Site from at least 6 m at the east abutment to surficial outcrops in close proximity to both dam abutments (RDCK 2019a). A steep drop in bedrock occurs south of the tailings dam from approximately 663 m above mean sea level (amsl) to 587 m amsl based on stratigraphy data for MW-01-2004(D) and MW-02- 2004(D).

Regional surficial geology in the area is composed of colluvial and mass wasting deposits. The major rivers in the region were deeply scoured by glaciers during Pleistocene time and subsequently infilled with deposits of silt, sand, gravel, and till. Stratigraphy encountered at the site consists of overburden materials (glacial and post-glacial deposits), ranging in thickness from 0 to 47.8 m (MW-02-2004(D)) overlying the bedrock surface. The overburden thickness is generally shallow beneath the original dam (3 to 6 meters) and increases in thickness south of the dam (14.3 m at MW-01-2004 located approximately 140 m down valley) (RDCK 2019a).

Approximately 1.5 m of tailings is present at the western edge of the tailings deposition area, overlying 0.6 m of silty gravel. The tailings thickness has an approximate maximum depth of 20 meters near the southcentral portion deposition area, immediately upstream of the dam. Soils beneath the tailings deposition area consist primarily of silty sand to silty sand and gravel with some clay (RDCK 2019a).

2.2.2.2 *Hydrogeology*

A bedrock ridge present immediately west of the tailings pond forms a major hydrogeological divide that constrains groundwater flow in the area of the Site to a predominantly southward flow path (CRA 2002). A landfill is located immediately north of the Site and is noted to be hydraulically connected with the Site (AMEC 2014). A groundwater flow divide is present beneath the landfill between flow from the landfill toward Sheep Creek to the north, and toward the Site to the south (AMEC 2014). The groundwater flow divide occurs at another bedrock ridge located beneath the landfill oriented in an approximate east-west direction. On the southern side of the ridge, groundwater is noted to flow westward from the landfill to the tailings area (AMEC 2014). From the tailings area, all groundwater flow is toward the south (AMEC 2014).

Historically, the bedrock formation was considered to be generally competent and of low permeability. With this interpretation, the bedrock surface topography would be expected to control the presence and movement of groundwater within the overburden soils; however, water levels observed in the bedrock well at MW-01-2004(D), immediately downgradient of the tailings dam, indicate that the bedrock is fractured and hydraulically connected to the shallow overburden at this location which is likely a result of the north-sound trending fault through the valley. Significant bedrock faults in the area could create preferential groundwater flowpaths. Groundwater flow beneath the tailings proceeds along the valley axis to the valley bottom aquifer.

2.3 Surrounding Property Use

Land use surrounding the site is summarized in the Table below.

Table 2-1: Surrounding Property Use

Direction	Land Use
North	The landfill area is located north and northeast of the site, followed by Emerald road, Sheep Creek and Sheep Creek Road. The town-centre for the Village of Salmo is located approximately 4 km northwest of the Site. Two seepage ponds are also located north and northeast of the site.
East	Undeveloped, forested land.
South	Immediately south/southwest of the Site is Highway 3, followed by agricultural land known as “Ross Property” located approximately 700 m southwest of the site.
West	A steep bedrock ridge is located immediately west of the site. Beyond the bedrock ridge, is the southern portion of the Village of Salmo.

2.4 Climate Data

The general climate for the region is characterized by warm, dry to moderately moist summers and cool, snowy winters. Precipitation in the region increases from south to north, from west to east and with increasing elevation (RDCK 2019a). Snowfall typically accumulates in November with maximum accumulation typically occurring near the end of March. Snow melt occurs in April, May, and June at a maximum sustained rate of 20 to 30 mm/day based on regional snow-survey stations (RDCK 2019a). Meteorological parameters are not measured at HB Mine Tailings Facility. Mean monthly temperature range from -3.6°C in January to 19.1°C in July. Mean monthly precipitation range from 35.9 mm in July to 103.3 mm in December.

The closest active station to the Facility is Castlegar Airport, BC (Climate ID: 1141455) located approximately 36 km northwest of the Facility in an adjacent valley at an elevation of 495 m AMSL. The amount of precipitation is believed to representative of site conditions, while temperatures at site are likely to be slightly cooler than indicated at the station. Based on the Castelgar Airport climate normal data, the site is expected to be snow covered an average of 90 days per year. In addition, temperatures at the site are zero degrees Celsius or below for an average of 120 days per year.

2.5 Previous Environmental Investigations

Information from the following reports were reviewed during the preparation of the HHERA:

- Canex 2000. Canex Landfill Hydrogeological Impact Assessment, prepared by Klohn-Crippen Consultants Ltd., July 31, 2000.
- CRA 2002. Revised Draft Text for Detailed Site Investigation Report. Canex Landfill Site, Salmo, British Columbia.
- CRA 2006. Southern Groundwater Flowpath. Central Landfill Site. Salmo, British Columbia.
- SNC 2013. Limited Risk-based Preliminary and Detailed Site Investigation and Human Health Risk Assessment. Blocks 3 and 4, District Lot 275, Plan NEP23118 and Lot A, Block 5, West Half of Block 6 and Block 7, Kootenay Land District, 6 km South of Salmo, BC.
- AMEC 2014. Five Year Hydrogeology Review, Central Landfill, Salmo, BC. Prepared for Regional District of Central Kootenay. April 2014.
- SRK Consulting (Canada) Ltd., 2016. HB Mine Tailings Facility Remediation and Closure Preliminary Assessment. Prepared for Regional District of Central Kootenay. SRK Project Number 1CR012.001. August.
- SRK 2017a. HB Mine Tailings Facility – 2016 Tailings Characterization Factual Report. Prepared for Regional District of Central Kootenay. SRK Project Number 1CR012.001. May.
- SRK 2017b. Prediction of Geochemical Performance of HB Tailings Under Proposed Remediation Conditions Memo. SRK Consulting. May 23, 2017.
- SRK 2017c. HB Mine Tailings Facility Closure Design – Hydrological Analysis – DRAFT Memo. SRK Consulting. May 23, 2017.
- SRK 2018. HB Mine Tailings Facility Closure Detailed Design Report – DRAFT. SRK Consulting. December 2018.
- SRK 2019. Draft HB Mine Water Quality Prediction Model, HB Mine Tailings Facility, Salmo BC. Undated.
- RDCK 2019a. HB Mines Reclamation and Closure Report- Draft. HB Mine Tailings Facility, Salmo, BC. 2019.
- RDCK 2019b. HB Mines Annual Reclamation reports dated 2007 to 2019.
- RDCK 2017. 2017 Annual Operation and Monitoring Report. OC16519 Central Landfill Salmo, BC.
- RDCK 2018. 2018 Annual Operation and Monitoring Report. OC16519 Central Landfill Salmo, BC.

Numerous environmental investigations have been conducted at the site and adjacent landfill area to characterize soil, groundwater, surface water and sediment impacts related to tailings area and landfill leachate. Based on these previous investigations, the following parameters have historically been identified as potential contaminants of concern in soil, groundwater, sediment and/or surface water at the site:

- Metals including aluminum, arsenic, barium, beryllium, cadmium, chromium (total), cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, selenium, tungsten, uranium and zinc;
- Organics including ammonia-N, chloride, nitrite (as N), nitrate (as N) and phosphorus; and
- Physical parameters including alkalinity, temperature and total organic carbon.

The groundwater plume beneath the site has been reported to be impacted by the tailings area as well as a landfill located hydraulically upgradient of the site (AMEC 2014). Metals parameters including manganese and iron and organic parameters including ammonia-N, chloride, nitrite (as N), nitrate (as N) and phosphorus measured in and downgradient of the tailings area have historically been attributed mainly to the landfill area, however the tailings may also be a source of some of these parameters (AMEC 2014).

In 2014, a five year hydrogeological assessment of the site and landfill area was conducted to satisfy BC ENV requirements for the landfill. The tailings area was included within the hydrogeological assessment to account for the groundwater flow downgradient of the landfill. The results of this assessment indicated that groundwater flows predominantly southward after entering the tailings area towards Highway 3 and the floodplain for the Salmo River (AMEC 2014). Surface water drainage was also noted to follow a southward flow path through the drainage channel south of the tailings area and across the flood plain to the Salmo River (AMEC 2014).

In 2013, ecological and human health (limited) risk assessments were completed for an agricultural property to the south of the site within the Salmo floodplain (The Ross Property). The risk assessments assessed exposure of ecological and human receptors on the Ross Property to metals impacts in surface water, soil and sediment believed to have originated from the site (Azimuth Consulting Group Partnership (Azimuth) 2013, SNC 2013). The ecological risk assessment (ERA) included ecological surveys and receptor identification, food chain modelling and toxicity testing for aquatic receptors (Azimuth 2013). The human health risk assessment considered human exposure to contaminants via bioaccumulation through the food chain as well as direct contact with soil. Ingestion of groundwater as a drinking water source was not considered in the HHRA based on the results of residential well sampling completed in support of the limited HHRA (SNC 2013).

Annual monitoring of groundwater and surface water at and downgradient of the site has been conducted as part of annual reclamation monitoring for the tailings area required as part of Mines Act Permit M-218 (“Permit”). The results of the 2019 annual reclamation monitoring indicated that groundwater concentrations met the CSR standards and guidelines at the downgradient property boundary in 2018 with the exception of lithium, which exceeded the CSR DW standard. Lithium concentrations were noted to be relatively constant overtime and unrelated to groundwater quality concerns (RDCK 2019b). Surface water at the downgradient property boundary was noted to exceed the AWF guidelines for cadmium and zinc in 2018. RDCK noted that sediment erosion and transport from the tailings area is possible during spring freshet, which can result in Outlet Ditch exceedances (RDCK 2019b).

As noted previously, SRK has prepared a report detailing the design for the closure, reclamation, and the remediation of the HB Mine Tailings Facility to support the eventual closure of the site (SRK, 2018). The report included plans for design and implementation of a dry cover over the entirety of the tailings area to mitigate surficial erosion of soil contaminants. Major components of the closure and reclamation plan include the following (based on SRK 2018):

- Construction of an upgraded spillway at the western abutment and tailings pond backfill placement to eliminate the pond upstream of the HB Dam and convey potential flood water through the impoundment;
- Expansion of the HB Dam toe berm to improve stability during seismic events and in the event that liquefaction occurs within the original dam fill;
- Construction of a till beach upstream of the dam to mitigate the risk of internal erosion and piping; and
- Construction of a tailings cover and lined channels to convey surface drainage over the tailings facility and to prevent the erosion, escape, and migration of the fine tailings from the tailings facility, remove the direct contact exposure pathway for human and most ecological receptors, and to provide a final surface that will aid in revegetation.

2.6 Receptors of Concern

As part of the problem formulation process, human and ecological receptors using the site and surrounding area (i.e., receptors of concern) were identified. The following sections present the information and approach used in determining the receptors of concern for the site.

2.6.1 Human Receptors

Human receptors of concern identified for the site are listed in Table 2-2.

Table 2-2: Human ROC Selection

Receptor Group	Receptor Group Details
On-site maintenance workers	Adults (20 + years). Expected to periodically visit the site to inspect the soil cap and facility.
Trespassers	Age toddler to adult (6 months to 20 + years). May trespass on the site to use the site and surrounding lands for recreational purposes such as hiking or camping.
Off-site residents/farmers	All age (< 6 months to 20 + years). Assumed to live and farm the land downgradient of the site (i.e. the Ross Property). Assumed to consume groundwater as a drinking water source as well as crops and livestock sourced from the Ross Property.

No trespassing signs will be posted at all entrances to the site, therefore recreational users are not permitted on the site. However, a trespasser who may use the site for recreational purposes was conservatively considered in the HHERA.

2.6.2 Ecological Receptors

A list of ecological receptors relevant to the site and surrounding area was developed by reviewing observations made during previous environmental investigations as well as the results of an ecological survey completed for the Ross Property. Future closure plans were also considered when selecting ecological ROCs. The following sections describe the ecological ROC selection for the site.

2.6.2.1 *Terrestrial Soil Invertebrates and Plants*

Following the installation of tailings cover, cap soil will be seeded with various plant species. Based on discussion with RDCK and Interior Seed & Fertilizer Ltd. the following species are proposed for the site and will be considered in ROC selection for the HHERA of the tailings area:

Table 2-3: Proposed Vegetation Species

Species	Latin Name
Slender Wheatgrass	*Elymus trachycaulus*
Pubescent Wheatgrass	*Thinopyrum intermedium*
Perennial Ryegrass	*Lolium perenne*
Alfalfa	*Medicago sativa*
Sheep Fescue	*Festuca ovina*
Creeping Red Fescue	*Festuca rubra*
Canada Bluegrass	*Poa compressa*
Redtop	*Agrostis gigantea*
Coated Fringed Brome	*Bromus ciliatus*
Annual ryegrass	*Lolium multiflorum*
Coated Tufted Hairgrass	*Deschampsia cespitosa*
Slender Wheatgrass	*Elymus trachycaulus*
American Slough grass	*Beckmannia syzigachne*
June grass	*Koeleria macrantha*

SLR reviewed average plant root-depths for the plant species identified above to determine whether exposure to subsurface soils below the cap layer is anticipated. BC technical guidance was preferentially reviewed for root depths for the selected plant species, followed by alternative sources where BC guidance for similar species was unavailable. Based on the review, root depths for the majority of the plant species listed above range from less than 0.33 m (Canada Bluegrass; Bonin et al. 2013) to 1.6 m (Slender Wheatgrass; CSAP 2013). Selected plant species with deeper rooting depths including Annual Ryegrass (up to 3.5 m based on CSAP 2013) and Alfalfa (over 6.1 m under favourable conditions [Undersander et al. 2011]).

Based on the review of historical information related to vegetation at the site, historical planting of grasses and fescue occurred at the site prior to 1982 as documented in the Stage 1 Submission for reactivation of the HB Mill report (International Environmental Consultants [IEC] Ltd., 1982). Based on the vegetation mix documented in the report (i.e. grasses, alfalfa etc.) species were similar to those documented above.

In addition, other plant-life such as trees and shrubs will be considered for potential long-term colonization of the site as well as for the portion of the site downgradient of the tailings area.

2.6.2.2 *Wildlife*

An ecological risk assessment (ERA) was completed by Azimuth for the agricultural property known as the “Ross Property” (“Ross Property ERA”; Azimuth 2013). The Ross Property ERA included the identification of receptors of concern (ROCs; including provincially and/or federally listed species at risk [SAR]) applicable to the Ross Property and surrounding area. ROC selection was based on the results of two field surveys completed in 2006 and 2011 (Azimuth 2013). Based on the proximity of the Ross Property to the site, terrestrial wildlife (excluding livestock) identified in the Ross Property ERA are assumed to be applicable to the site. The following terrestrial wildlife ROCs were identified in the Ross Property ERA:

Table 2-4: Ross Property Terrestrial Receptors of Concern

Common Name	Latin Name	Common Name	Latin Name
Birds			
European starling	*Sturnus vulgaris*	tree swallow	*Tachycineta bicolor*
Song sparrow	*Melospiza melodia*	cliff swallow	*Petrochelidon pyrrhonota*
Cedar waxwing	Bombycilla cedrorum	northern flicker	*Colaptes auratus*
lazuli bunting	*Passerina amoena*	barn swallow[1]	*Hirundo rustica*
American robin	*Turdus migratorius*	Great blue heron[1]	*Ardea Herodias*
Mammals			
White-tailed deer	*Odocoileus virginianus*	Red squirrel	*Sciurus vulgaris*
Northern pocket gopher	*Thomomys talpoides*	Meadow vole	*Microtus pennsylvanicus*
Columbian ground squirrel	*Spermophilus columbianus*	Black bear	*Ursus americanus*
Yellow- pine chipmunk	*Tamias amoenus*	American beaver	*Castor Canadensis*
Coyote	*Canis latrans*	-	-
Reptiles			
Garter snake	*Thamnophis spp.*	-	-

1 - blue-listed species; threatened

Aquatic-dependent mammals and birds were not considered ROCs as part of the Azimuth report (2013) as they were not expected to forage for any length of time in the channel between Highway 3 and the Salmo River "*due to the ephemeral nature of the aquatic habitat and the proximity to better aquatic/riparian habitat near the Salmo River*". Similarly, SLR has not selected aquatic dependent-wildlife as ROCs in this prospective HHERA based on the same rationale and habitat observations made in August 2017.

2.6.2.3 *Aquatic Life*

Aquatic life is defined as aquatic plants, aquatic invertebrates, fish and amphibians.

In 2013, Azimuth completed an ecological risk assessment of the portion of the drainage ditch located on the west side of Highway 3 which is downgradient and outside of the drainage ditch within the site boundary. This off-site section of the channel was described as having poor to fair fish habitat value. Azimuth (2013) reported that brook trout had been documented as having been rearing, spawning and overwintering in the off-site drainage ditch prior to 2008. However, Azimuth noted that since 2008 the off-site drainage ditch had been dry during the fall and early winter contributing to a decrease in the quality of fish habitat. The off-site drainage ditch on the west side of the highway is (seasonally) connected the Salmo River. The Azimuth ERA report lists the fish species residing in the Salmo River as: rainbow trout (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), brook trout (*Salvelinus fontinalis*), Westslope cutthroat trout (*O. clarki lewisi*), kokanee (*O. nerka*), mountain whitefish (*Prosopium williamsoni*), longnose dace

(*Rhinichthys cataractae*), northern pikeminnow (*Ptycheilus oregonensis*), largescale sucker (*Catostomus macrocheilus*), longnose sucker (*C. catostomus*), slimy sculpin (*Cottus cognatus*), and redside shiner (*Richardsonius balteatus*).

The Azimuth report (2013) noted that brook trout had been found in off-site drainage ditch during high flow period in 2006 (Masse and Miller Consulting 2008, as cited in Azimuth 2013). Azimuth added that the brook trout were thought to have originated from the tailings pond. As indicated above, no fish were observed in the tailings pond during the September 2018 biological survey.

In August 2017, SLR walked the drainage ditch from the tailings pond to the highway culvert. The channel was mainly dry with the exception of limited areas with shallow water pooling. Water depth in these areas ranged from 2 to 10 cm. The width of the channel (bankfull, at select locations) ranged from 2.0 m to 4.9 m. The dominant substrate observed in the stream channel was cobble with interspaced gravel. Fine sediment was limited to depositional zones. The channel had abundant large woody debris creating numerous log jams. The channel was also generally overgrown. The channel banks were undercut showing ongoing erosion during high flow events. Aquatic plants were not observed during the site visit. Small fish and amphibians were observed in isolated pools.

SLR completed a biological survey of the tailings pond on September 12 and 13, 2018. A total of seven baited minnow traps were deployed in the tailings pond to determine fish presence. No fish were observed in the pond or captured in the minnow traps during the biological assessment. The September 2018 biological survey completed by SLR included an amphibian survey. Columbia spotted frogs (*Rana luteiventris*) were observed at the northern and northeastern seepage ponds located north of the tailings area. Multiple turtles were also observed within the ponded area; the species could not be identified due to the distance at which the observations were made.

Based on the above information the following aquatic receptor groups considered in this HHERA include:

- Aquatic Invertebrates
- Fish
- Amphibians

2.6.2.4 *Species at Risk*

Risk assessment guidance recommends species listed as rare, endangered, or threatened with habitats confirmed to be present within the study area or likely to be present in the future, be included as receptors in a risk assessment (Environment Canada, 2012). The federal Canadian Species at Risk Act (SARA) lists species which are extirpated, endangered, threatened or of special concern in Schedule 1 of the Act. General prohibitions for species in this schedule, with the exception of special concern, specify that: "*No person shall damage or destroy the residence of one or more individuals of a wildlife species that is listed as an endangered species or a threatened species, or that is listed as an extirpated species if a recovery strategy has recommended the reintroduction of the species into the wild in Canada.*" Species listed in Schedules 2 and 3 of SARA are designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and are reassessed before addition to Schedule 1.

A desktop review was completed to identify the potential species-at-risk which may occur within the general project area utilizing a search of the BC Species and Ecosystem Explorer (BC CDC 2019). This included a search for vertebrate and invertebrate species listed as Endangered, Threatened or Special Concern under the Species at Risk Act and by the Committee on the Status of Wildlife in Canada and Provincially Red or Blue-listed identified a total of 43 listed species with the potential to occur within the ICH BEC zone and the Central Kootenay Regional District (BC CDC 2019). This includes three amphibian, thirteen mammal, twenty-two bird and five reptile species. Of these 43 listed species, twenty-six are listed under SARA and/or COSEWIC including:

- Four mammal species: wolverine (luscus subspecies), caribou (*rangifer tarandu*; southern mountain population), american badger (*taxidea taxus*) and grizzly bear (*ursus arctos*);
- Four fish species: bull trout (*salvelinus confluentus),* cutthroat trout, lewisi subspecies (*Oncorhynchus clarkii lewisi*), columbia sculpin (*Cottus hubbsi*), White Sturgeon (Kootenay River population; *Acipenser transmontanus* pop. 1);
- Three vegetation or moss species: margined streamside moss (*scouleria marginata*), banded cord-moss (*Entosthodon fascicularis),* whitebark pine *(pinus albicaulis);*
- Ten bird species: long-billed curlew (*numenius americanus),* Lewis's woodpecker *(melanerpes lewis*), western screech-owl, macfarlanei subspecies (*megascops kennicottii macfarlanei), y*ellow-breasted chat *(Icteria virens),* barn swallow *(Hirundo rustica), bobolink (dolichonyx oryzivorus),* Black Swift (*Cypseloides niger),* Olive-sided Flycatcher *(Contopus cooperi),* short-eared owl *(Asio flammeus), Western Grebe (Aechmophorus occidentalis);*
- Two insect/invertebrate species: magnum mantleslug (*magnipelta mycophaga*), monarch (*Danaus plexippus)*; and
- Three amphibians or reptile species: northern leopard frog (l*ithobates pipiens),* painted turtle - Intermountain - Rocky Mountain Population *(Chrysemys picta pop. 2),* western skink (p*lestiodon skiltonianus).*

Personal communication from RDCK also indicated that a 2008 West Kootenay amphibian study reported observation of western toad at the tailings deposition area.

Search results are provided in Appendix D.

In addition, the Ross Property ERA identified the following SAR:

- Great Blue Heron
- Common Nighthawk
- Olive-sided Flycatcher
- Barn Swallow
- Townsend’s Big-eared Bat
- American Badger
- Rubber Boa
- Western Skink
- Western Toad

Based on a review of the habitat requirements for each of the species at risk, the barn swallow, great blue heron, western grebe, black swift and long-billed curlew are unlikely to occur at the site, although the great blue heron is known to occur at the Ross Property (Azimuth 2013). In addition, the plant species identified above will not be located on-Site post-closure, and therefore are only applicable to the areas downgradient of the tailings area. According to the BC conservation data centre mapping tool (CDC imap) none of the above-noted species have been observed within 1500 metres of the site, however the olive-sided flycatcher, wolverine, barn swallow, cutthroat trout, and grizzly bear were not mapped by BC ENV as they are wide spread and/or wide-ranging species. None of the four listed fish species are expected to occur in the drainage channels (downstream of the spillway and on top of the tailings pond) based on their known distribution, habitat requirements, the fact that these channels will be ephemeral and that they will not offer suitable spawning habitat. Amphibians have been observed in small isolated pools in the downstream channel in August 2017 and suitable forested and riparian area present along the channel.

Based on a review of the species above, the olive-sided flycatcher, wolverine and grizzly bear may be present at the site. With respect to large wildlife such as the wolverine or grizzly bear, the site's habitat areas are will represent only a small fraction of the foraging/home range. Although the olive-sided fly-catcher may be present at the site since it forages by fly-catching, its exposure is expected to be low compared to other receptors.

2.6.2.5 *Ecological Receptor of Concern Selection*

As it is not realistic or necessary to quantify risks for all ecological receptors identified at the site, surrogate ROCs were selected to be representative of the ecological receptors identified in the Sections above. The ROCs selected for further assessment in the HHERA are presented in the Tables below.

Table 2-5: Ecological ROC Selection

Receptor Group	Receptor Type	Include in ERA? (Yes/No)	Rationale	Surrogate ROC
Aquatic plants	Macrophyte	Yes	Aquatic plants were not observed in the downstream channel during SLR site visit; however, SRK noted that vegetation was expected to establish in the drainage channel over the tailings.	Community level
Aquatic invertebrates	Zooplankton	No	The channels are expected to be ephemeral, with at time shallow water depth thus epifauna and infauna are considered better surrogate ROCs for aquatic invertebrates.	Community level
	Epifauna and infauna	Yes	Benthic invertebrates are likely present in the channels and/or isolated pools during the summer months.	Community level
Fish	Benthivorous and piscivorous	Yes	Sculpin have been observed to use the channel downstream of Highway 3 and may migrate upstream during higher spring flow. Brook trout have been observed to use the channel downstream of Highway 3 and may migrate upstream during higher spring flow	Fish at the community level - rainbow trout will be the surrogate ROC as it is a contaminant sensitive species and the species for which

Receptor Group	Receptor Type	Include in ERA? (Yes/No)	Rationale	Surrogate ROC
				most toxicity information is available
Amphibians	Carnivorous	Yes	Amphibians have been observed in small isolated pools in the downstream channel in August 2017; suitable forested and riparian area present along the channel.	Wood Frog
Terrestrial Plants (rooting depths < 0.3 m)	Select grasses	No	Unlikely to be exposed to soil below 0.3 m.	N/A
Terrestrial Plants (rooting depths > 0.3 m)	Grass, shrubs, forbs	**Yes**	Exposure to contaminants in subsurface soil; provide a dietary contaminant source to higher trophic levels.	N/A Community Level Assessment
Terrestrial Plants downgradient of tailings area	Trees, shrubs, forbs	**Yes**	Exposure to contaminants in groundwater; provide a dietary contaminant source to higher trophic levels.	N/A Community Level Assessment
Invertebrates	Ground-dwelling	**Yes***	Important role in the food chain. Likely to be exposed to soil < 0.3 m only.	N/A Community Level Assessment
	Aerial	**Yes***	Important role in the food chain. Likely to be exposed to soil < 0.3 m only.	
Mammals	Herbivorous	**Yes**	Possible exposure to contaminants through ingestion of vegetation and water	White-tailed deer, northern pocket gopher
	Insectivorous	**Yes**	Possible exposure to contaminants through ingestion of invertebrates and water.	Vagrant shrew
	Herbivorous	**Yes**	Burrowing mammals may be exposed to contaminants via ingestion of subsurface soil.	Northern pocket gopher
	Omnivorous	No	May be exposed via bioaccumulation through the food chain, however unlikely to have significant exposure based on home range size	Black bear
	Omnivorous	**Yes**	Possible exposure to contaminants through ingestion of water and food items.	Deer mouse
Birds	Herbivorous	**Yes**	Potentially present based on Ross Property ERA. Possible exposure to contaminants through ingestion of water and terrestrial Plants.	Song Sparrow
	Insectivorous	**Yes**	Possible exposure of contaminants through ingestion of water and food items.	Barn swallow
	Carnivorous	**Yes**	May be exposed via bioaccumulation through the food chain.	American kestrel
	Omnivorous	**Yes**	Potentially present based on Ross Property	American robin

Receptor Group	Receptor Type	Include in ERA? (Yes/No)	Rationale	Surrogate ROC
			ERA. Possible exposure through ingestion of water and food items.	
Reptiles	Omnivorous	**Yes**	Exposure through ingestion of food and water.	Common gartersnake

*No COPCs identified for exposure to these receptors. Included in ERA for bioaccumulation assessment only.
** Considered for portion of the site downgradient of the tailings area only.
N/A – Not applicable

2.7 Selection of Risk Assessment Contaminants of Potential Concern

Contaminants identified as part of the previous report review were further evaluated to identify those contaminants considered to be COPCs, i.e. those warranting further evaluation via risk assessment. The process used to identify COPCs is described below.

2.7.1 Dataset Descriptions

Historical data from the reports in Section 2.5 were compiled for assessment in the HHERA. The datasets for soil, groundwater and sediment considered in the HHERA are provided in Appendix A. Media-specific descriptions of the datasets for soil groundwater and sediment are provided below. Based on the prospective nature of the HHERA, a historical dataset was not compiled for surface water. The HHERA instead considered the expected future surface water conditions by using recent (2016-2018) and modelled future contaminant concentrations. A description of the future surface water dataset is provided in Section 2.7.1.3. All sample locations are presented on Drawing 3.

2.7.1.1 *Soil Chemistry Data*

Soil data was compiled from historical investigations completed between 2016 and 2019. Data collected from outside the boundaries of the site (i.e. within the landfill area) were not considered for the HHERA dataset. The soil dataset was divided into two datasets based on soil horizon and expected receptor-exposure scenarios. The soil datasets include the following:

- Surficial soil (0-0.3 m): Consists of soil from the borrow-pit area located east of the landfill. This soil will comprise the 0.3 m cap installed across the tailings area during closure. The 0 – 0.3 mbg depth interval was chosen to represent potential exposure to human health, terrestrial invertebrates (as per BC ENV Protocol 1) and most wildlife.
- Full depth soil (0-12.5 m): Consists of all soil within the soil chemistry dataset. The top 0-0.3 m of soil consists of the borrow-pit soil described above, soil below 0.3 m consists of tailings material within the tailings area. The full depth soil interval was used in the identification of COPC for plants based on the potential depth of roots as well as burrowing wildlife.

The soil datasets are provided in Appendix A. Individual sample locations are indicated on Drawing 5.

2.7.1.2 *Groundwater Chemistry Data*

Since future (i.e. modelled) data was not available, data representative of current conditions from the historical reports in Section 2.5 was conservatively used to assess groundwater. The groundwater dataset consisted of all available groundwater data collected from within the boundaries of the site (i.e. within the tailings area as well as downgradient). The landfill located northeast of the site was capped with soil cover in 2016 as part of formal landfill closure to mitigate leaching of landfill contaminants to groundwater. Groundwater data collected prior to 2016 was therefore not considered for the groundwater dataset. Groundwater data collected from within the landfill area was also excluded from the HHERA dataset. The groundwater dataset was comprised of groundwater samples collected in April 2016, May 2017 and May 2018.

Groundwater data collected from monitoring well MW-05-01 located upgradient of the site and landfill area was also excluded from the dataset, but retained for comparison as a background sample location.

The groundwater dataset is presented in Appendix A and Drawing 6 presents the monitoring well locations.

2.7.1.3 *Surface Water Chemistry Data*

The surface water dataset includes water quality data representing the post-closure tailings configuration. SRK provided water quality predictions for the drainage ditch downstream of the tailings pond using a simple water and load balance model. The paragraph below describes the process used by SRK for the selection of parameters included in the model.

SRK examined surface water data obtained at the Outlet Ditch during an eight-year sampling period (2011-2018). Water quality data at the Outlet Ditch was screened for COPCs. COPCs were identified by comparing site water quality results with the BC WQG and the BC CSR AW. If a parameter exceeded the water quality thresholds, it was identified as a COPC, and was included as a model parameter. The COPC's determined by SRK were the following: aluminum, cadmium, chromium, copper, iron, lead, manganese, nitrate, sulfate, sulphide, uranium, and zinc. Sulphate, sulphide and all metals displayed multiple exceedances at the Outlet Ditch throughout the eight-year sampling period. Nitrate exceeded the BC WQG only once in 2017. Surface water predictions were then made for two locations to support the HHERA: 1) at the confluence of the spillway with dam seepage (immediately downstream of the dam) and 2) at the Outlet Ditch upstream of Highway 3. Predictions made for the first location represent potential exposure in the upper reach of the ditch while predictions made at the second location represent exposure in the lower reaches of the ditch as well as predicted water quality at the property line. The model is described in SRK report entitled: HB Mine Water Quality Prediction Model (SRK, 2019). SRK provided SLR with monthly water quality data predictions in Excel format for the two locations described above.

As described in Section 2.2., the tailings pond will be drained and backfilled during closure to prevent future water impoundment against the upstream face of the dam. The closure and remediation design will include three lined surface water drainage channels, constructed over the tailings cover to convey surface runoff to the spillway: the Main Channel and the North and South Spur Channels (Drawing 4). The Main Channel and the North Spur Channel will convey runoff from the covered landfill as well as background runoff. The South Spur Channel will convey background runoff only.

Surface water quality in these channels is expected to be comparable to the runoff currently monitored at locations SW1-07 (landfill plus background runoff), SW2-07 (landfill plus background runoff) and SW3-07 (background runoff) (Drawing 8). For this reason, analytical surface water quality results obtained at locations SW1-07 in April and November 2016, May 2017 and May 2018 analytical surface water quality results obtained at locations SW1-02 in April and November 2016, May 2017 and May and October 2018 were included in the surface water dataset. Analytical surface water quality results obtained at location SW-3-07 were used to characterize the background surface water quality (i.e., surface water quality not influenced by the landfill or tailings inputs).

Based on the proposed design, it is assumed that the drainage channels and downstream channel will provide habitat for benthic invertebrates and amphibians. Fish are not expected to utilize the drainage channels over the tailings pond once built. Fish may, however, migrate in the downstream channel from the Salmo River during period of higher flow. The surface water dataset used to identify COPCs for aquatic life reflects these assumptions as shown in Table 2-6.

Table 2-6: Dataset Used to Calculate Exposure Point Concentrations – Aquatic Life

Dataset	Location	Receptors	Total number of samples (up to)
Entire dataset (drainage[a] and downstream[b] channels)	SW1, SW2 outlet ditch*, tailings outlet and seepages*	Benthic invertebrates	34
Downstream channel only	Outlet ditch*, tailings outlet and seepages*	Fish	24
Entire dataset (drainage and downstream channels)	SW1, SW2, outlet ditch*, tailings outlet and seepages*	Amphibians	34

*Predicted concentrations

[a]- Main channel, North Spur Channel and South Spur Channel. All three channels will convey flow over the tailings.

[b] – Channel located between the spillway and highway 3.

Note that the total number of samples may vary as not all parameters have been analyzed for all samples.

In addition, one sample location SW3-07, was selected to represent background water quality. This location captures surface water from a natural, unimpacted catchment (SRK, 2019).

The surface water dataset is provided in Appendix A and Drawing 8 presents the surface water sampling locations.

2.7.1.4 *Sediment Chemistry Data*

The sediment dataset consists of eight sediment samples collected in the downstream channel by SLR in August 2017.

The sediment dataset is provided in Appendix A and Drawing 7 presents the sediment sampling locations.

2.7.1.5 *Tissue Data*

Plant tissue samples collected during the Vegetation Metals Uptake Study (SLR 2018) were used for the compilation of the on-site plant tissue dataset. Tissue data from reference samples 1 & 2 were excluded from the dataset but retained for comparison as a background sample location. The plant tissue dataset is provided in Appendix A and Drawing 9 presents the tissue sampling locations.

2.7.2 Selection of Parameters Carried into COPC Screening

Parameters were included in the COPC screening process if concentrations in one or more samples within the identified datasets (Appendix A) were greater than the guidelines and standards identified in Section 2.1. Metal parameters analyzed in groundwater were carried into the COPC screening process based on dissolved metal results and metal parameters analyzed in surface water were carried into the COPC screening process based on total metal results. For plant tissue, COPCs were carried forward if they were significantly different than background sample results, based on the conclusions of the Metals Uptake Study (SLR 2018, Appendix E).

Table 2-7 below summarizes the parameters that are site contaminants now or in the future and were carried forward into the COPC screening process based on the lowest applicable guidelines/standards.

Table 2-7: Summary of Prospective Site Contamination

Media	Parameters exceeding the BC CSR Standards
Surficial soil (0-0.3 m)	Arsenic
Full depth soil (0-12.8 m)	Arsenic, cadmium, lead, selenium, zinc
Groundwater	Arsenic, barium, iron, lithium, manganese, molybdenum, tungsten, uranium, zinc, ammonia as N, fluoride, sulfate
Surface Water	Aluminum, beryllium, cadmium, chromium (total), copper, iron, lead, lithium, mercury, nitrite, sulphide
Sediment	Arsenic, cadmium, lead, zinc
Plant Tissue*	Arsenic, cadmium, lead, zinc

**Carried through due to the absence of a media-specific standard or guideline*

In addition, CSR standards or BC guidelines were unavailable for select parameters detected in soil, groundwater, surface water and/or sediment (bismuth, calcium, gallium, gold, lanthanum, magnesium, potassium, scandium, sodium, tellurium, thorium, titanium, zirconium, phosphorus). Many of these parameters are generally common in soil and are considered essential nutrients for plants and organisms. In addition, the Salmo area is known to be mineral-rich and is the subject of numerous mineral claims due to the presence of important deposits of tungsten, gold, silver, lead and zinc among other minerals (Mineral Exploration Report, Sheep Creek Gold Camp, 1982). These parameters are not considered to related to site activities and were not carried forward in COPC screening.

2.7.3 COPC Screening Benchmarks

Screening benchmarks are values used to help identify chemicals requiring risk characterization. Chemicals with concentrations above screening benchmarks are identified as COPCs since adverse effects may result from exposure above these levels. Chemicals with concentrations below screening benchmarks are not expected to be associated with potential adverse effects and can be eliminated from further consideration. COPC screening is conducted to simplify the risk assessment process by eliminating chemical parameters from evaluation in the HHERA that are not present in high enough concentrations to warrant risk characterization.

2.7.3.1 *Soil*

Parameter concentrations in each soil dataset were compared to the receptor-specific standards outlined in Section 2.1.1.1 following the process described below:

1. Humans: surficial soil (0-0.3 m) data was compared to the CSR WL_R Matrix Numerical Soil Standards for human intake of contaminated soil.
2. Invertebrates: surficial soil (0-0.3 m) data was compared to the CSR WL Matrix Numerical Soil Standards for plants and soil invertebrates as well as the Generic Numerical Soil Standards to protect ecological health.
3. Plants and burrowing wildlife: Full depth (0-12.8 m) soil data was compared to the CSR WL Matrix Numerical Soil Standards for plants and soil invertebrates as well as the Generic Numerical Soil Standards to protect ecological health.
4. Wildlife: surficial soil (0-0.3 m) data was compared to the CSR WL Matrix Numerical Soil Standards for plants and soil invertebrates as well as the Generic Numerical Soil Standards to protect ecological health. These values were used because wildlife-specific guidelines have not been developed by the BC CSR.

As groundwater and surface water sample results were available for this site, soil standards protective of groundwater used for drinking water and surface water used by freshwater aquatic life were not considered. Rather, COPCs for the protection of humans consuming groundwater as potable water will be selected using the available groundwater data, and COPCs for the protection of aquatic life will be selected using the available surface water data.

The Region 4 Kootenay background soil values identified in Section 2.1.1.1 were also used for screening (Section 2.7.4).

Since the CSR soil standards do not consider bioaccumulation of contaminants in the food chain, all parameters with concentrations above the lowest of the soil standards outlined in Section 1.3.1.2 were retained for a bioaccumulation assessment.

2.7.3.2 *Groundwater*

Parameter concentrations in the groundwater dataset were compared to the receptor-specific standards outlined Section 2.1.1.2 following the process described below:

1. Human Health: Groundwater samples were compared to the BC CSR DW for drinking water.
2. Plants: Groundwater samples were compared to the BC CSR IW standards.

3. Aquatic Life: Groundwater samples were compared to the BC CSR standards for flow to freshwater aquatic life.

The IW standards were selected for screening root contact with groundwater in the absence of receptor-specific screening values.

Although data was initially screened for AWF (and provided for reference in Table 11 after the text), groundwater COPCs were not identified for groundwater flow to surface water used by freshwater aquatic life (Section 2.1.1.2). The COPC screening process for aquatic life instead used current and predicted (i.e., future) surface water dataset developed by SRK (SRK 2019). Future surface water concentrations developed by SRK considered current groundwater concentrations in contact with the tailings on the site (SRK 2019). In addition, based on hydrogeological information reviewed for the site (Section 2.1.1.3 and Appendix B), as well as the seepage assessment completed by SRK (SRK 2018c), groundwater is unlikely to significantly recharge surface water bodies on the site under post-closure conditions. Therefore, the predictive surface water concentrations are likely more representative of the media to which aquatic life could be exposed under post closure conditions.

2.7.3.3 *Surface Water*

Parameter concentrations in the surface water dataset were compared to the receptor-specific standards outlined Section 2.1.1.3.

2.7.3.4 *Sediment*

Parameter concentrations in the sediment dataset were compared to the aquatic receptor-specific standards outlined Section 2.1.1.4.

For human health, sediment data was compared to the CSR WL Matrix Numerical Soil Standards for human intake of contaminated soil.

2.7.3.5 *Tissue Data*

Tissue data COPCs were selected by reviewing the results of the metals uptake study (SLR 2018; Appendix E). The metals uptake study compared on-site tissue sample results to reference samples collected northeast of the site (R1 and R2).

2.7.4 COPC Screening Process

COPC screening was conducted by comparing the maximum detected parameter concentrations in affected media to the screening benchmarks for the protection of human health and ecological receptors described above. A chemical was retained as a COPC if the maximum measured concentration in the dataset was greater than the selected screening benchmark.

2.7.4.1 *Consideration of Background Concentrations*

The concentrations of COPCs were also compared to background concentrations. This step eliminates COPCs that may be naturally occurring or may originate from off-site (anthropogenic or natural geological) sources and; thus, focuses the risk assessment to the COPCs associated with site activities.

The Region 4 Kootenay background soil values were used to screen soil data.

As indicated in Section 3.7.1.3, the surface water data obtained at location SW3-07 between 2016 and 2018 were used to characterize the background surface water quality. The 95th percentiles were calculated as upper limit estimates of the COPC concentrations at this background location. This is consistent with the procedure recommended as part of the derivation of water quality objectives in British Columbia (BC MOE, 2013). The 95th percentiles are also recommended as upper limits when deriving background groundwater concentrations (ENV, Non-Dated).

2.7.4.2 *Consideration of Bioaccumulation Potential*

Bioaccumulation refers to the net accumulation of a chemical by a living organism as a result of uptake from all routes of exposure (e.g. water, diet) (Oregon Department of Environmental Quality (DEQ), 2007).

Biomagnification, is defined as the process by which chemical concentrations in living organisms (plants or animals) increase relative to food from transfer through the food web (e.g. predators have greater concentrations of a COPC than their prey) (Azimuth, 2012).

The bioaccumulation of COPCs into living organism at the base of the food chain and their subsequent transfer through the food web provides an exposure pathway to higher-level organisms (Oregon DEQ, 2007). For this reason, further screening was completed to identify bioaccumulative COPCs. Bioaccumulative COPCs will be carried forward in a food chain model to characterize the potential risks to humans and wildlife ingesting them.

Bioaccumulation of residual contamination was assessed in two ways, the review of listings of bioaccumulative substances in available literature and the collection of on-site tissue data. Substances this HHERA has assumed to be <u>potentially bioaccumulative</u> are those which are:

1. Listed as bioaccumulative in the CSAP technical guidance document entitled "*Bioaccumulation Research Project"* (CSAP 2015) or by TCEQ (2018)[3] as being bioaccumulative from specific media; and
2. If analysed, identified as potentially bioaccumulating in on-site plants in the Metals Uptake Study (SLR 2018) presented in Appendix E.
3. Evaluation of contaminant specific chemical properties and distribution to assess bioaccumulative potential. The degree a contaminant bioaccumulates within the food web is determined by several factors, including its chemical properties such as: logarithm of its octanol water partition coefficient (log K_{ow}), its bioconcentration factor (BCF) and/or its bioaccumulation factor (BAF) (TCEQ, 2018).

Results of the bioaccumulation potential screening are presented in the Section 2.7.5.1, below.

[3] TCEQ decision making on a substances bioaccumulation potential was based on multiple factors including substances BCF/BAF (90th percentile dw BAF > 1 for soil invertebrates, plants, benthic invertebrates; ww BCF > 1000 for aquatic invertebrates and fish), log KoW, and in some cases consideration of potential for effects to higher trophic level consumers.

Parameters noted above were carried forward as bioaccumulative COPCs if they exceeded the most conservative CSR standard (for soil and surface water) and/or the Protocol 4 values (for soil).

2.7.5 COPC Screening Results

A summary of soil, groundwater, surface water and plant tissue COPCs are summarized in Table 2-8 below.

Tables 1 through 14 provided after the text show the details of the parameters screened, including the number of samples in the dataset, the number of detectable concentrations, the maximum concentration of each contaminant, the selected screening benchmark, and the rationale for retaining/dismissing contaminants as COPCs.

Table 2-8: COPCs Summary

Media	ROC	COPC
Human Health		
Surficial soil (0-0.3 m)	On-site; Trespassers, maintenance workers	None
Full depth soil (0-12.8 m)	On-site; Trespassers, maintenance workers	None- dataset not applicable to human receptors
Groundwater	Off-site residents/farmers	Arsenic, barium, iron, lithium, manganese, tungsten, uranium, zinc, fluoride, sulfate
Surface Water	On-site; Trespassers, maintenance workers. Off-site residents/farmers.	Lead
Sediment	On-site; Trespassers, maintenance workers	Lead
Plant Tissue	Trespassers	Arsenic, cadmium, lead, zinc
Ecological Health		
Surficial soil (0-0.3 m)	wildlife, plants, invertebrates	None
Full depth soil (0-12.8 m)	Plants	Arsenic, cadmium, lead, zinc
	Burrowing Wildlife (Pocket Gopher)	Arsenic, cadmium, lead, zinc
Groundwater	Plants	Iron, manganese, molybdenum, uranium, zinc, fluoride.
	Aquatic Life	None selected. See surface water results.
Surface Water	Irrigation of Crops (off-site)	Aluminum, chromium (trivalent)
	Wildlife and Livestock (off-site)	Aluminum
	Aquatic Life - Invertebrates, plants and amphibians	Aluminum, beryllium, cadmium, chromium, copper, iron, lead, zinc, and nitrite
	Aquatic Life – Fish	Aluminum, cadmium, chromium, copper and zinc
Sediment	Aquatic Life	Arsenic, cadmium, lead, zinc

Plant Tissue	Terrestrial Plants	Arsenic, cadmium, lead, zinc

2.7.5.1 *Bioaccumulative Potential Assessment Results*

Comparison of the COPCs summarized in Table 2-8 to chemicals listed in Table 1 of the CSAP guidance document (CSAP, 2015) is presented below in Table 2-8. This comparison indicated that arsenic, cadmium, lead and zinc are potentially bioaccumulative COPCs for the terrestrial ecosystem and that arsenic, cadmium, chromium, copper, lead and zinc are potentially bioaccumulative COPCs for the aquatic ecosystem.

The Plant Metals Uptake Study (SLR 2018) indicated that arsenic, cadmium, lead, and zinc were found in higher concentrations in plant tissue samples obtained from the site than from reference locations. Iron was found at similar concentrations on-site compared to the reference locations. Based on these findings, arsenic, cadmium, lead and zinc were retained as bioaccumulative COPC for the terrestrial ecosystem.

Potential bioaccumualtive COPCs for the aquatic ecosystem were further evaluated based on their chemical specific properties and criteria defined by TCEQ, as presented below:

- BCF > 1000 (aquatic life species, water-to-organisms)
- BCF > 1 (aquatic life species, sediment-to-organisms)
- Log Kow >3.8 and < 8.0
- Molecular Weights < 700

As summarized in Table 2-9, cadmium, copper, chromium, lead and zinc were identified as potentially bioaccumulative COPCs in surface water.

Table 2-9: Bioaccumulation Potential of COPCs

COPC	Media	ROCs	Table 1 of CSAP Guidance Document				Bioaccumulation Potential
			BC TRGs	Hoffman, 2007	TCEQ, 2014	Corl, 2001	
Arsenic	Full depth soil Sediment	Plants Aquatic life		x		x	**Considered bioaccumulative**
Beryllium	Surface water	Aquatic life	-	-	-	-	Not considered bioaccumulative
Cadmium	Full depth soil Surface water Sediment	Plants Aquatic life		x	x	x	**Considered bioaccumulative**
Chromium (total)	Surface water	Aquatic life		x	x	x	**Considered bioaccumulative**
Copper	Surface water	Aquatic life		x	x	x	**Considered bioaccumulative**
Iron	Groundwater Surface water	Plants Aquatic life	-	-	-	-	Not listed as bioaccumulative*
Lead	Full depth soil Surface water Sediment	Plants Aquatic life		x	x	x	**Considered bioaccumulative**
Fluoride	Groundwater	plants	-	-	-	-	Not considered bioaccumulative
Manganese	Groundwater	plants	-	-	-	-	Not considered bioaccumulative
Molybdenum	Groundwater	plants	-	-	-	-	Not considered bioaccumulative
Nitrite	Surface water	Aquatic life	-	-	-	-	Not considered bioaccumulative
Zinc	Full depth soil; Groundwater Surface water Sediment	Plants Aquatic life		x	x	x	**Considered bioaccumulative**

"-" not included in the list provided in CSAP Guidance Document (SLR, 2015)

*Not considered in the bioaccumulation studies reviewed

2.8 Site Conceptual Exposure Model

Risk assessments commonly perform a qualitative evaluation of the potential for receptors to be exposed to site COPCs. This includes consideration of the following:

2.8.1 Evaluation of Exposure Pathways

The movement of a COPC from an external environmental medium into a receptor of concern is described as an exposure pathway. An exposure pathway is typically defined by the following four components:

- A source and mechanism of constituent release to the environment.
- An environmental transport medium (e.g., soil) for the released constituent(s).

- Potential contact (exposure point) between a receptor and the affected environmental medium.
- An exposure route (e.g., ingestion, dermal contact) at the exposure point

Exposure pathways have been evaluated based on professional judgement and have been categorized as follows:

- Exposure pathway is potentially complete, quantitative assessment is recommended;
- Exposure pathway is potentially complete but insignificant (no final COPCs, or infrequent exposure/low dose), quantitative assessment is not recommended; and
- Exposure pathway is incomplete, quantitative assessment is not necessary.

Evaluation of exposure pathways was completed in the CSM in Appendix B. Exposure pathways between receptors and site COPCs are shown on chart-type conceptual site models (Drawing 10). The following sections summarize potentially complete exposure pathways between the investigated media at the site and the identified receptor groups evaluated in the CSM.

2.8.1.1 *Human Exposure Pathways*

<u>Soil</u>

No COPCs for the protection of human health were identified in surficial soil (0-0.3 mbg). The direct contact with soil, incidental ingestion of soil particles and inhalation of soil particulates are thus considered insignificant and will not be assessed further in the HHERA. Based on the anticipated activities at the site (i.e. hiking, non-intrusive work by maintenance workers etc.), human receptors are considered unlikely to be exposed to subsurface soil/ tailings below the 30 cm cap.

<u>Groundwater</u>

No potentially complete human health exposure pathways were identified for on-site groundwater.

Although COPCs were identified for off-site human health in groundwater (arsenic, barium, iron, lithium, manganese, sulphate, tungsten, zinc), a review of groundwater use and hydrogeological conditions in the vicinity of the site (Appendix B) indicated that no complete exposure pathways are present between groundwater COPCs on-site and potable water use to the north and west of the site.

Based on the direction of groundwater flow, exposure to off-Site receptors south of the site is a potentially complete exposure pathway. However, results of groundwater sampling completed in 2018 indicated that all parameters met the BC CSR drinking water standards on the downgradient property boundary with the exception of lithium, which has been historically elevated at this location. As well, historical sampling has also been completed at the closest drinking water well locations (the Ross Property) as part of a human health risk assessment (HHRA; SNC 2013) and reclamation monitoring (RDCK 2019b). The results of the HHRA and reclamation monitoring indicated that COPC concentrations in well water were below CSR drinking water standards, with the exception of iron in 2015, which failed aesthetic criteria. Drinking water wells on the Ross Property have not been sampled since 2015 because the property was noted to be vacant and condemned. Based on the results of the historical sampling, exposure via potable water use is considered an incomplete based on drinking water well results and will not be assessed further in the HHERA.

A potentially complete and significant exposure pathway for potential future groundwater users immediately south of the site may be present for lithium in groundwater. The source of the lithium in groundwater has not been confirmed. RDCK indicated that the lithium concentrations appeared to be stable downgradient, and were likely not related to groundwater quality concerns at the site (SLR 2019b). The concentration of lithium in the downgradient wells indicated that concentrations have historically been higher than groundwater concentrations measured within the Tailings Area and lithium has been below detection limits in all soil samples collected within the tailings area, (RDCK 2019b), supporting this assessment. Future potable water use downgradient was not further assessed in the HHERA. Uncertainty related to future groundwater use is discussed in Section 4.0.

Surface Water

Although lead was identified as a COPC for consumption of surface water on-Site, surface water bodies on-site are noted to be ephemeral in nature and are therefore expected to be dry during the warmest parts of the year when trespassing and recreational activities may occur. In addition, based on the types of human receptors expected to have exposure to the site (i.e. maintenance workers and trespassers), time spent at the site is likely to be limited, as is contact with surface water on-Site. Finally, based on a review ofSRK's predictive model, lead is only expected to exceed the drinking water screening benchmark at one on-site location and is not expected to exceed the screening benchmark at any of the downgradient surface water locations. Therefore, direct contact and consumption of on-site or off-site surface water is considered an insignificant exposure pathway and will not be considered further in the HHERA.

Sediment

Although lead was identified as a COPC in sediment for human health, exposure to sediment for human receptors is assumed to be negligible based on the small area of the site where sediment is present, the percentage of the year sediment is expected to be either water or snow-covered, the steep topography of the downstream drainage channel, and lead was not identified as a COPC in soil over the remaining area of the site. Lead in sediment was not carried forward for quantitative assessment in the HHERA.

Plant Tissue/ Food Items

Since bioaccumulative COPCs were identified in plant tissue on-Site (arsenic, cadmium, lead, zinc), human Trespassers may also be exposed to contaminants through consumption of plant-life. A review of the vegetation planned for the site following closure indicated that no edible plants (i.e. berries etc.) are planned for the site area (Section 2.4.2). Based on the limited exposure for a trespasser and availability of edible plants, significant foraging on-site is not expected to occur, and risks to human health due to consumption of plant-life is expected to be insignificant.

Should unauthorized hunting occur on-site, trespassers could in theory be exposed to COPCs in wildlife tissue. Livestock tissue sampling was completed as part of the Ross Property ERA to assess potential bioaccumulation of contaminants into food items. Based on the results of the Ross Property ERA, contaminants were concluded not to be bioaccumulating in wildlife tissue at concentrations that may pose a risk to human health (Azimuth 2013). The Ross Property ERA assessment is expected to be more conservative than the conditions on site as livestock tend to be confined to feeding within a particular area, continuously exposed to a single contaminant source. In addition, the planned soil cap for the site will restrict incidental ingestion and exposure to site contaminants, reducing overall exposure. Based on the results of the 2013 ERA and expected future conditions, bioaccumulation of contaminants in the human food chain is expected to be insignificant.

All bioaccumulative parameters in surface water met the CSR standards for livestock watering and irrigation of crops with the exception of chromium (trivalent). Although trivalent chromium exceeded the CSR standard, a review of the predictive surface water modelling results indicated that concentrations of chromium (total) exceeded the CSR IW standard at only one location at one previous sampling event (SW2-07; October 30, 2018) and is not expected to exceed the IW or WL standards at any of the future sampling events. Therefore, no bioaccumulative COPCs were retained for off-site surface water use for human health.

2.8.1.2 *Ecological Exposure Pathways*

Potentially complete ecological exposure pathways considered for the site include:

- Ingestion of COPCs in surface water by wildlife;
- Root contact with COPCs in subsurface soil and groundwater by plants;
- Direct contact with soil for burrowing wildlife;
- Uptake of COPCs to plants and subsequent bioaccumulation through the food chain; and
- Direct contact of aquatic receptors with COPCs in sediment and surface water;

<u>Soil</u>

No COPCs were identified for direct contact with surficial soil for soil invertebrates or wildlife. Based on the surficial cap planned for the site, surficial wildlife and soil invertebrates are unlikely to be exposed to subsurface soil and this pathway is considered incomplete. Based on the anticipated burrowing depths of invertebrates noted in Protocol 1 of 15 cm (BC ENV 1998), the majority of invertebrates are not expected to be in contact with subsurface soil/ tailings at the site.

Arsenic, cadmium, lead and zinc were identified as COPCs in soil (full depth) for plants and burrowing wildlife (i.e. pocket gopher). Therefore, root contact and direct contact with COPCs in subsurface soil is a potentially complete exposure pathways for plants and burrowing wildlife.

<u>Groundwater</u>

Root contact with and uptake of COPCs from groundwater was identified as a complete and potentially significant exposure pathway. Based on a review of groundwater depths in the area of the site (Appendix B), root contact with groundwater is expected to be a potentially complete pathway on-site as groundwater is expected to be within 1.5 mbg within the tailings area under future conditions.

Downgradient of the tailings area, root contact with groundwater may be a complete exposure pathway in close proximity to the site (groundwater depths range from less than 1 mbg to 2.61 mbg at MW-05-01, and from 1.16 mbg to 3.62 mbg at MW MW-01-2004 (S)). Considering downgradient monitoring well locations MW99-1(S) and MW-02-2004(S) have groundwater depths ranging from 6 to greater than 12 mbg, this pathway is unlikely to be completed further downgradient of the site.

Surface water

Aluminum, beryllium, cadmium, chromium, copper, iron, lead, zinc and nitrite were retained as aquatic life COPCs in surface water. Direct contact with surface water COPCs is the main exposure pathway for aquatic invertebrates, aquatic plants and fish. Amphibians may also be exposed to surface water COPCs through direct contact (via adsorption through the skin). As such, complete and potentially significant exposure pathways were identified for aquatic invertebrates, aquatic plants fish and amphibians and risks will be characterized in the HHERA.

Wildlife receptors can potentially use surface water as a source of drinking water. Aluminum was identified as a COPC for ingestion of surface water by wildlife. Cadmium, copper, chromium, lead, and zinc were identified as bioaccumualtive COPCs in surface water. Based on the ephemeral nature of the future surface water bodies on-site as we as well as the limited aerial extent of the surface water bodies compared to the site as a whole bioaccumulation of COPCs via ingestion of surface water only is not considered to represent a significant exposure pathway at the Site for wildlife. Ingestion of surface water will only be considered for bioaccumulative COPCs also present in other media at the site. Based on this decision criterion, the ingestion of cadmium, lead and zinc from surface water will be evaluated as part of the food chain model.

Aluminum was identified as a COPC for livestock watering and irrigation of crops for surface water. Chromium (trivalent) was also identified as a COPC for irrigation of crops. Although trivalent chromium and aluminum exceeded the CSR standard, a review of the predictive surface water modelling results indicated that concentrations of chromium (total) and aluminium exceeded the CSR IW and LW standard at only one location at one previous sampling event (SW2-07; October 30, 2018) and are not expected to exceed the IW or WL standards at any of the future sampling events at this location or either of the downgradient locations (Outlet Ditch and Spillway and Seepage). This pathway was considered insignificant and was not further assessed.

Aquatic-dependent wildlife species may also be directly exposed to COPCs in water via dermal contact. This exposure pathway was considered to be complete, but not a source of significant exposure as the integument (e.g., fur and feathers) of mammals and birds acts as a barrier to chemical exchange (BC MELP, non-dated).

Sediment

Arsenic, cadmium, lead and zinc were selected as COPC of potential concern for aquatic life. Complete exposure pathways were identified for benthic invertebrates.

Food chain

For wildlife species, ingestion of contaminated food (e.g. prey) represents the principal exposure pathway for bioaccumulative COPCs. Arsenic, cadmium, lead, zinc were identified as bioaccumulative COPCs in terrestrial environmental media (soil and or plant tissue). Uptake of COPCs to plants and subsequent bioaccumulation through the food chain was identified as a potentially complete exposure pathways for ecological receptors and will be characterized in the HHERA.

Cadmium, copper, chromium, lead and zinc were identified as bioaccumualtive COPCs in surface water and/or sediment. Based on the type of habitats available on site and on the wildlife species most likely to use this habitat, the ingestion of aquatic food (e.g. prey) is not considered to represent a significant exposure pathway for bioaccumulative aquatic COPCs. The completion of an aquatic food chain model is not warranted as part of the HHERA.

2.9 Problem Formulation Summary

Table 2-10: Problem Formulation Summary

Media	Relevant Receptor Exposure Route	COPCs	Pathways Requiring Quantification or Additional Assessment
Human Health (on-Site)			
Surficial soil (0-0.3 m)	Direct contact with on-site soil (dermal and incidental Ingestion)	None	None
Full depth soil (0-12.8 m)	None	None	None
Groundwater (all)	Off-site potable water use	Arsenic, barium, iron, lithium, tungsten, zinc, sulfate	None (pathway incomplete or insignificant)
Surface Water	Direct contact, on-site potable water use. Off-site potable use.	Lead	None (pathway insignificant)
Sediment	Direct contact (dermal and incidental Ingestion)	Lead	None (pathway insignificant)
Plant Tissue/ Food Items	Ingestion (hunting, off-site agricultural land use)	Arsenic, cadmium, lead, iron, zinc	None (pathway incomplete (on-site) or insignificant (off-site)
Ecological Health			
Surficial soil (0-0.3 m)	Direct contact (wildlife, plants, invertebrates)	None	None
Full depth soil (0-12.8 m)	Root Contact (Plants)	Arsenic, cadmium, lead, zinc	**YES**
	Burrowing Wildlife	Arsenic, cadmium, lead, zinc	**YES**
	Bioaccumulation in the food chain	Arsenic, cadmium, lead, zinc	**YES**
Groundwater (on and off-site)	Root Contact (Plants)	Iron, manganese, molybdenum, uranium, zinc, fluoride.	**YES**
	Bioaccumulation in the food chain (on and off-Site)	zinc	**YES**
Surface Water	Ingestion by Wildlife	Aluminum	None, (pathway insignificant)
	Aquatic plants	Aluminum, beryllium, cadmium, chromium, copper, iron, lead, zinc and nitrite	**YES**
	Benthic Invertebrates		**YES**
	Amphibians		**YES**
	Fish	Aluminum, cadmium, chromium, copper and zinc	**YES**
	Off-Site irrigation of crops	Aluminum, Chromium (trivalent)	None, (pathway insignificant)
	Off-Site Livestock Watering	Aluminum	None, (pathway insignificant)
Sediment	Benthic invertebrates	Arsenic, cadmium, lead, zinc	**YES**
Plant tissue/ foods items	Bioaccumulation in the terrestrial food chain	Arsenic, cadmium, lead, iron, zinc	**YES**
	Bioaccumulation in the aquatic food chain	Cadmium, copper, chromium, lead and zinc	None, (exposure pathway is potentially complete but insignificant)

3.0 QUANTITATIVE ECOLOGICAL RISK ASSESSMENT

Information regarding the site setting presented in the Problem Formulation Section (2.0) and Appendix B have been relied on for the completion of quantitative ecological risk assessment (ERA).

3.1 Ecological Protection Goals

A protection goal is a narrative statement that defines the desirable level of protection for a receptor or receptor group (Environment Canada, 2012). Given the site is consider reverted wildlands, protection goals for the site include long term health (survival, growth, reproduction) of the wildlife using the site, and the communities of plants and aquatic life using the site.

3.2 Ecological Assessment Endpoints and Measurement Endpoints

Assessment and measurement endpoints are used in ecological risk assessment to define what is being protected and how the effects are measured. An assessment endpoint is defined as "*the attribute of the receptors of concern that are to be protected (e.g. abundance or viability of a mammal population)*" (Azimuth, 2012). Ecological assessment endpoints for this HHERA include:

- Survival and growth of the TSF plant community;
- Survival, growth, reproduction of wildlife (individuals, local population) using the TSF; and
- Survival, growth, reproduction of fish sub-population and benthic invertebrate community in the reach of stream from discharge to road, and downgradient.

A measurement endpoint is defined as the tool used to measure changes in assessment endpoints (Azimuth, 2012). The measurement endpoint for the ecological assessment will include one line of evidence; the calculation of hazard quotients (HQs).

3.3 Exposure Assessment

The Exposure Assessment quantifies the exposure for the complete exposure pathway-receptor combinations identified in the Problem Formulation. The exposure assessment uses concentration estimates of COPCs in relevant media (e.g., soil, groundwater, surface water and sediment) and the concentrations of COPCs in food items to estimate an average daily dose (ADD) to wildlife receptors based on a food chain model.

As presented in Section 2.0, the following exposure pathway – receptor combinations were identified for further quantitative evaluation:

- Ingestion of COPCs in surface water by wildlife and livestock (off-site);
- Root contact with COPCs in subsurface soil and groundwater by plants;
- Off-site irrigation watering;
- Uptake of COPCs to plants and subsequent bioaccumulation through the food chain;
- Incidental ingestion of subsurface soil/tailings for burrowing mammals and
- Direct contact of aquatic receptors with COPCs in sediment and surface water;

3.3.1 Exposure Measures and Exposure Point Concentrations

3.3.1.1 *Terrestrial Plant Exposure*

Terrestrial plants are exposed to COPCs through root contact with soils and groundwater. The measures of exposure for terrestrial plants considered in this ERA include concentrations of COPCs in soil (Full depth) and overburden groundwater.

The 95% upper confidence limit of the mean (UCLM) concentration of full depth soil (i.e. the cap and tailings material) was used to assess risks to plants due to root contact. The 95% UCLM was selected since plant roots will be exposed to both surficial cap soil (where no COPCs were identified) as well as subsurface tailings material. The selected EPCs are presented below.

Table 3-1: Exposure Point Concentrations – Terrestrial Plants (on-site)

COPC	Soil (Full Depth) EPC (mg/kg)	Statistical Basis	Overburden Groundwater EPC (µg/L)	Statistical Basis
Arsenic	56	95% UCLM	-	-
Cadmium	22	95% UCLM	-	-
Lead	1,083	95% UCLM	-	-
Manganese	-	-	5,430	Maximum
Molybdenum	-	-	20.2	Maximum
Iron	-	-	31,700	Maximum
Fluoride	-	-	1.25	Maximum
Uranium			14	Maximum
Zinc	2,140	95% UCLM	14,300	Maximum

3.3.1.2 *Wildlife Exposure*

3.3.1.2.1 Bioaccumulation

A food chain model was used to calculate average daily dose (ADD) of COPCs for each of the surrogate ecological species selected. The food chain model considers the primary routes of exposure to wildlife receptors as the direct ingestion of prey/forage items, ingestion of water and the incidental ingestion of soil (for burrowing mammals) in calculating the ADD.

Receptor Characteristics

Receptor characteristics (e.g., food and soil ingestion rates, body weights) of the selected surrogate species were generally obtained from the habitat assessment completed for the Ross Property by Gebauer & Associates Ltd in support of the 2013 Ross Property ESA (Azimuth 2013) or standardized characteristics provided in the FCSAP ERA Guidance (EC, 2012). The selected receptor characteristics are presented in Appendix C. When no information was available on the percentage of soil incidentally ingested by a given receptor, soil ingestion rates were assumed to be 2%, as recommended by BC ENV and EC (2012).

Although Environment Canada provided some characteristics for the Western Toad, food ingestion rates (and TRVs) were not available. Consequently, risks associated with food chain uptake could not be assessed for this receptor.

Exposure Point Concentrations – Food Chain Modelling

Site measured concentrations of COPCs in soil, groundwater, surface water (future concentrations) and vegetation (where available) were used directly in the estimate of exposures. Tissue COPC concentrations for terrestrial invertebrates were estimated using concentrations in 0-30 cm soil and COPC-specific uptake factors where measured tissue concentrations were not available. Uptake factors describe the relationships between chemical concentrations in these environmental media and concentrations in biota.

Tissue concentrations of COPCs in other prey items (e.g. birds and small mammals) were calculated based on the Total Daily Dose and a chemical-receptor specific transfer factor. Details of this calculation, along with additional methods for the food chain modelling, are presented in Appendix C.

The 95% UCLM of measured concentrations was used as the exposure point concentration (EPCs) surface water, groundwater and incidental ingestion of soil by wildlife based on the expected mobility of the receptors. The maximum concentration was retained for plant tissue due to the limited available dataset for the site area. EPCs in soil, groundwater, surface water and biota used in the calculation of COPC daily intakes for each of the terrestrial wildlife receptors are presented below.

Table 3-2: Measured Exposure Point Concentrations – Food Chain Modelling

COPC	Surficial Soil (mg/kg)	Surface Water (µg/L)	Plant Tissue (mg/kg ww)
	95 % UCLM	95% UCLM	Maximum
Arsenic	10.85	2.34	0.1
Cadmium	0.391	0.395	8.02
Lead	16.76	4.098	0.685
Zinc	97.42	104.9	334

Shade	EPC for a COPC identified in given media
Unshaded	EPC for a COPC needed for food chain modelling to account for background conditions
-	No COPCs and/or complete exposure pathways identified for given media

Measured prey tissue concentrations were not available and were therefore modelled using surficial soil, surface water and plant tissue concentrations and bioaccumulation/bioconcentration or biotransfer factors. Modelled concentrations are provided in Appendix C.

Burrowing Wildlife

Burrowing wildlife such as the pocket gopher may be exposed to subsurface soil via ingestion of soil. 95% UCLMs were selected for EPCs for this receptor group based on the mobility of receptors and variability in burrow depths (i.e. not all burrows will be greater than 30 cm in depth). Ingestion of subsurface soil will be quantified in conjunction with the food chain modelling for this receptor group. EPCs are presented in the table below:

Table 3-3: Exposure Point Concentrations – Burrowing Wildlife (on-site)

COPC	Soil (Full Depth) EPC (mg/kg)	Statistical Basis
Arsenic	56	95% UCLM
Cadmium	22	95% UCLM
Lead	1,083	95% UCLM
Zinc	2,140	95% UCLM

3.3.2 Aquatic Life Exposure

Aquatic receptor groups (benthic invertebrates, fish and amphibian) are exposed to COPCs via direct contact (e.g. transport across the gills or other surface membranes) or ingestion, though measure of exposure for aquatic life is generally not discussed in terms of these specific routes; but rather as concentrations in the exposure media, in this case surface water and sediment. For this reason, EPCs representing the concentrations of individual COPCs at the point of contact with a receptor, are provided in the exposure assessment for aquatic life.

3.3.2.1 *Surface water*

As indicated in Section 3.7.1.3, based on the proposed closure and remediation design it was assumed that the drainage channels over the tailings and downstream channel would provide habitat for aquatic plants, aquatic invertebrates and amphibians. Fish are not expected to be able to access the drainage channels over the tailings and; thus, only the downstream channel was considered potential fish habitat. Based on these assumptions EPCs were calculated for: 1) the drainage channels and downstream channel COPCs and 2) the downstream channel.

Table 3-4: Surface Water EPC (µg/L) for Aquatic Life

Dataset	COPCs	95% UCLM[a]	Statistic
Drainage channels over the tailings and downstream channel*	aluminum	843	95% BCA Bootstrap
	beryllium	nc	only 1 detectable value
	cadmium	0.4	95% BCA Bootstrap
	chromium	1.6	95% KM (BCA) UCL
	copper	4.0	95% BCA Bootstrap
	iron	867	95% BCA Bootstrap
	lead	4.1	95% BCA Bootstrap
	zinc	105	95% BCA Bootstrap
	nitrite (as N)	0.03	95% KM (Percentile Bootstrap) UCL
Downstream channel**	aluminum	106	95% BCA Bootstrap
	cadmium	0.5	95% BCA Bootstrap
	chromium	1.3	95% Student's-t UCL
	copper	3.4	95% BCA Bootstrap
	zinc	128	95% BCA Bootstrap

Notes:
*- Locations: SW01-07; SW02-07; spillway and dam seepage; outlet ditch
**- Locations: spillway and dam seepage; outlet ditch
[a] -95% UCLM are calculated for the above locations and include multiple dates for each location as described in Section 2.7.1.3.

3.3.2.2 *Sediment*

In August 2017, SLR collected eight sediment samples (plus one duplicate sample) from the downstream channel (Drawing 7). Sample S-9 was collected from fine sediment accumulated in the depositional zone created by a silt fence closest to the stilling basin outlet and as thus, is considered to be the sample closest resembling the tailings and may not be representative of sediment in the downstream channel.

Summary statistics for the four sediment COPCs arsenic, cadmium, lead and zinc are presented in Table 3-5. As indicated above, sample S-9, was obtained from fine sediment accumulated in the depositional zone created by a silt fence. S-9 had the highest metals concentrations and a particle size distribution similar to the tailings. Based on these observations, S-9 is considered to be representative of tailings entrained in the downstream channel and retained by the silt fence. As this sample was obtained on top of a silt fence, the 95% UCLM were calculated with and without this sample.

Table 3-5: Summary Statistics for Arsenic, Cadmium, Lead and Zinc (mg/kg)

	Sample Set	Arsenic	Cadmium	Lead	Zinc
Minimum	including S-9	5.8	0.877	201	176
	excluding S-9	5.8	0.877	201	176
Maximum	including S-9	25.7	11.9	427	2280
	excluding S-9	12.4	3.39	145	1120
95% UCLM	including S-9	16.2	6.6	226	1372
	excluding S-9	10.3	2.6	113	794

3.4 Effects Assessment

A detailed review of the toxicity of each of the COPCs to each of the ecological receptor groups was beyond the scope of this ERA. As a simpler conservative approach, the following concentration-based benchmarks that are believed to represent values above which there may be low-level adverse biological effects to sensitive species were used as toxicological reference values.

3.4.1 TRV Selection

Exposure to COPCs in site media and food items has the potential to adversely affect ecological receptors. In order to assess the potential effects and characterize the potential risks to these receptors, toxicological reference values (TRVs) were compiled for receptor groups. A TRV is a receptor-specific concentration of a chemical, above which adverse effects have the potential to occur, and below which there is a low likelihood that adverse effects will occur. The selected TRVs are then used to quantify the potential risks.

Generally, TRVs were selected from following relevant guidance (i.e., BC ENV Technical guidance 7; BC ENV 2017). Specifically, US EPA Ecological Soil Screening Level documents were used to select/develop TRVs for terrestrial biota, and the BC WQGs were reviewed for selection of aquatic life TRVs. No observed adverse effect level (NOAEL) and lowest observed adverse effect level (LOAEL) values were considered in the absence of effects level based values (e.g., LC_{50} and EC_{20}). Where COPC and receptor-specific TRVs had been derived as part of the Ross Property ERA- these values were also considered in selection of TRVs.

BC CSR Protocol 1 and more recent CSR standards development have developed standards for abiotic media that reflect no more than an EC20/25 level of effect to aquatic life and terrestrial biota. Risk practitioners have generally assumed these represent low level effects to 20% of a community or population of individuals, or conversely a 20% inhibition in individuals (IC20) of a population level affecting biological attribute (e.g. reproduction and growth). SLR has incorporated this general low level of effects specified by ENV for risk assessment into the selection of TRVs, where applicable. The following sections present the selected TRVs for each of the ecological receptor groups included in the assessment.

3.4.1.1 *TRVs for Plants*

For terrestrial plants, the USEPA soil concentration based Eco SSLs were preferentially selected as soil TRVs following BC ENV guidance. Where the Eco SSL was lower than the BC CSR plant and soil invertebrate standard, the BC CSR value was retained as the TRV.

The BC WQGs were reviewed for the selection of TRVs for root contact with groundwater, where available. TRV selection is presented in Table F-1 in Appendix F.

3.4.1.2 *TRVs for Wildlife*

For wildlife, TRV selection included a review of ingestion dose based ecotoxicity values from the following sources:

- Toxicological reference value selection completed by Azimuth, 2013; and
- US EPA Eco SSL documents.

Most TRVs developed by the US EPA are based on the geometric mean of the NOAELs for growth and reproduction. Developing TRVs based on NOAEL is a very conservative approach when assessing the risk for birds and mammals at the population levels. TRVs which are based on NOAEL values are more consistent with policy goals of protecting at-risk species at the individual level, and even then don't necessarily reflect a dose associated with adverse effects given they are doses for no effects. LOAELs while less conservative provide a more realistic evaluation of the potential for adverse ecological effects to wildlife populations from exposure to COPCs. In many cases LOAELs are also based on a low level of effect.

The US EPA Eco-SSLs list numerous substance-specific NOAELs and LOAELs separately for birds and mammals. The listed values result from an extensive literature review by the US EPA and include only data from studies which scored a total of 66 or more when evaluated against ten attributes (US EPA, 2003a).

TRVs for wildlife used in this ERA were derived using toxicological studies deemed acceptable by the US EPA when deriving the Eco-SSLs. Average LOAEL-based TRVs were calculated as the geometric mean of all of the LOAEL endpoints for growth and reproduction provided in the Eco-SSL studies. This approach recommended by the US EPA (US EPA 2003a), utilizes all of the available data, rather than simply selecting one study for derivation of the TRV, and assumes that any differences in the data are due to study design, variability in measurement, *etc*. rather than on differences in how the animal is reacting to the chemical. NOAEL based TRVs were not necessary as no listed species requiring assessment were identified on the site.

TRV selection is presented in Table F-1 in Appendix F. TRVs for each ROC are presented in Table C-4 in Appendix C.

3.4.1.3 *TRVs for Aquatic Life*

Surface Water

The selection of TRVs for aquatic life included a review of direct contact ecotoxicity values from the following sources:

- Technical supporting documents published by BC MOE as part of the BC AWQG, and WWQG;
- Technical supporting documents published by CCME as part of the Canadian Environmental Quality Guidelines for the protection of aquatic life;
- Technical supporting documents published by the USEPA to support the Ambient Water Quality Guidelines;
- Technical supporting document published by the Ontario Ministry of Energy and Environment as part of the provincial sediment quality standards;
- Publications of peer reviewed toxicology literature, accessed from Web of Science citation indexing service; and
- Preference was given to chronic toxicity data for reproduction, growth and survival endpoints, when selecting TRVs. EC20 values were considered appropriate TRVs where available, which is in keeping with the BC CSR Protocol 1 (BC ENV 1998) protection goal for aquatic organisms. ENV's risk-based approach to managing sites is not to protect each individual from a toxic effect, but rather to protect enough individuals so that a viable population and community of organisms can be maintained.

The proposed TRVs are outlined in Table 3-6 and described in Appendix F.

Table 3-6: Surface Water TRVs for Aquatic Life (µg/L)

COPC	Receptor Groups			
	Aquatic Plant	Aquatic Invertebrates	Fish	Amphibians
Aluminum	500	320	500	320
Beryllium	5.3	5.3	-	5.3
Cadmium	23.3	Long term average BC WQG	0.76	209
Chromium	10	10	10	10
Copper	Long term average BC WQG			
Iron	1740	1740	-	1740
Lead	Long term average BC WQG			
Zinc	1113	41.59	90	107.7
Nitrite	Long term average BC WQG		-	Long term average BC WQG

"-" Not a COPC for fish

<u>Sediment</u>

The BC CSR SedFS were used to identify the COPCs for inclusion in the HHERA. The BC CSR sediment standards for freshwater for typical use (SedTS) were adopted as TRVs to assess risks to aquatic life, including amphibians associated with exposure to sediment COPCs. This approach was adopted because the downstream channel is ephemeral and is considered to provide limited habitat to sediment-dwelling organisms. The SedTS represent concentrations at which there is a 50% probability of observing roughly a 20% or more reduction in survival.

Table 3-7: Sediment TRV for Aquatic Life (mg/kg)

COPC	TRV
Arsenic	20
Cadmium	4.2
Lead	110
Zinc	380

3.5 Risk Characterization

Risks to ecological receptors was quantified using a single line of evidence, namely the calculation of hazard quotients using the equation below. Hazard quotients represent the ratio of the exposure concentration to the toxicological reference value, or conversely the magnitude by which exposure exceeds the TRV.

Hazard Quotient (Plants, Aquatic Life) = Exposure Concentration / TRV

Hazard Quotient (Wildlife) = ADD or EPC / TRV

Where:

HQ = Hazard Quotient (unitless)
EPC = Exposure Point Concentration (e.g., mg/kg or mg/L)
ADD = Average Daily Dose (mg/kg/day exposure)
TRV = Toxicological Reference Value (e.g., mg/kg or mg/kg/day)

Hazard quotients that exceed a value of one are often viewed as representing the potential for adverse effects. The 2008 Detailed Ecological Risk Assessment (DERA) BC technical guidance document (SAB 2008 as referenced in Azimuth 2016) provides guidance for the use of narrative descriptors of risk, specifically; negligible, low, moderate and high risk descriptors. These descriptors are defined as follows (Azimuth 2016):

Negligible risks: Implies that adverse effects, based on the totality of available data, are very unlikely to be present, and that the risk assessor has high confidence that adverse effects will not be present in the future.

Low risk: Adverse effects are unlikely to be present, although some data may indicate limited adverse effects, or the uncertainty is such that one cannot definitively exclude potential adverse effects in the future. Risk management or remediation is not necessary.

Moderate risks: Implies that some degree of adverse effects are likely, based on the totality of data available.

High risks: Implies that adverse effects are likely (and of relatively high magnitude) based on the totality of data.

For this risk assessment, hazard quotients have been qualitatively categorized as representing different degrees of risk. While some risk assessment guidance indicates magnitude of risk should not be inferred based on hazard quotient values, higher hazard quotients should represent a greater potential for biological effects, and greater magnitude of effects, than lower hazard quotients. Risk characterization is shown in the table below.

Table 3-8: Qualitative Descriptors of Risk

	Negligible Risk	Low to Moderate Risk	High Risk
HQ	<1	1-10	>10

This qualitative categorization of risk is judgement based, and reflects the fact that there is conservativism with the approach used to quantify risks for ROCs (i.e. TRVs chosen, assumptions included in EPC selection, food chain modelling assumptions and equations) and whether or not these values truly represent threshold concentrations for low to moderate levels of effects to the majority of species.

With respect to the TRVs used, negligible risk has been used to describe a scenario when the HQ is less than 1 and potential for adverse effects are considered unlikely. Low risk represents circumstances in which some low level of adverse effects (likely more of the sublethal type) to more sensitive species may be possible. Moderate risk represents the expectation that some adverse effects are anticipated, potentially of higher magnitude and to more than just sensitive species. High risk represents a scenario with an even greater probability of adverse effects, to more species as well as more severe effects, potentially including lethality.

Note that these qualitative descriptors of risk simply apply to the HQ value, and the spatial scope of that HQ. For example, a site as a whole may have a negligible or low risk to the community of plants and invertebrates that inhabit the property as a whole, while at the same time small groups of these biota inhabiting contaminant hotspots could be at moderate or high risk for contaminant induced adverse effects. Where risks are identified above 1, other lines or evidence (i.e. biological observations, historical information etc.) were also used where available to help interpret qualitative risk levels. Uncertainty related to this approach is discussed in Section 5.2.4.

3.5.1 Terrestrial Plants

Exposure of plants to arsenic, cadmium lead and zinc in the subsurface tailings material was assessed using a conservative quantitative risk evaluation (i.e. calculation of hazard quotients) and through site observations and a review of historical planting information for the site. Results of both assessments are provided below.

Hazard Quotients

Arsenic, cadmium, lead and zinc were identified as final COPCs for plant root contact with soil. Manganese, molybdenum, fluoride, lead and zinc were identified as final COPCs for plant root contact with groundwater. Site wide hazard quotients for plants for both soil and groundwater are shown in the table below along with a qualitative categorization of associated risk.

Table 3-9: Hazard Quotients and Associated Risk for Plants

COPC	EPC	TRV	HQ	Associated Risk	Number of Locations with HQ>1
Soil (µg/g)					
Arsenic	56	25	*2.2*	Low	12
Cadmium	22	32	0.7	Negligible	8
Lead	1,083	550	*2.0*	Low	12
Zinc	2,140	450	**4.8**	Moderate	12
Groundwater (µg/L)					
Manganese	5,430	1,000	**5.4**	Moderate	7
Molybdenum	20.2	30	0.7	Negligible	1
Fluoride	1250	1,000	*1.3*	Low	1
Uranium	14	10	*1.4*	Low	1
Zinc	14,300	5,000	*2.9*	Moderate	2

TRV - toxicity reference value
HQ - Hazard quotient, HQ=EPC/TRV

Risk estimates above 1 were identified for arsenic, lead and zinc in soil and manganese, fluoride, uranium and zinc in groundwater. Molybdenum, fluoride and uranium were identified above applicable standards at only 1 of 18 of monitoring well locations (less than 6% of sample locations) and zinc was measured above applicable standards and guidelines at only 2 monitoring well locations (11% of sample locations). Based on the distribution of these parameters across the site, the site wide risk, i.e. risk to the entire community of plants at the site as a whole is likely to be negligible.

Site Observations

Based on the review of historical information related to vegetation at the site (Section 2.6.2), historical planting of grasses and fescue occurred at the site prior to 1982 as documented in the Stage 1 Submission for reactivation of the HB Mill report (IEC Ltd., 1982). Based on the report, planting was successful within the tailings area of the site, as a reported 88% of the tailings area was vegetated with grasses, legumes, mosses, and litter, with only 12% bare of any plant cover (IEC Ltd., 1982). Based on the vegetation mix documented in the report (i.e. grasses, alfalfa etc.) species were similar to those planned for post closure activities. Therefore, although low to moderate risks were identified for plants in soil, documented successful historical planting of vegetation in worst-case conditions (i.e. directly on the tailings in the absence of a cap) indicate that the planned vegetation species are tolerant to the conditions at the site, and risks to plant-life are expected to be low.

Risks to plant-life was assessed based on vegetation planned as part of closure activities for the site. Uncertainty related to other plants that may colonize the site in the future are discussed in Section 4.0.

Summary of Potential Risks to Plant Life

Based on the results of the quantitative evaluation combined with site observations, risk to the entire community of plants at the site is likely to be negligible.

3.5.2 Wildlife

Hazard Quotients

To evaluate potential exposure to arsenic, cadmium, lead and zinc through the food chain for wildlife ADD (modelled daily ingestion of the COPCs) were compared to TRVs specific to birds or mammals. A summary of the calculated HQs is presented in the table below.

Table 3-10: Hazard Quotient Summary for Wildlife – Bioaccumulation in the Food Chain

Receptor	HQ			
	Arsenic	Cadmium	Lead	Zinc
Song Sparrow	6.0E-02	**1.4E+00**	2.3E-02	**2.1E+00**
American Robin	9.4E-02	9.9E-01	2.7E-02	**1.7E+00**
Barn Swallow	1.4E-01	2.1E-01	3.3E-02	6.9E-01
American Kestrel	1.0E-01	1.5E-01	2.5E-02	5.5E-01
Vagrant Shrew	7.9E-02	1.4E-01	5.6E-03	2.6E-01
Northern Pocket Gopher	3.0E-02	4.8E-01	2.7E-03	4.7E-01
White Tailed Deer	2.5E-02	1.5E-01	8.5E-04	1.4E-01
Deer Mouse	4.8E-02	1.9E-01	3.1E-03	3.7E-01
Gartersnake	1.7E-02	1.1E-02	3.0E-03	2.8E-02

As noted above, the risks to wildlife associated with soil to plant bioaccumulation, and ingestion of site food items and soil are expected to be negligible for all ROCs for arsenic and lead (i.e. HQ<1). Risks are also expected to be negligible for cadmium and zinc for all ROCs with the exception of the song sparrow (HQ of 1.4 and 2.1, respectively) and american robin (zinc, HQ = 1.6), where the risk estimates were marginally above the target risk level (HQ = 1).

Due to the size of the available dataset, risk estimates for wildlife were calculated based on maximum plant tissue concentrations collected from the site. This may result in an overestimate of risks to plant-consuming ROCs such as the song sparrow and American robin. Based on the qualitative risk levels defined in Section 3.3, risks to song birds such as the song sparrow and american robin are expected to be low, however uncertainty with risks to these receptors are expected to be high due to the limited dataset, and limited on-site receptor information (Section 4.0).

Burrowing Mammals

To evaluate potential exposure to arsenic, cadmium, iron, lead and zinc for burrowing mammals such as the pocket gopher who may ingest COPCs in deeper soil/tailings while burrowing, the food chain model was run using soil EPCs for burrowing wildlife (3.3.1.2.1). Resulting HQs were compared to TRVs specific to mammals. A summary of the calculated HQs is presented in the table below.

Table 3-11: Hazard Quotient Summary for Burrowing Wildlife

Receptor	HQ			
	Arsenic	Cadmium	Lead	Zinc
Northern Pocket Gopher	4.17E-02	4.72E-01	1.10E-02	4.76E-01

As noted above, the risks for burrowing wildlife due to incidental ingestion of soil are expected to be negligible for arsenic, cadmium, lead and zinc (i.e. HQ<1).

3.5.3 Aquatic Life

Aquatic life HQs were calculated for the COPCs in surface water and in sediment. The HQs for surface water are provided in Table 3-12 and the HQs for sediment are provided in Table 3-13.

3.5.3.1 *Surface Water*

Hazard Quotients

The results of the HQ step of risk characterization indicated that potential risks to most receptor groups were negligible or low (Table 3-12). A summary of the HQ evaluation identified:

- Potential risks to aquatic plants were negligible for beryllium, cadmium, chromium, iron, lead and zinc and low for aluminum, copper and nitrite.
- Potential risks to aquatic invertebrates were negligible for beryllium, chromium, iron and lead low for aluminum, cadmium, copper, zinc and nitrite.
- Potential risks to fish were negligible for aluminum, cadmium, and chromium and low for copper and zinc.
- Potential risks to amphibians were negligible for beryllium, cadmium, chromium, iron, lead and zinc and low for aluminum, copper and nitrite.

Table 3-12: Surface Water Hazard Quotients for Aquatic Life

COPCs	Aquatic Plant			Aquatic Invertebrates			Fish			Amphibians		
	EPC	TRV	HQ	EPC	TRV	HQ	EPC	TRV	HQ	EPC	TRV	HQ
aluminum	843	500	**1.7**	843	320	**1.7**	92.9	500	0.2	843	320	**2.6**
beryllium	0.23	5.3	0.04	0.23	5.3	0.04	-	-	-	0.23	5.3	0.04
cadmium	0.4	23.3	0.02	0.4	0.19	**2.1**	0.44	0.76	0.6	0.4	209	0.002
chromium	1.6	10	0.2	1.6	10	0.2	1.3	10	0.1	1.6	10	0.2
copper	4.0	2.6	**1.5**	4.0	2.6	**1.5**	3.4	3.5	**1.0**	4.0	2.6	**1.5**
iron	867	1740	0.5	867	1740	0.5	-	-	-	867	1740	0.5
lead	4.1	6.0	0.7	4.1	6.0	0.7	-	-	-	4.1	6.0	0.7
zinc	105	1113	0.1	105	41.59	**2.5**	129	90	**1.4**	105	107.7	0.9
nitrite (as N)	0.03	0.02	**1.5**	0.03	0.02	**1.5**	-	-	-	0.03	0.02	**1.5**

- The low risk characterization obtained for aluminum, cadmium, copper, zinc and nitrite based on HQ >1 but less than 3 was further supported by the following:
- Aluminum concentrations exceeding the TRV are limited to location SW02-07 and predicted concentrations for the downstream channel are less than the TRV.
- The BC long-term WQG conservatively calculated with the minimum hardness value of 66 mg/L was adopted as the TRV for aquatic invertebrate for total cadmium. When the BC long-term WQG is used to calculate a TRV for each surface water sample based on the sample-specific hardness, HQs greater than 1 (maximum 1.8) are only obtained for May, April and June.
- The BC long-term WQG conservatively calculated with the minimum hardness value of 66 mg/L was adopted as the TRV for aquatic plants, aquatic invertebrates and amphibians for copper. Similarly, to cadmium, the BC long-term WQG was used to calculate a TRV for each surface water sample based on the sample-specific hardness. Only two out of 34 samples had resulting HQs above 1.
- Zinc concentrations in the downstream channel were predicted for each month. The risk to aquatic invertebrates is driven by the predicted concentrations in the downstream channel as most of the samples representing water quality in the drainage channels would be less than the TRV. A review of the data also indicates that concentrations of zinc would be less than the TRV in the spring when fish can migrate into the downstream channel.
- The BC long-term WQG conservatively calculated with the minimum chloride value of 0.8 mg/L was selected as the TRV for nitrite. The BC long-term WQG was used to calculate a TRV for each surface water sample based on the sample-specific chloride concentration. Only one out of nine samples had resulting HQs greater than 1.
- HQs for aluminum, cadmium, copper and zinc are based on total concentrations which overestimate the bioavailable metals.

- The downstream channel consists of a steep channel with fast flowing water during high flow and is dry generally during low flow. Fish are unlikely to use the channel during critical period of their life cycle. Similarly, aquatic plants and aquatic invertebrates are unlikely to be established in significant numbers (e.g. die-off during dry periods).

3.5.3.2 *Sediment*

Arsenic, cadmium, lead and zinc were identified as final COPCs in surface water for aquatic life including amphibians. Site wide HQs are shown in Table 3-13. As indicated in Section 4.1.2.2, HQs were calculated based on all samples collected in the downstream channel and without sample S9. Sample S9 was collected on top of a silt fence at the bottom of the outlet channel and may not represent the typical exposure in the channel.

Table 3-13: Sediment Hazard Quotients for Aquatic Life

COPC	EPC	TRV	HQ	Associated Risk	Number of Locations with HQ>1
Including S9 (n=9)					
Arsenic	16.2	20	0.8	Negligible	1
Cadmium	6.6	4.2	**1.6**	Low	1
Lead	226	110	**2.1**	Low	3
Zinc	1372	380	**3.6**	Moderate	6
Excluding S9 (n=8)					
Arsenic	10.3	20	0.5	Negligible	0
Cadmium	2.6	4.2	0.6	Negligible	0
Lead	113	110	**1.0**	Low	2
Zinc	794	380	**2.1**	Low	5

As shown in Table 3-13, risks to aquatic life are driven by sample S9. Sample S9 was collected on top of a silt fence at the bottom of the outlet channel and may not represent the typical exposure in the channel. Based on this observation risk to aquatic life exposed arsenic, cadmium and lead in sediment over the entire length of the downstream channel, downstream of the current silt fence are expected to be negligible to low.

Risks to aquatic life exposed to zinc are expected to be low to moderate. Zinc concentrations exceed the TRV at six out of the eight sediment sampling locations. The magnitude of exceedance was low at four of the locations (S1, S3, S4 and S10) with concentrations less than two times the TRV. Location S9 and S6 are associated with a higher magnitude of exceedance (about three times the TRV at S6 and six times the TRV at S9).

4.0 UNCERTAINTY

General uncertainties inherent in this HHERA are described below.

4.1 Problem Formulation Uncertainties

4.1.1 Site Characterization Uncertainties

Risk assessments are only as accurate as the accuracy of site investigation sampling, analyses, and reporting. We have assumed the site investigation work and the resulting datasets that this HHERA relies on meet provincial requirements, and that investigation uncertainties should therefore be minimal.

Uncertainties related to data collection are summarized below:

- The plant tissue assessment was based on the results of the 2018 Metals Uptake Study (SLR 2018). The Metals Uptake study indicated that based on the limited size of the dataset, additional vegetation sampling may also be worthwhile, to increase samples sizes for more definitive statistics and results interpretations, and to obtain off-site concentrations in willow.
- The surface water assessment was based on the results of predictive modelling completed by SRK. Results of the assessment rely on the approaches and assumptions employed by SRK and uncertainties in that assessment.
- During investigations, areas thought to be free of contamination are often investigated to a lesser extent. Data collected in this manner, rather than through random grid sampling, results in biased datasets for a site as a whole, whereby datasets are more heavily weighted with contaminated samples. This may bias the HHERA in identifying COPCs that in reality are of less concern and could potentially not be retained as COPCs if sampling was more evenly distributed across a site.

4.1.2 COPC Screening Uncertainties

The COPC screening process is designed to be conservative to avoid inadvertently omitting compounds which may adversely affect ecological or human receptors during the screening analysis. The conservative nature of the screening process is predicated on using dataset maximum concentrations.

COPC screening also contains assumptions regarding exposure. The process focusses on media to which there is assumed exposure. For example, in identifying aquatic life COPCs the process uses surface water and sediment data, and consideration is not given to soil quality and soil standards to protect groundwater. Inherent in this decision is the assumption that site surface water is adequately characterized and future concentrations accurately predicted. The process also assumes different receptor types will have exposure to certain depth ranges for soil and groundwater.

COPC screening is also typically based mainly on BC ENV guidelines and CSR standards, as the intent of HHERA is to determine if site contamination, i.e. substances exceeding numeric standards, meets risk-based standards. Such an approach could in theory miss identifying contaminants/COPCs for unregulated substances and could therefore underestimate site risks.

This uncertainty was mitigated through by considering unregulated substances that may be site related as described in the section below.

Chromium in water occurs as trivalent or hexavalent forms as reflected by the available water quality guidelines. Surface water samples collected at SW01-07 and SW02-07 and predicted surface water quality are expressed in terms of total chromium. There is a high level of uncertainty with respect to chromium valency.

4.1.2.1 *Parameters with no Screening Guidelines*

Barium, tungsten, ammonia-N and sulphate were identified as in groundwater but there are no screening benchmarks for root contact with groundwater.

Downgradient samples of all of the above noted parameters were below the most conservative standard or guideline. Based on the limited distribution of these parameters and groundwater downgradient below all applicable standards and guidelines, uncertainty related to these parameters is expected to be low.

In addition, sodium was identified as a parameter in soil due to the absence of relevant regulated parameter analysis (i.e. sodium absorption ratio or "SAR"). The SAR in soil has the potential to impact plant health at the site, therefore risks may be underestimated for terrestrial plants in the absence of this data. Based on the success of historical planting activities at the site (IEC Ltd., 1982) in worst-case conditions (i.e. directly on the tailings in the absence of a cap) risks to plant-life are expected to be low.

Lithium, mercury and sulphide were identified in surface water. Lithium has no screening benchmark and the maximum concentration (5.1 µg/L) exceeded the reference concentration (< 1 µg/L). A study on the toxicity of lithium to freshwater organisms indicated that toxicity of lithium was mitigated by the presence of sodium. In waters with little sodium (2.8 mg/L), concentrations of lithium inhibiting reproduction by 25% (IC25) were 138 µg/L for fish (fathead minnow) and 320 µg/L invertebrates (*Ceriodaphnia dubia*) (Kszos et al., 2003). Based on this information, lithium is not considered to be a risk driver. The uncertainty associated with not evaluating the potential contribution of lithium as a surface water COPC for aquatic life is considered to be low.

Mercury had one (0.0081 µg/L) out of nine samples exceeding BC ENV WQG (0.00125 µg/L). Mercury was not detected in the remaining eight samples; however, the detection limit (0.005 µg/L) exceeded the BC WQG. The BC WQG provides three mercury values in function of the percentage of methyl mercury. 0.0081 µg/L assumes 8% of methyl mercury. The second lowest WQG value is 0.01 µg/L and assumes 1% of methyl mercury. All mercury concentrations are below the second WQG value. Mercury has not been identified as a COPC associated with the tailings or wit the central landfill in previous report. The uncertainty associated with not evaluating the potential contribution of mercury as a surface water COPC for aquatic life is considered to be low.

Total sulphide was conservatively identified as an uncertain COPC based on the detection limit exceeding the BC Working WQG for unionized sulphide. The uncertainty associated with identifying total sulphide as an uncertain COP are high as this parameters as not been detected in surface water and the predicted concentrations are based on concentrations which are less than the detection limit.

4.1.3 Receptor Selection Uncertainties

Human and ecological receptors selected for evaluation in HHERA are usually general broad groups. Receptor selection seldom includes those individuals that could have abnormally high exposure to site contaminants (e.g., an individual with a Pica disorder – deliberate soil ingestion) or an atypical sensitivity to site contaminants. In theory the HHERA could underestimate risks to some unique individuals and types of ecological receptors.

Ecological receptors were selected based on site observations, review of available online resources and the results of ecological surveys completed at nearby properties. The uncertainty is associated with the selection of ecological ROCs when an ecological and SAR survey has not been completed specifically for the site.

Species were assumed to be exposed via root contact and uptake of contaminants in both surficial (cap) soil and subsurface tailings, however risks may be underestimated should plant life root predominantly within the subsurface horizon where tailings are present. Since deep-rooting plants are not planned for the tailings area of the site, community-level risks for deep rooting plants are likely to be low.

4.1.4 Exposure Pathway Evaluation Uncertainties

Exposure pathway evaluation is performed using professional judgement. Exposure pathways were categorized as being 1) potentially complete and recommended for quantitative risk assessment, 2) potentially complete but insignificant (no final COPCs, or infrequent exposure/low dose), or 3) incomplete, quantitative assessment is not necessary.

The decision regarding whether a pathway is significant is based on several factors, including expected magnitude of exposure (e.g., spatial area of contamination, contaminant concentrations, frequency and duration of exposure, etc.), likelihood of exposure, whether exposure was being considered via other media and the need to address additive exposures, and availability of methods to quantify exposure and risk. Dismissing an exposure pathway as being insignificant or failing to include an exposure pathway in an additive evaluation of risks through multiple exposure pathways could in theory underestimate risks.

Exposure of off-site receptors to groundwater via potable water use was considered an insignificant exposure pathway to the south of the site based on the results of historical groundwater well sampling at the Ross Property as well as the current locations of water wells. There is some uncertainty in exposure to potential future downgradient potable water users based on the concentrations of lithium measured in the downgradient bedrock groundwater in 2018. The source of the lithium in groundwater has not been confirmed. RDCK indicated that the lithium concentrations appeared to be stable downgradient, and were likely not related to groundwater quality concerns at the site (SLR 2019b). The concentration of lithium in the downgradient wells indicated that concentrations have historically been higher than groundwater concentrations measured within the Tailings Area and lithium has been below detection limits in all soil samples collected within the tailings area, (RDCK 2019b), supporting this assessment. However since the source of the lithium has not been confirmed, uncertainty related to lithium in groundwater is considered moderate.

Exposure to human and ecological receptors was assessed under post-closure conditions assuming a 30 cm cap present across the tailings area. This assessment may underestimate risks to human and ecological receptors should subsurface tailings material be exposed via processes such as erosion, bioturbation, sloughing or seismic events.

Invertebrates were assumed to be exposed to the top 30 cm of soil only, and were assumed not to be exposed to the subsurface/tailings below the cap. Risks may be underestimated should invertebrates burrow into the subsurface below the cap. Based on the expected compaction of the tailings compared to the new cap material, the majority of invertebrates are expected to be present in the top 30 cm of soil, therefore uncertainty is expected to be low. In addition, since the borrow-pit material will consistent mainly of silty sand and gravel material (SRK 2018b) organic content is expected to be low therefore invertebrate populations will likely also be low.

4.2 Quantitative Ecological Risk Assessment Uncertainty

4.2.1 Exposure Point Concentrations (EPCs)

The main uncertainties associated with the exposure concentrations for soil, groundwater, surface water, sediment and plant tissue include the following:

- Use of 95% UCLM of COPCs for COPCs with more than ten records.
- Use of maximum highest concentrations of COPCs with less than ten records or for which 95% UCLM concentrations could not be calculated due to a high percentage of samples with results indicated to be less than the analytical detection limit.

The use of 95% UCLM and maximum is conservative and will tend to overestimate exposure as these exposure point concentrations are not likely distributed evenly throughout the exposure unit.

Exposure point concentrations of COPCs in vegetation were based on measured tissue concentrations in vegetation samples collected at four sample locations at the tailings area (SLR 2018a). The maximum measured vegetation concentration was used in the ecological food modelling to represent actual site concentrations. This approach may lead to overestimation of risks if plants are assimilating COPC at higher concentrations in the more contaminated areas.

Exposure point concentrations of COPCs in surface water were based on surface water samples obtained between 2016 and 2018 and on predicted monthly concentrations developed by SRK. As the 95% UCLM included monthly data it is possible for a 95% UCLM for a given COPC to be lower than one or several individual monthly concentration(s). For this reason, for COPCs for which HQ above 1 were obtained, monthly concentrations were also compared to the TRVs (as discussed in Section 3.5.3). In addition, two COPCs, iron and lead were found to have 95% UCLM values less than their TRVs, but monthly concentrations exceeding their TRVs. One out of thirty-three samples exceeded the TRV for iron and two out of thirty-three samples exceeded the TRV for lead. Based on these observations the level of uncertainty associated with the use of 95% UCLM as surface water EPCs is considered to be low.

Exposure point concentrations of COPCs in sediment were based on sediment samples obtained in 2017 by SLR. The 95% UCLM was calculated with eight records, as ten data points were not available. While the sample size for the sediment dataset was small, the 2017 sampling program focused on depositional areas and fine bed material as it aimed to capture the highest concentrations of COPCs. The 95% UCML for sediment was thus considered to be a conservative estimate of the average site-wide sediment concentrations to which the receptors may be exposed.

4.2.2 Food Chain Modelling

To calculate uptake from all exposure pathways, the food chain model incorporated measured results from soil, surface water and plant tissue to predict uptake from these media as well as to model exposure concentrations in unsampled biological tissues (i.e. invertebrates and prey items).

The estimation of COPC concentrations in biological tissue used maximum or the 95% ULCM (where available) concentrations from soil, sediment, and surface water and bioaccumulation factors derived in the laboratory where organisms are exposed to constant concentration for specified period of time. This likely would lead to overestimation in the concentration of biological tissue.

Published biotransfer factors (BTFs) were used to estimate tissue concentrations for wildlife consumed as prey by other wildlife receptors. Biotransfer factors for surrogate species were selected to best represent the ROCs. Through the use of these BTFs it was assumed that COPCs are 100% available for assimilation into tissues. This is assumption is likely to overestimate tissue concentrations which in turn overestimates exposure. Due to the absence of dietary information for amphibians, uncertainty related to this receptor group is high.

Finally, when snow accumulation is present, foraging exposures for wildlife may be limited. The approach and modelling conducted in this risk assessment do not consider exposure adjustments for snow cover (the modelling assumes that soils will be exposed for the entire year). Therefore, risks may be overestimated.

4.2.3 Toxicity Assessment Uncertainties

Risks were characterized, i.e. quantified, for plants, wildlife and aquatic life. US EPA Eco SSLs, BC CSR plant and soil standards and BC CSR SedTC were used as TRVs. The use of such values as TRVs may overestimate risk, as such values are thought to be conservative. However, that conservativism has also been accounted for in the manner in which risks have been qualitatively classified for the resulting HQ values.

Technical supporting documents for the provincial and federal WQGs were used to select TRVs for surface water. The TRVs that were selected are described in Appendix F. The level of uncertainty associated with these TRVS is discussed below.

The species-specific TRVs for aluminum are based on chronic studies selected by BC ENV to derive the aluminum WGC and pH values representing the receiving environment. A low uncertainty is associated with these TRVs.

The BC WQGs for copper, lead and nitrite were adopted as TRV for all aquatic receptor groups. In addition, the BC WQG for cadmium was adopted as the TRV for aquatic invertebrates. These TRVs are considered to be conservative values that may overestimate risks.

Limited information was available on beryllium toxicity. The lowest reported concentration obtained in a chronic study with invertebrates (endpoint: reproduction) was adopted as the TRV. This TRV was also applied to aquatic plants, fish and amphibians as chronic studies with these receptor groups were not available. There is a high level of uncertainty with the TRV for beryllium.

The TRV for cadmium for fish was based on the lowest chronic toxicity values for fish obtained at a hardness of 50 mg/L. A low level of uncertainty is associated with this TRV as it is derived on a chronic study for a fish that may be present in the receiving environment (sculpin) an dis based on a growth endpoint. A moderate level of uncertainty is associated with the TRV for aquatic plants and amphibians based on the limited data available.

The TRV for chromium was based on the lowest chronic toxicity values for invertebrates and fish (10 µg/L). Invertebrates were identified as the most sensitive organisms in deriving the BC WQG for chromium. A low level of uncertainty is associated with this TRV. A higher level of uncertainty is associated with the application of this TRV as it was applied to total chromium concentrations and as thus may overestimate risks.

The TRV for total iron was based on a second benchmark of 1740 µg/L presented in the BC ENV supporting document for iron allowing for a slight to moderate changes in community population (i.e., loss of some rare species and/or replacement of sensitive ubiquitous taxa with more tolerant taxa). A moderate level of uncertainty is associated with this TRV and its application to the receiving environment as it is not receptor specific.

The species-specific TRVs were selected for zinc. These TRVs were selected based on the toxicity values used by CCME to update the zinc WQG (CCME 2018). The toxicity values provided in the CCME were normalized to an average hardness of 145 mg/L for aquatic plants, invertebrates and amphibians and to an average harness of 152 mg/L for fish. There is uncertainty associated with using average hardness values to normalize the toxicity values based on which the TRVs were selected as the toxicity of zinc decrease with increasing hardness. For example, for fish, seven out of the twenty-four predicted hardness values were lower than the average hardness value. Lower hardness values are predicted to occur during the spring (April, May and June). During these months, zinc concentrations are also predicted to be at their lowest (50 to 60 µg/L). At a lower hardness of 100 mg/L the TRV for fish would be 60 µg/L (based on normalized toxicity values); thus the predicted concentrations would be less than or at the TRV. In addition, the TRV for fish species was based on the lowest chronic toxicity value obtained for sculpin. The CCME data indicated that brook trout, cutthroat and rainbow trout were less sensitive to zinc toxicity (toxicity values ranging from 130 to 553 µg/L; hardness 100 mg/L). Based on these observations the level of uncertainty associated with the zinc TRV is considered to be low.

4.2.4 Risk Characterization Uncertainties

The characterization of ecological risks was limited to a single line of evidence, namely the calculation of hazard quotients. The hazard quotient line of evidence can overpredict risks. For this site, the conservative nature of this chemistry-based line of evidence has been accounted for in the manner in which risks have been qualitatively classified for the resulting HQ value. In addition, hazard quotients were interpreted using historical site observations within the site area.

Risks to plants under post-closure conditions were quantified using species mixes chosen for planting during closure activities. Although species were assumed to be exposed via root contact and uptake of contaminants in both surficial (cap) soil and subsurface tailings, risks may be underestimated for future plant life that may root predominantly within the subsurface horizon where tailings are present. Since deep-rooting plants are not planned for the tailings area of the site, community-level risks for deep rooting plants are likely to be low.

There is uncertainty related to the use of a qualitative risk characterization scheme for HQs > 1 (i.e. low, moderate and high risks). This qualitative categorization of risk is judgement based and reflects the fact that there is a degree of conservativism within the approach for quantifying risks (i.e. TRVs chosen, assumptions included in EPC selection, food chain modelling assumptions and equations) and whether or not these values truly represent threshold concentrations for low to moderate levels of effects to the majority of species.

In addition, the evaluation of risks to aquatic life compared EPCs based on total concentrations to TRV generally based on dissolved concentrations. This likely overestimate the potential risks as total metals are less bioavailable than dissolved metals.

5.0 CONCLUSIONS

5.1 Human Health Risks

Based on the results of the HHERA problem formulation, no complete or significant exposure pathways were identified for human health. Exposure to on-site contaminants is expected to be negligible for on-site Trespassers and maintenance workers and off-site residents and farmers under post-closure conditions.

No complete exposure pathways were identified between groundwater COPCs on-site and potable water use to the north and west of the site. Based on the direction of groundwater flow, exposure to off-Site receptors south of the site is a potentially complete exposure pathway. However, based on the results of the historical sampling, exposure via potable water use is considered an insignificant pathway based on current land uses south of the site.

A potentially complete and significant exposure pathway was identified for potential future groundwater users immediately south of the site for lithium in groundwater. The source of the lithium in groundwater has not been confirmed. RDCK indicated that the lithium concentrations appeared to be stable downgradient, and were likely not related to groundwater quality concerns at the site (SLR 2019b). The concentration of lithium in the downgradient wells indicated that concentrations have historically been higher than groundwater concentrations measured within the Tailings Area and lithium has been below detection limits in all soil samples collected within the tailings area, (RDCK 2019b), supporting this assessment.

5.2 Ecological Risks

The risks to wildlife associated with soil to plant bioaccumulation, and ingestion of site food items and soil are expected to be negligible for all ROCs for arsenic and lead (i.e. HQ<1). Risks are also expected to be negligible for cadmium and zinc for all ROCs with the exception of the song sparrow (HQ of 1.4 and 2.1, respectively) and american robin (zinc, HQ = 1.6), where the risk estimates were marginally above the target risk level (HQ = 1).

Based on the results of the quantitative evaluation combined with site observations, risks to plant communities at the site was concluded to be negligible. A summary of the results of the vegetation assessment is provided below:

- Although risk estimates above the risk target level (i.e. HQ=1) were identified for plant root contact with arsenic, lead and zinc in subsurface soil (i.e. tailings material) and manganese, fluoride, uranium and zinc in groundwater, based on the frequency of exceedances across the site, the site wide risk at the site as a whole is likely to be negligible.
- Based on the review of historical information related to vegetation at the site, historical planting of grasses and fescue occurred at the site prior to 1982 as documented in the Stage 1 Submission for reactivation of the HB Mill report (IEC Ltd., 1982). Based on a review of historical planting activities at the site risks to the vegetation species expected to be planted during closure (i.e. grasses, alfalfa etc.) are expected to be negligible.

Risks for wildlife due to bioaccumulation in the food chain are expected to be negligible for arsenic, and lead (i.e. HQ<1). Risks are also expected to be negligible for cadmium and zinc for all ROCs with the exception of the song sparrow (cadmium and zinc) and American robin (zinc only), where the risk estimate was marginally above the target risk level (HQ = 1). Risks to burrowing mammals are also expected to be negligible (i.e. HQ<1).

Due to the size of the available dataset, risk estimates for wildlife were calculated based on maximum plant tissue concentrations collected from the site. This may result in an overestimate of risks to plant-consuming ROCs such as the song sparrow and American robin. Risks for these receptors were recalculated based on the 95th percentile and geometric mean of the plant tissue concentrations for cadmium and zinc. The HQs calculated using geometric mean plant tissue concentrations risks to song birds are expected to be low, however uncertainty with risks to these receptors are expected to be high due to the limited dataset, and limited on-site receptor information.

The results of the HQ step of risk characterization for aquatic life indicated that potential risks to most receptor groups were negligible or low, however the results of the risk characterization for surface water indicated potential risks for the following COPCs-ecological receptor group combinations:

- Aquatic plants exposed to aluminum, copper and nitrite;
- Aquatic invertebrates exposed to aluminum, copper, zinc and nitrite;
- Fish exposed to zinc; and
- Amphibians exposed to aluminum, copper and nitrite.

In addition, exposure to sediment were associated with potential risks to aquatic life from exposure to cadmium, lead and zinc.

Based on the low magnitude of the HQs obtained for surface water and sediment, the ephemeral nature of the habitat provided by the channels and the conservative assumptions made in the risk assessment (e.g. use of total metal in the exposure assessment), the potential risks are considered to be low.

6.0 STATEMENT OF LIMITATIONS

This report has been prepared and the work referred to in this report has been undertaken by SLR Consulting (Canada) Ltd. (SLR) for Regional District of Central Kootenay, hereafter referred to as the “Client”. It is intended for the sole and exclusive use of Regional District of Central Kootenay. Other than by the Client and as set out herein, copying or distribution of this report or use of or reliance on the information contained herein, in whole or in part, is not permitted unless payment for the work has been made in full and express written permission has been obtained from SLR.

This report has been prepared for specific application to this site and conditions existing at the time work for the report was completed. Any conclusions or recommendations made in this report reflect SLR’s professional opinion based on limited investigations including: visual observation of the site, surface and subsurface investigation at discrete locations and depths, and laboratory analysis of specific chemical parameters. The results cannot be extended to previous or future site conditions, portions of the site that were unavailable for direct investigation, subsurface locations which were not investigated directly, or chemical parameters and materials that were not addressed. Substances other than those addressed by the investigation may exist within the site; and substances addressed by the investigation may exist in areas of the site not investigated in concentrations that differ from those reported. SLR does not warranty information from third party sources used in the development of investigations and subsequent reporting.

Nothing in this report is intended to constitute or provide a legal opinion. SLR expresses no warranty to the accuracy of laboratory methodologies and analytical results. SLR expresses no warranty with respect to the toxicity data presented in various references or the validity of toxicity studies on which it was based. Scientific models employed in the evaluations were selected based on accepted scientific methodologies and practices in common use at the time and are subject to the uncertainties on which they are based.

SLR makes no representation as to the requirements of compliance with environmental laws, rules, regulations or policies established by federal, provincial or local government bodies. Revisions to the regulatory standards referred to in this report may be expected over time. As a result, modifications to the findings, conclusions and recommendations in this report may be necessary.

Regional District of Central Kootenay may submit this report to the BC Ministry of Environment and/or related BC environmental regulatory authorities or persons for review and comment purposes.

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TABLES

Regional District of Central Kootenay
Prospective Human Health and Ecological Risk Assessment
HB Mine Tailings Management Facility
SLR Project No.: 204.03242.00004

TABLE 1: CONTAMINANTS OF POTENTIAL CONCERN (COPC) SCREENING - HUMAN HEALTH - POST CLOSURE SURFICIAL SOIL CAP (0-0.3mbg)

PARAMETERS							HUMAN SCREENING		
			Maximum		95% UCLM		Screening Benchmarks		
Chemical	No. of Samples Analyzed (+ DUP)	No. of Detects (+DUP)	µg/g	Sample Location	µg/g		CSR Human Health Wildlands Reverted Intake of Contaminated Soil	BC P4 Region 4 -Kootenay Background Concentration	COPC?
arsenic	13	13	14.50	TP18-13	nc		40	4	No; maximum concentration < selected screening benchmark

Notes:
na - not applicable
nc - not calculated
ns- no standard
- selected screening benchmark
DUP- blind field duplicate sample

TABLE 2: CONTAMINANTS OF POTENTIAL CONCERN (COPC) SCREENING - HUMAN HEALTH - GROUNDWATER

PARAMETERS						HUMAN SCREENING		
Chemical	No. of Samples Analyzed (+ DUP)	No. of Detects (+DUP)	Maximum Concentration				Guidelines and Standards (µg/g)	COPC?
			µg/L	Sample Location	Sample Date		BC CSR DW	
arsenic (dissolved)	57(+5)	47(+4)	22	MW-02D-03	2017-May-9		10	Yes; maximum concentration > selected screening benchmark
barium (dissolved)	57(+5)	50(+4)	1430	MW-02-05	2018-May-10		1000	Yes; maximum concentration > selected screening benchmark
iron (dissolved)	57(+5)	40(+3)	31700	MW-02D-03	2017-May-9		6500	Yes; maximum concentration > selected screening benchmark
lithium (dissolved)	57(+5)	42(+3)	247	MW99-1(D)	2016-Apr-27		8	Yes; maximum concentration > selected screening benchmark
manganese (dissolved)	57(+5)	57(+5)	5430	MW-01C-03	2018-May-8		1500	Yes; maximum concentration > selected screening benchmark
molybdenum (dissolved)	57(+5)	39(+2)	20.2	MW-03S-05	2017-May-10		250	No; maximum concentration < selected screening benchmark
tungsten (dissolved)	19(+2)	9	7.02	MW-05-05	2018-May-10		3	Yes; maximum concentration > selected screening benchmark
uranium (dissolved)	57(+5)	45(+3)	14	MW-01A-03	2017-May-8		20	Yes; maximum concentration > selected screening benchmark
zinc (dissolved)	57(+5)	28(+2)	14300	MW-06-01	2018-May-15		3000	Yes; maximum concentration > selected screening benchmark
fluoride	7(+1)	6(+1)	1250	MW-05-05	2018-May-10		1500	Yes; maximum concentration > selected screening benchmark
sulfate	57(+5)	55(+5)	1890	MW-06-01	2016-Apr-25		500	Yes; maximum concentration > selected screening benchmark

Notes:
na - not applicable
nc - not calculated
ns- no standard
[yellow] - selected screening benchmark
DUP- blind field duplicate sample

TABLE 3: CONTAMINANTS OF POTENTIAL CONCERN (COPC) SCREENING - HUMAN HEALTH - SURFACE WATER

PARAMETERS						HUMAN SCREENING			
			Maximum Concentration			Guidelines and Standards (µg/L)			
Chemical	No. of Samples Analyzed	No. of Detects	µg/L	Sample Location	Sample Date	BC WQG	BC WQG	CSR DW	COPC?
						Recreation	Drinking Water		
aluminum	33(+1)	33(+1)	5410	SW2-07	2018-Oct-30	ng	95000	-	No; maximum concentration < selected screening benchmark
beryllium	9(+1)	1	0.23	SW2-07	2018-Oct-30	ng	ng	8	No; maximum concentration < selected screening benchmark
cadmium	33(+1)	33(+1)	0.69	Spillway + Seepage	predicted August	ng	5	-	No; maximum concentration < selected screening benchmark
chromium (III and VI)	33(+1)	30	5.55	SW2-07	2018-Oct-30	ng	-	50[b]	No; maximum concentration < selected screening benchmark
copper	33(+1)	33(+1)	12.2	SW1-07	2016-Nov-4	ng	1000[a]	1500	No; maximum concentration < selected screening benchmark
iron	33(+1)	33(+1)	4860	SW2-07	2018-Oct-30	ng	30[a]	6500	No; maximum concentration < selected screening benchmark
lead	33(+1)	33(+1)	13.9	SW1-07	2018-May-17	ng	10	-	**Yes; max conc. > selected screening benchmark**
mercury	9(+1)	1	0.0082	SW1-07	2016-Nov-4	ng	1	-	No; maximum concentration < selected screening benchmark
selenium	9(+1)	9(+1)	0.697	SW2-07	2018-Oct-30	ng	10	-	No; maximum concentration < selected screening benchmark
uranium	33(+1)	33(+1)	8.51	SW1-07	2016-Apr-26	ng	ng	20	No; maximum concentration < selected screening benchmark
zinc	33(+1)	33(+1)	180	Spillway and Seepage	predicted August	ng	5,000[a]	3000	No; maximum concentration < selected screening benchmark
nitrate (as N)	33(+1)	33(+1)	1410	SW1-07	2017-May-15	10000	10000	-	No; maximum concentration < selected screening benchmark
nitrite (as N)	9(+1)	5(+1)	60.5	SW1-07	2016-Nov-4	1000	1000	-	No; maximum concentration < selected screening benchmark
phosphorous	9(+1)	8(+1)	154	SW1-07	2016-Nov-4	10[a]	10[a]	-	No; No toxicity-based guideline available. Guideline based on lakes.
Sulphate	33(+1)	33(+1)	154000	Spillway and Seepage	predicted August	-	500000[a]	500000[a]	No; maximum concentration < selected screening benchmark

Notes:
na - not applicable
nc - not calculated
ng-no guideline
(yellow shading) - selected screening benchmark
DUP- blind field duplicate sample
a - aesthetic objective
HC DWQG - Health Canada Drinking Water Quality Guideline
b- guideline for hexavalent chromium

TABLE 4: CONTAMINANTS OF POTENTIAL CONCERN (COPC) SCREENING - HUMAN HEALTH - SEDIMENT

PARAMETERS								INTERTIDAL AQUATIC LIFE SCREENING	
Chemical	No. of Samples Analyzed (+DUP)	No. of Detects (+DUP)	Maximum Concentration			95% UCLM		CSR Human Health Wildlands Reverted	COPC?
			µg/g	Sample Location	Sample Depth (mbg)	µg/g		Intake of Contaminated Soil	Preliminary Screening
arsenic	8(+1)	8(+1)	25.7	S-9	0.1	17		40	No; maximum concentration < selected screening benchmark
cadmium	8(+1)	8(+1)	11.9	S-9	0.1	6		40	No; maximum concentration < selected screening benchmark
lead	8(+1)	8(+1)	247	S-9	0.1	238		120	**Yes: maximum concentration > selected screening benchmark**
zinc	8(+1)	8(+1)	2280	S-9	0.1	1290		25000	No; maximum concentration < selected screening benchmark

Notes:
na - not applicable
nc - not calculated
ns- no standard
- selected screening benchmark
DUP- blind field duplicate sample

TABLE 5: CONTAMINANTS OF POTENTIAL CONCERN (COPC) SCREENING - PLANTS AND SOIL INVERTEBRATES - POST CLOSURE SURFICIAL SOIL CAP (0-0.3 mbg)

PARAMETERS								PLANTS AND INVERTEBRATES SCREENING						
Chemical	No. of Samples Analyzed (+DUP)	No. of Detects (+DUP)	Maximum		90th Percentile	95% UCLM		Guidelines and Standards (µg/g)						COPC?
								CSR Ecological Health Wildlands Reverted		BC P4 Region 4 - Kootenay Background Concentration	Reference sample Locations			
			µg/g	Sample ID	µg/g	µg/g		Generic Ecological	Toxicity to Soil Invertebrates and Plants		SSREF-1	SSREF-2		
Substances Exceeding Guidelines/Standards														
arsenic	13	13	14.5	TP18-13	nc	nc		ns	25	4	11.3	9.85		No; max conc. < selected screening benchmark

Notes:
na - not applicable
nc - not calculated
ns - no standard
- selected screening benchmark
DUP- blind field duplicate sample

TABLE 6: CONTAMINANTS OF POTENTIAL CONCERN (COPC) SCREENING - PLANTS - SOIL (FULL DEPTH)

PARAMETERS								PLANT SCREENING						
			Maximum Concentration			90th Percentile	95% UCLM		Guidelines and Standards (µg/g)					
									CSR Ecological Health Wildlands Reverted		BC P4 Region 4 - Kootenay Background Concentration	Reference sample Locations		
Chemical	No. of Samples Analyzed (+DUP)	No. of Detects (+DUP)	µg/g	Sample ID	Sample Depth (mbg)[1]	µg/g	µg/g		Generic Ecological	Toxicity to Soil Invertebrates and Plants		SSREF-1	SSREF-2	COPC?
Substances Exceeding Guidelines/Standards														
arsenic	27(+2)	27(+2)	185	SS2-1	0.3-0.6	103	56.4		ns	25	4	11.3	9.85	**Yes; maximum concentration > selected screening benchmark**
cadmium	27(+2)	27(+2)	51.6	SS2-1	0.3-0.6	40	22.0		ns	30	0.4	1.71	0.656	**Yes; maximum concentration > selected screening benchmark**
lead	27(+2)	27(+2)	2840	SS2-1	0.3-0.6	2050	1083		ns	550	120	58.3	27.3	**Yes; maximum concentration > selected screening benchmark**
selenium	27(+2)	11(+2)	1.26	SS2-1	0.3-0.6	0.70	0.45		ns	1.5	4	<0.5	<0.5	No; maximum concentration < screening benchmark
zinc	27(+2)	27(+2)	5050	SS2-1	0.3-0.6	4216	2140		ns	450	200	198	94.4	**Yes; maximum concentration > selected screening benchmark**

Notes:
na - not applicable
nc - not calculated
ns - no standard
(shaded) - selected screening benchmark
DUP- blind field duplicate sample
1 - Sample depths are from post closure ground surface, assuming a minimum cap depth of 0.3 metres

TABLE 7: CONTAMINANTS OF POTENTIAL CONCERN (COPC) SCREENING - PLANTS - GROUNDWATER

PARAMETERS						PLANTS SCREENING				
			Maximum Concentration			Screening Benchmarks (µg/L)				COPC?
							Upgradient Reference Locations			
Chemical	No. of Samples Analyzed (+DUP)	No. of Detects (+DUP)	µg/L	Sample ID	Sample Date	BC CSR IW	MW05-1	MW09-02S (2016 - 2018)	MW09-02D (2016 - 2018)	Final Screening
Substances Exceeding Guidelines/Standards										
arsenic (dissolved)	57(+5)	47(+4)	21.6	MW-02D-03	2017-May-9	100	0.3 - <0.5	0.11 - <0.5	2.7- 3.39	No; maximum concentration < selected screening benchmark
iron (dissolved)	57(+5)	40(+3)	31700	MW-02D-03	2017-May-9	5000	< 10 - < 30	<10 - <30	57 - 150	**Yes; maximum concentration > selected screening benchmark**
lithium (dissolved)	57(+5)	42(+3)	247	MW99-1(D)	2016-Apr-27	2500	2.5 - 2.8	<1	<1 - 1	No; maximum concentration < selected screening benchmark
manganese (dissolved)	57(+5)	57(+5)	5430	MW-01C-03	2018-May-8	200	1.61 - 2.59	0.29 - 0.94	352 - 394	**Yes; maximum concentration > selected screening benchmark**
molybdenum (dissolved)	57(+5)	39(+2)	20.2	MW-03S-05	2017-May-10	10	0.71 - <1	0.108 - <1	1.99 - 2.2	**Yes; maximum concentration > selected screening benchmark**
uranium (dissolved)	57(+5)	45(+3)	14	MW-01A-03	2017-May-8	10	1.3 - 1.76	0.138 - <0.2	7.17 - 8.15	**Yes; maximum concentration > selected screening benchmark**
zinc (dissolved)	57(+5)	28(+2)	14300	MW-06-01	2018-May-15	1000 @ pH < 6.0 2000 @ pH 6.0<7.0 5000 @ pH ≥ 7.0	1 - <5	2.6 - <5	2 - <5	**Yes; maximum concentration > selected screening benchmark**
fluoride	7(+1)	6(+1)	1250	MW-05-05	2018-May-10	1000	-	36	78	**Yes; maximum concentration > selected screening benchmark**

Notes:
na - not applicable
nc - not calculated
ng - no guideline
nv - no value
(shaded) - selected screening benchmark
DUP- blind field duplicate sample
BC CSR IW - British Columbia CSR standards - irrigation water

TABLE 8: CONTAMINANTS OF POTENTIAL CONCERN (COPC) SCREENING - WILDLIFE AND OFF-SITE LIVESTOCK - SURFACE WATER

PARAMETERS					Wildlife COPC Screening						
Chemical	No. of Samples Analyzed (+DUP)	Maximum Concentration			Background location		Guidelines and Standards (µg/L)				COPC?
		µg/L	Sample ID	Sample Date	SW3-07 (n=4)		BC WQG		BC DWG	CSR DW	
					Max	95th percentile	Wildlife (Short Term)	Wildlife Water Supply (Long Term)	Drinking Water		
Substances Exceeding Guidelines/Standards											
aluminum	33(+1)	5410	SW2-07	2018-Oct-30	38.8	36.9	5000[b]	ng	-	-	**Yes; maximum concentration > selected screening benchmark**
beryllium	9(+1)	0.23	SW2-07	2018-Oct-30	<1	1	ng	100	-	-	No; maximum concentration < selected screening benchmark
cadmium	33(+1)	0.69	Spillway + Seepage	predicted August	0.02	0.02	ng	80	-	-	No; maximum concentration < selected screening benchmark
chromium (III and VI)	33(+1)	5.55	SW2-07	2018-Oct-30	<1	1	ng	50	-	-	No; maximum concentration < selected screening benchmark
copper	33(+1)	12.2	SW1-07	2016-Nov-4	<1	1	300	ng	-	-	No; maximum concentration < selected screening benchmark
lead	33(+1)	13.9	SW1-07	2018-May-17	0.123	0.5	100	ng	-	-	No; maximum concentration < selected screening benchmark
mercury	9(+1)	0.0082	SW1-07	2016-Nov-4	<0.005	0.005	2	ng	-	-	No; maximum concentration < selected screening benchmark
selenium	9(+1)	0.697	SW2-07	2018-Oct-30	0.09	0.09	ng	30	-	-	No; maximum concentration < selected screening benchmark
uranium	33(+1)	8.51	SW1-07	2016-Apr-26	0.11	0.2	200	ng	ng	20	No; maximum concentration < selected screening benchmark
zinc	33(+1)	180	Spillway and Seepage	predicted August	6.60	6.36	ng	2000	-	-	No; maximum concentration < selected screening benchmark
nitrate (as N)	33(+1)	1410	SW1-07	2017-May-15	1210	1030	100000	ng	-	-	No; maximum concentration < selected screening benchmark
nitrite (as N)	9(+1)	60.5	SW1-07	2016-Nov-4	18	15.5	10000	ng	-	-	No; maximum concentration < selected screening benchmark
phosphorous	9(+1)	154	SW1-07	2016-Nov-4	37.8	0.0482	ng	ng	10[c]	-	No; No toxicity-based guideline available. Guideline based on lakes.
Sulphate	33(+1)	154,000	Spillway and Seepage	predicted August	8230	8094	ng	1000000	-	-	No; maximum concentration < selected screening benchmark

Notes:
na - not applicable
nc - not calculated
ng - no guideline
nv - no value
(shaded) - selected screening benchmark
DUP- blind field duplicate sample
Dependant standards are calculated based on the minimum measured hardness of 66.1 mg/L, minimum pH of 7.78, or minimum chloride of 0.81 as needed
* Applicable to nitrate + nitrite
BC WQG - British Columbia Water Quality Guideline
a - BC WWQG - British Columbia Working Water Quality Guideline
b - guideline is for total aluminum
c- aesthetic objective only
BC DWQ - British Columbia Drinking Water Quality Guideline
HC DWQG - Health Canada Drinking Water Quality Guideline

TABLE 9: CONTAMINANTS OF POTENTIAL CONCERN (COPC) SCREENING - OFF-SITE CROP IRRIGATION - SURFACE WATER

PARAMETERS					Wildlife COPC Screening			
Chemical	No. of Samples Analyzed (+DUP)	Maximum Concentration			Background location		Guidelines and Standards (µg/L)	COPC?
		µg/L	Sample ID	Sample Date	SW3-07 (n=4)		BC CSR IW	
					Max	95th percentile		
Substances Exceeding Guidelines/Standards								
aluminum	33(+1)	5410	SW2-07	2018-Oct-30	38.8	36.9	5000	**Yes; maximum concentration > selected screening benchmark**
beryllium	9(+1)	0.23	SW2-07	2018-Oct-30	<1	1	100	No; maximum concentration < selected screening benchmark
cadmium	33(+1)	0.69	Spillway + Seepage	predicted August	0.02	0.02	5	No; maximum concentration < selected screening benchmark
chromium (III and VI)	33(+1)	5.55	SW2-07	2018-Oct-30	<1	1	trivalent = 5 hexavalent = 8	**Yes; maximum concentration > selected screening benchmark**
copper	33(+1)	12.2	SW1-07	2016-Nov-4	<1	1	200	No; maximum concentration < selected screening benchmark
iron	33(+1)	4860	SW2-07	2018-Oct-30	<30	30	5000	No; maximum concentration < selected screening benchmark
lead	33(+1)	13.9	SW1-07	2018-May-17	0.123	0.5	200	No; maximum concentration < selected screening benchmark
mercury	9(+1)	0.0082	SW1-07	2016-Nov-4	<0.005	0.005	1	No; maximum concentration < selected screening benchmark
selenium	9(+1)	0.697	SW2-07	2018-Oct-30	0.09	0.09	20[e]	No; maximum concentration < selected screening benchmark
uranium	33(+1)	8.51	SW1-07	2016-Apr-26	0.11	0.2	10	No; maximum concentration < selected screening benchmark
zinc	33(+1)	180	Spillway and Seepage	predicted August	6.60	6.36	1000 @ pH < 6.0 2000 @ pH 6.0<7.0 5000 @ pH ≥ 7.0	No; maximum concentration < selected screening benchmark

Notes:
na - not applicable
nc - not calculated
ng - no guideline
nv - no value
- selected screening benchmark
DUP- blind field duplicate sample
Dependant standards are calculated based on the minimum measured hardness of 66.1 mg/L, minimum pH of 7.78, or minimum chloride of 0.81 as needed
b - guideline is for total aluminum
d - lowest of the trivalent and hexavalent standards for chromium
e - standard for continuous irrigation of crops
BC CSR IW - British Columbia CSR standards - irrigation water

TABLE 10: CONTAMINANTS OF POTENTIAL CONCERN (COPC) SCREENING - FRESHWATER AQUATIC LIFE - SURFACE WATER

PARAMETER					AQUATIC LIFE SCREENING					
		Maximum Concentration			Background location SW3-07 (n=4)		Screening Benchmarks (μg/L) BC WQG			
Chemical	No. of Samples	μg/L	Sample Location	Date	Max	95th percentile	AWF (Approved) Long- Term	AWF (Approved) Short- Term	AWF (Working) Long- Term	COPC?
aluminum	33(+1)	5410	SW2-07	2018-Oct-30	38.8	36.94	50*	100*	ng	**Yes; mac conc. > selected screening benchmark**
beryllium	9(+1)	0.23	SW2-07	2018-Oct-30	<1	1	ng	ng	0.13	**Yes; mac conc. > selected screening benchmark**
cadmium	33(+1)	0.69	Spillway + Seepage	predicted August	0.02	0.02	0.16*	0.38	ng	**Yes; maximum concentration > selected screening benchmark**
chromium	33(+1)	5.55	SW2-07	2018-Oct-30	<1	1	ng	ng	1	**Yes; maximum concentration > selected screening benchmark**
copper	33(+1)	12.2	SW1-07	2016-Nov-4	<1	1	2.64	8.21	ng	**Yes; maximum concentration > selected screening benchmark**
iron	33(+1)	4860	SW2-07	2018-Oct-30	14.00	nc	ng	1000	ng	**Yes; maximum concentration > selected screening benchmark**
lead	33(+1)	13.9	SW1-07	2018-May-17	0.123	0.5	5.19	48.20	ng	**Yes; maximum concentration > selected screening benchmark**
mercury	9(+1)	0.0082	SW1-07	2016-Nov-4	<0.005	0.005	0.00002	ng	ng	**uncertain COPC; only one sample with concentration > guideline in 2016. All other samples were undetected but detection limit > WQG.**
uranium	9(+1)	8.51	SW1-07	2016-Apr-26	0.11	0.2	ng	ng	8.5	No; maximum concentration < selected screening benchmark
zinc	33(+1)	180	Spillway and Seepage	predicted August	6.60	6.36	7.5	33	ng	**Yes; maximum concentration > selected screening benchmark**
nitrate (as N)	33(+1)	1.41 mg/L	SW1-07	2017-May-15	1.21	1.03	3	32.8	ng	No; maximum concentration < selected screening benchmark
nitrite (as N)	9(+1)	0.0605 mg/L	SW1-07	2016-Nov-4	0.018	0.016	0.02	0.06	ng	**Yes; maximum concentration > selected screening benchmark**
sulphide (mg/L)	33(+1)	0.13 mg/L	Outlet ditch	predicted May			ng	ng	0.002	**Uncertain COPC; maximum concentration is less than the detection limit but > WQG. The WQG should be applied to un-ionized sulphide**
sulphate (mg/L)	33(+1)	154 mg/L	Spillway and Seepage	predicted August	8.23	8.09	218	ng	ng	No; maximum concentration < selected screening benchmark

Notes:
na - not applicable
nc - not calculated
ns- no standard
*WQG developed for dissolved metal; used in the absence of WQG for total metal
- selected screening benchmark
DUP- blind field duplicate sample
Dependant standards are calculated based on the minimum measured hardness of 66.1 mg/L, minimum pH of 7.78, or minimum chloride of 0.81 as needed.

TABLE 11: CONTAMINANTS OF POTENTIAL CONCERN (COPC) SCREENING - FRESHWATER AQUATIC LIFE - SURFACE WATER

PARAMETER					AQUAIC LIFE SCREENING					
		Maximum Concentration			Background location		Guidelines and Standards (µg/L unless specifed)			
					SW3-07 (n=4)		BC WQG			
Chemical	No. of Samples	µg/L	Sample Location	Date	Max	95th percentile	AWF (Approved) Long- Term	AWF (Approved) Short- Term	AWF (Working) Long- Term	COPC?
aluminum	24	134	Outlet ditch	predicted July	38.8	36.90	50*	100*	ng	**Yes; maximum concentration > selected screening benchmark**
cadmium	24	0.69	Spillway + Seepage	predicted August	0.02	0.02	0.19*	0.52	ng	**Yes; maximum concentration > selected screening benchmark**
chromium	24	1.6	Spillway + Seepage	predicted July to December	<1	1	ng	ng	1	**Yes; maximum concentration > selected screening benchmark**
copper	24	4.4	Spillway + Seepage	predicted July to December	<1	1	3.52	10.27	ng	**Yes; maximum concentration > selected screening benchmark**
iron	24	200	Spillway + Seepage	predicted August	14.00	nc	ng	1000	ng	No; maximum concentration < selected screening benchmark
lead	24	4.3	Spillway + Seepage	predicted February	0.123	0.5	6.02	69.38	ng	No; maximum concentration < selected screening benchmark
zinc	24	180	Spillway and Seepage	predicted August	6.60	6.36	7.5	33	ng	**Yes; maximum concentration > selected screening benchmark**
sulphide (mg/L)	24	0.13	Outlet ditch	predicted May			ng	ng	0.002	**Uncertain COPC; maximum concentration is less than the detection limit but > the WQG. The WQG should be applied to un-ionized sulphide**
sulphate (mg/L)	24	154	Spillway and Seepage	predicted August	8.23	8.09	218	ng	ng	No; maximum concentration < selected screening benchmark

Notes:
na - not applicable
nc - not calculated
ns- no standard
*WQG developed for dissoved metal; used in the absence of WQG for total metal
[shaded] - selected screening benchmark
DUP- blind field duplicate sample
Dependant standards are calculated based on the minimum measured hardness of 66.1 mg/L, minimum pH of 7.78, or minimum chloride of 0.81 as needed

TABLE 12 : CONTAMINANTS OF POTENTIAL CONCERN (COPC) SCREENING - FRESHWATER AQUATIC LIFE - GROUNDWATER

PARAMETER						AQUATIC LIFE SCREENING	
			Maximum Concentration			Guidelines and Standards (µg/L)	
Chemical	No. of Samples Analyzed (+DUP)	No. of Detectable Concentrations (+DUP)	µg/L	Sample Location	Date	BC CSR AWF	COPC?
arsenic (dissolved)	57(+5)	47(+4)	21.6	MW-02D-03	2017-May-9	50	No; maximum concentration < selected screening benchmark
barium (dissolved)	57(+5)	50(+4)	1430	MW-02-05	2018-May-10	1000	No; maximum concentration < selected screening benchmark
molybdenum (dissolved)	57(+5)	39(+2)	20.2	MW-03S-05	2017-May-10	10000	No; maximum concentration < selected screening benchmark
uranium (dissolved)	57(+5)	45(+3)	14	MW-01A-03	2017-May-8	85	No; maximum concentration < selected screening benchmark
zinc (dissolved)	57(+5)	28(+2)	**14300**	MW-06-01	2018-May-15	75 @ H < 90 150 @ H 90<100 900 @ H 100<200 1650 @ H 200<300 2400 @ H 300<400	**No; maximum concentration > selected screening benchmark, however aquatic life assessed based on predictive surface water**
ammonia as N	57(+5)	48(+3)	**3290**	MW-03S-05	2018-May-15	1,310 @ pH ≥ 8.5 3,700 @ pH 8.0<8.5 11,300 @ pH 7.5<8.0 18,500 @ pH 7.0<7.5 18,400 @ pH < 7.0	**No; maximum concentration > selected screening benchmark, however aquatic life assessed based on predictive surface water**
fluoride	7(+1)	6(+1)	1250	MW-05-05	2018-May-10	2000 @ H < 50 3000 @ H ≥ 50	No; maximum concentration < selected screening benchmark
sulfate	57(+5)	55(+5)	1890	MW-06-01	2016-Apr-25	1280 mg/L @ H≤30 2180 mg/L @H 31-75 3090 mg/L @H 76-180 4390 mg/L@H>180	No; maximum concentration < selected screening benchmark

Notes:
na - not applicable
nc - not calculated
ns- no standard
- selected screening benchmark
DUP- blind field duplicate sample

TABLE 13: CONTAMINANTS OF POTENTIAL CONCERN (COPC) SCREENING - FRESHWATER AQUATIC LIFE - SEDIMENT

PARAMETER								AQUATIC LIFE SCREENING			
Chemical	No. of Samples Analyzed (+DUP)	No. of Detects (+DUP)	Maximum Concentration			90th Percentile	95% UCLM			COPC?	
			µg/g	Sample Location	Sample Depth (mbg)	µg/g	µg/g	BC CSR Sed Freshwater Sensitive	No. Exceedances (+DUP)	Preliminary Screening	Final Screening
arsenic	8(+1)	8(+1)	25.7	S-9	0.1	16.4	16	11	2	Yes: maximum concentration > selected screening benchmark	Yes; 90th percentile & 95 UCLM > selected screening benchmark
cadmium	8(+1)	8(+1)	11.9	S-9	0.1	5.94	7	2.2	5(+1)	Yes: maximum concentration > selected screening benchmark	Yes; 90th percentile & 95 UCLM > selected screening benchmark
lead	8(+1)	8(+1)	247	S-9	0.1	230	226	57	6(+1)	Yes: maximum concentration > selected screening benchmark	Yes; 90th percentile & 95 UCLM > selected screening benchmark
zinc	8(+1)	8(+1)	2280	S-9	0.1	1470	1372	200	7(+1)	Yes: maximum concentration > selected screening benchmark	Yes; 90th percentile & 95 UCLM > selected screening benchmark

Notes:
na - not applicable
nc - not calculated
ns- no standard
(blue shading) - selected screening benchmark
DUP- blind field duplicate sample

TABLE 14: CONTAMINANTS OF POTENTIAL CONCERN (COPC) SCREENING - PLANT TISSUE (mg/kg ww)								
Chemical	**Maximum Concentration (mg/kg ww)**	**Sample ID**	**Vegetation Type**	**Reference sample locations**				**COPC based on SLR 2018a?**
				REF1-1 Grass 04-Jun-2018	**REF1-2 Snowberry 04-Jun-2018**	**REF2-1 Grass 04-Jun-2018**	**REF2-2 Rosehip 04-Jun-2018**	
Arsenic	0.1	S2-4	Willow	<0.011	<0.015	<0.011	<0.018	**YES**
Cadmium	8.02	S4-2	Willow	0.0099	0.0271	0.0089	0.0515	**YES**
Iron	27.9	S4-2	Willow	12.3	20.3	9.7	18.9	No; similar to off-site concentrations
Lead	0.685	S2-1	Grass	0.0457	0.103	0.103	0.126	**YES**
Zinc	334	S2-2	Willow	8.27	11.7	8.57	10.4	**YES**

Notes:
m - metres
REF - reference area samples collected from outside tailings area
mg/kg - milligrams per wet kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
* The metals uptake study indicated that metals concentrations in plant tissue were similar at on and off-site locations
ns - no standard listed

DRAWINGS

Regional District of Central Kootenay
Prospective Human Health and Ecological Risk Assessment
HB Mine Tailings Management Facility
SLR Project No.: 204.03242.00004

Basedata:

National Road Network and National Railway Network, Geobase® Downloaded March 2014; BC regional Districts and Municipalities, GeoBC, Downloaded March 2014:Fresh Water Atlas, GeoBC®, Downloaded December 2014

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0 1,250 2,500 5,000 Meters

WHEN PLOTTED CORRECTLY AT 8.5 x 11 PAGE SIZE

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REGIONAL DISTRICT OF CENTRAL KOOTENAY
HB MINE TAILINGS MANAGEMENT FACILITY
SALMO, BC

Report	PROSPECTIVE CONTAMINANT HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT
Drawing	SITE LOCATION MAP
Date	April 09, 2019
Project No.	204.03242.00004
Drawing No.	1

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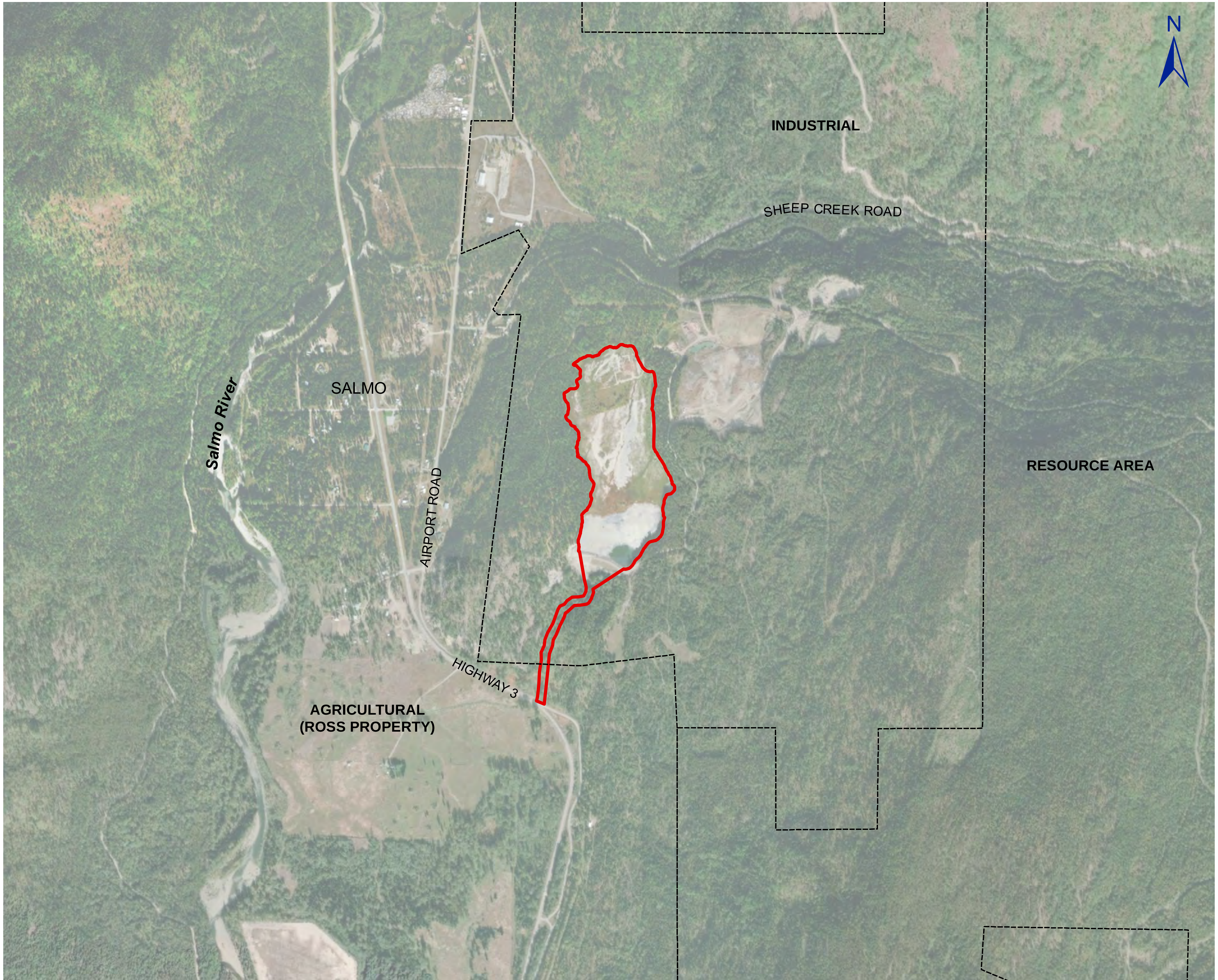

NOTES:

LEGEND

ZONING BOUNDARY

SITE BOUNDARY

0 200 400 800 Meters

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REGIONAL DISTRICT OF CENTRAL KOOTENAY
HB MINE TAILINGS MANAGEMENT FACILITY
SALMO, BC

PROSPECTIVE HUMAN HEALTH
AND ECOLOGICAL RISK ASSESSMENT

SURROUNDING LAND USE PLAN

Date: April 29, 2019	Drawing No. 2
Project No. 204.03242.00004	

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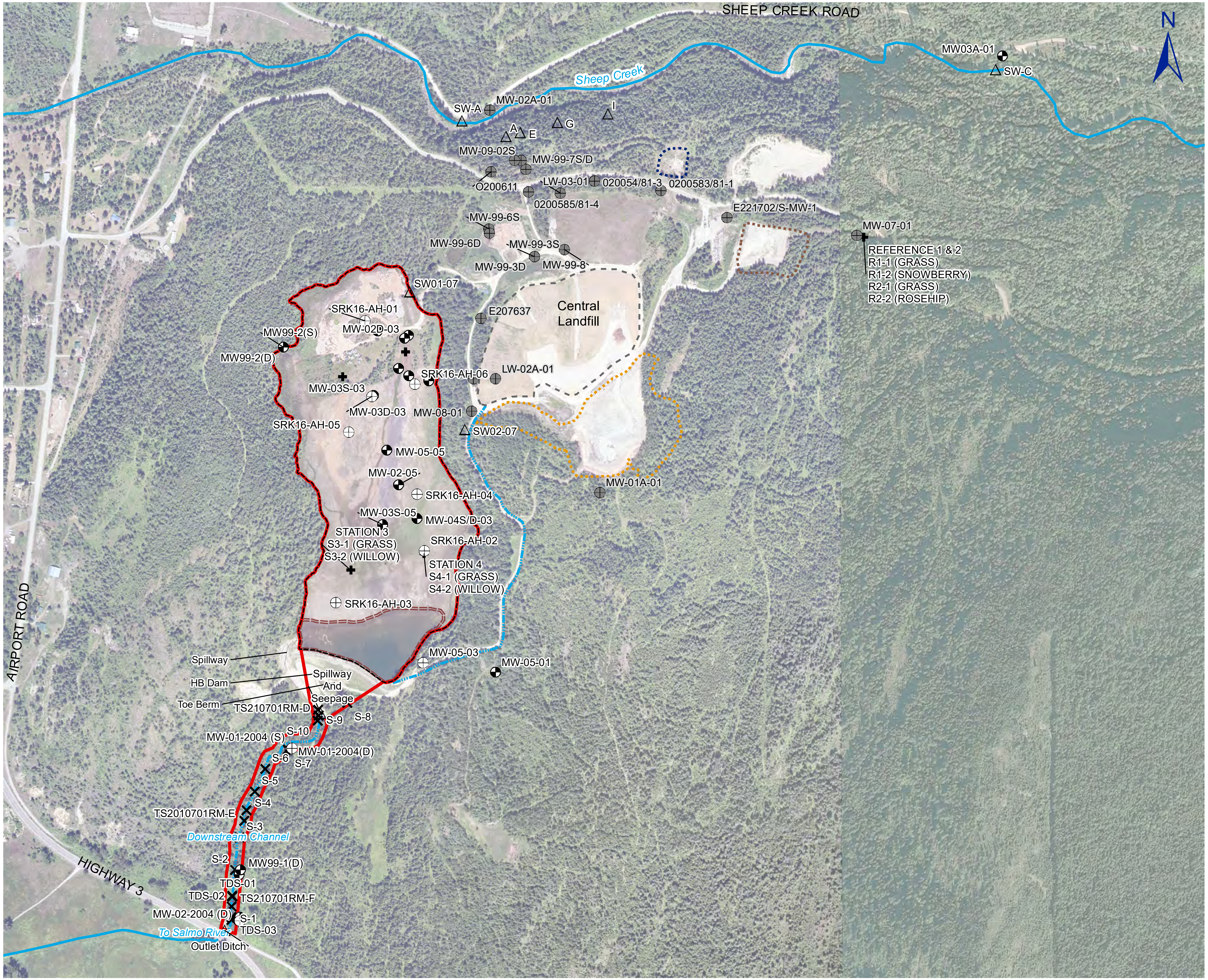

NOTES:

LEGEND

- BOREHOLE
- CENTRAL LANDFILL WELL
- MONITORING WELL
- SEDIMENT SAMPLE
- TISSUE SAMPLE
- SURFACE WATER SAMPLE
- TAILINGS DEPOSITION AREA
- SITE BOUNDARY
- TAILINGS POND
- LANDFILL SAND AND GRAVEL BORROW AREA
- NORTH SAND AND GRAVEL BORROW AREA
- BORROW PIT
- WATERCOURSE
- EPHEMERAL WATERCOURSE

0 125 250 500 Meters

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REGIONAL DISTRICT OF CENTRAL KOOTENAY
HB MINE TAILINGS MANAGEMENT FACILITY
SALMO, BC

PROSPECTIVE HUMAN HEALTH
AND ECOLOGICAL RISK ASSESSMENT

SITE PLAN AND SAMPLE LOCATIONS

Date: May 28, 2019		Drawing No.
Project No. 204.03242.00004		3

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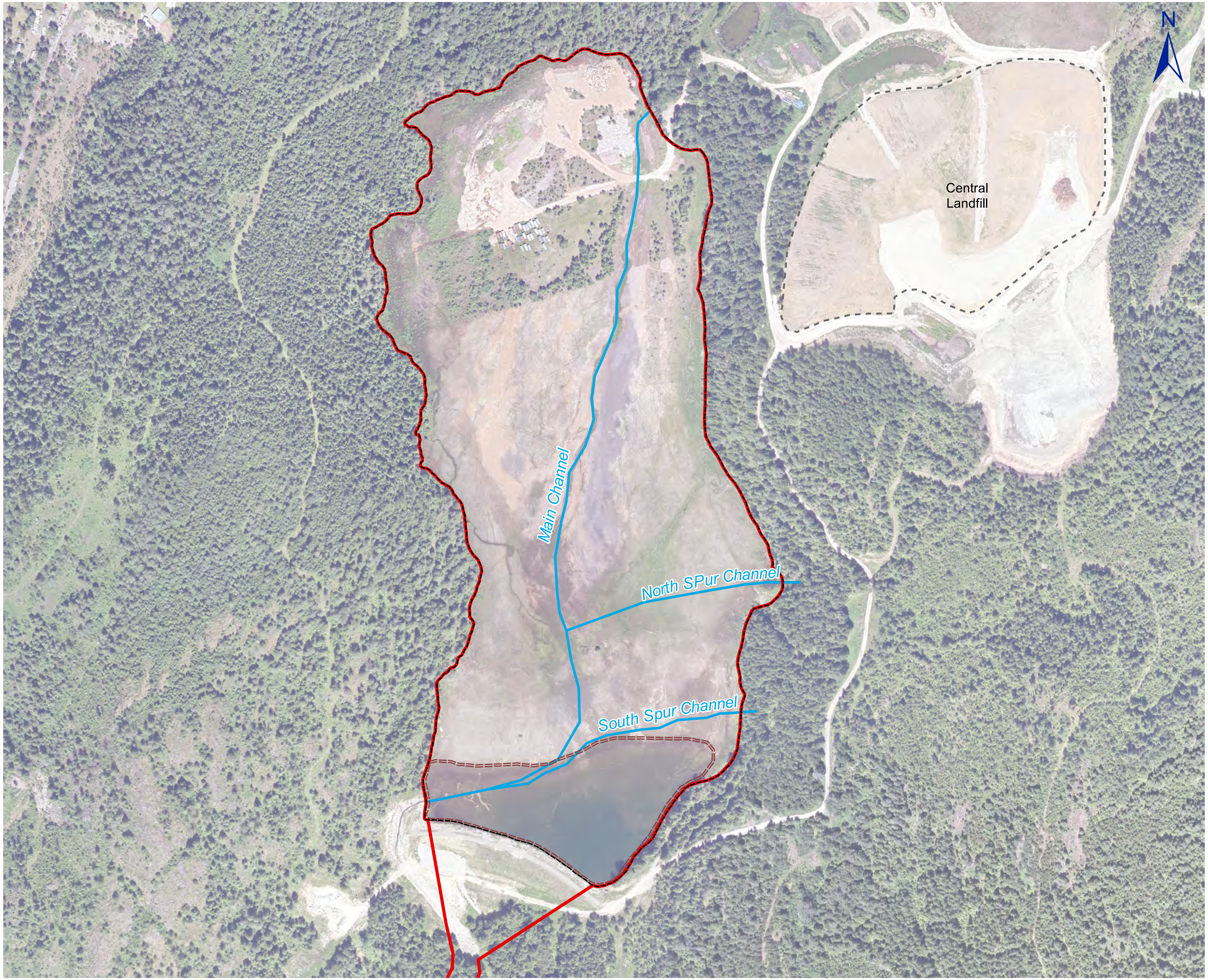

NOTES:

LEGEND

SITE BOUNDARY

TAILINGS DEPOSITION AREA

TAILINGS POND

SURFICIAL CHANNEL

0 62.5 125 250 Meters

1:4,000

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REGIONAL DISTRICT OF CENTRAL KOOTENAY
HB MINE TAILINGS MANAGEMENT FACILITY
SALMO, BC

PROSPECTIVE HUMAN HEALTH
AND ECOLOGICAL RISK ASSESSMENT

SURFICIAL CHANNEL LOCATIONS

Date: May 28, 2019	Drawing No. 4
Project No. 204.03242.00004	

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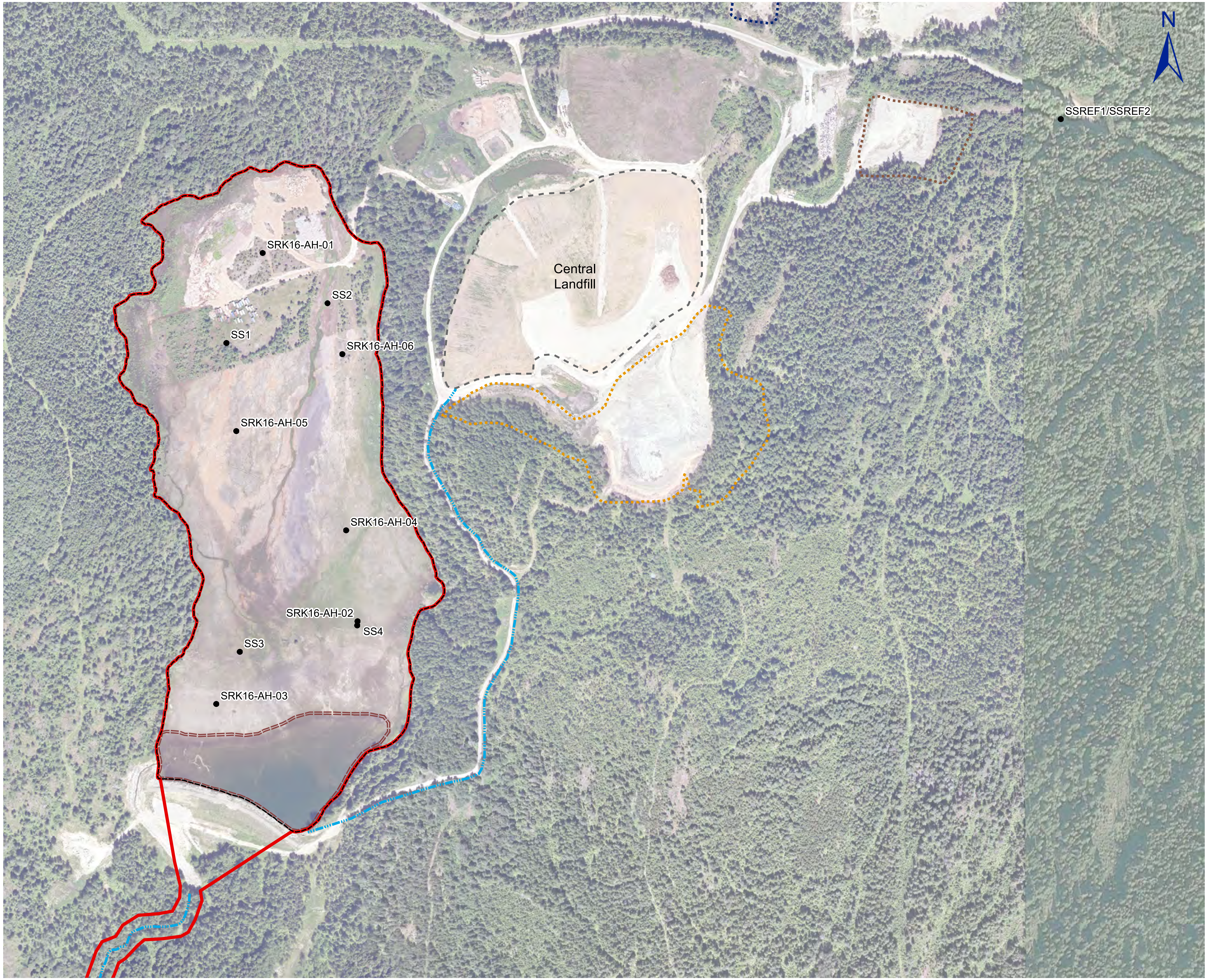

NOTES:

LEGEND

- SOIL SAMPLE
- SITE BOUNDARY
- TAILINGS DEPOSITION AREA
- TAILINGS POND
- LANDFILL SAND AND GRAVEL BORROW
- NORTH SAND AND GRAVEL BORROW
- BORROW PIT
- WATERCOURSE
- EPHEMERAL WATERCOURSE

0 75 150 300 Meters

1:5,000

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REGIONAL DISTRICT OF CENTRAL KOOTENAY
HB MINE TAILINGS MANAGEMENT FACILITY
SALMO, BC

PROSPECTIVE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

PRE CLOSURE SOIL SAMPLE LOCATIONS

Date: May 28, 2019

Project No. 204.03242.00004

Drawing No. 5

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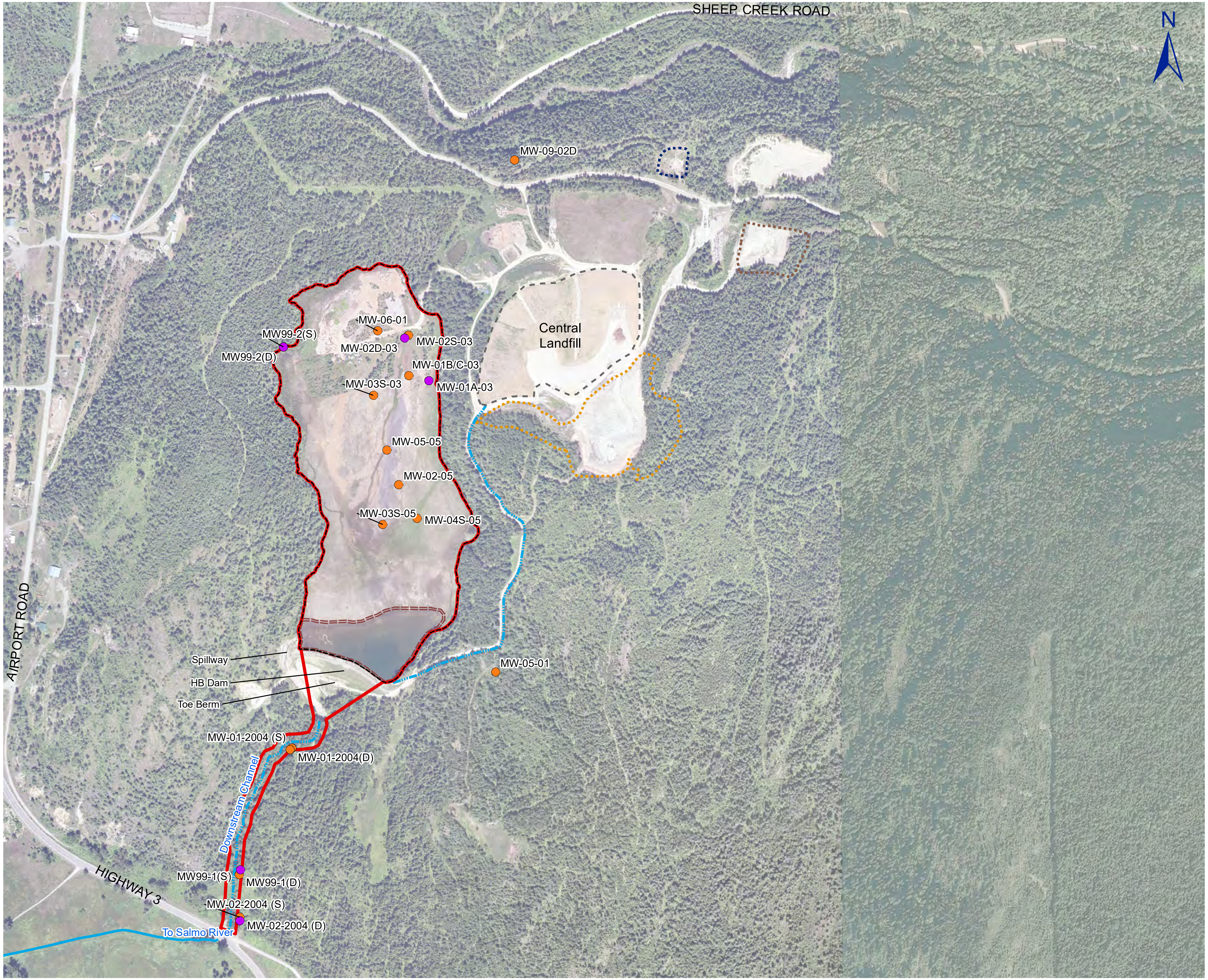

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NOTES:

LEGEND

- BEDROCK GROUNDWATER SAMPLE
- OVERBURDEN GROUNDWATER SAMPLE
- SITE BOUNDARY
- TAILINGS DEPOSITION AREA
- TAILINGS POND
- LANDFILL SAND AND GRAVEL BORROW
- NORTH SAND AND GRAVEL BORROW
- BORROW PIT
- WATERCOURSE
- EPHEMERAL WATERCOURSE

0 125 250 500 Meters

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REGIONAL DISTRICT OF CENTRAL KOOTENAY
HB MINE TAILINGS MANAGEMENT FACILITY
SALMO, BC

PROSPECTIVE HUMAN HEALTH
AND ECOLOGICAL RISK ASSESSMENT

GROUNDWATER SAMPLE LOCATIONS

Date:	May 28, 2019	Drawing No. 6
Project No.	204.03242.00004	

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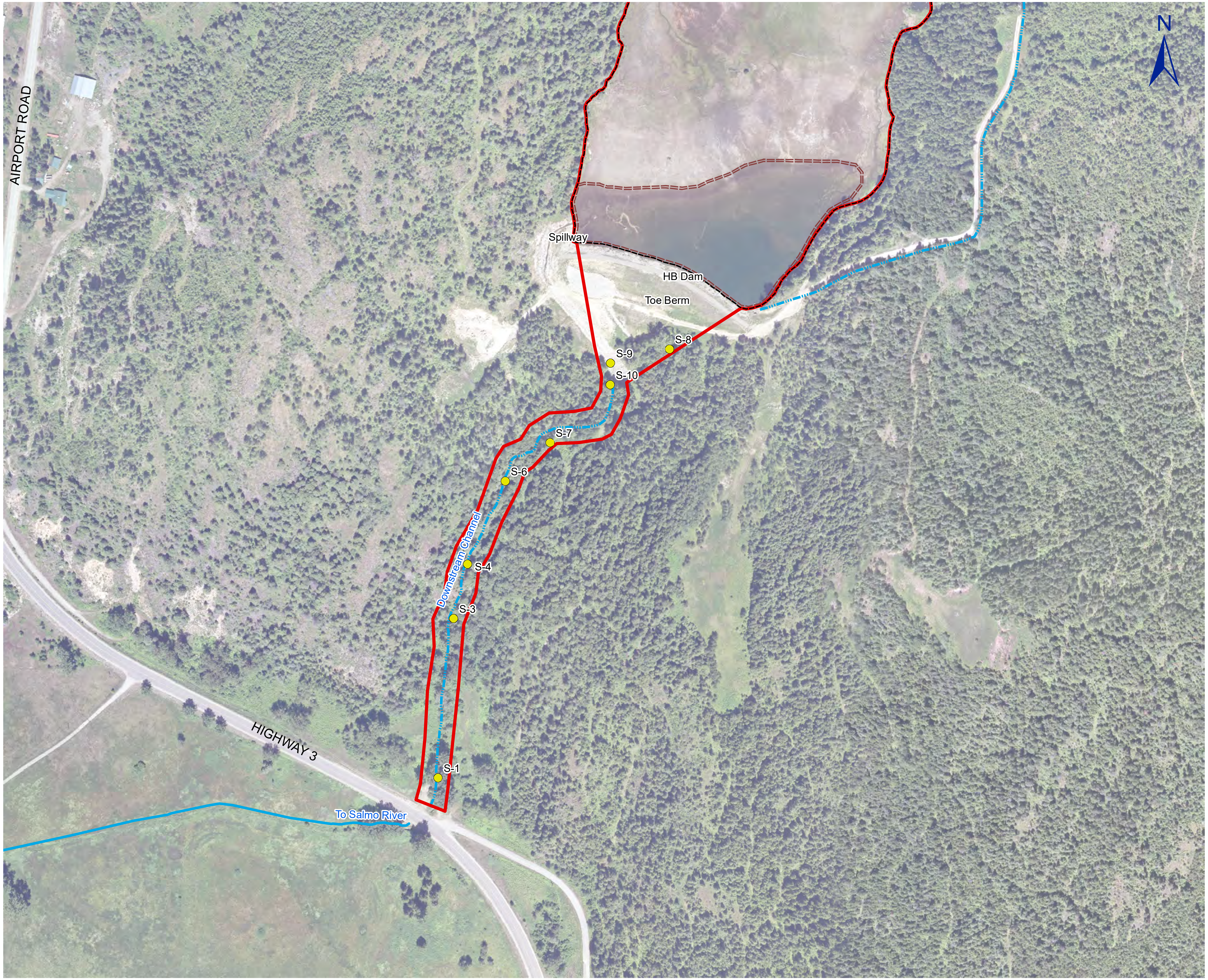

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NOTES:

LEGEND

- SEDIMENT SAMPLE
- SITE BOUNDARY
- TAILINGS DEPOSITION AREA
- TAILINGS POND
- FeaturesWater
- WATERCOURSE
- EPHEMERAL WATERCOURSE

0 62.5 125 250 Meters

1:4,000

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NAD 1983 UTM Zone 10 U

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REGIONAL DISTRICT OF CENTRAL KOOTENAY
HB MINE TAILINGS MANAGEMENT FACILITY
SALMO, BC

PROSPECTIVE HUMAN HEALTH
AND ECOLOGICAL RISK ASSESSMENT

SEDIMENT SAMPLE LOCATIONS

Date: May 28, 2019	Drawing No. 7
Project No. 204.03242.00004	

SLR
global environmental solutions

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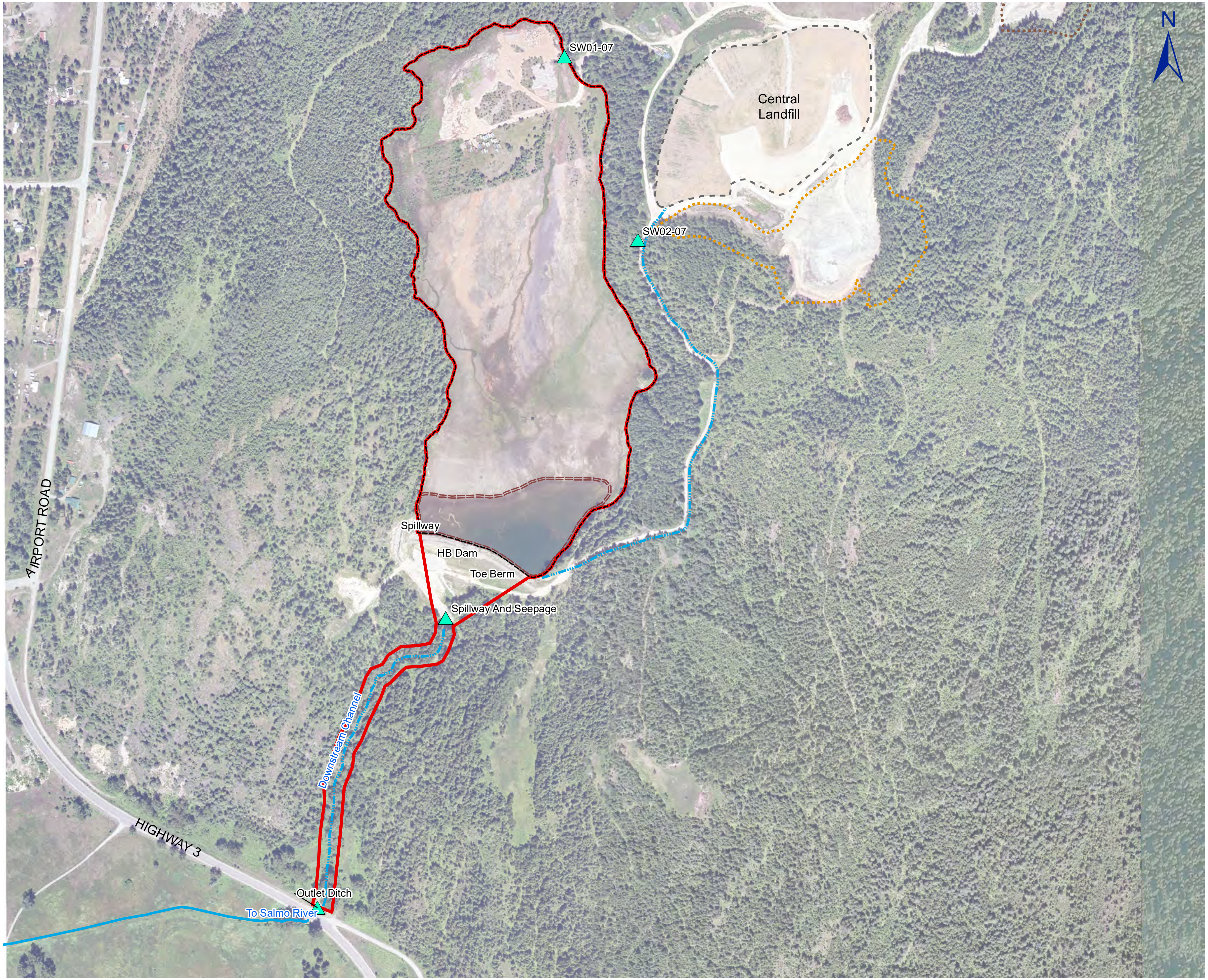

NOTES:

LEGEND

- SURFACE WATER SAMPLE
- SITE BOUNDARY
- TAILINGS DEPOSITION AREA
- TAILINGS POND
- LANDFILL SAND AND GRAVEL BORROW AREA
- NORTH SAND AND GRAVEL BORROW AREA
- BORROW PIT
- WATERCOURSE
- EPHEMERAL WATERCOURSE

0 90 180 360 Meters

1:6,000

WHEN PLOTTED CORRECTLY AT 11 x 17 PAGE SIZE
NAD 1983 UTM Zone 10 U

THIS DRAWING IS FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY AND NOT ALL STRUCTURES ARE SHOWN.

REGIONAL DISTRICT OF CENTRAL KOOTENAY
HB MINE TAILINGS MANAGEMENT FACILITY
SALMO, BC

PROSPECTIVE CONTAMINANT HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

SURFACE WATER SAMPLE LOCATIONS

Date: May 28, 2019	Drawing No. 8
Project No. 204.03242.00004	

SLR
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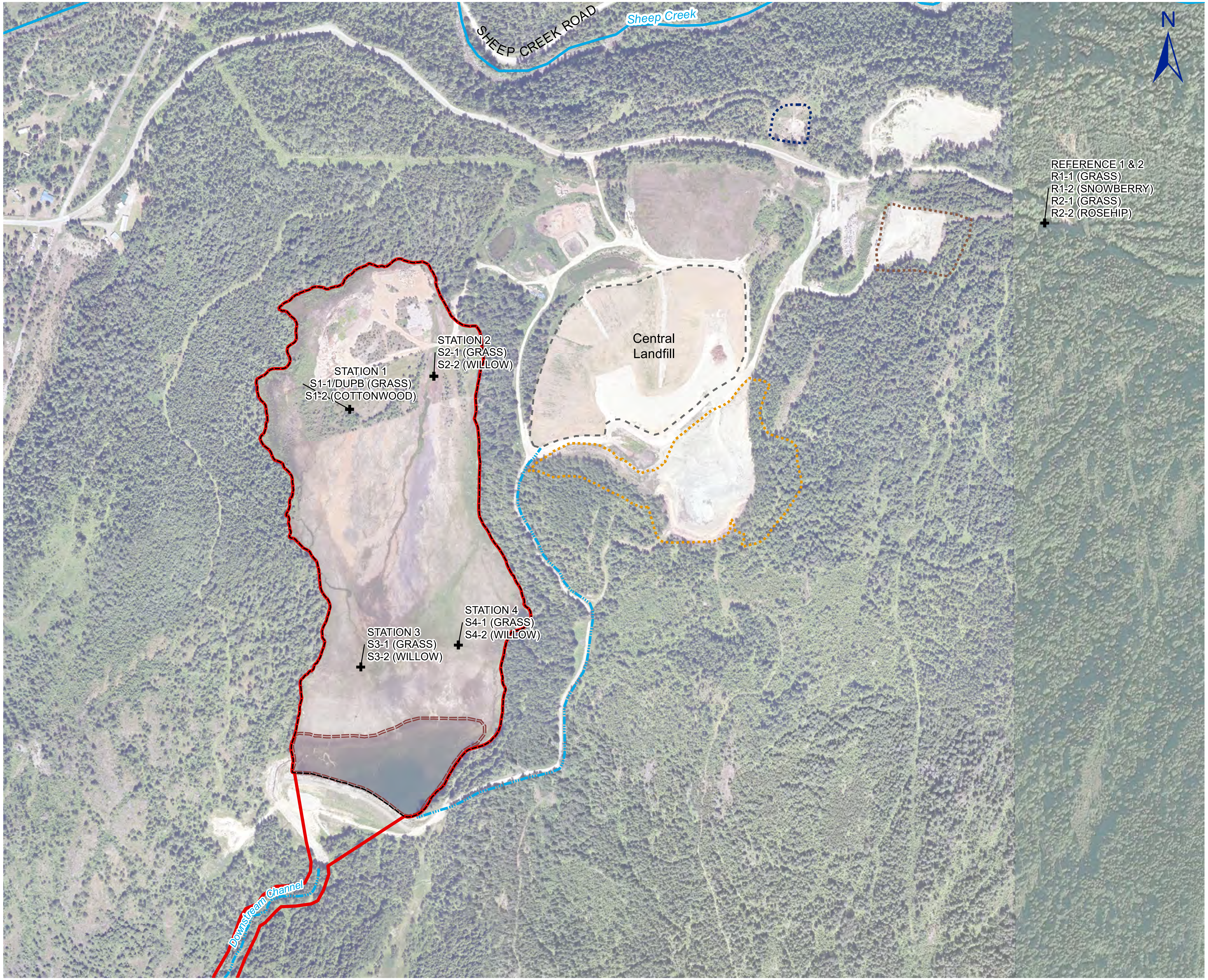

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NOTES:

LEGEND

- ✚ TISSUE SAMPLE
- SITE BOUNDARY
- TAILINGS DEPOSITION AREA
- TAILINGS POND
- LANDFILL SAND AND GRAVEL BORROW AREA
- NORTH SAND AND GRAVEL BORROW AREA
- BORROW PIT
- WATERCOURSE
- EPHEMERAL WATERCOURSE

0 95 190 380 Meters

1:6,000

WHEN PLOTTED CORRECTLY AT 11 x 17 PAGE SIZE
NAD 1983 UTM Zone 11 U

THIS DRAWING IS FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY AND NOT ALL STRUCTURES ARE SHOWN.

REGIONAL DISTRICT OF CENTRAL KOOTENAY
HB MINE TAILINGS MANAGEMENT FACILITY
SALMO, BC

PROSPECTIVE HUMAN HEALTH
AND ECOLOGICAL RISK ASSESSMENT

VEGETATION TISSUE SAMPLE LOCATIONS

Date: May 28, 2019	Drawing No. 9
Project No. 204.03242.00004	

SLR
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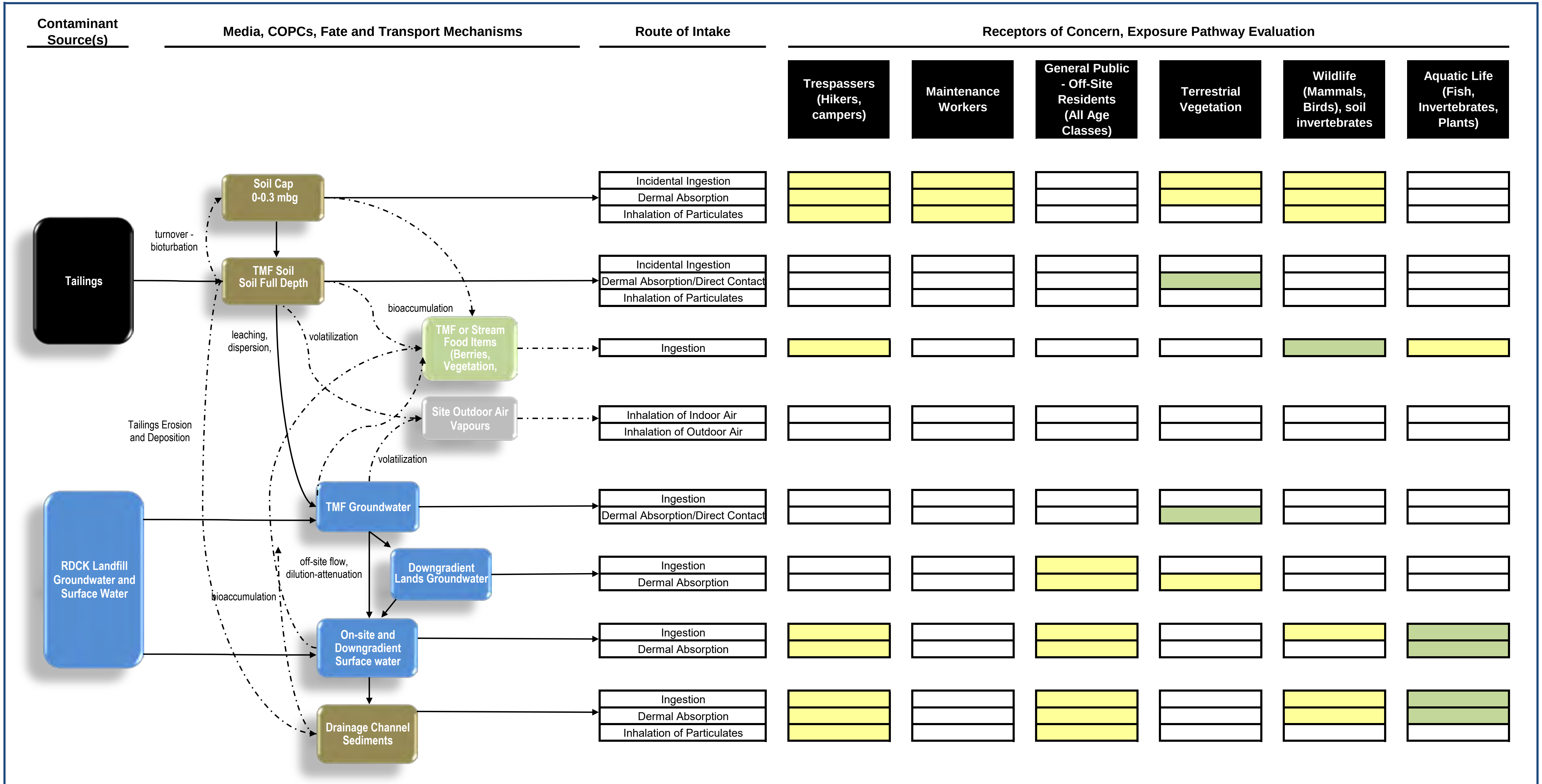

Exposure Pathway Evaluation Legend:

Exposure pathway is potentially complete, quantitative assessment is recommended

Exposure pathway is potentially complete but insignificant (no final COPCs, or infrequent exposure/low dose), quantitative assessment is not recommended

Exposure pathway is incomplete, quantitative assessment is not necessary

Complete transport mechanism

Incomplete transport mechanism

HB MINE TAILINGS MANAGEMENT FACILITY, SALMO, BC	
PROSPECTIVE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT	
CHART-TYPE CONCEPTUAL SITE MODEL	Drawing No. **10**
May 2019	SLR Project No.: 204.03242.00000

SLR

PHOTOGRAPHS

Regional District of Central Kootenay
Prospective Human Health and Ecological Risk Assessment
HB Mine Tailings Management Facility
SLR Project No.: 204.03242.00004

Photo 1: Tailings Deposition Area Looking North (1)

Photo 2: Tailings Deposition Area Looking North (2)

Photo 3: Downstream Drainage Channel (Dry)

Photo 4: Downstream Drainage Channel (Wet)

APPENDIX A
TSF Datasets

Regional District of Central Kootenay
Prospective Human Health and Ecological Risk Assessment
HB Mine Tailings Management Facility
SLR Project No.: 204.03242.00004

TABLE 1: VEGETATION ANALYTICAL RESULTS - METALS PARAMETERS (mg/kg ww)

Sample ID	S1-1	DUP B	S1-2	S2-1	S2-2	S3-1	S3-2	S4-1	S4-2	REF1-1	REF1-2	REF2-1	REF2-2
Vegetation	**Grass**	**Grass**	**Cottonwood**	**Grass**	**Willow**	**Grass**	**Willow**	**Grass**	**Willow**	**Grass**	**Snowberry**	**Grass**	**Rosehip**
Date	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**
Moisture %	77	76	65	72	69	71	67	76	68	78	69	78	64
Aluminum	0.79	1.39	2.59	2.37	4.98	0.53	2.76	0.43	4.66	1.00	11.7	0.88	5.48
Antimony	0.0020	0.0019	0.0037	0.0025	0.0027	0.0020	0.0023	<0.0012	0.0036	<0.0011	0.0020	0.0014	0.0046
Arsenic	0.020	0.047	0.054	<0.014	<0.015	0.049	0.044	0.034	0.100	<0.011	<0.015	<0.011	<0.018
Barium	0.382	2.13	0.969	2.94	7.67	1.28	0.273	1.98	0.517	0.852	11.9	0.679	11.3
Beryllium	<0.023	<0.024	<0.035	<0.028	<0.031	<0.029	<0.033	<0.024	<0.032	<0.022	<0.031	<0.023	<0.036
Bismuth	<0.023	<0.024	<0.035	<0.028	<0.031	<0.029	<0.033	<0.024	<0.032	<0.022	<0.031	<0.023	<0.036
Boron	2.17	1.10	6.77	1.47	13.0	1.01	7.27	1.20	11.9	1.28	5.19	1.11	6.78
Cadmium	0.0783	0.0151	5.99	1.20	4.34	0.0271	1.24	0.0127	8.02	0.0099	0.0271	0.0089	0.0515
Calcium	1920	599	2910	1590	3280	1010	3070	576	3020	803	3110	679	4670
Chromium (total)	0.129	0.203	<0.070	0.203	<0.062	0.318	<0.065	0.281	<0.064	0.110	0.073	0.161	<0.072
Cobalt	0.0119	0.0054	0.0461	0.0094	0.0137	0.0194	0.0456	0.0056	0.0599	<0.0044	0.0111	<0.0045	0.0106
Copper	1.19	1.87	2.83	1.02	1.33	3.60	2.47	1.93	4.22	1.98	1.60	2.41	1.86
Iron	19.4	10.6	19.2	13.8	21.0	16.9	24.7	8.8	27.9	12.3	20.3	9.7	18.9
Lead	0.213	0.240	0.403	0.685	0.573	0.135	0.262	0.153	0.295	0.0457	0.103	0.103	0.126
Magnesium	549	295	635	683	784	356	1040	296	1410	270	494	254	1080
Manganese	13.8	15.5	11.2	15.7	5.68	22.2	10.7	15.4	17.7	5.81	84.9	6.18	34.6
Mercury	<0.0023	<0.0024	<0.0035	<0.0028	<0.0031	<0.0029	<0.0033	<0.0024	<0.0032	<0.0022	0.0039	<0.0023	<0.0036
Molybdenum	0.235	0.068	0.056	0.677	0.107	0.118	0.038	0.057	0.020	0.945	0.102	0.889	0.749
Nickel	0.331	0.198	0.324	0.400	0.208	0.534	0.126	0.251	0.188	0.120	0.270	0.132	0.149
Phosphorus	269	297	404	350	612	305	582	371	576	713	696	704	1330
Potassium	4570	5230	2400	4620	2080	7030	3430	6610	2820	7040	3210	7280	4300
Selenium	<0.011	<0.012	0.021	<0.014	<0.015	0.018	<0.016	<0.012	0.017	<0.011	<0.015	<0.011	<0.018
Silver	<0.0045	<0.0049	0.0105	0.0056	<0.0062	0.0129	<0.0065	<0.0049	<0.0064	<0.0044	<0.0061	<0.0045	<0.0072
Sodium	3.3	<2.4	4.0	9.2	<3.1	3.0	3.7	<2.4	<3.2	<2.2	<3.1	<2.3	<3.6
Strontium	3.88	1.85	7.71	5.23	8.58	2.82	9.24	1.82	8.26	1.85	15.3	1.73	15.4
Thallium	0.0216	0.0267	0.0152	0.0326	0.193	0.00800	0.0357	0.0226	0.0524	<0.00044	<0.00061	<0.00045	<0.00072
Tin	0.073	<0.024	0.039	0.037	0.032	0.033	0.034	<0.024	0.036	0.073	0.166	0.026	0.064
Titanium	<0.23	<0.24	<0.35	<0.28	0.39	<0.29	<0.33	<0.24	<0.32	<0.22	0.68	<0.23	<0.36
Uranium	0.00280	0.00140	0.00400	0.00450	0.00790	0.00130	0.00160	<0.00049	0.00210	<0.00044	0.00130	<0.00045	<0.00072
Vanadium	<0.045	<0.049	<0.070	<0.056	<0.062	<0.059	<0.065	<0.049	<0.064	<0.044	<0.061	<0.045	<0.072
Zinc	25.6	46.4	123	201	334	51.6	159	50.6	157	8.27	11.7	8.57	10.4

Notes:
m - metres
REF - referece area samples collected from outsite tailings area
mg/kg - milligrams per wet kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed

TABLE 2: - FIELD MEASUREMENTS

							Field						Physical Parameters					Carbon		Metals																							
Site Area	Location Type	Sample Location	Sample Date	Sample ID	SampleComments	Matrix Type	temp (field)	pH (field)	EC (field)	Oxidation-Reduction Potential (field)	DO (field)	turbidity	alkalinity (bicarbonate as CaCO3)	alkalinity (carbonate as CaCO3)	alkalinity (hydroxide) as CaCO3	alkalinity (total) as CaCO3	Electrical Conductivity (lab)	Total Organic Carbon	Total Inorganic Carbon	hardness as CaCO3	pH (lab)	aluminum (Filtered)	antimony (Filtered)	arsenic (Filtered)	barium (Filtered)	beryllium (Filtered)	bismuth (Filtered)	boron (Filtered)	cadmium (Filtered)	calcium (Filtered)	cesium (Filtered)	chromium (III+VI) (Filtered)	cobalt (Filtered)	copper (Filtered)	iron (Filtered)	lead (Filtered)	lithium (Filtered)	magnesium (Filtered)	manganese (Filtered)	mercury	mercury (Filtered)	molybdenum (Filtered)	nickel (Filtered)
							oC	pH_Units	µS/cm	mV	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	pH_Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BC CSR DW																						9500	6	10	1000	8		5000	5			50	20[#1]	1500	6500	10	8		1500	1	1	250	80
BC CSR AWF																							90	50	10000	1.5		12000	0.5 - 4 *			10	40	20 - 90 *		40 - 160 *				0.25	0.25	10000	250 - 1500 *
BC CSR IW																						5000		100		100		500 - 6000 *	5			5	50	200	5000	200	2500		200	1	1	10[#3]	200
BC CSR LW																						5000		25		100		5000	80	1000		50	1000	300		100	5000			2	2	50	1000
Downgradient	Bedrock	MW-01-2004(D)	2016-Apr-28	E303723	Downgradient Bedrock	groundwater	6.9	8.07	319.3	-	-	6.87	-	-	-	151	494	0.66	35.4	257	8.15	<5	<0.5	1.01	111	<1	-	<100	0.0052	79.2	-	<1	<0.3	<1	<30	<0.5	3.1	14.5	13	-	<0.005	1.7	<1
			2017-May-15				7.2	7.7	319.8	-	-	5.46	-	-	-	149	478	0.77	34.4	221	8.15	<5	<0.5	1	121	<0.1	-	<100	0.0077	66.9	-	<1	<0.3	<1	<30	<0.5	4.9	13.1	3.84	-	<0.005	1.8	<1
			2018-May-17				7.7	7.3	338	-	-	3.47	147	8.2	<1	156	456,000	0.69	-	225	8.43	2.3	<0.1	0.86	117	<0.1	<0.05	<10	0.009	68.2	0.107	<0.1	<0.1	1.05	16	0.1	**8.2**	13.2	2.85	-	<0.005	1.85	<0.5
		MW-02-2004(D)	2016-Apr-27	E303725	Downgradient Bedrock	groundwater	8.1	7.7	300.8	-	-	0.22	-	-	-	191	452	0.6	46.4	185	8.02	<5	<0.5	<0.5	64	<1	-	<100	0.029	59.6	-	<1	0.31	<1	<30	<0.5	**27.3**	8.67	**752**	-	<0.005	1.7	1.1
			2017-May-11				8.2	7.49	304.5	-	-	2.65	-	-	-	187	432	0.6	37.2	175	8.09	<5	<0.5	<0.5	54	<0.1	-	<100	0.0206	55.8	-	<1	<0.3	<1	<30	<0.5	**27.2**	8.72	151	-	<0.005	1.8	<1
			2018-May-16				11.6	7.67	358.6	-	-	2.52	188	9.6	<1	198	440,000	0.66	-	168	8.43	1.4	0.22	0.42	50.1	<0.1	<0.05	29	<0.005	53.2	0.028	0.5	<0.1	0.71	16	<0.05	**35.3**	8.47	0.82	-	<0.005	1.59	<0.5
		MW99-1(D)	2016-Apr-27	E240501	Downgradient Bedrock	groundwater	7.2	7.72	534	-	-	5.15	-	-	-	403	826	0.96	95.7	184	8.12	<5	<0.5	<0.5	70	<1	-	160	0.0143	52.4	-	<1	<0.3	<1	<30	<0.5	**247**	12.8	2.77	-	<0.005	<1	<1
			2017-May-11				9.7	7.42	578	-	-	2.09	-	-	-	402	791	<0.5	80.9	180	8.1	<5	<0.5	<0.5	73	<0.1	-	160	0.0254	50.7	-	<1	<0.3	<1	<30	<0.5	**240**	13	76.6	-	<0.005	<1	<1
			2018-May-16				8.7	7.59	564	-	-	4.43	343	14	<1	357	702,000	0.51	-	176	8.43	<1	<0.1	0.41	73.5	<0.1	<0.05	143	0.009	49.2	4.09	0.12	<0.1	0.31	23	<0.05	**228**	12.9	127	-	<0.005	0.52	0.58
		MW99-2(D)	2016-Apr-25	E240502	Background Bedrock	groundwater	9.9	7.55	461.5	-	-	4.1	-	-	-	301	661	<0.5	76	363	7.89	<5	<0.5	<0.5	55	<1	-	<100	0.0077	86.1	-	<1	<0.3	<1	711	<0.5	6.5	36	152	-	<0.005	<1	<1
			2017-May-10				10.2	7.44	465.5	-	-	5.35	-	-	-	286	627	0.55	60.2	337	8	<5	<0.5	<0.5	53	<0.1	-	<100	0.006	80.5	-	<1	<0.3	<1	826	<0.5	7	33.1	126	-	<0.005	<1	<1
			2018-May-14				13.9	7.41	514	-	-	7.39	-	-	-	282	624,000	0.61	74.1	366	8.36	<1	<0.1	0.35	61.1	<0.1	<0.05	<10	0.0105	86.4	0.969	<0.1	0.25	0.29	764	<0.05	7.1	36.6	133	-	<0.005	0.362	0.72
	Overburden	MW-01-2004(S)	2016-Apr-28	E303722	Downgradient Overburden	groundwater	5.9	7.03	115.9	-	-	44.8	-	-	-	96.1	184	1.83	25.3	83.3	7.39	<5	<0.5	1.35	<20	<1	-	<100	0.311	23.9	-	<1	<0.3	<1	<30	<0.5	<1	5.73	**3880**	-	<0.005	6.6	<1
			2017-May-15				5.6	6.97	123.2	-	-	51.2	-	-	-	99.5	195	2.87	26.9	85.9	7.5	<5	<0.5	1.49	<20	<0.1	-	<100	0.306	25	-	<1	<0.3	<1	<30	<0.5	<1	5.73	**4000**	-	<0.005	6.7	<1
			2018-May-17				7.6	7.07	125.5	-	-	8.89	105	<1	<1	105	180,000	1.22	-	82.1	8.19	2.6	<0.1	0.84	13.4	<0.1	<0.05	<10	0.239	23.6	<0.01	<0.1	0.23	0.88	<10	0.053	<1	5.61	**4510**	-	<0.005	8.22	<0.5
		MW-02-2004(S)	2016-Apr-27	E303724	Downgradient Overburden	groundwater	11.2	7.11	272.6	-	-	0.63	-	-	-	82.6	380	1.5	22.1	183	7.45	<5	0.94	<0.5	34	<1	-	<100	0.0431	55.2	-	<1	<0.3	1.1	<30	<0.5	<1	11	0.23	-	<0.005	1.3	<1
			2017-May-11				7.1	7.11	226	-	-	0.77	-	-	-	80.2	332	1.26	20.6	158	7.6	<5	0.81	<0.5	28	<0.1	-	<100	0.0346	46.4	-	<1	<0.3	<1	<30	<0.5	<1	10.1	0.35	-	<0.005	1.5	<1
			2018-May-16	E303724	Downgradient Overburden	groundwater	7.6	7.27	253	-	-	9.63	76.2	<1	<1	76.2	351,000	1.08	-	176	8.2	1.9	0.47	0.15	32.2	<0.1	<0.05	16	0.0472	52	<0.01	0.12	<0.1	0.65	<10	<0.05	<1	11.3	1.74	-	<0.005	0.885	<0.5
				DUPLICATE-1 (GW)			-	-	-	-	-	-	75	<1	<1	75	359,000	1.05	-	177	8.18	1.5	0.49	0.14	32	<0.1	<0.05	18	0.0395	52.4	<0.01	0.14	<0.1	0.68	<10	<0.05	<1	11.3	1.6	-	<0.005	0.904	<0.5
		MW99-1(S)	2016-Apr-27	E275563	Downgradient Overburden	groundwater	9.4	7.05	173.6	-	-	49.8	-	-	-	94.8	236	1.69	25.8	115	7.45	<5	<0.5	<0.5	56	<1	-	<100	0.0054	33.8	-	<1	<0.3	<1	4630	<0.5	**17.2**	7.45	**215**	-	<0.005	<1	1.5
			2017-May-11	E275563	Downgradient Overburden	groundwater	8.3	7.06	169	-	-	>201	-	-	-	85.7	231	3.61	28.8	109	7.29	<5	<0.5	<0.5	62	<0.1	-	<100	0.0054	31.7	-	<1	<0.3	<1	2210	<0.5	**17.9**	7.13	**242**	-	<0.005	<1	<1
				GW DUPLICATE-2			-	-	-	-	-	-	-	-	-	86	229	3.51	25.1	109	7.34	<5	<0.5	<0.5	62	<0.1	-	<100	0.0055	31.6	-	<1	<0.3	<1	2160	<0.5	**17.2**	7.28	**239**	-	<0.005	<1	<1
			2018-May-16	E275563	Downgradient Overburden	groundwater	8.4	7.52	188.7	-	-	136	85.7	<1	<1	85.7	261,000	1.85	-	123	8.09	<1	<0.1	0.16	56.9	<0.1	<0.05	19	0.0053	35.8	<0.01	<0.1	0.19	0.31	205	<0.05	**9.3**	8.23	152	-	<0.005	0.417	<0.5
		MW99-2(S)	2016-Apr-25	E275543	Shallow Bedrock	groundwater	7.8	6.62	392.4	-	-	0.34	-	-	-	116	586	2.09	33.4	313	6.89	<5	<0.5	6.51	45	<1	-	<100	0.0188	96.5	-	<1	8.33	<1	4060	<0.5	1.3	17.5	**2450**	-	<0.005	<1	6.8
			2017-May-10				6.9	6.78	306.7	-	-	0.72	-	-	-	112	458	2.26	28.2	227	7.35	<5	<0.5	6.39	33	<0.1	-	<100	0.0185	70.4	-	<1	6.89	<1	3030	<0.5	1.5	12.3	**2120**	-	<0.005	<1	5.9
			2018-May-14				10.5	6.85	421	-	-	0.75	-	-	-	108	566,000	2.35	35.9	301	7.83	2.1	<0.1	6.47	46.3	<0.1	<0.05	<10	0.0267	93.3	0.078	<0.1	9.49	0.5	3730	0.108	1.4	16.6	**2310**	-	<0.005	0.423	7.99
Tailings Area	Bedrock	MW-01A-03	2016-Apr-20	E254757	SOUTHERN CAZ	groundwater	16.7	7.86	417.7	-	-	1.26	-	-	-	176	502	<0.5	42.3	165	8.1	<5	<0.5	1.16	47	<1	-	120	0.0095	45.8	-	<1	<0.3	<1	<30	<0.5	**23.6**	12.2	0.82	<0.005	-	5.2	<1
			2017-May-8				10.9	7.55	359.8	67.9	2.6	1.33	-	-	-	179	483	0.6	35.1	140	8.22	<5	0.77	1.74	41	<0.1	-	<100	0.0129	39.4	-	<1	<0.3	<1	<30	<0.5	**24.3**	10.2	1.95	<0.005	-	5.5	<1
			2018-May-8	E254757	SOUTHERN CAZ	groundwater	-	-	-	-	-	-	-	-	-	175	457	<0.5	41.1	147	8.39	<1	0.16	1.92	43.9	<0.1	<0.05	100	0.0062	40.2	0.132	0.13	<0.1	0.32	<10	<0.05	**25.3**	11.3	1.87	-	<0.005	5.68	<0.5
				DUPLICATE-2 (DUP-GW-2)			-	-	-	-	-	-	-	-	-	174	453	<0.5	41.8	149	8.38	<2	0.15	1.95	43.2	<0.1	<0.05	101	<0.005	40.8	0.127	0.25	<0.1	0.31	<10	0.091	**25.6**	11.4	1.7	-	<0.005	5.59	<0.5
		MW-02D-03	2016-Apr-21	E254756	SOUTHERN CAZ	groundwater	11.9	7.25	684	-	-	13.7	-	-	-	390	837	4.33	102	427	7.4	<5	<0.5	**20**	260	<1	-	<100	<0.005	135	-	<1	<0.3	<1	**31,400**	<0.5	<1	21.9	**1550**	<0.005	-	<1	<1
			2017-May-9	E254756	SOUTHERN CAZ	groundwater	9.2	7.07	640	-165.9	0	1.86	-	-	-	393	819	4.7	88	367	7.71	<5	<0.5	**21.6**	251	<0.1	-	<100	<0.005	114	-	<1	<0.3	<1	**31,700**	<0.5	<1	20.1	**1440**	<0.005	-	<1	1
				MW-02D-03			9.2	7.07	640	-165.9	0	1.86	-	-	-	394	805	4.45	91.5	362	7.59	<5	<0.5	**19.9**	244	<0.1	-	<100	<0.005	114	-	<1	<0.3	<1	**31,000**	<0.5	<1	19	**1390**	<0.005	-	<1	1.1
			2018-May-15	E254756	SOUTHERN CAZ	groundwater	-	-	-	-	-	-	-	-	-	384	763	4.55	123	379	8.31	3.8	<0.1	**18**	248	<0.1	<0.05	28	0.0053	120	<0.01	0.23	0.1	<0.2	**29,600**	<0.05	<1	18.9	**1410**	-	<0.005	0.731	1.08
	Overburden	MW-01C-03	2016-Apr-21	E254759	SOUTHERN CAZ	groundwater	13.4	6.91	582	-	-	0.29	-	-	-	277	762	2.25	75.3	377	7.42	<5	<0.5	1.38	23	<1	-	<100	0.0511	129	-	<1	1.3	<1	277	<0.5	2.3	13.6	**3990**	<0.005	-	<1	2.6
			2017-May-8				9	6.74	571	7	0.1	0.99	-	-	-	290	811	2.8	69.4	371	7.71	<5	<0.5	1.43	24	<0.1	-	<100	0.0698	125	-	<1	1.4	<1	328	<0.5	1.9	13.9	**4170**	<0.005	-	<1	2.9
			2018-May-8				-	-	-	-	-	-	-	-	-	280	868	3.41	77.6	460	8.19	<1	<0.1	1.42	29.3	<0.1	<0.05	68	0.0826	156	<0.01	0.22	1.59	<0.2	356	0.237	2.3	17.3	**5430**	-	<0.005	0.244	3.52
		MW-02-05	2016-Apr-20	E266346	SOUTHERN CAZ	groundwater	9.8	8.83	249.1	-	-	20.4	-	-	-	188	355	3.27	43.5	185	8.46	<5	<0.5	6.02	**1280**	<1	-	<100	<0.005	5.98	-	<1	<0.3	<1	39	<0.5	**16.6**	41.3	26.9	<0.005	-	3.6	<1
			2017-May-9				9.4	8.66	243.4	-136.3	2	61.6	-	-	-	190	350	3.9	41.5	161	8.47	<5	<0.5	5.93	**1260**	<0.1	-	<100	0.0072	6.13	-	<1	<0.3	<1	<30	<0.5	**13.9**	35.3	23.9	<0.005	-	3.2	<1
			2018-May-10				-	-	-	-	-	-	-	-	-	201	338	3.98	47.5	168	8.53	4.4	0.28	6.39	**1430**	<0.1	<0.05	27	0.0059	6.61	0.49	<0.1	0.1	<0.2	15	0.261	**14.7**	36.7	22.6	-	<0.005	3.49	<0.5
		MW-02S-03	2016-Apr-21	E254755	SOUTHERN CAZ	groundwater	10.1	7	1222	-	-	1.03	-	-	-	346	1690	2.53	91.9	1030	7.16	<5	<0.5	9.98	25	<1	-	<100	0.0761	315	-	<1	4.5	<1	**13,500**	0.66	<1	58.5	**1510**	<0.005	-	<1	46.5
			2017-May-9				7.2	6.88	1162	-76.5	0	22.6	-	-	-	312	1700	3.6	80.7	976	7.42	<5	<0.5	7.28	<20	<0.1	-	<100	0.0842	303	-	<1	1.7	<1	**13,900**	<0.5	<1	53.1	**1360**	<0.005	-	<1	34
			2018-May-15				-	-	-	-	-	-	-	-	-	350	1650	2.85	99.9	939	8.13	1.2	<0.1	5.17	17.5	<0.1	<0.05	21	0.137	287	0.707	<0.1	2.09	<0.2	**12,800**	0.077	1.1	54.3	**1280**	-	<0.005	0.517	37
		MW-03S-03	2016-Apr-21	E254760	SOUTHERN CAZ	groundwater	11.6	8.52	972	-	-	0.64	-	-	-	49.8	1320	2.82	11.3	808	7.92	<5	<0.5	0.76	<20	<1	-	<100	<0.005	90.6	-	<1	<0.3	<1	395	<0.5	**11.3**	141	22	<0.005	-	<1	<1
			2017-May-9				9.9	8.22	870	-237.6	0	0.84	-	-	-	55.1	1210	2.8	13.6	670	7.86	<5	<0.5	0.76	<20	<0.1	-	<100	<0.005	73.7	-	<1	<0.3	<1	409	<0.5	**9.9**	118	18.8	<0.005	-	<1	<1
			2018-May-8				-	-	-	-	-	-	-	-	-	58.8	1060	2.99	25	633	7.83	<2	<0.1	0.86	12.5	<0.1	<0.05	36	<0.005	71.3	0.075	<0.1	<0.1	<0.2	372	<0.05	**9.6**	110	22.2	-	<0.005	0.776	<0.5
		MW-03S-05	2016-Apr-26	E266348	SOUTHERN CAZ	groundwater	9.1	8.2	233.7	-	-	18.2	-	-	-	167	339	5.04	42.7	89.1	8.11	<5	<0.5	**15.7**	238	<1	-	<100	<0.005	22.1	-	<1	<0.3	<1	395	<0.5	**8.7**	8.22	186	<0.005	-	**13.5**	<1
			2017-May-10				8.7	8	230.2	-166.5	1.2	>168	-	-	-	168	323	8.3	43.5	68.1	7.88	<5	0.85	**15.5**	176	<0.1	-	<100	<0.005	17.2	-	<1	<0.3	<1	<30	<0.5	**9.6**	6.1	139	<0.005	-	**20.2**	<1
			2018-May-15				-	-	-	-	-	-	-	-	-	168	329	5.14	42.4	75.7	8.26	2	<0.1	**14.2**	191	<0.1	<0.05	21	0.015	18.4	0.024	<0.1	<0.1	<0.2	222	0.451	**9.2**	7.2	151	-	<0.005	**16.9**	<0.5
		MW-04S-05	2016-Apr-20	E266349	SOUTHERN CAZ	groundwater	14.7	7.16	479.3	-	-	3.99	-	-	-	313	608	1.35	82.3	331	7.56	<5	<0.5	3.06	79	<1	-	<100	<0.005	108	-	<1	1.3	<1	1900	<0.5	<1	15.2	**2210**	<0.005	-	1.1	1.7
			2017-May-10				9.3	7.36	286.1	-56.9	1.6	5.28	-	-	-	191	396	1.7	37.8	209	8.04	<5	<0.5	3.54	46	<0.1	-	<100	0.0415	67	-	<1	1.1	<1	156	3.53	<1	10.1	**787**	<0.005	-	1.1	2.5
			2018-May-9				-	-	-	-	-	-	-	-	-	233	420	1.79	72	283	8.17	1.9	<0.1	3.2	73.3	<0.1	<0.05	<10	0.0227	91.9	<0.01	<0.1	1.13	0.22	1490	1.05	<1	13.1	**1710**	-	<0.005	1.19	1.82
		MW-05-05	2016-Apr-20	E266350	SOUTHERN CAZ	groundwater	10.5	9.12	282.2	-	-	26.3	-	-	-	98.3	398	4.33	21.2	150	8.52	<5	<0.5	3.31	195	<1	-	<100	0.0053	7.58	-	<1	0.7	<1	52	<0.5	**30.3**	31.8	21.9	<0.005	-	9.9	<1
			2017-May-9				9.7	9.01	281.4	-177.9	1.2	26.9	-	-	-	94.9	401	4.4	20.1	137	8.42	<5	<0.5	3.32	202	<0.1	-	<100	0.0142	7.53	-	<1	0.7	<1	53	0.51	**27.6**	28.7	19	<0.005	-	8.8	<1
			2018-May-10				-	-	-	-	-	-	-	-	-	99.7	399	3.8	24.2	136	8.17	4.2	<0.1	3.38	195	<0.1	<0.05	24	0.0229	7.91	0.638	<0.1	0.64	<0.2	66	0.85	**28.3**	28.1	17.7	-	<0.005	9.42	<0.5
		MW-06-01	2016-Apr-25	E252594	SOURCE CONCENTRATION	groundwater	8.8	6.97	2151	-	-	35.9	-	-	-	319	3080	12.9	87.1	1960	7.01	<5	<0.5	1.96	<20	<1	-	<100	1.44	554	-	<1	2.99	<1	**21,800**	1.24	6.9	141	**1040**	<0.005	-	<1	28.2
			2017-May-10	E252594	SOURCE CONCENTRATION	groundwater	8	6.8	1840	-85.2	0.1	34.7	-	-	-	263	2570	10.9	72.8	1760	7.34	<5	<0.5	2.37	<20	<0.2	-	200	1.24	555	-	<1	2.14	<1	**17,900**	1.86	5.3	91.5	**782**	<0.005	-	<1	16.4
				MW-06-01			8	6.8	1840	-85.2	0.1	34.7	-	-	-	268	2580	10.8	72.9	1760	7.47	<5	<0.5	2.59	<20	<0.2	-	200	1.37	539	-	<1	2.32	<1	**19,100**	1.9	4.9	101	**876**	<0.005	-	<1	17.3
			2018-May-15	E252594	Source Concentration	groundwater	9.3	7.4	2094	-	-	31.4	-	-	-	312	2,840,000	7.1	87.1	1810	8.01	2.6	<0.2	1.76	10.1	<0.2	<0.1	227	1.67	536	0.851	<0.2	4.76	<0.4	**18,000**	1.53	4.2	115	**977**	-	<0.005	0.45	36.2

TABLE 2: -
FIELD MEASUREMENTS

Site Area	Location Type	Sample Location	Sample Date	Sample ID	SampleComments	Matrix Type	Field: temp (field) (oC)	Field: pH (field) (pH_Units)	Field: EC (field) (µS/cm)	Field: Oxidation-Reduction Potential (field) (mV)	Field: DO (field) (mg/L)	Field: turbidity (NTU)	Physical Parameters: alkalinity (bicarbonate as CaCO3) (mg/L)	Physical Parameters: alkalinity (carbonate as CaCO3) (mg/L)	Physical Parameters: alkalinity (hydroxide) as CaCO3 (mg/L)	Physical Parameters: alkalinity (total) as CaCO3 (mg/L)	Physical Parameters: Electrical Conductivity (lab) (µS/cm)	Carbon: Total Organic Carbon (mg/L)	Carbon: Total Inorganic Carbon (mg/L)
Upgradient Reference			2016-Apr-26				6.8	7.43	158.2	-	-	1.08	-	-	-	122	248	<0.5	35.6
		MW-05-01	2017-May-10	E252593	Background Overburden	groundwater	5.9	7.14	154.3	-	-	5.37	-	-	-	121	238	0.79	25.4
			2018-May-14				7.4	7.34	159	-	-	1.7	-	-	-	117	238,000	<0.5	29.9
			2016-Apr-12				12.5	7.91	458.9	-	-	3.59	-	-	-	225	603	1.63	50.7
	Overburden	MW-09-02D	2017-May-2	E252600	NORTHERN CAZ	groundwater	10.2	7.6	484.7	-120.8	0.1	19.2	-	-	-	241	651	2.3	48.7
			2018-May-3				-	-	-	-	-	-	-	-	-	255	671	2.95	68.8
			2016-Apr-11				9	6.62	170.8	-	-	0	-	-	-	94	254	1.04	21.3
		MW-09-02S	2017-May-2	E252601	NORTHERN CAZ	groundwater	7.4	6.5	154.2	124.5	9.6	0.49	-	-	-	85	230	1	22
			2018-May-3				-	-	-	-	-	-	-	-	-	97.1	232	0.71	28.1
Statistical Summary																			
Number of Results							54	54	54	14	14	54	7	7	7	68	68	68	61
Number of Detects							54	54	54	14	14	54	7	3	0	68	68	61	61
Minimum Concentration							5.6	6.5	115.9	-237.6	0	0	75	<1	<1	49.8	184	<0.5	11.3
Minimum Detect							5.6	6.5	115.9	ND	0.1	0.22	75	8.2	ND	49.8	184	0.51	11.3
Maximum Concentration							16.7	9.12	2151	124.5	9.6	201	343	14	<1	403	2840000	12.9	123
Maximum Detect							16.7	9.12	2151	124.5	9.6	201	343	14	ND	403	2840000	12.9	123
Average Concentration							9.2	7.4	517	-91	1.3	20	146	5.1	1	195	103776	2.7	51
Median Concentration							9.05	7.35	348.3	-103	0.1	4.79	105	1	1	175.5	605.5	1.97	42.3
Standard Deviation							2.2	0.61	485	101	2.5	40	96	5.4	0	104	373500	2.6	27
Number of Guideline Exceedances							0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)							0	0	0	0	0	0	0	0	0	0	0	0	0

Sample Location / Guideline	Sample Date	Metals: hardness as CaCO3 (mg/L)	pH (lab) (pH_Units)	aluminum (Filtered) (µg/L)	antimony (Filtered) (µg/L)	arsenic (Filtered) (µg/L)	barium (Filtered) (µg/L)	beryllium (Filtered) (µg/L)	bismuth (Filtered) (µg/L)
BC CSR DW				**9500**	**6**	**10**	**1000**	**8**	
BC CSR AWF					**90**	**50**	**10000**	**1.5**	
BC CSR IW				**5000**		**100**		**100**	
BC CSR LW				**5000**		**25**		**100**	
MW-05-01	2016-Apr-26	129	7.73	<5	<0.5	<0.5	21	<1	-
MW-05-01	2017-May-10	116	7.8	20.5	<0.5	<0.5	<20	<0.1	-
MW-05-01	2018-May-14	127	8.19	2.4	<0.1	0.3	20.4	<0.1	<0.05
MW-09-02D	2016-Apr-12	313	8.23	<5	<0.5	3	89	<1	-
MW-09-02D	2017-May-2	329	8.21	<5	<0.5	3.39	97	<0.1	-
MW-09-02D	2018-May-3	330	8.26	14.5	0.19	2.7	121	<0.1	<0.05
MW-09-02S	2016-Apr-11	115	7.12	<5	<0.5	<0.5	68	<1	-
MW-09-02S	2017-May-2	101	7.59	<5	<0.5	<0.5	59	<0.1	-
MW-09-02S	2018-May-3	97.6	8.17	<1	<0.1	0.11	58.8	<0.1	<0.05
Number of Results		68	68	68	68	68	68	68	23
Number of Detects		68	68	16	11	53	59	0	0
Minimum Concentration		68.1	6.89	<1	<0.1	0.11	10.1	<0.1	<0.05
Minimum Detect		68.1	6.89	1.2	0.15	0.11	10.1	ND	ND
Maximum Concentration		1960	8.53	20.5	0.94	21.6	1430	<1	<0.1
Maximum Detect		1960	8.53	20.5	0.94	21.6	1430	ND	ND
Average Concentration		359	7.9	4.4	0.4	3.7	129	0.38	0.052
Median Concentration		184.5	8.065	5	0.5	1.425	54.5	0.1	0.05
Standard Deviation		425	0.42	2.8	0.21	5.3	268	0.42	0.01
Number of Guideline Exceedances		0	0	0	0	7	3	0	0
Number of Guideline Exceedances(Detects Only)		0	0	0	0	7	3	0	0

Sample Location / Guideline	Sample Date	boron (Filtered) (µg/L)	cadmium (Filtered) (µg/L)	calcium (Filtered) (mg/L)	cesium (Filtered) (µg/L)	chromium (III+VI) (Filtered) (µg/L)	cobalt (Filtered) (µg/L)	copper (Filtered) (µg/L)	iron (Filtered) (µg/L)	lead (Filtered) (µg/L)	lithium (Filtered) (µg/L)	magnesium (Filtered) (mg/L)	manganese (Filtered) (µg/L)	mercury (µg/L)	mercury (Filtered) (µg/L)	molybdenum (Filtered) (µg/L)	nickel (Filtered) (µg/L)
BC CSR DW		**5000**	**5**			**50**	**20**[#1]	**1500**	**6500**	**10**	**8**		**1500**	**1**	**1**	**250**	**80**
BC CSR AWF		**12000**	**0.5 - 4 ***			**10**	**40**	**20 - 90 ***		**40 - 160 ***				**0.25**	**0.25**	**10000**	**250 - 1500 ***
BC CSR IW		**500 - 6000 ***	**5**			**5**	**50**	**200**	**5000**	**200**	**2500**		**200**	**1**	**1**	**10**[#3]	**200**
BC CSR LW		**5000**	**80**	**1000**		**50**	**1000**	**300**		**100**	**5000**			**2**	**2**	**50**	**1000**
MW-05-01	2016-Apr-26	<100	0.0112	36.6	-	1.1	<0.3	<1	<30	<0.5	2.5	9.03	1.61	-	<0.005	<1	<1
MW-05-01	2017-May-10	<100	0.0117	32.9	-	<1	<0.3	<1	<30	<0.5	2.8	8.35	2.59	-	<0.005	<1	<1
MW-05-01	2018-May-14	<10	0.0073	36	<0.01	1.3	<0.1	<0.2	<10	0.101	2.6	9	2.06	-	<0.005	0.71	<0.5
MW-09-02D	2016-Apr-12	<100	<0.005	93.7	-	<1	<0.3	<1	57	<0.5	<1	19.3	**391**	<0.005	-	2.2	2.6
MW-09-02D	2017-May-2	<100	<0.005	95.8	-	<1	<0.3	<1	150	<0.5	1	21.8	**394**	<0.005	-	2	<1
MW-09-02D	2018-May-3	12	0.0147	93.8	<0.01	0.19	<0.1	0.35	70	<0.05	1	23.3	**352**	-	<0.005	1.99	1.25
MW-09-02S	2016-Apr-11	<100	0.168	36	-	<1	<0.3	<1	<30	<0.5	<1	6.19	0.46	<0.005	-	<1	<1
MW-09-02S	2017-May-2	<100	0.164	30.6	-	<1	<0.3	<1	<30	<0.5	<1	6	0.29	<0.005	-	<1	<1
MW-09-02S	2018-May-3	16	0.161	29.6	<0.01	<0.1	<0.1	0.2	<10	<0.05	<1	5.76	0.94	-	<0.005	0.108	0.78
Number of Results		68	68	68	23	68	68	68	68	68	68	68	68	26	42	68	68
Number of Detects		22	54	68	13	11	25	15	43	18	48	68	68	0	0	43	26
Minimum Concentration		<10	<0.005	5.98	<0.01	<0.1	<0.1	<0.2	<10	<0.05	<1	5.61	0.23	<0.005	<0.005	0.108	<0.5
Minimum Detect		12	0.0052	5.98	0.024	0.12	0.1	0.2	15	0.053	1	5.61	0.23	ND	ND	0.108	0.58
Maximum Concentration		227	1.67	555	4.09	1.3	9.49	1.1	31700	3.53	247	141	5430	<0.005	<0.005	20.2	46.5
Maximum Detect		227	1.67	555	4.09	1.3	9.49	1.1	31700	3.53	247	141	5430	ND	ND	20.2	46.5
Average Concentration		85	0.12	98	0.37	0.73	0.98	0.79	3978	0.51	18	28	815	0.005	0.005	2.8	4.4
Median Concentration		100	0.0123	55.5	0.028	1	0.3	1	68	0.5	4.55	13.15	151	0.005	0.005	1	1
Standard Deviation		48	0.34	128	0.87	0.41	1.8	0.33	8513	0.52	49	33	1294	0	0	3.9	9.7
Number of Guideline Exceedances		0	0	0	0	0	0	0	11	0	27	0	30	0	0	3	0
Number of Guideline Exceedances(Detects Only)		0	0	0	0	0	0	0	11	0	27	0	30	0	0	3	0

Standard/Guideline Descriptions

- BC CSR DW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Drinking Water
- BC CSR AWF:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Freshwater Aquatic Life
- BC CSR IW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Irrigation
- BC CSR LW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Livestock

Standard/Guideline Comments

#1:Interim background groundwater concentration estimate
#2:results with hardness >500 mg/L should be evaluated on a site by site basis; refer to BC Protocol 10
#3:Standard varies with crop type, soil drainage and Mo:Cu ratio.

TABLE 2: - FIELD MEASUREMENTS

Site Area	Location Type	Sample Location	Sample Date	Sample ID	SampleComments	Matrix Type	potassium (Filtered)	rubidium (Filtered)	selenium (Filtered)	silver (Filtered)	sodium (Filtered)	strontium (Filtered)	tellurium (Filtered)	thallium (Filtered)	thorium (Filtered)	tin (Filtered)	titanium (Filtered)	tungsten (Filtered)	uranium (Filtered)	vanadium (Filtered)	zinc (Filtered)	zirconium (Filtered)	ammonia as N	anions total	cations total	ionic balance	bromide	chloride	COD	fluoride	kjeldahl nitrogen total	nitrate (as N)	nitrite (as N)	phosphorus	phosphorus (Filtered)	silicon (Filtered)	sulfate	sulphide	sulphur as S (Filtered)
							Metals																Inorganics																
							µg/L	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	meq/L	meq/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
BC CSR DW									10	20	200	2500				2500		3	20	20	3000							250		1.5		10	1				500		
BC CSR AWF									20	0.5 - 15 *				3			1000		85		75#2 - 3150#2 *		1.31 - 18.5 *					1500		2 - 3 *		400	0.2 - 2 *				1280 - 4290 *		
BC CSR IW									20 - 50 *										10	100	1000 - 5000 *							100		1									
BC CSR LW									30										200	100	2000							600		1		100	10				1000		
Downgradient	Bedrock	MW-01-2004(D)	2016-Apr-28	E303723	Downgradient Bedrock	groundwater	2100	-	<0.05	<0.02	5.4	-	-	<0.2	-	<0.5	<10	-	1.99	<0.5	<5	-	<0.005	5.24	5.43	1.8	0.052	2.53	<20	-	<0.05	0.124	0.0023	0.111	-	-	103	<0.02	-
			2017-May-15				2000	-	<0.05	<0.05	5.9	-	-	<0.2	-	<0.5	<10	-	2.14	<0.5	<5	-	<0.005	5.18	4.73	-4.6	<0.05	2.75	<20	-	0.068	0.111	<0.001	0.0925	-	-	102	<0.018	-
			2018-May-17				2030	0.00085	<0.05	<0.01	8.04	328	<0.2	<0.01	<0.1	<0.1	<0.3	<0.1	2.05	<0.5	4.7	-	<0.005	-	-	-	-	2.84	<20	-	<0.05	0.102	<0.001	0.0559	<0.05	9	95.5	<0.018	31.1
		MW-02-2004(D)	2016-Apr-27	E303725	Downgradient Bedrock	groundwater	2800	-	<0.05	<0.02	26.4	-	-	<0.2	-	<0.5	<10	-	2.17	<0.5	<5	-	0.0451	4.83	4.94	1.1	0.398	3.59	<20	-	0.09	0.108	<0.001	0.0137	-	-	43.5	<0.02	-
			2017-May-11				3000	-	<0.05	<0.02	26.6	-	-	<0.2	-	<0.5	<10	-	2.37	<0.5	<5	-	0.0083	4.75	4.74	-0.1	0.396	3.55	<20	-	0.076	0.234	<0.001	0.0253	-	-	42.8	<0.018	-
			2018-May-16				2950	0.00192	<0.05	<0.01	37.3	607	<0.2	<0.01	<0.1	<0.1	<0.3	<0.1	2.33	<0.5	1.5	-	<0.005	-	-	-	-	5.11	<20	-	0.104	0.336	<0.001	0.0371	<0.05	6.93	41.7	<0.018	13.2
		MW99-1(D)	2016-Apr-27	E240501	Downgradient Bedrock	groundwater	4000	-	<0.05	<0.02	122	-	-	<0.2	-	<0.5	<10	-	0.56	<0.5	<5	-	0.0429	9.21	9.08	-0.7	<0.25	7.5	<20	-	0.133	1.3	<0.005	0.143	-	-	40.6	<0.02	-
			2017-May-11				4200	-	<0.05	<0.02	119	-	-	<0.2	-	<0.5	<10	-	0.63	<0.5	<5	-	0.993	9.09	8.95	-0.8	<0.25	7.4	<20	-	1.05	0.354	0.0058	0.116	-	-	39.2	<0.018	-
			2018-May-16				3950	0.0086	<0.05	<0.01	121	716	<0.2	<0.01	<0.1	<0.1	<0.3	0.62	0.671	<0.5	3.2	-	1.46	-	-	-	-	7.29	<20	-	1.36	0.149	0.0137	0.128	0.119	7.84	40.7	<0.018	13.3
		MW99-2(D)	2016-Apr-25	E240502	Background Bedrock	groundwater	<2000	-	<0.05	<0.02	8.5	-	-	<0.2	-	<0.5	<10	-	1.8	<0.5	6.1	-	0.0245	0.0075	0.00767	0.0011	<0.05	<0.5	<20	-	0.091	<0.005	<0.001	0.0411	-	-	71.7	<0.02	-
			2017-May-10				<2000	-	<0.05	<0.02	7.8	-	-	<0.2	-	<0.5	<10	-	2.11	<0.5	10.9	-	0.0165	7.17	7.13	-0.3	<0.05	<0.5	<20	-	<0.05	<0.005	<0.001	0.0339	-	-	70.5	<0.018	-
			2018-May-14				1230	0.0021	<0.05	<0.01	8.33	672	<0.2	<0.01	<0.1	<0.1	<0.3	0.1	2.18	<0.5	1.5	-	0.0276	7.12	7.73	4.1	<0.05	<0.5	<20	-	<0.05	<0.005	<0.001	0.0361	<0.05	10.7	70.9	<0.018	23.9
	Overburden	MW-01-2004(S)	2016-Apr-28	E303722	Downgradient Overburden	groundwater	<2000	-	0.065	<0.02	2.9	-	-	<0.2	-	<0.5	<10	-	0.9	1.17	<5	-	0.206	1.96	1.95	-0.2	<0.05	<0.5	<20	-	0.303	0.0085	<0.001	0.27	-	-	1.68	<0.02	-
			2017-May-15				<2000	-	<0.05	<0.02	2.9	-	-	<0.2	-	<0.5	<10	-	1.06	1.1	<5	-	0.365	2.03	2.02	-0.4	<0.05	<0.5	<20	-	0.534	0.0078	<0.001	1.25	-	-	2.08	<0.018	-
			2018-May-17				1050	0.00021	<0.05	<0.01	2.82	148	<0.2	<0.01	<0.1	<0.1	<0.3	<0.1	1.13	1.01	9.1	-	0.238	-	-	-	-	<0.5	<20	-	0.272	0.0061	<0.001	0.0678	<0.05	11.2	1.62	<0.018	0.54
		MW-02-2004(S)	2016-Apr-27	E303724	Downgradient Overburden	groundwater	2500	-	0.161	<0.02	4.6	-	-	<0.2	-	<0.5	<10	-	0.96	<0.5	<5	-	<0.005	3.76	3.93	2.2	<0.05	3.44	<20	-	0.077	0.057	<0.001	0.0069	-	-	96.5	<0.02	-
			2017-May-11				2100	-	0.159	<0.02	3.8	-	-	<0.2	-	<0.5	<10	-	1.18	<0.5	<5	-	<0.005	3.43	3.37	-0.9	<0.05	2.68	<20	-	0.065	0.0157	<0.001	0.0041	-	-	84	<0.018	-
			2018-May-16	E303724	Downgradient Overburden	groundwater	2010	0.00057	0.143	<0.01	3.45	190	<0.2	<0.01	<0.1	<0.1	<0.3	<0.1	0.826	<0.5	4.9	-	<0.005	-	-	-	-	1.87	<20	-	0.075	0.0869	<0.001	0.033	<0.05	4.84	104	<0.018	37.9
				DUPLICATE-1 (GW)			2040	0.00057	0.145	<0.01	3.43	190	<0.2	<0.01	<0.1	<0.1	<0.3	<0.1	0.87	<0.5	4.4	<0.06	<0.005	-	-	-	-	1.89	<20	-	<0.05	0.0913	<0.001	0.0323	<0.05	4.86	108	<0.018	35.8
		MW99-1(S)	2016-Apr-27	E275563	Downgradient Overburden	groundwater	<2000	-	<0.05	<0.02	4.2	-	-	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	-	0.372	2.43	2.77	6.4	<0.05	1.34	<20	-	0.448	0.0165	<0.001	3.19	-	-	24.1	<0.02	-
			2017-May-11	E275563	Downgradient Overburden	groundwater	<2000	-	<0.05	<0.02	4	-	-	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	-	0.188	2.47	2.48	0.2	<0.05	1.4	<20	-	0.325	0.066	0.0048	10.9	-	-	34.4	<0.018	-
				GW DUPLICATE-2			<2000	-	<0.05	<0.02	4	-	-	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	-	0.182	2.48	2.48	0.1	<0.05	1.4	<20	-	0.314	0.083	0.0054	9.74	-	-	34.4	<0.018	-
			2018-May-16	E275563	Downgradient Overburden	groundwater	1280	0.00039	0.081	<0.01	3.83	189	<0.2	<0.01	<0.1	<0.1	<0.3	0.19	0.11	<0.5	4.9	-	0.087	-	-	-	-	1.37	<20	-	0.161	0.0924	0.0039	4.14	0.202	11.4	50.8	<0.018	16.6
		MW99-2(S)	2016-Apr-25	E275543	Shallow Bedrock	groundwater	2200	-	<0.05	<0.02	2.7	-	-	<0.2	-	<0.5	<10	-	0.38	<0.5	15.4	-	0.0499	0.00618	0.00674	0.0043	<0.05	<0.5	<20	-	0.158	<0.005	<0.001	<0.002	-	-	185	<0.02	-
			2017-May-10				<2000	-	<0.05	<0.02	2.2	-	-	<0.2	-	<0.5	<10	-	0.38	<0.5	17.9	-	0.0423	4.79	4.87	0.8	<0.05	<0.5	<20	-	0.116	<0.005	<0.001	0.0033	-	-	122	<0.018	-
			2018-May-14				1950	0.00086	<0.05	<0.01	2.64	306	<0.2	<0.01	<0.1	<0.1	<0.3	<0.1	0.514	<0.5	9.9	-	0.0531	5.95	6.43	3.8	<0.05	<0.5	<20	-	0.134	<0.005	<0.001	0.0058	<0.05	6.99	182	<0.018	61.4
Tailings Area	Bedrock	MW-01A-03	2016-Apr-20	E254757	SOUTHERN CAZ	groundwater	2500	-	<0.05	<0.02	49.1	-	-	<0.2	-	<0.5	<10	-	10	<0.5	<5	-	<0.005	5.18	5.49	2.9	<0.05	1.55	21	-	0.051	0.136	<0.001	0.0807	-	-	77.9	<0.02	-
			2017-May-8				2200	-	<0.05	<0.02	47	-	-	<0.2	-	<0.5	<10	-	**14**	<0.5	<5	-	<0.005	5.15	4.9	-2.5	<0.05	1.3	<20	-	<0.05	0.0903	<0.001	0.0845	-	-	74.1	<0.018	-
			2018-May-8	E254757	SOUTHERN CAZ	groundwater	2340	0.00189	<0.05	<0.01	51	2310	<0.2	<0.01	<0.1	<0.1	<0.3	<0.1	**13.6**	<0.5	1.4	<0.06	0.0057	-	-	-	<0.05	1.17	-	0.474	<0.05	0.088	<0.001	0.0888	0.085	5.07	71.5	<0.018	23.7
				DUPLICATE-2 (DUP-GW-2)			2340	0.00184	<0.05	<0.01	51.3	2310	<0.2	<0.01	<0.1	<0.1	<0.3	<0.1	**13.9**	<0.5	1.7	<0.06	<0.005	-	-	-	<0.05	1.17	-	0.474	<0.05	0.0873	<0.001	0.0899	0.086	5.03	71.5	<0.018	23.7
		MW-02D-03	2016-Apr-21	E254756	SOUTHERN CAZ	groundwater	4300	-	<0.05	<0.02	17.6	-	-	<0.2	-	<0.5	11	-	<0.2	1.75	<5	-	0.922	8.96	11.2	11.2	<0.25	39.6	<20	-	1.05	<0.025	<0.005	0.159	-	-	2.3	<0.02	-
			2017-May-9	E254756	SOUTHERN CAZ	groundwater	4000	-	0.074	<0.02	17.2	-	-	<0.2	-	<0.5	<10	-	<0.2	1.7	<5	-	0.938	9.04	10	5	<0.25	39.9	<20	-	1.04	<0.025	<0.005	0.177	-	-	3.5	<0.018	-
				MW-02D-03			3900	-	0.082	<0.02	16.5	-	-	<0.2	-	<0.5	<10	-	<0.2	1.61	<5	-	0.922	8.98	9.82	4.5	<0.25	37.2	<20	-	1.07	<0.025	<0.005	0.182	-	-	3.2	<0.018	-
			2018-May-15	E254756	SOUTHERN CAZ	groundwater	3760	0.00418	<0.05	<0.01	16.9	544	<0.2	<0.01	<0.1	<0.1	<0.3	0.19	0.125	1.67	<1	0.587	0.94	-	-	-	<0.25	35.7	-	-	1.05	0.029	<0.005	0.151	0.133	12.7	3.6	<0.018	1.25
	Overburden	MW-01C-03	2016-Apr-21	E254759	SOUTHERN CAZ	groundwater	2000	-	<0.05	<0.02	20.3	-	-	<0.2	-	<0.5	<10	-	5.36	<0.5	<5	-	0.115	8.01	8.64	3.8	<0.25	25.7	<20	-	0.191	<0.025	<0.005	<0.002	-	-	83.5	<0.02	-
			2017-May-8				2000	-	<0.05	<0.02	20.6	-	-	<0.2	-	<0.5	<10	-	6.76	<0.5	<5	-	0.12	9.3	8.53	-4.3	<0.25	27.3	<20	-	0.212	<0.025	<0.005	0.0097	-	-	132	<0.018	-
			2018-May-8				2250	0.00074	<0.05	<0.01	23.3	645	<0.2	0.012	<0.1	<0.1	<0.3	<0.1	8.11	<0.5	2.3	<0.06	0.13	-	-	-	<0.25	22	-	<0.1	0.239	<0.025	<0.005	0.0033	<0.05	6.9	185	<0.018	60.8
		MW-02-05	2016-Apr-20	E266346	SOUTHERN CAZ	groundwater	3500	-	<0.05	<0.02	4.9	-	-	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	-	**1.85**	3.84	4.14	3.7	<0.05	2.8	<20	-	1.94	<0.005	<0.001	0.0478	-	-	0.4	0.039	-
			2017-May-9				3000	-	<0.05	<0.02	4.4	-	-	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	-	**1.71**	3.88	3.6	-3.7	<0.05	2.92	<20	-	1.97	<0.005	<0.001	0.072	-	-	0.4	0.028	-
			2018-May-10				2890	0.0097	<0.05	<0.01	4.49	746	<0.2	<0.01	<0.1	<0.1	<0.3	**5.72**	0.02	<0.5	1.2	<0.06	1.73	-	-	-	<0.05	2.9	-	0.819	2.01	<0.005	<0.001	0.0836	<0.05	3.11	0.45	0.039	<0.5
		MW-02S-03	2016-Apr-21	E254755	SOUTHERN CAZ	groundwater	4300	-	<0.05	<0.02	10.2	-	-	<0.2	-	<0.5	15	-	3.13	<0.5	**8060**	-	0.102	21.3	22.1	2	<0.5	24.5	<20	-	0.211	<0.05	<0.01	<0.01	-	-	**655**	<0.02	-
			2017-May-9				5900	-	<0.05	<0.02	8.4	-	-	<0.2	-	<0.5	<10	-	3.12	<0.5	**7150**	-	0.0858	21.2	21	-0.3	<0.5	22.1	<20	-	0.296	<0.05	<0.01	0.0048	-	-	**688**	<0.018	-
			2018-May-15				4180	0.0128	<0.05	<0.01	7.84	632	<0.2	0.028	<0.1	<0.1	<0.3	<0.1	3.81	<0.5	**7280**	<0.06	0.175	-	-	-	<0.5	19	-	-	0.298	<0.05	<0.01	<0.006	<0.05	8.34	**703**	<0.018	233
		MW-03S-03	2016-Apr-21	E254760	SOUTHERN CAZ	groundwater	3700	-	<0.05	<0.02	4.4	-	-	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	-	1	15.8	16.5	2.2	<0.25	8.6	<20	-	1.12	<0.025	<0.005	0.0119	-	-	**700**	0.087	-
			2017-May-9				3400	-	0.227	<0.02	4.2	-	-	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	-	0.938	14.4	13.7	-2.4	<0.25	9.5	<20	-	1.11	<0.025	<0.005	0.0136	-	-	**627**	0.106	-
			2018-May-8				3440	0.00846	<0.05	<0.01	3.94	1600	<0.2	<0.01	<0.1	<0.1	<0.3	3	0.031	<0.5	12.9	<0.06	0.922	-	-	-	<0.25	10.2	-	0.83	1.15	<0.025	<0.005	0.0121	<0.05	4.19	**533**	0.118	181
		MW-03S-05	2016-Apr-26	E266348	SOUTHERN CAZ	groundwater	13,200	-	<0.05	<0.02	34.2	-	-	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	-	2.74	3.42	3.83	5.6	0.00274	2.64	<20	-	3.56	<0.005	<0.001	0.133	-	-	<0.3	<0.02	-
			2017-May-10				11,400	-	0.061	<0.02	37.2	-	-	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	-	2.85	3.46	3.48	0.3	0.24	3.39	46	-	4.15	<0.005	0.0086	0.339	-	-	<0.3	0.018	-
			2018-May-15				11,900	0.00868	<0.05	<0.01	30	117	<0.2	<0.01	<0.1	<0.1	<0.3	**5.16**	0.153	<0.5	1.2	<0.06	3.29	-	-	-	0.187	2.68	-	-	4.42	<0.005	0.0021	0.138	0.081	4.6	0.69	<0.018	3.22
		MW-04S-05	2016-Apr-20	E266349	SOUTHERN CAZ	groundwater	3100	-	<0.05	<0.02	5	-	-	<0.2	-	<0.5	<10	-	5.36	<0.5	<5	-	0.242	6.48	7.12	4.7	0.191	2	<20	-	0.324	0.0087	0.0234	0.0219	-	-	8.3	<0.02	-
			2017-May-10				2200	-	<0.05	<0.02	4.1	-	-	<0.2	-	<0.5	<10	-	3.69	<0.5	31.9	-	0.138	4.43	4.45	0.3	0.078	2.67	<20	-	0.229	0.0119	0.0047	0.0151	-	-	25.5	<0.018	-
			2018-May-9				2870	0.00112	<0.05	<0.01	4.95	420	<0.2	0.026	<0.1	<0.1	<0.3	<0.1	5.15	<0.5	16.8	<0.06	0.27	-	-	-	0.173	3	-	0.054	0.366	0.0157	0.0024	0.0197	<0.05	8.3	10.2	<0.018	3.37
		MW-05-05	2016-Apr-20	E266350	SOUTHERN CAZ	groundwater	13,200	-	<0.05	<0.02	17.9	-	-	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	-	**2.12**	3.92	4.26	4.2	0.062	2.59	22	-	2.33	<0.005	<0.001	0.0504	-	-	90.5	0.38	-
			2017-May-9				12,300	-	0.379	<0.02	16.1	-	-	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	-	**1.99**	3.89	3.9	0.1	0.069	2.56	<20	-	2.36	<0.005	<0.001	0.056	-	-	92.4	0.139	-
			2018-May-10				11,600	0.0153	<0.05	<0.01	15.3	587	<0.2	<0.01	<0.1	<0.1	<0.3	**7.02**	0.02	<0.5	2.2	<0.06	2.11	-	-	-	0.074	2.5	-	**1.25**	2.59	<0.005	<0.001	0.0665	<0.05	1.75	96.3	0.134	33.2
		MW-06-01	2016-Apr-25	E252594	SOURCE CONCENTRATION	groundwater	15,900	-	<0.1	<0.02	50.2	-	-	0.71	-	<0.5	<10	-	4.34	<1	**10,900**	-	2.38	46.3	43.5	-3.1	<1	24	39	-	3.92	<0.1	<0.02	0.016	-	-	**1890**	0.032	-
			2017-May-10	E252594	SOURCE CONCENTRATION	groundwater	18,100	-	<0.1	<0.02	28.5	-	-	0.68	-	<0.5	<10	-	3.6	<1	**6440**	-	2.61	36.9	38.3	1.9	<1	12	33	-	3.2	<0.1	<0.02	0.016	-	-	**1500**	0.065	-
				MW-06-01			18,500	-	<0.1	<0.02	30.1	-	-	0.73	-	<0.5	<10	-	4.01	<1	**7220**	-	2.68	37	38.4	1.9	<1	12	32	-	3.23	<0.1	<0.02	0.0172	-	-	**1500**	0.064	-
			2018-May-15	E252594	Source Concentration	groundwater	11,700	0.0355	<0.1	<0.02	9.64	890	<0.4	1.74	<0.2	<0.2	<0.6	<0.2	5.07	<1	**14,300**	<0.12	0.996	-	-	-	<1	<10	22	-	1.53	<0.1	<0.02	0.0034	<0.1	5.97	**1800**	<0.018	560

TABLE 2: - FIELD MEASUREMENTS

Metals

Site Area	Location Type	Sample Location	Sample Date	Sample ID	SampleComments	Matrix Type	potassium (Filtered)	rubidium (Filtered)	selenium (Filtered)	silver (Filtered)	sodium (Filtered)	strontium (Filtered)	tellurium (Filtered)	thallium (Filtered)	thorium (Filtered)	tin (Filtered)	titanium (Filtered)	tungsten (Filtered)	uranium (Filtered)	vanadium (Filtered)	zinc (Filtered)	zirconium (Filtered)
							µg/L	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BC CSR DW									**10**	**20**	**200**	**2500**				**2500**		**3**	**20**	**20**	**3000**	
BC CSR AWF									**20**	**0.5 - 15 ***				**3**			**1000**		**85**		**75[#2] - 3150[#2] ***	
BC CSR IW									**20 - 50 ***										**10**	**100**	**1000 - 5000 ***	
BC CSR LW									**30**										**200**	**100**	**2000**	
Upgradient Reference	Overburden	MW-05-01	2016-Apr-26	E252593	Background Overburden	groundwater	<2000	-	0.125	<0.02	4.7	-	-	<0.2	-	<0.5	<10	-	1.3	<0.5	<5	-
			2017-May-10				<2000	-	0.123	<0.02	4.6	-	-	<0.2	-	<0.5	<10	-	1.66	0.63	<5	-
			2018-May-14				1100	<0.0002	0.118	<0.01	4.56	368	<0.2	<0.01	<0.1	<0.1	<0.3	<0.1	1.76	0.73	1	-
		MW-09-02D	2016-Apr-12	E252600	NORTHERN CAZ	groundwater	3000	-	<0.05	<0.02	8.2	-	-	<0.2	-	<0.5	<10	-	7.17	<0.5	<5	-
			2017-May-2				2600	-	<0.05	<0.02	7.5	-	-	<0.2	-	<0.5	<10	-	7.72	<0.5	<5	-
			2018-May-3				3000	0.00099	<0.05	<0.01	8.19	695	<0.2	<0.01	<0.1	<0.1	0.65	0.21	8.15	<0.5	2	<0.06
		MW-09-02S	2016-Apr-11	E252601	NORTHERN CAZ	groundwater	5300	-	0.189	<0.02	3.6	-	-	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	-
			2017-May-2				4400	-	0.147	<0.02	2.9	-	-	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	-
			2018-May-3				4190	<0.0002	0.139	<0.01	2.92	203	<0.2	<0.01	<0.1	<0.1	<0.3	<0.1	0.138	<0.5	2.6	<0.06
Statistical Summary																						
Number of Results							68	23	68	68	68	23	23	68	23	68	68	23	68	68	68	14
Number of Detects							58	21	17	0	68	23	0	7	0	0	3	9	52	9	32	1
Minimum Concentration							1050	<0.0002	<0.05	<0.01	2.2	117	<0.2	<0.01	<0.1	<0.1	<0.3	<0.1	0.02	<0.5	<1	<0.06
Minimum Detect							1050	0.00021	0.061	ND	2.2	117	ND	0.012	ND	ND	0.65	0.1	0.02	0.63	1	0.587
Maximum Concentration							18500	0.0355	0.379	<0.05	122	2310	<0.4	1.74	<0.2	<0.5	15	7.02	14	1.75	14300	0.587
Maximum Detect							18500	0.0355	0.379	ND	122	2310	ND	1.74	ND	ND	15	7.02	14	1.75	14300	0.587
Average Concentration							4395	0.0051	0.076	0.017	18	670	0.21	0.18	0.1	0.37	6.8	1	2.6	0.63	907	0.1
Median Concentration							2880	0.00184	0.05	0.02	7.94	587	0.2	0.2	0.1	0.5	10	0.1	1.095	0.5	5	0.06
Standard Deviation							4163	0.008	0.055	0.0062	26	611	0.042	0.24	0.021	0.19	4.7	2.1	3.4	0.31	2813	0.14
Number of Guideline Exceedances							0	0	0	0	0	0	0	0	0	0	0	3	3	0	7	0
Number of Guideline Exceedances(Detects Only)							0	0	0	0	0	0	0	0	0	0	0	3	3	0	7	0

Inorganics

Sample Location	Sample Date	ammonia as N	anions total	cations total	ionic balance	bromide	chloride	COD	fluoride	kjeldahl nitrogen total	nitrate (as N)	nitrite (as N)	phosphorus	phosphorus (Filtered)	silicon (Filtered)	sulfate	sulphide	sulphur as S (Filtered)
		mg/L	meq/L	meq/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
BC CSR DW							**250**		**1.5**		**10**	**1**				**500**		
BC CSR AWF		**1.31 - 18.5 ***					**1500**		**2 - 3 ***		**400**	**0.2 - 2 ***				**1280 - 4290 ***		
BC CSR IW							**100**		**1**									
BC CSR LW							**600**		**1**		**100**	**10**				**1000**		
MW-05-01	2016-Apr-26	<0.005	0.00263	0.00277	0.0027	<0.05	<0.5	<20	-	<0.05	0.0099	<0.001	0.0075	-	-	8.76	<0.02	-
	2017-May-10	<0.005	2.59	2.53	-1.3	<0.05	<0.5	<20	-	<0.05	0.0123	<0.001	0.0142	-	-	8.31	<0.018	-
	2018-May-14	<0.005	2.52	2.73	4.1	<0.05	<0.5	<20	-	<0.05	0.011	<0.001	0.0095	<0.05	8.21	9.16	<0.018	2.75
MW-09-02D	2016-Apr-12	0.0203	6.46	6.71	1.9	0.191	35.2	<20	-	0.108	<0.005	<0.001	0.0578	-	-	46.4	<0.02	-
	2017-May-2	0.0233	6.96	7	0.3	<0.25	43.7	<20	-	0.112	<0.025	<0.005	0.0943	-	-	44.1	<0.018	-
	2018-May-3	0.0144	-	-	-	0.214	49.2	-	0.078	0.114	<0.005	<0.001	0.0585	<0.05	7.29	41.3	<0.018	14.3
MW-09-02S	2016-Apr-11	<0.005	2.52	2.6	1.4	0.062	11.1	<20	-	0.051	0.646	<0.001	0.0041	-	-	13.7	<0.02	-
	2017-May-2	<0.005	2.19	2.26	1.6	<0.05	8.26	<20	-	<0.05	0.63	<0.001	<0.002	-	-	10	<0.018	-
	2018-May-3	<0.005	-	-	-	0.052	10.1	-	0.036	0.147	1.07	<0.001	0.0068	<0.05	5.81	5.26	<0.018	1.5
Statistical Summary																		
Number of Results		68	48	48	48	61	68	56	9	68	68	68	68	23	23	68	68	23
Number of Detects		51	48	48	48	16	55	7	8	56	34	11	63	6	23	66	13	22
Minimum Concentration		<0.005	0.00263	0.00277	-4.6	0.00274	<0.5	<20	0.036	<0.05	<0.005	<0.001	<0.002	<0.05	1.75	<0.3	<0.018	<0.5
Minimum Detect		0.0057	0.00263	0.00277	ND	0.00274	1.17	21	0.036	0.051	0.0061	0.0021	0.0033	0.081	1.75	0.4	0.018	0.54
Maximum Concentration		3.29	46.3	43.5	11.2	<1	49.2	46	1.25	4.42	1.3	0.0234	10.9	0.202	12.7	1890	0.38	560
Maximum Detect		3.29	46.3	43.5	11.2	0.398	49.2	46	1.25	4.42	1.3	0.0234	10.9	0.202	12.7	1890	0.38	560
Average Concentration		0.61	8	8.2	1.2	0.2	9.4	21	0.46	0.8	0.1	0.0042	0.48	0.07	7	200	0.033	60
Median Concentration		0.1175	4.99	4.885	0.55	0.069	2.87	20	0.474	0.2205	0.025	0.001	0.0391	0.05	6.93	48.6	0.018	23.7
Standard Deviation		0.9	9.6	9.6	3	0.25	13	4.8	0.43	1.1	0.23	0.0055	1.8	0.038	2.8	413	0.051	123
Number of Guideline Exceedances		4	0	0	0	0	0	0	1	0	0	0	0	0	0	10	0	0
Number of Guideline Exceedances(Detects Only)		4	0	0	0	0	0	0	1	0	0	0	0	0	0	10	0	0

Standard/Guideline Descriptions

- BC CSR DW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Drinking Water
- BC CSR AWF:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Freshwater Aquatic Life
- BC CSR IW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Irrigation
- BC CSR LW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Livestock

Standard/Guideline Comments

#1:Interim background groundwater concentration estimate
#2:results with hardness >500 mg/L should be evaluated on a site by site basis; refer to BC Protocol 10
#3:Standard varies with crop type, soil drainage and Mo:Cu ratio.

TABLE 3: SURFACE WATER DATASET

											Field				Physical Parameters					Carbon		Metals													
											temp (field)	pH (field)	EC (field)	turbidity	alkalinity (bicarbonate as CaCO3)	alkalinity (carbonate as CaCO3)	alkalinity (hydroxide) as CaCO3	alkalinity (total) as CaCO3	Electrical Conductivity (lab)	Total Organic Carbon	Total Inorganic Carbon	hardness as CaCO3	pH (lab)	aluminum	antimony	arsenic	barium	beryllium	bismuth	boron	cadmium	calcium	cesium	chromium (III+VI)	cobalt
											oC	pH_Units	µS/cm	NTU	mg/L	mg/L	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	pH_Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L
BC WQG, Recreation											[#1]	**5-9**		**50**																					
BC WQG (Approved) AWF, Long-term												**6.5-9**		[#3]																**1200**[#4]					**4**[#5]
BC WQG (Approved) AWF, Short-term												**6.5-9**		[#3]												**5**[#9]									**110**[#9]
BC WQG (Working) AWF, Long-term															**10**[#4]										**9**[#4]		**1000**[#4]	**0.13**[#4]						**1**[#11]	
BC WQG (Approved) Wildlife Water Supply, Short-term														[#3]										**5000**[#9]		**25**[#9]				**5000**[#9]					
BC WQG (Approved) Wildlife Water Supply, Long-term														[#3]																					
BC WQG Wildlife Water Supply																																			
BC WQG (Approved) IW, Short-term														[#3]										**5000**[#9]		**100**[#9]									
BC WQG (Approved) IW, Long-term																														**500**[#14]					
BC WQG (Approved) LW, Short-term											[#17]			[#3]										**5000**[#9]		**25**[#9]									
BC WQG (Approved) LW, long-term											[#20]																			**5000**					
Monitoring_Zone	**Alternative_Name**	**Location_Code**	**Well_Screen_Interval**	**Sampled_Date_Time**	**Monitoring_Unit**	**Sample_Type**	**Field_ID**	**SampleComment**	**SampleCode**	**Lab_Report_Number**																									
Central Landfill	SW1-07	SW1-07	-	4/26/2016		Normal	E303730		E303730__26 Apr 16		14	7.78	636	3.35	-	-	-	297	805	11.2	77.1	353	8.17	49	<0.5	1.27	78	<1	-	310	0.142	87.4	-	<1	1
Central Landfill	SW1-07	SW1-07	-	11/4/2016		Normal	E303730		E303730__04 Nov 16		6.6	7.5	350.5	16.2	-	-	-	196	532	24.9	47.4	254	7.78	925	<0.5	3.27	93	<1	-	110	0.362	68.6	-	**2.1**	1.5
Central Landfill	SW1-07	SW1-07	-	5/15/2017		Normal	E303730		E303730W__15 May 17		13.6	7.55	550	3.29	-	-	-	274	688	14.4	63.7	307	8.14	49.7	<0.5	1.94	75	<0.1	-	240	0.111	81	-	<1	0.92
Central Landfill	SW1-07	SW1-07	-	5/15/2017		Field_D	SW DUPLICATE-1		SW DUPLICATE-1W__15 May 17		-	-	-	-	-	-	-	278	685	14.3	64.2	309	8.26	41	<0.5	1.86	75	<0.1	-	260	0.108	82.2	-	<1	0.88
Central Landfill	SW1-07	SW1-07	-	5/17/2018		Normal	E303730		E303730__17 May 18		17	7.62	628	8.73	**282**	21.8	<1	304	690,000	14.8	-	327	8.52	80.8	0.33	3.16	70.1	<0.1	<0.05	285	0.185	89.2	0.017	0.69	1.31
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	1/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Jan 20		-	-	-	-	-	-	-	-	-	-	-	178	-	57	-	-	-	-	-	-	0.46	-	-	0.9	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	2/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Feb 20		-	-	-	-	-	-	-	-	-	-	-	184	-	57	-	-	-	-	-	-	0.48	-	-	0.9	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	3/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Mar 20		-	-	-	-	-	-	-	-	-	-	-	147	-	58	-	-	-	-	-	-	0.34	-	-	0.9	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	4/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Apr 20		-	-	-	-	-	-	-	-	-	-	-	104	-	60	-	-	-	-	-	-	0.18	-	-	0.9	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	5/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 May 20		-	-	-	-	-	-	-	-	-	-	-	99	-	60	-	-	-	-	-	-	0.16	-	-	0.9	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	6/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Jun 20		-	-	-	-	-	-	-	-	-	-	-	102	-	60	-	-	-	-	-	-	0.18	-	-	0.9	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	7/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Jul 20		-	-	-	-	-	-	-	-	-	-	-	141	-	133	-	-	-	-	-	-	0.37	-	-	**1.5**	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	8/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Aug 20		-	-	-	-	-	-	-	-	-	-	-	202	-	128	-	-	-	-	-	-	0.6	-	-	**1.5**	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	9/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Sep 20		-	-	-	-	-	-	-	-	-	-	-	192	-	129	-	-	-	-	-	-	0.56	-	-	**1.5**	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	10/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Oct 20		-	-	-	-	-	-	-	-	-	-	-	182	-	130	-	-	-	-	-	-	0.52	-	-	**1.5**	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	11/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Nov 20		-	-	-	-	-	-	-	-	-	-	-	170	-	131	-	-	-	-	-	-	0.48	-	-	**1.5**	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	12/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Dec 20		-	-	-	-	-	-	-	-	-	-	-	166	-	131	-	-	-	-	-	-	0.46	-	-	**1.5**	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	1/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Jan 20		-	-	-	-	-	-	-	-	-	-	-	198	-	53	-	-	-	-	-	-	0.53	-	-	1	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	2/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Feb 20		-	-	-	-	-	-	-	-	-	-	-	205	-	53	-	-	-	-	-	-	0.55	-	-	1	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	3/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Mar 20		-	-	-	-	-	-	-	-	-	-	-	162	-	54	-	-	-	-	-	-	0.39	-	-	1	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	4/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Apr 20		-	-	-	-	-	-	-	-	-	-	-	112	-	56	-	-	-	-	-	-	0.21	-	-	1	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	5/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 May 20		-	-	-	-	-	-	-	-	-	-	-	107	-	56	-	-	-	-	-	-	0.19	-	-	1	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	6/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Jun 20		-	-	-	-	-	-	-	-	-	-	-	110	-	56	-	-	-	-	-	-	0.2	-	-	1	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	7/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Jul 20		-	-	-	-	-	-	-	-	-	-	-	155	-	134	-	-	-	-	-	-	0.43	-	-	**1.6**	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	8/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Aug 20		-	-	-	-	-	-	-	-	-	-	-	225	-	129	-	-	-	-	-	-	0.69	-	-	**1.6**	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	9/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Sep 20		-	-	-	-	-	-	-	-	-	-	-	213	-	130	-	-	-	-	-	-	0.64	-	-	**1.6**	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	10/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Oct 20		-	-	-	-	-	-	-	-	-	-	-	202	-	130	-	-	-	-	-	-	0.6	-	-	**1.6**	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	11/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Nov 20		-	-	-	-	-	-	-	-	-	-	-	189	-	132	-	-	-	-	-	-	0.55	-	-	**1.6**	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	12/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Dec 20		-	-	-	-	-	-	-	-	-	-	-	184	-	132	-	-	-	-	-	-	0.54	-	-	**1.6**	-
Tailings Storage	SW2-07	SW2-07	-	4/28/2016		Normal	E303731		E303731__28 Apr 16		6.8	8.26	91.4	16.4	-	-	-	64.5	142	2.57	16	66.1	7.97	983	<0.5	0.59	42	<1	-	<100	0.0187	19.5	-	**1.1**	0.32
Tailings Storage	SW2-07	SW2-07	-	11/4/2016		Normal	E303731		E303731__04 Nov 16		5.1	7.96	114.8	14.1	-	-	-	64.4	182	3.56	15.3	85	7.83	1230	<0.5	0.86	42	<1	-	<100	0.0255	23.4	-	**1.2**	<0.3
Tailings Storage	SW2-07	SW2-07	-	5/15/2017		Normal	E303731		E303731__15 May 17		6.5	7.6	206.6	13.3	-	-	-	133	315	8.73	30.3	154	8.2	422	<0.5	1.69	54	<0.1	-	<100	0.0519	45.2	-	<1	0.61
Tailings Storage	SW2-07	SW2-07	-	5/17/2018		Normal	E303731		E303731__17 May 18		13.7	7.6	164.8	19.1	**97.1**	3.2	<1	100	201,000	2.84	-	102	8.32	288	0.13	0.67	35.6	<0.1	<0.05	16	0.0172	31.3	0.068	0.48	0.23
Tailings Storage	SW2-07	SW2-07	-	10/30/2018		Normal	E303731		E303731__30 Oct 18		5.7	8.83	227.4	**91**	-	-	-	97.3	335,000	3.61	23.7	171	8.12	**5410**	0.27	2.92	123	**0.23**	0.07	46	0.0921	50.5	0.778	**5.55**	1.62

TABLE 3: SURFACE WATER DATASET

	Field				Physical Parameters					Carbon	
	temp (field)	pH (field)	EC (field)	turbidity	alkalinity (bicarbonate as CaCO3)	alkalinity (carbonate as CaCO3)	alkalinity (hydroxide) as CaCO3	alkalinity (total) as CaCO3	Electrical Conductivity (lab)	Total Organic Carbon	Total Inorganic Carbon
	oC	pH_Units	µS/cm	NTU	mg/L	mg/L	mg/L	mg/L	µS/cm	mg/L	mg/L
BC WQG, Recreation	#1	5-9		50							
BC WQG (Approved) AWF, Long-term		6.5-9		#3							
BC WQG (Approved) AWF, Short-term		6.5-9		#3							
BC WQG (Working) AWF, Long-term					10[#4]						
BC WQG (Approved) Wildlife Water Supply, Short-term				#3							
BC WQG (Approved) Wildlife Water Supply, Long-term				#3							
BC WQG Wildlife Water Supply											
BC WQG (Approved) IW, Short-term				#3							
BC WQG (Approved) IW, Long-term											
BC WQG (Approved) LW, Short-term	#17			#3							
BC WQG (Approved) LW, long-term	#20										

	Metals													
	hardness as CaCO3	pH (lab)	aluminum	antimony	arsenic	barium	beryllium	bismuth	boron	cadmium	calcium	cesium	chromium (III+VI)	cobalt
	mg/L	pH_Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L
BC WQG, Recreation														
BC WQG (Approved) AWF, Long-term									1200[#4]					4[#5]
BC WQG (Approved) AWF, Short-term					5[#9]									110[#9]
BC WQG (Working) AWF, Long-term				9[#4]		1000[#4]	0.13[#4]						1[#11]	
BC WQG (Approved) Wildlife Water Supply, Short-term			5000[#9]		25[#9]				5000[#9]					
BC WQG (Approved) Wildlife Water Supply, Long-term														
BC WQG Wildlife Water Supply														
BC WQG (Approved) IW, Short-term			5000[#9]		100[#9]									
BC WQG (Approved) IW, Long-term									500[#14]					
BC WQG (Approved) LW, Short-term			5000[#9]		25[#9]									
BC WQG (Approved) LW, long-term									5000					

Monitoring_Zone Alternative_Name Location_Code Well_Screen_Interval Sampled_Date_Time Monitoring_Unit Sample_Type Field_ID SampleComment SampleCode Lab_Report_Number

Env Stds Description

BC WQG, Recreation:BC Water Quality Guidelines, Recreation Water
BC WQG (Approved) AWF, Long-term:BC Approved Water Quality Guidelines, Freshwater Aquatic Life, Long-term (January 2017)
BC WQG (Approved) AWF, Short-term:BC Approved Water Quality Guidelines, Freshwater Aquatic Life, Short-term (January 2017)
BC WQG (Working) AWF, Long-term:BC Working Water Quality Guidelines, Freshwater Aquatic Life, Long-term (January 2017)
BC WQG (Approved) Wildlife Water Supply, Short-term:BC Approved Water Quality Guidelines, Wildlife Water Supply, Short-term (January 2017)
BC WQG (Approved) Wildlife Water Supply, Long-term:BC Approved Water Quality Guidelines, Wildlife Water Supply, Long-term (January 2017)
BC WQG Wildlife Water Supply:BC Water Quality Guidelines, Wildlife Drinking Water
BC WQG (Approved) IW, Short-term:BC Approved Water Quality Guidelines, Drinking Water, Short-term (January 2017)
BC WQG (Approved) IW, Long-term:BC Approved Water Quality Guidelines, Irrigation Water, Long-term (January 2017)
BC WQG (Approved) LW, Short-term:BC Approved Water Quality Guidelines, Livestock Water, Short-term (January 2017)
BC WQG (Approved) LW, long-term:BC Approved Water Quality Guidelines, Livestock Water, Long-term (January 2017)
BC CSR DW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Drinking Water
BC CSR AWF:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Freshwater Aquatic Life
BC CSR IW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Irrigation
BC CSR LW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Livestock

Env Stds Comments

#1:Should not cause an apreciable increase or decrease in the deep body temperature of swimmers
#2:Guideline applies only to lakes; there is no proposed BC WQG guideline for phosphorus in streams for recreation
#3:Dependent on natural background. Refer to Table 44 of BC Water Quality Guidelines Summary Report
#4:30 day
#5:30 Day
#6:Guideline is dependent on water hardness. Conservative hardness ranges used for comparison purposes. Exceedances to be confirmed against the formula in the regulatory guidance document.
#7:Guideline is dependent on water hardness in mg/L CaCO3
#8:Guideline applies only to lakes to protect against eutrophication; there is no proposed BC WQG guideline for phosphorus in streams for the protection of aquatic life
#9:Max
#10:Max (total iron)
#11:30 day; guideline is for Cr(VI), speciated results supercede total chromium results
#12:Average
#13:400 ug/L for neutral & alkaline fine-textured soils OR 200 ug/L for all other soils
#14:crop-dependent; see WQG table 4B
#15:Guideline depends on soil drainage, Cu:Mo ratio and crop variety. See Table 24 of BC Water Quality Guidelines Summary Report
#16:1000 ug/L for soil pH <6 OR 2000 ug/L for soil pH >=6 and <7 OR 5000 ug/L for soil pH > 7
#17:should not change more than ± 0.5 deg.C hourly
#18:0.08 mg/L for livestock consuming forages not irrigated or if no molybdenum containing fertilizers are applies to grow feed consumed by livestock OR .05 mg/L for all other livestock
#19:1.5 mg/L for dairy cows, breeding stock (long lived animals) OR 2 mg/L for livestock with high fluoride diets, mineral or bone meal, feed additives OR 4 mg/L for all other livestock with normal diet
#20:should not change more than ± 1 deg.C from ambien background
#21:1 mg/L for dairy cows, breeding stock (long lived animals) OR 1 mg/L for livestock with high fluoride diets, mineral or bone meal, feed additives OR 2 mg/L for all other livestock with normal diet
#22:Interim background groundwater concentration estimate
#23:results with hardness >500 mg/L should be evaluated on a site by site basis; refer to BC Protocol 10
#24:Standard varies with crop type, soil drainage and Mo:Cu ratio.

TABLE 3: SURFACE WATER DATASET

											Metals																						
Monitoring_Zone	Alternative_Name	Location_Code	Well_Screen_Interval	Sampled_Date_Time	Monitoring_Unit	Sample_Type	Field_ID	SampleComment	SampleCode	Lab_Report_Number	copper	iron	lead	lithium	magnesium	manganese	mercury	molybdenum	nickel	potassium	rubidium	selenium	silver	sodium	strontium	tellurium	thallium	thorium	tin	titanium	tungsten	uranium	vanadium
											µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BC WQG, Recreation																																	
BC WQG (Approved) AWF, Long-term											**2[#6] - 8[#6] ***		**3.4[#6] - 19[#6] ***			**770[#6] - 2500[#6] ***	**0.00125[#4]**	**1000[#4]**				**1[#4]**	**0.05[#7] - 1.5[#7] ***										
BC WQG (Approved) AWF, Short-term											**3.2[#6] - 39.6[#6] ***	**1000[#10]**	**3[#6] - 402[#6] ***			**810[#6] - 3300[#6] ***		**2000[#9]**					**0.1[#7] - 3[#7] ***										
BC WQG (Working) AWF, Long-term																			**25[#6] - 150[#6] ***								**0.8[#4]**					**8.5[#4]**	
BC WQG (Approved) Wildlife Water Supply, Short-term											**300[#9]**		**100[#9]**					**50[#9]**															
BC WQG (Approved) Wildlife Water Supply, Long-term																																	
BC WQG Wildlife Water Supply																						**2**											
BC WQG (Approved) IW, Short-term											**200**		**200[#13]**				**2**	**50[#9]**															
BC WQG (Approved) IW, Long-term																		**10[#15]**				**10[#4]**											
BC WQG (Approved) LW, Short-term											**300**		**100**				**3**	**50[#18]**															
BC WQG (Approved) LW, long-term																						**30[#4]**											
Central Landfill	SW1-07	SW1-07	-	4/26/2016		Normal	E303730		E303730__26 Apr 16		2	421	6.07	2.5	32.6	339	<0.005	1.5	6.8	8800	-	0.134	<0.02	39.7	-	-	<0.2	-	<0.5	<10	-	**8.51**	0.51
Central Landfill	SW1-07	SW1-07	-	11/4/2016		Normal	E303730		E303730__04 Nov 16		**12.2**	**1240**	4.1	2.5	20	675	**0.0082**	2.1	7.5	6600	-	0.275	0.073	12.8	-	-	<0.2	-	<0.5	33	-	8.27	2.78
Central Landfill	SW1-07	SW1-07	-	5/15/2017		Normal	E303730		E303730W__15 May 17		3.4	544	4.88	1.8	25.5	239	<0.005	<1	6	8400	-	0.119	<0.02	29.2	-	-	<0.2	-	<0.5	<10	-	6.41	0.75
Central Landfill	SW1-07	SW1-07	-	5/15/2017		Field_D	SW DUPLICATE-1		SW DUPLICATE-1W__15 May 17		3.3	498	4.89	1.9	25.3	237	<0.005	<1	5.8	7800	-	0.115	<0.02	28.4	-	-	<0.2	-	<0.5	<10	-	6.36	0.71
Central Landfill	SW1-07	SW1-07	-	5/17/2018		Normal	E303730		E303730__17 May 18		2.5	**1280**	13.9	2.2	25.3	673	<0.005	2.03	6.44	7700	0.00223	0.144	0.015	28.8	537	<0.2	<0.01	<0.1	<0.1	3.28	<0.1	7.68	1.2
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	1/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Jan 20		1.7	140	3.7	-	-	23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	2/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Feb 20		1.7	140	3.8	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	3/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Mar 20		1.6	120	3.1	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	4/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Apr 20		1.5	80	2.3	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	5/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 May 20		1.5	80	2.2	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	6/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Jun 20		1.5	80	2.3	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	7/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Jul 20		3.9	140	2.5	-	-	34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	8/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Aug 20		4	190	1.2	-	-	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	9/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Sep 20		4	180	1.3	-	-	39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	10/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Oct 20		4	170	1.4	-	-	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	11/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Nov 20		3.9	170	1.6	-	-	37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	12/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P__01 Dec 20		3.9	160	1.6	-	-	37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	1/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage__01 Jan 20		1.8	150	4.2	-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	2/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage__01 Feb 20		1.9	150	4.3	-	-	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	3/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage__01 Mar 20		1.8	120	3.5	-	-	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	4/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage__01 Apr 20		1.7	80	2.6	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	5/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage__01 May 20		1.7	80	2.5	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	6/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage__01 Jun 20		1.7	80	2.6	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	7/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage__01 Jul 20		4.4	150	2.9	-	-	39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	8/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage__01 Aug 20		4.4	200	4.2	-	-	46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	9/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage__01 Sep 20		4.4	190	3.9	-	-	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	10/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage__01 Oct 20		4.4	180	3.7	-	-	44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	11/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage__01 Nov 20		4.4	170	3.5	-	-	42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	12/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage__01 Dec 20		4.4	170	3.4	-	-	42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings Storage	SW2-07	SW2-07	-	4/28/2016		Normal	E303731		E303731__28 Apr 16		**2.9**	1000	0.6	1.4	4.21	22.7	<0.005	<1	1.7	<2000	-	0.067	<0.02	2.7	-	-	<0.2	-	<0.5	22	-	0.62	1.19
Tailings Storage	SW2-07	SW2-07	-	11/4/2016		Normal	E303731		E303731__04 Nov 16		1.6	754	0.63	1.3	6.45	48	<0.005	<1	1.2	<2000	-	0.462	<0.02	3.1	-	-	<0.2	-	<0.5	28	-	4.16	1.82
Tailings Storage	SW2-07	SW2-07	-	5/15/2017		Normal	E303731		E303731__15 May 17		4.3	431	0.57	1.3	10	33.9	<0.005	1.8	2.9	2600	-	0.269	<0.02	5.2	-	-	<0.2	-	<0.5	<10	-	7.59	1.09
Tailings Storage	SW2-07	SW2-07	-	5/17/2018		Normal	E303731		E303731__17 May 18		1.93	646	0.325	1.2	5.83	27.5	<0.005	1.24	1.22	1460	0.00085	0.153	<0.01	2.43	175	<0.2	<0.01	0.22	<0.1	5.96	<0.1	5.02	0.88
Tailings Storage	SW2-07	SW2-07	-	10/30/2018		Normal	E303731		E303731__30 Oct 18		**7.37**	**4860**	3.71	5.1	10.9	83.5	<0.05	1.4	5.93	3060	0.00782	0.697	0.032	4.13	307	<0.2	0.051	2.76	0.17	124	<0.1	7.8	6.67

TABLE 3: SURFACE WATER DATASET

	Metals																						
	copper	iron	lead	lithium	magnesium	manganese	mercury	molybdenum	nickel	potassium	rubidium	selenium	silver	sodium	strontium	tellurium	thallium	thorium	tin	titanium	tungsten	uranium	vanadium
	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BC WQG, Recreation																							
BC WQG (Approved) AWF, Long-term	2[#6] - 8[#6] *		3.4[#6] - 19[#6] *			770[#6] - 2500[#6] *	0.00125[#4]	1000[#4]				1[#4]	0.05[#7] - 1.5[#7] *										
BC WQG (Approved) AWF, Short-term	3.2[#6] - 39.6[#6] *	1000[#10]	3[#6] - 402[#6] *			810[#6] - 3300[#6] *		2000[#9]					0.1[#7] - 3[#7] *										
BC WQG (Working) AWF, Long-term									25[#6] - 150[#6] *								0.8[#4]					8.5[#4]	
BC WQG (Approved) Wildlife Water Supply, Short-term	300[#9]		100[#9]					50[#9]															
BC WQG (Approved) Wildlife Water Supply, Long-term																							
BC WQG Wildlife Water Supply												2											
BC WQG (Approved) IW, Short-term	200		200[#13]				2	50[#9]															
BC WQG (Approved) IW, Long-term								10[#15]				10[#4]											
BC WQG (Approved) LW, Short-term	300		100				3	50[#18]															
BC WQG (Approved) LW, long-term												30[#4]											

Monitoring_Zone	Alternative_Name	Location_Code	Well_Screen_Interval	Sampled_Date_Time	Monitoring_Unit	Sample_Type	Field_ID	SampleComment	SampleCode	Lab_Report_Number
Env Stds Description										

BC WQG, Recreation:BC Water Quality Guidelines, Recreation Water
BC WQG (Approved) AWF, Long-term:BC Approved Water Quality Guidelines, Freshwater Aquatic Life, Long-term (January 2017)
BC WQG (Approved) AWF, Short-term:BC Approved Water Quality Guidelines, Freshwater Aquatic Life, Short-term (January 2017)
BC WQG (Working) AWF, Long-term:BC Working Water Quality Guidelines, Freshwater Aquatic Life, Long-term (January 2017)
BC WQG (Approved) Wildlife Water Supply, Short-term:BC Approved Water Quality Guidelines, Wildlife Water Supply, Short-term (January 2017)
BC WQG (Approved) Wildlife Water Supply, Long-term:BC Approved Water Quality Guidelines, Wildlife Water Supply, Long-term (January 2017)
BC WQG Wildlife Water Supply:BC Water Quality Guidelines, Wildlife Drinking Water
BC WQG (Approved) IW, Short-term:BC Approved Water Quality Guidelines, Drinking Water, Short-term (January 2017)
BC WQG (Approved) IW, Long-term:BC Approved Water Quality Guidelines, Irrigation Water, Long-term (January 2017)
BC WQG (Approved) LW, Short-term:BC Approved Water Quality Guidelines, Livestock Water, Short-term (January 2017)
BC WQG (Approved) LW, long-term:BC Approved Water Quality Guidelines, Livestock Water, Long-term (January 2017)
BC CSR DW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Drinking Water
BC CSR AWF:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Freshwater Aquatic Life
BC CSR IW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Irrigation
BC CSR LW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Livestock

Env Stds Comments
#1:Should not cause an apreciable increase or decrease in the deep body temperature of swimmers
#2:Guideline applies only to lakes; there is no proposed BC WQG guideline for phosphorus in streams for recreation
#3:Dependent on natural background. Refer to Table 44 of BC Water Quality Guidelines Summary Report
#4:30 day
#5:30 Day
#6:Guideline is dependent on water hardness. Conservative hardness ranges used for comparison purposes. Exceedances to be confirmed against the formula in the regulatory guidance document.
#7:Guideline is dependent on water hardness in mg/L CaCO3
#8:Guideline applies only to lakes to protect against eutrophication; there is no proposed BC WQG guideline for phosphorus in streams for the protection of aquatic life
#9:Max
#10:Max (total iron)
#11:30 day; guideline is for Cr(VI), speciated results supercede total chromium results
#12:Average
#13:400 ug/L for neutral & alkaline fine-textured soils OR 200 ug/L for all other soils
#14:crop-dependent; see WQG table 4B
#15:Guideline depends on soil drainage, Cu:Mo ratio and crop variety. See Table 24 of BC Water Quality Guidelines Summary Report
#16:1000 ug/L for soil pH <6 OR 2000 ug/L for soil pH >=6 and <7 OR 5000 ug/L for soil pH > 7
#17:should not change more than ± 0.5 deg.C hourly
#18:0.08 mg/L for livestock consuming forages not irrigated or if no molybdenum containing fertilizers are applies to grow feed consumed by livestock OR .05 mg/L for all other livestock
#19:1.5 mg/L for dairy cows, breeding stock (long lived animals) OR 2 mg/L for livestock with high fluoride diets, mineral or bone meal, feed additives OR 4 mg/L for all other livestock with normal diet
#20:should not change more than ± 1 deg.C from ambien background
#21:1 mg/L for dairy cows, breeding stock (long lived animals) OR 1 mg/L for livestock with high fluoride diets, mineral or bone meal, feed additives OR 2 mg/L for all other livestock with normal diet
#22:Interim background groundwater concentration estimate
#23:results with hardness >500 mg/L should be evaluated on a site by site basis; refer to BC Protocol 10
#24:Standard varies with crop type, soil drainage and Mo:Cu ratio.

TABLE 3: SURFACE WATER DATASET

											Metals	Inorganics															
											zinc	ammonia as N	anions total	cations total	ionic balance	bromide	chloride ion	COD	fluoride	kjeldahl nitrogen total	nitrate (as N)	nitrite (as N)	phosphorus	silicon	sulfate	sulphide	sulphur as S
											µg/L	mg/L	meq/L	meq/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
BC WQG, Recreation																					10	1	0.01[#2]				
BC WQG (Approved) AWF, Long-term											7.5[#6] - 315[#6] *	0.102 - 2.08 *					150[#4]				3[#4]	0.02[#4] - 0.2[#4] *	0.005[#8]		128[#7] - 429[#7] *		
BC WQG (Approved) AWF, Short-term											33[#6] - 340.5[#6] *	0.682 - 28.7 *					600[#9]		0.4[#6] - 1.84[#6] *		32.8[#9]	0.06[#9] - 0.6[#9] *	0.005[#8]				
BC WQG (Working) AWF, Long-term																											
BC WQG (Approved) Wildlife Water Supply, Short-term																			1.5[#9]		100[#9]	10[#9]					
BC WQG (Approved) Wildlife Water Supply, Long-term																			1[#12]								
BC WQG Wildlife Water Supply																	600										
BC WQG (Approved) IW, Short-term																	100[#9]		2								
BC WQG (Approved) IW, Long-term											1000[#16]						100[#4]		1								
BC WQG (Approved) LW, Short-term																	600[#9]		1.5[#19]		100[#9]	10[#4]			1000		
BC WQG (Approved) LW, long-term											2000						600[#4]		1[#21]						1000		
Monitoring_Zone	**Alternative_Name**	**Location_Code**	**Well_Screen_Interval**	**Sampled_Date_Time**	**Monitoring_Unit**	**Sample_Type**	**Field_ID**	**SampleComment**	**SampleCode**	**Lab_Report_Number**																	
Central Landfill	SW1-07	SW1-07	-	4/26/2016		Normal	E303730		E303730__26 Apr 16		27	0.0387	0.00859	0.00904	2.5	<0.25	47.7	32	-	0.983	0.207	0.0105	**0.0378**	-	62.1	<0.02	-
Central Landfill	SW1-07	SW1-07	-	11/4/2016		Normal	E303730		E303730__04 Nov 16		50.2	0.908	5.83	6.06	1.9	<0.05	15.7	81	-	2.9	0.528	0.0605	**0.154**	-	69.1	<0.02	-
Central Landfill	SW1-07	SW1-07	-	5/15/2017		Normal	E303730		E303730W__15 May 17		25.5	0.0567	7.55	7.67	0.8	<0.25	34.1	49	-	1.82	1.41	0.0298	**0.0812**	-	48.7	<0.018	-
Central Landfill	SW1-07	SW1-07	-	5/15/2017		Field_D	SW DUPLICATE-1		SW DUPLICATE-1W__15 May 17		25.3	0.0577	7.59	7.66	0.5	<0.25	33.4	46	-	1.81	1.39	0.0251	**0.0831**	-	47.6	<0.018	-
Central Landfill	SW1-07	SW1-07	-	5/17/2018		Normal	E303730		E303730__17 May 18		32.7	0.0316	-	-	-	-	35.9	46	-	1.39	0.0589	0.0076	**0.09**	4.09	48.3	<0.018	18.1
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	1/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P __01 Jan 20		**140**	-	-	-	-	-	-	-	-	-	-	-	-	-	113	0.0088	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	2/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P __01 Feb 20		**140**	-	-	-	-	-	-	-	-	-	-	-	-	-	118	0.0082	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	3/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P __01 Mar 20		**100**	-	-	-	-	-	-	-	-	-	-	-	-	-	87	0.0143	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	4/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P __01 Apr 20		**50**	-	-	-	-	-	-	-	-	-	-	-	-	-	51	0.0715	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	5/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P __01 May 20		**50**	-	-	-	-	-	-	-	-	-	-	-	-	-	47	0.1306	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	6/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P __01 Jun 20		**50**	-	-	-	-	-	-	-	-	-	-	-	-	-	50	0.0846	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	7/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P __01 Jul 20		**90**	-	-	-	-	-	-	-	-	-	-	-	-	-	84	0.0202	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	8/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P __01 Aug 20		**160**	-	-	-	-	-	-	-	-	-	-	-	-	-	134	0.0066	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	9/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P __01 Sep 20		**140**	-	-	-	-	-	-	-	-	-	-	-	-	-	126	0.0075	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	10/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P __01 Oct 20		**130**	-	-	-	-	-	-	-	-	-	-	-	-	-	118	0.0085	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	11/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P __01 Nov 20		**120**	-	-	-	-	-	-	-	-	-	-	-	-	-	108	0.0102	-
Tailings Storage	OUTLET DITCH	OUTLET DITCH	-	12/1/2020		Normal	Outlet Ditch_P	Predicted Base Case	Outlet Ditch_P __01 Dec 20		**120**	-	-	-	-	-	-	-	-	-	-	-	-	-	105	0.011	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	1/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Jan 20		**160**	-	-	-	-	-	-	-	-	-	-	-	-	-	130	0.0089	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	2/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Feb 20		**160**	-	-	-	-	-	-	-	-	-	-	-	-	-	136	0.0089	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	3/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Mar 20		**120**	-	-	-	-	-	-	-	-	-	-	-	-	-	100	0.0091	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	4/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Apr 20		**60**	-	-	-	-	-	-	-	-	-	-	-	-	-	59	0.0094	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	5/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 May 20		**50**	-	-	-	-	-	-	-	-	-	-	-	-	-	54	0.0094	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	6/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Jun 20		**60**	-	-	-	-	-	-	-	-	-	-	-	-	-	57	0.0094	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	7/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Jul 20		**100**	-	-	-	-	-	-	-	-	-	-	-	-	-	96	0.0077	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	8/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Aug 20		**180**	-	-	-	-	-	-	-	-	-	-	-	-	-	154	0.0074	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	9/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Sep 20		**170**	-	-	-	-	-	-	-	-	-	-	-	-	-	144	0.0074	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	10/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Oct 20		**150**	-	-	-	-	-	-	-	-	-	-	-	-	-	135	0.0075	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	11/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Nov 20		**140**	-	-	-	-	-	-	-	-	-	-	-	-	-	124	0.0075	-
Tailings Storage	Spillway and Seepage	Spillway and Seepage	-	12/1/2020		Normal	Spillway + Seepage	Predicted Base Case	Spillway + Seepage __01 Dec 20		**130**	-	-	-	-	-	-	-	-	-	-	-	-	-	120	0.0076	-
Tailings Storage	SW2-07	SW2-07	-	4/28/2016		Normal	E303731		E303731__28 Apr 16		**12.1**	<0.005	1.43	1.6	5.7	<0.05	1.1	<20	-	0.111	0.088	<0.001	**0.0378**	-	4.98	<0.02	-
Tailings Storage	SW2-07	SW2-07	-	11/4/2016		Normal	E303731		E303731__04 Nov 16		**8.9**	<0.005	1.9	2.01	3	<0.05	1	<20	-	0.136	0.0661	<0.001	**0.0294**	-	27.6	<0.02	-
Tailings Storage	SW2-07	SW2-07	-	5/15/2017		Normal	E303731		E303731__15 May 17		7.7	0.382	3.47	3.47	0.1	<0.05	2.2	<20	-	1.12	1.32	**0.0531**	**0.0468**	-	31.7	<0.018	-
Tailings Storage	SW2-07	SW2-07	-	5/17/2018		Normal	E303731		E303731__17 May 18		9.2	<0.005	-	-	-	-	0.81	<20	-	0.122	0.0211	<0.001	**<0.05**	6.86	10	<0.018	3.81
Tailings Storage	SW2-07	SW2-07	-	10/30/2018		Normal	E303731		E303731__30 Oct 18		**70.3**	<0.005	-	-	-	0.125	13.8	-	0.11	0.263	0.0359	<0.001	**0.134**	13.1	55.7	-	20.4

TABLE 3: SURFACE WATER DATASET

	Metals	Inorganics															
	zinc	ammonia as N	anions total	cations total	ionic balance	bromide	chloride ion	COD	fluoride	kjeldahl nitrogen total	nitrate (as N)	nitrite (as N)	phosphorus	silicon	sulfate	sulphide	sulphur as S
	µg/L	mg/L	meq/L	meq/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
BC WQG, Recreation											**10**	**1**	**0.01[#2]**				
BC WQG (Approved) AWF, Long-term	**7.5[#6] - 315[#6] ***	**0.102 - 2.08 ***					**150[#4]**				**3[#4]**	**0.02[#4] - 0.2[#4] ***	**0.005[#8]**		**128[#7] - 429[#7] ***		
BC WQG (Approved) AWF, Short-term	**33[#6] - 340.5[#6] ***	**0.682 - 28.7 ***					**600[#9]**		**0.4[#6] - 1.84[#6] ***		**32.8[#9]**	**0.06[#9] - 0.6[#9] ***	**0.005[#8]**				
BC WQG (Working) AWF, Long-term																	
BC WQG (Approved) Wildlife Water Supply, Short-term									**1.5[#9]**		**100[#9]**	**10[#9]**					
BC WQG (Approved) Wildlife Water Supply, Long-term									**1[#12]**								
BC WQG Wildlife Water Supply							**600**										
BC WQG (Approved) IW, Short-term							**100[#9]**		**2**								
BC WQG (Approved) IW, Long-term	**1000[#16]**						**100[#4]**		**1**								
BC WQG (Approved) LW, Short-term							**600[#9]**		**1.5[#19]**		**100[#9]**	**10[#4]**			**1000**		
BC WQG (Approved) LW, long-term	**2000**						**600[#4]**		**1[#21]**						**1000**		

Monitoring_Zone	Alternative_Name	Location_Code	Well_Screen_Interval	Sampled_Date_Time	Monitoring_Unit	Sample_Type	Field_ID	SampleComment	SampleCode	Lab_Report_Number

Env Stds Description

BC WQG, Recreation:BC Water Quality Guidelines, Recreation Water
BC WQG (Approved) AWF, Long-term:BC Approved Water Quality Guidelines, Freshwater Aquatic Life, Long-term (January 2017)
BC WQG (Approved) AWF, Short-term:BC Approved Water Quality Guidelines, Freshwater Aquatic Life, Short-term (January 2017)
BC WQG (Working) AWF, Long-term:BC Working Water Quality Guidelines, Freshwater Aquatic Life, Long-term (January 2017)
BC WQG (Approved) Wildlife Water Supply, Short-term:BC Approved Water Quality Guidelines, Wildlife Water Supply, Short-term (January 2017)
BC WQG (Approved) Wildlife Water Supply, Long-term:BC Approved Water Quality Guidelines, Wildlife Water Supply, Long-term (January 2017)
BC WQG Wildlife Water Supply:BC Water Quality Guidelines, Wildlife Drinking Water
BC WQG (Approved) IW, Short-term:BC Approved Water Quality Guidelines, Drinking Water, Short-term (January 2017)
BC WQG (Approved) IW, Long-term:BC Approved Water Quality Guidelines, Irrigation Water, Long-term (January 2017)
BC WQG (Approved) LW, Short-term:BC Approved Water Quality Guidelines, Livestock Water, Short-term (January 2017)
BC WQG (Approved) LW, long-term:BC Approved Water Quality Guidelines, Livestock Water, Long-term (January 2017)
BC CSR DW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Drinking Water
BC CSR AWF:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Freshwater Aquatic Life
BC CSR IW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Irrigation
BC CSR LW:BC Contaminated Sites Regulation, Schedule 3.2 Generic Numerical Water Standards, Livestock

Env Stds Comments

#1:Should not cause an apreciable increase or decrease in the deep body temperature of swimmers
#2:Guideline applies only to lakes; there is no proposed BC WQG guideline for phosphorus in streams for recreation
#3:Dependent on natural background. Refer to Table 44 of BC Water Quality Guidelines Summary Report
#4:30 day
#5:30 Day
#6:Guideline is dependent on water hardness. Conservative hardness ranges used for comparison purposes. Exceedances to be confirmed against the formula in the regulatory guidance document.
#7:Guideline is dependent on water hardness in mg/L CaCO3
#8:Guideline applies only to lakes to protect against eutrophication; there is no proposed BC WQG guideline for phosphorus in streams for the protection of aquatic life
#9:Max
#10:Max (total iron)
#11:30 day; guideline is for Cr(VI), speciated results supercede total chromium results
#12:Average
#13:400 ug/L for neutral & alkaline fine-textured soils OR 200 ug/L for all other soils
#14:crop-dependent; see WQG table 4B
#15:Guideline depends on soil drainage, Cu:Mo ratio and crop variety. See Table 24 of BC Water Quality Guidelines Summary Report
#16:1000 ug/L for soil pH <6 OR 2000 ug/L for soil pH >=6 and <7 OR 5000 ug/L for soil pH > 7
#17:should not change more than ± 0.5 deg.C hourly
#18:0.08 mg/L for livestock consuming forages not irrigated or if no molybdenum containing fertilizers are applies to grow feed consumed by livestock OR .05 mg/L for all other livestock
#19:1.5 mg/L for dairy cows, breeding stock (long lived animals) OR 2 mg/L for livestock with high fluoride diets, mineral or bone meal, feed additives OR 4 mg/L for all other livestock with normal diet
#20:should not change more than ± 1 deg.C from ambien background
#21:1 mg/L for dairy cows, breeding stock (long lived animals) OR 1 mg/L for livestock with high fluoride diets, mineral or bone meal, feed additives OR 2 mg/L for all other livestock with normal diet
#22:Interim background groundwater concentration estimate
#23:results with hardness >500 mg/L should be evaluated on a site by site basis; refer to BC Protocol 10
#24:Standard varies with crop type, soil drainage and Mo:Cu ratio.

TABLE 3b: SURFACE WATER DATASET - REFERENCE LOCATION

	Field				Physical Parameters		Carbon		Metals																													
	temp (field)	pH (field)	EC (field)	turbidity	alkalinity (total) as CaCO3	Electrical Conductivity (lab)	Total Organic Carbon	Total Inorganic Carbon	hardness as CaCO3	pH (lab)	aluminum	antimony	arsenic	barium	beryllium	bismuth	boron	cadmium	calcium	cesium	chromium (III+VI)	cobalt	copper	iron	lead	lithium	magnesium	manganese	mercury	molybdenum	nickel	potassium	rubidium	selenium	silver	sodium	strontium	tellurium
	oC	pH_Units	µS/cm	NTU	mg/L	µS/cm	mg/L	mg/L	mg/L	pH_Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L
BC WQG, Recreation	#1	5-9		50																																		
BC WQG (Approved) AWF, Long-term		6.5-9		#3													1200[#4]					4[#5]	2[#6] - 9[#6] *		3.4[#6] - 19[#6] *			770[#6] - 2500[#6] *	0.00125[#4]	1000[#4]				1[#4]	0.05[#7] - 1.5[#7] *			
BC WQG (Approved) AWF, Short-term		6.5-9		#3									5[#9]									110[#9]	3.2[#6] - 39.6[#6] *	1000[#10]	3[#6] - 402[#6] *			810[#6] - 3300[#6] *		2000[#9]					0.1[#7] - 3[#7] *			
BC WQG (Working) AWF, Long-term												9[#4]		1000[#4]	0.13[#4]						1[#11]										25[#6] - 150[#6] *							
BC WQG (Approved) Wildlife Water Supply, Short-term				#3							5000[#9]		25[#9]				5000[#9]						300[#9]		100[#9]					50[#9]								
BC WQG (Approved) Wildlife Water Supply, Long-term				#3																																		
BC WQG Wildlife Water Supply																																		2				
BC WQG (Approved) IW, Short-term				#3							5000[#9]		100[#9]										200		200[#12]				2	50[#9]								
BC WQG (Approved) IW, Long-term																	500[#13]													10[#14]				10[#4]				
BC WQG (Approved) LW, Short-term	#16			#3							5000[#9]		25[#9]										300		100				3	50[#17]								
BC WQG (Approved) LW, long-term	#18																5000																	30[#4]				

Monitoring_Zone	Alternative_Name	Location_Code	Sampled_Date_Time	Sample_Type	Field_ID	SampleComments	temp (field)	pH (field)	EC (field)	turbidity	alkalinity (total) as CaCO3	Electrical Conductivity (lab)	Total Organic Carbon	Total Inorganic Carbon	hardness as CaCO3	pH (lab)	aluminum	antimony	arsenic	barium	beryllium	bismuth	boron	cadmium	calcium	cesium	chromium (III+VI)	cobalt	copper	iron	lead	lithium	magnesium	manganese	mercury	molybdenum	nickel	potassium	rubidium	selenium	silver	sodium	strontium	tellurium
Tailings Storage	SW3-07	SW3-07	4/26/2016	Normal	E303732	Background	9.8	7.85	83.5	0.16	53.9	120	1.17	14.4	56.1	7.93	17.7	<0.5	<0.5	<20	<1	-	<100	0.0074	17.7	-	<1	<0.3	<1	<30	<0.5	<1	2.87	2.86	<0.005	<1	<1	<2000	-	0.053	<0.02	<2	-	-
Tailings Storage	SW3-07	SW3-07	11/4/2016	Normal	E303732	Background	7.3	7.9	75.9	0.17	52.5	111	2.79	12.8	52.4	7.57	38.8	<0.5	<0.5	<20	<1	-	<100	0.0099	16.3	-	<1	<0.3	<1	<30	<0.5	<1	2.83	1.01	<0.005	<1	<1	<2000	-	0.083	<0.02	<2	-	-
Tailings Storage	SW3-07	SW3-07	5/15/2017	Normal	E303732	Background	5.7	8.02	68.2	1.03	49.1	108	1.4	11.5	51.6	7.79	26.4	<0.5	<0.5	<20	<0.1	-	<100	0.0079	16.3	-	<1	<0.3	<1	<30	<0.5	<1	2.68	2.53	<0.005	<1	<1	<2000	-	<0.05	<0.02	<2	-	-
Tailings Storage	SW3-07	SW3-07	5/14/2018	Normal	E303732	Background	11.5	7.37	78.8	1.12	47.2	106	1.56	11.5	51.3	7.89	11.9	<0.1	0.2	9.21	<0.1	<0.05	<10	0.0164	16	<0.01	<0.1	<0.1	<0.5	14	0.123	<1	2.73	1.68	<0.005	0.165	<0.5	1170	0.00057	0.086	<0.01	1.3	79.6	<0.2

Env Stds Description

BC WQG, Recreation:BC Water Quality Guidelines, Recreation Water
BC WQG (Approved) AWF, Long-term:BC Approved Water Quality Guidelines, Freshwater Aquatic Life, Long-term (January 2017)
BC WQG (Approved) AWF, Short-term:BC Approved Water Quality Guidelines, Freshwater Aquatic Life, Short-term (January 2017)
BC WQG (Working) AWF, Long-term:BC Working Water Quality Guidelines, Freshwater Aquatic Life, Long-term (January 2017)
BC WQG (Approved) Wildlife Water Supply, Short-term:BC Approved Water Quality Guidelines, Wildlife Water Supply, Short-term (January 2017)
BC WQG (Approved) Wildlife Water Supply, Long-term:BC Approved Water Quality Guidelines, Wildlife Water Supply, Long-term (January 2017)
BC WQG Wildlife Water Supply:BC Water Quality Guidelines, Wildlife Drinking Water
BC WQG (Approved) IW, Short-term:BC Approved Water Quality Guidelines, Drinking Water, Short-term (January 2017)
BC WQG (Approved) IW, Long-term:BC Approved Water Quality Guidelines, Irrigation Water, Long-term (January 2017)
BC WQG (Approved) LW, Short-term:BC Approved Water Quality Guidelines, Livestock Water, Short-term (January 2017)
BC WQG (Approved) LW, long-term:BC Approved Water Quality Guidelines, Livestock Water, Long-term (January 2017)

Env Stds Comments

#1:Should not cause an apreciable increase or decrease in the deep body temperature of swimmers
#2:Guideline applies only to lakes; there is no proposed BC WQG guideline for phosphorus in streams for recreation
#3:Dependent on natural background. Refer to Table 44 of BC Water Quality Guidelines Summary Report
#4:30 day
#5:30 Day
#6:Guideline is dependent on water hardness. Conservative hardness ranges used for comparison purposes. Exceedances to be confirmed against the formula in the regulatory guidance document.
#7:Guideline is dependent on water hardness in mg/L CaCO3
#8:Guideline applies only to lakes to protect against eutrophication; there is no proposed BC WQG guideline for phosphorus in streams for the protection of aquatic life.
#9:Max
#10:Max (total iron)
#11:30 day; guideline is for Cr(VI), speciated results supercede total chromium results
#12:400 ug/L for neutral & alkaline fine-textured soils OR 200 ug/L for all other soils
#13:crop-dependent; see WQG table 4B
#14:Guideline depends on soil drainage, Cu:Mo ratio and crop variety. See Table 24 of BC Water Quality Guidelines Summary Report
#15:1000 ug/L for soil pH <6 OR 2000 ug/L for soil pH >=6 and <7 OR 5000 ug/L for soil pH > 7
#16:should not change more than ± 0.5 deg.C hourly
#17:0.08 mg/L for livestock consuming forages not irrigated or if no molybdenum containing fertilizers are applies to grow feed consumed by livestock OR .05 mg/L for all other livestock.
#18:should not change more than ± 1 deg.C from ambien background

TABLE 3b: SURFACE WATER DATASET - REFERENCE LOCATION

	Metals								Inorganics														
	thallium	thorium	tin	titanium	tungsten	uranium	vanadium	zinc	ammonia as N	anions total	cations total	ionic balance	bromide	chloride	COD	kjeldahl nitrogen total	nitrate (as N)	nitrite (as N)	phosphorus	silicon	sulfate	sulphide	sulphur as S
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	meq/L	meq/L	%	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
BC WQG, Recreation																	**10**	**1**	**0.01[#2]**				
BC WQG (Approved) AWF, Long-term								**7.5[#6] - 315[#6] ***	**0.102 - 2.08 ***					**150[#4]**			**3[#4]**	**0.02[#4] - 0.2[#4] ***	**0.005[#8]**		**128[#7] - 429[#7] ***		
BC WQG (Approved) AWF, Short-term								**33[#6] - 340.5[#6] ***	**0.682 - 28.7 ***					**600[#9]**			**32.8[#9]**	**0.06[#9] - 0.6[#9] ***	**0.005[#8]**				
BC WQG (Working) AWF, Long-term	**0.8[#4]**					**8.5[#4]**																	
BC WQG (Approved) Wildlife Water Supply, Short-term																	**100[#9]**	**10[#9]**					
BC WQG (Approved) Wildlife Water Supply, Long-term																							
BC WQG Wildlife Water Supply														**600**									
BC WQG (Approved) IW, Short-term														**100[#9]**									
BC WQG (Approved) IW, Long-term								**1000[#15]**						**100[#4]**									
BC WQG (Approved) LW, Short-term														**600[#9]**			**100[#9]**	**10[#4]**			**1000**		
BC WQG (Approved) LW, long-term								**2000**						**600[#4]**							**1000**		

Monitoring_Zone	Alternative_Name	Location_Code	Sampled_Date_Time	Sample_Type	Field_ID	SampleComments	thallium	thorium	tin	titanium	tungsten	uranium	vanadium	zinc	ammonia as N	anions total	cations total	ionic balance	bromide	chloride	COD	kjeldahl nitrogen total	nitrate (as N)	nitrite (as N)	phosphorus	silicon	sulfate	sulphide	sulphur as S
Tailings Storage	SW3-07	SW3-07	4/26/2016	Normal	E303732	Background	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	<0.005	0.00123	0.00112	-4.6	<0.05	<0.5	<20	0.068	<0.005	<0.001	**0.0378**	-	7.32	<0.02	-
Tailings Storage	SW3-07	SW3-07	11/4/2016	Normal	E303732	Background	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	<0.005	1.18	1.05	-5.8	<0.05	<0.5	<20	0.089	<0.005	<0.001	0.0047	-	6.33	<0.02	-
Tailings Storage	SW3-07	SW3-07	5/15/2017	Normal	E303732	Background	<0.2	-	<0.5	<10	-	<0.2	<0.5	<5	<0.005	1.24	1.03	-9	<0.05	<0.5	<20	0.061	1.21	0.018	<0.002	-	8.23	<0.018	-
Tailings Storage	SW3-07	SW3-07	5/14/2018	Normal	E303732	Background	<0.01	<0.1	<0.1	0.35	<0.1	0.111	<0.5	6.6	<0.005	1.07	1.11	1.9	<0.05	<0.5	<20	0.067	<0.005	<0.001	**<0.05**	6.22	6.18	<0.018	2.15

Env Stds Description

BC WQG, Recreation:BC Water Quality Guidelines, Recreation Water
BC WQG (Approved) AWF, Long-term:BC Approved Water Quality Guidelines, Freshwater Aquatic Life, Long-term (January 2017)
BC WQG (Approved) AWF, Short-term:BC Approved Water Quality Guidelines, Freshwater Aquatic Life, Short-term (January 2017)
BC WQG (Working) AWF, Long-term:BC Working Water Quality Guidelines, Freshwater Aquatic Life, Long-term (January 2017)
BC WQG (Approved) Wildlife Water Supply, Short-term:BC Approved Water Quality Guidelines, Wildlife Water Supply, Short-term (January 2017)
BC WQG (Approved) Wildlife Water Supply, Long-term:BC Approved Water Quality Guidelines, Wildlife Water Supply, Long-term (January 2017)
BC WQG Wildlife Water Supply:BC Water Quality Guidelines, Wildlife Drinking Water
BC WQG (Approved) IW, Short-term:BC Approved Water Quality Guidelines, Drinking Water, Short-term (January 2017)
BC WQG (Approved) IW, Long-term:BC Approved Water Quality Guidelines, Irrigation Water, Long-term (January 2017)
BC WQG (Approved) LW, Short-term:BC Approved Water Quality Guidelines, Livestock Water, Short-term (January 2017)
BC WQG (Approved) LW, long-term:BC Approved Water Quality Guidelines, Livestock Water, Long-term (January 2017)

Env Stds Comments

#1:Should not cause an apreciable increase or decrease in the deep body temperature of swimmers
#2:Guideline applies only to lakes; there is no proposed BC WQG guideline for phosphorus in streams for recreation
#3:Dependent on natural background. Refer to Table 44 of BC Water Quality Guidelines Summary Report
#4:30 day
#5:30 Day
#6:Guideline is dependent on water hardness. Conservative hardness ranges used for comparison purposes. Exceedances to be confirmed against the formula in the regulatory guidance document.
#7:Guideline is dependent on water hardness in mg/L CaCO3
#8:Guideline applies only to lakes to protect against eutrophication; there is no proposed BC WQG guideline for phosphorus in streams for the protection of aquatic life.
#9:Max
#10:Max (total iron)
#11:30 day; guideline is for Cr(VI), speciated results supercede total chromium results
#12:400 ug/L for neutral & alkaline fine-textured soils OR 200 ug/L for all other soils
#13:crop-dependent; see WQG table 4B
#14:Guideline depends on soil drainage, Cu:Mo ratio and crop variety. See Table 24 of BC Water Quality Guidelines Summary Report
#15:1000 ug/L for soil pH <6 OR 2000 ug/L for soil pH >=6 and <7 OR 5000 ug/L for soil pH > 7
#16:should not change more than ± 0.5 deg.C hourly
#17:0.08 mg/L for livestock consuming forages not irrigated or if no molybdenum containing fertilizers are applies to grow feed consumed by livestock OR .05 mg/L for all other livestock.
#18:should not change more than ± 1 deg.C from ambien background

TABLE 4: SOIL

Site Area	Sample Location	Pre-Cap Sample Depth (mbg)	Sample Date	Sample ID	CO2 (Total)	Net Neutralization Potential	Neutralization Potential Ratio	Electrical Conductivity (lab)	pH (lab)	aluminum	antimony	arsenic	barium	beryllium	bismuth	boron	cadmium	calcium	chromium (III+VI)	cobalt	copper	gallium	gold	iron	lanthanum	lead	lithium	magnesium	manganese	mercury	molybdenum	nickel	potassium	scandium	selenium	silver	sodium	strontium	tellurium
					Acid Base Accounting			Physical Parameters	Metals																														
					µg/g	kg CaCO3/tonne	N/A	µS/cm	pH_Units	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
Reported Detection Limit									0.1	40	0.1	0.3	1	0.1		2	0.04		1	0.1	0.4			20		0.2	0.1		0.4	0.04	0.1	0.6			0.2	0.1		0.2	
BC CSR WLr h										40000	500					15000								35000			65									400		20000	
BC CSR WLr e											20																									20			
BC CSR WLr dw												10	350	1 - 2500 *			1 - 70 *		60	25	250 - 100000 *					120 - 8500 *			2000		15	70 - 500 *			1				
BC CSR WLr fw												10	3500	1 - 500 *			1 - 50 *		60	25	75 - 7500 *					200 - 90000 *					650	90 - 9500 *			1				
BC CSR WLr i												40	15000	150			40		250	25	7500					120			10000	25	400	900			400				
BC CSR WLr t												25	700	150			30		200	45	150					550			2000	40	80	150			1.5				
BC P4 Region 4 Kootenay										25000	4[#1]	4[#1]	350	0.8		1[#1]	0.4[#1]		35[#2]	15	35			30000		120			2000	0.085[#3]	1[#1]	50			4[#1]	1[#1]		150	
Tailings Storage	SRK16-AH-01	0.8-3.7	2016-Dec-14	SRK-1 COMP.	0.003502	579	4.3	1150	8.05	2500	4.8	**109**	54	-	0.5	<20	**38**	170,000	17	4.9	15.1	1	0.007	**47,900**	4	**1370**	-	79,300	374	0.07	2.1	15.7	900	1.3	<0.5	1.5	30	106	<0.2
		8.8-9.4		SRK-1-G07	0.003499	586	3.9	1200	8.52	1700	2.7	**22.6**	64	-	0.8	<20	**50.2**	154,000	12	5.8	16.7	1	0.0046	**48,800**	5	**2370**	-	76,900	349	0.09	2.7	25.3	500	0.9	0.7	1.9	20	109	<0.2
	SRK16-AH-0-2	0.6-3.4	2016-Dec-15	SRK-2 COMP.	0.003736	724	8.4	1380	8.1	2000	12.7	**98.4**	58	-	0.5	<20	**34.4**	172,000	14	3.4	50	<1	0.0289	33,400	4	**1840**	-	88,700	425	0.07	2	13.2	700	1	0.6	2.1	40	113	<0.2
	SRK16-AH-03	0.6-3.4	2016-Dec-15	SRK-3 COMP.	0.003872	632	8.1	1510	8.44	2800	3.1	**26**	65	-	0.7	<20	**33.9**	187,000	12	3.4	51.2	1	0.0053	25,200	4	**1560**	-	90,400	425	0.09	1.5	10.9	1300	1.2	<0.5	1.4	40	125	<0.2
	SRK16-AH-04	0.6-3.4	2016-Dec-16	SRK-4 COMP.	0.004063	779	8.9	1190	8.29	1200	3.3	**31.8**	50	-	0.4	<20	25.5	175,000	11	2.8	20.8	<1	0.009	31,500	4	**1170**	-	89,700	387	0.06	1.5	10.8	600	0.8	<0.5	1.1	30	110	<0.2
	SRK16-AH-05	0.6-1.8	2016-Dec-16	SRK-5 COMP.	0.004026	770	8.2	1260	8.22	1100	5.7	**55.8**	44	-	0.5	<20	25.6	179,000	12	2.6	20	<1	0.0056	30,800	4	**1290**	-	90,200	401	0.05	1.7	10.8	500	0.8	<0.5	1.4	20	110	<0.2
		11.9-12.5		SRK-5-G07	0.003857	706	6.4	1090	8.72	1200	2.6	**22.7**	57	-	0.4	<20	**33.3**	165,000	18	3.8	33.2	<1	0.0017	34,400	5	**1410**	-	88,400	347	0.08	2.5	18.7	400	0.8	<0.5	1.7	30	113	<0.2
	SRK16-AH-06	0.6-3.4	2016-Dec-16	SRK-6 COMP.	0.003627	601	4.2	1250	8.36	1500	3.5	**52.5**	39	-	0.5	<20	**40.7**	157,000	10	3.7	14.1	1	0.0068	**48,600**	4	**1950**	-	76,200	342	0.08	1.8	15.8	700	0.9	0.7	1.6	20	100	<0.2
				SRK-6 COMP. DUP	0.003616	589	4.1	1250	8.38	1500	3.4	**52.3**	41	-	0.5	<20	**43.5**	166,000	11	4.3	14.6	1	0.0078	**50,000**	4	**1990**	-	78,400	378	0.08	1.8	16.1	700	0.9	0.5	1.8	10	106	<0.2
	SS1-1	0-0.3	2018-Jun-4	SS1-1	-	-	-	-	7.67	3690	5.64	**67.5**	71.3	0.37	2.32	1.4	18.1	126,000	12.9	4.06	107	-	-	**35,600**	-	**1170**	<5	-	462	<0.05	1.85	18.1	1210	-	0.52	2.91	<100	83.4	-
				DUP A	-	-	-	-	7.71	4100	5.39	**62.7**	74.2	0.36	2.68	1.4	17.5	111,000	14.1	4.55	121	-	-	34,400	-	**1190**	<5	-	467	0.057	1.76	18.5	1360	-	0.56	3.26	<100	73.3	-
	SS2-1	0-0.3	2018-Jun-4	SS2-1	-	-	-	-	7.85	642	13	**185**	19.4	0.27	0.24	<1	**51.6**	146,000	3.4	4.76	15.8	-	-	**101,000**	-	**2840**	<5	-	352	0.112	2.97	23.7	216	-	**1.26**	3.46	<100	74.7	-
	SS3-1	0-0.3	2018-Jun-4	SS3-1	-	-	-	-	7.71	592	11.5	**148**	20.4	0.28	0.2	<1	**37.9**	170,000	2.9	3.86	15.1	-	-	**83,300**	-	**2140**	<5	-	344	0.079	2.44	19.3	217	-	0.96	2.57	<100	91.6	-
	SS4-1	0-0.3	2018-Jun-4	SS4-1	-	-	-	-	7.86	1070	9.64	**82.1**	43.4	0.35	0.14	<1	**24.7**	236,000	5.6	2.09	37	-	-	**44,500**	-	**1620**	<5	-	441	0.06	2.55	11.4	436	-	0.63	2.21	<100	129	-
	SSREF-1	0-0.3	2018-Jun-4	SSREF-1	-	-	-	-	6.18	21,100	0.63	**11.3**	159	0.59	0.37	1.7	**1.71**	4630	31.7	9.92	19.9	-	-	23,300	-	58.3	17.7	-	666	<0.05	0.83	28.3	1600	-	<0.5	0.352	148	31.1	-
	SSREF-2	0-0.3	2018-Jun-4	SSREF-2	-	-	-	-	5.68	10,900	0.39	9.85	99.5	0.38	0.31	<1	0.656	2860	34.2	10.7	20.3	-	-	21,000	-	27.3	11.8	-	337	<0.05	1.12	28.6	1760	-	<0.5	0.296	100	17	-
Borrow Pit	TP18-1-comp		2018-Oct-10	TP18-1-comp	-	-	-	-	8.03	11,700	0.41	7.73	152	0.57	-	<2	0.419	-	20.4	6.96	18	-	-	18,800	-	13.4	12.5	-	417	0.053	0.65	22.4	-	-	0.28	0.14	-	52.5	-
	TP18-2-comp		2018-Oct-10	TP18-2-comp	-	-	-	-	8.13	14,000	0.38	8.5	139	0.68	-	2.1	0.301	-	21.2	7.79	17.9	-	-	21,300	-	14	14.8	-	516	0.042	0.55	21.9	-	-	0.23	0.11	-	37	-
	TP18-3-comp		2018-Oct-10	TP18-3-comp	-	-	-	-	8.04	13,800	0.44	**11.6**	177	0.78	-	2	0.335	-	22.4	9.22	18.2	-	-	22,800	-	18.3	14.7	-	533	<0.04	0.61	27.5	-	-	0.24	0.16	-	60.2	-
	TP18-05		2019-Feb-5	TP18-05	-	-	-	-	6.64	15,700	0.37	9.75	121	0.53	-	<2	0.426	-	34.5	8.12	23.1	-	-	21,400	-	14	17.9	-	533	<0.04	0.71	25.9	-	-	<0.2	0.23	-	22.8	-
	TP18-06		2019-Feb-5	TP18-06	-	-	-	-	6.98	23,000	0.49	8.91	190	0.59	-	<2	0.341	-	45.8	13.1	42.4	-	-	31,900	-	18.4	23.4	-	782	<0.04	1.31	35.1	-	-	<0.2	<0.1	-	52.4	-
	TP18-07		2019-Feb-5	TP18-07	-	-	-	-	6.55	19,800	0.48	**11.8**	168	0.64	-	<2	0.256	-	38.1	10.9	33.6	-	-	27,100	-	16.8	19	-	597	<0.04	1.1	29.8	-	-	<0.2	<0.1	-	34.6	-
	TP18-08		2019-Feb-5	TP18-08	-	-	-	-	6.75	15,100	0.41	**10.9**	123	0.57	-	<2	0.199	-	21.8	7.33	20.3	-	-	20,500	-	13.5	13.8	-	445	<0.04	0.8	22.7	-	-	<0.2	<0.1	-	21.2	-
	TP18-09		2019-Feb-5	TP18-09	-	-	-	-	7.12	16,100	0.37	**13**	110	0.44	-	<2	0.241	-	38.5	9.86	26.8	-	-	25,400	-	14.3	16.4	-	428	<0.04	0.6	31.6	-	-	<0.2	0.18	-	24.3	-
	TP18-13		2019-Feb-5	TP18-13	-	-	-	-	7.22	23,200	0.53	**14.5**	164	0.7	-	<2	0.65	-	37.9	11.2	32	-	-	27,500	-	23.5	29.1	-	542	<0.04	0.78	44	-	-	<0.2	0.18	-	26.2	-
	TP18-14		2019-Feb-5	TP18-14	-	-	-	-	8.25	12,200	0.37	**10.4**	161	0.63	-	2	0.248	-	21	8.31	17.8	-	-	21,500	-	15.1	12.1	-	674	<0.04	0.66	28.5	-	-	0.21	0.17	-	60.3	-
	TP18-18-comp		2018-Oct-11	TP18-18-comp	-	-	-	-	5.99	18,800	0.23	5.37	148	0.54	-	<2	0.267	-	29.4	8.46	23.8	-	-	22,200	-	12.8	16.1	-	468	<0.04	0.73	20.9	-	-	<0.2	<0.1	-	25.1	-
	TP18-19-comp		2018-Oct-11	TP18-19-comp	-	-	-	-	8.49	7120	0.19	3.2	73.3	0.3	-	<2	0.245	-	12.1	3.53	9.91	-	-	12,700	-	8.06	8.58	-	202	<0.04	0.35	9.32	-	-	<0.2	0.15	-	17	-
	TP18-20-comp		2018-Oct-11	TP18-20-comp	-	-	-	-	7.95	11,400	0.27	8.23	130	0.55	-	<2	0.284	-	15.7	5.55	11.7	-	-	16,800	-	13.3	10.4	-	464	<0.04	0.36	12.9	-	-	<0.2	0.13	-	20.9	-

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- BC CSR WLr e:BC Contaminated Sites Regulation, Schedule 3.1 Part 3 Generic Numerical Soil Standards to Protect Ecological Health, Wildlands (Reverted)
- BC CSR WLr dw:BC Contaminated Sites Regulation, Schedule 3.1 Part 1 Numerical Soil Standards, Groundwater used for drinking water- Wildlands (Reverted)
- BC CSR WLr fw:BC Contaminated Sites Regulation, Schedule 3.1 Part 1 Numerical Soil Standards, Groundwater flow to surface water used by aquatic life (Freshwater) - Wildlands (Reverted)
- BC CSR WLr i:BC Contaminated Sites Regulation, Schedule 3.1 Part 1 Numerical Soil Standards, Intake of Contaminated Soil - Wildlands (Reverted)
- BC CSR WLr t:BC Contaminated Sites Regulation, Schedule 3.1 Part 1 Numerical Soil Standards, Toxicity to soil invertebrates and plants - Wildlands (Reverted)
- BC P4 Region 4 Kootenay:BC CSR Protocol 4 Table 1: Regional estimates for background concentrations in soil for inorganic substances (Region 4 Kootenay)

Standards / Guidelines Comments:

#1:Regional estimate is one-halve the mean detection limit
#2:Chromium = total chromium
#3:Mercury = inorganic mercury

Notes:

m - metres
mbg - metres below grade
< - less than reported detection limit
'-' - sample not analyzed for parameter indicated
• formatting of cells indicates exceedances of like-formatted standards
• formatting indicates the least stringent standard/guideline exceeded
• samples collected from the same location, date and depth interval are blind field duplicate / parent sample pairs
• laboratory analytical reports detail detection limits, testing protocols and QA/QC procedures
µg/g - micrograms per gram
ns, ng - no standard or guideline listed
* - range of pH-dependent standards; value is compared to standard derived from pH of individual sample
• metals with pH-dependent standards:
Be - beryllium, Cd - cadmium, Cu - copper, Pb - lead, Ni = nickel, Zn - zinc
• water uses:
DW - drinking water, AWF - aquatic life (freshwater)
• most conservative standard of chromium(III) or (VI) applied to chromium (total)

*** BC CSR pH-Dependent Standards**

Be - DW	Cd - DW	Cu - DW	Pb - DW	Ni - DW
1 @ pH < 5.5	1 @ pH < 7.0	250 @ pH < 5.0	120 @ pH < 5.5	70 @ pH < 7.5
1.5 @ pH 5.5<6.0	4.5 @ pH 7.0<7.5	500 @ pH 5.0<5.5	150 @ pH 5.5<6.0	250 @ pH 7.5<8.0
4 @ pH 6.0<6.5	30 @ pH 7.5<8.0	2,000 @ pH 5.5<6.0	800 @ pH 6.0<6.5	500 @ pH ≥ 8.0
20 @ pH 6.5<7.0	70 @ pH ≥ 8.0	10,000 @ pH 6.0<6.5	3,500 @ pH 6.5<7.0	
150 @ pH 7.0<7.5		50,000 @ pH 6.5<7.0	7,500 @ pH 7.0<7.5	
1,000 @ pH 7.5<8.0		100,000 @ pH ≥ 7.0	8,500 @ pH ≥ 7.5	
2,500 @ pH ≥ 8.0				

Be - AWF	Cd - AWF	Cu - AWF	Pb - AWF	Ni - AWF
1 @ pH < 6.5	1 @ pH < 7.0	75 @ pH < 5.5	200 @ pH < 5.0	90 @ pH < 5.0
4 @ pH 6.5<7.0	3 @ pH 7.0<7.5	100 @ pH 5.5<6.0	350 @ pH 5.0<5.5	100 @ pH 5.0<5.5
30 @ pH 7.0<7.5	20 @ pH 7.5<8.0	700 @ pH 6.0<6.5	1,500 @ pH 5.5<6.0	150 @ pH 5.5<6.0
250 @ pH 7.5<8.0	50 @ pH ≥ 8.0	3,000 @ pH 6.5<7.0	8,500 @ pH 6.0<6.5	200 @ pH 6.0<6.5
500 @ pH ≥ 8.0		6,500 @ pH 7.0<7.5	35,000 @ pH 6.5<7.0	300 @ pH 6.5<7.0
		7,500 @ pH ≥ 7.5	80,000 @ pH 7.0<7.5	900 @ pH 7.0<7.5
			90,000 @ pH ≥ 7.5	5,000 @ pH 7.5<8.0
				9,500 @ pH ≥ 8.0

TABLE 4: SOIL

Site Area	Sample Location	Pre-Cap Sample Depth (mbg)	Sample Date	Sample ID	Metals: thallium	thorium	tin	titanium	tungsten	uranium	vanadium	zinc	zirconium	Inorganics: phosphorus	sulphide	sulphur as S	SPOCAS: HCl Extractable Sulfur
					µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	%S
Reported Detection Limit					0.1		0.2		0.2	0.05	1	2					
BC CSR WLr h							**50000**		**25**								
BC CSR WLr e					**9**		**50**										
BC CSR WLr dw										**30**	**100**	**200 - 5500 ***					
BC CSR WLr fw										**150**		**150 - 3000 ***					
BC CSR WLr i										**250**	**400**	**25000**					
BC CSR WLr t										**500**	**150**	**450**					
BC P4 Region 4 Kootenay							4[#1]				40	200				950	
Tailings Storage	SRK16-AH-01	0.8-3.7	2016-Dec-14	SRK-1 COMP.	0.5	1	-	100	1.1	2	19	**3680**	-	260	0.000568	0.000592	0.24
		8.8-9.4		SRK-1-G07	0.8	0.5	-	130	0.3	2.5	25	**4560**	-	340	0.000636	0.000641	0.05
	SRK16-AH-0-2	0.6-3.4	2016-Dec-15	SRK-2 COMP.	0.5	0.6	-	70	0.8	2.2	21	**3040**	-	290	0.000311	0.000362	0.51
	SRK16-AH-03	0.6-3.4	2016-Dec-15	SRK-3 COMP.	0.6	1	-	170	0.3	2.3	21	**3150**	-	280	0.000283	0.000292	0.09
	SRK16-AH-04	0.6-3.4	2016-Dec-16	SRK-4 COMP.	0.5	0.5	-	60	0.3	2.2	17	**2380**	-	230	0.000315	0.000366	0.51
	SRK16-AH-05	0.6-1.8	2016-Dec-16	SRK-5 COMP.	0.5	0.4	-	50	0.3	2.5	20	**2510**	-	260	0.000343	0.000353	0.1
		11.9-12.5		SRK-5-G07	0.6	0.3	-	100	0.2	2.5	29	**3020**	-	350	0.000417	0.000422	0.05
	SRK16-AH-06	0.6-3.4	2016-Dec-16	SRK-6 COMP.	0.6	0.5	-	90	0.3	2.2	18	**3970**	-	290	0.000608	0.000644	0.36
				SRK-6 COMP. DUP	0.6	0.6	-	90	0.3	2.6	20	**4040**	-	300	0.000607	0.000641	0.34
	SS1-1	0-0.3	2018-Jun-4	SS1-1	0.4	-	0.73	-	5.3	1.76	19.7	**2170**	1.22	467	-	-	-
				DUP A	0.39	-	0.81	-	6.35	1.77	18.4	**1920**	1.41	437	-	-	-
	SS2-1	0-0.3	2018-Jun-4	SS2-1	0.781	-	0.27	-	<0.5	3.56	17.6	**5050**	<0.5	373	-	-	-
	SS3-1	0-0.3	2018-Jun-4	SS3-1	0.805	-	0.32	-	<0.5	2.57	19	**4480**	<0.5	321	-	-	-
	SS4-1	0-0.3	2018-Jun-4	SS4-1	0.569	-	0.23	-	<0.5	2.25	22.3	**2910**	<0.5	301	-	-	-
	SSREF-1	0-0.3	2018-Jun-4	SSREF-1	0.162	-	0.66	-	2.32	1.92	45.3	198	4.76	1130	-	-	-
	SSREF-2	0-0.3	2018-Jun-4	SSREF-2	0.118	-	0.37	-	2.31	1.31	37.3	94.4	0.9	756	-	-	-
Borrow Pit	TP18-1-comp		2018-Oct-10	TP18-1-comp	<0.1	-	0.34	-	<0.2	1.38	31.1	67.9	-	-	-	-	-
	TP18-2-comp		2018-Oct-10	TP18-2-comp	0.11	-	0.5	-	<0.2	2.01	25.7	58.7	-	-	-	-	-
	TP18-3-comp		2018-Oct-10	TP18-3-comp	0.11	-	0.35	-	<0.2	2.04	24.9	65.3	-	-	-	-	-
	TP18-05		2019-Feb-5	TP18-05	0.12	-	0.34	-	0.22	1.8	47.4	71.2	-	-	-	-	-
	TP18-06		2019-Feb-5	TP18-06	0.21	-	0.53	-	0.56	1.79	73.9	117	-	-	-	-	-
	TP18-07		2019-Feb-5	TP18-07	0.18	-	0.44	-	0.45	2.08	59.9	101	-	-	-	-	-
	TP18-08		2019-Feb-5	TP18-08	0.11	-	0.42	-	0.22	1.13	33	66	-	-	-	-	-
	TP18-09		2019-Feb-5	TP18-09	0.12	-	0.35	-	0.24	1.52	43.1	62.9	-	-	-	-	-
	TP18-13		2019-Feb-5	TP18-13	0.17	-	0.52	-	0.2	1.86	52.3	166	-	-	-	-	-
	TP18-14		2019-Feb-5	TP18-14	<0.1	-	0.31	-	<0.2	1.64	24.3	59.7	-	-	-	-	-
	TP18-18-comp		2018-Oct-11	TP18-18-comp	0.14	-	0.31	-	<0.2	1.25	57	74.7	-	-	-	-	-
	TP18-19-comp		2018-Oct-11	TP18-19-comp	<0.1	-	<0.2	-	<0.2	0.861	27	36.1	-	-	-	-	-
	TP18-20-comp		2018-Oct-11	TP18-20-comp	<0.1	-	0.33	-	<0.2	1.33	23.2	48.7	-	-	-	-	-

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- BC CSR WLr e:BC Contaminated Sites Regulation, Schedule 3.1 Part 3 Generic Numerical Soil Standards to Protect Ecological Health, Wildlands (Reverted)
- BC CSR WLr dw:BC Contaminated Sites Regulation, Schedule 3.1 Part 1 Numerical Soil Standards, Groundwater used for drinking water- Wildlands (Reverted)
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- BC CSR WLr t:BC Contaminated Sites Regulation, Schedule 3.1 Part 1 Numerical Soil Standards, Toxicity to soil invertebrates and plants - Wildlands (Reverted)
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Standards / Guidelines Comments:

#1:Regional estimate is one-halve the mean detection limit
#2:Chromium = total chromium
#3:Mercury = inorganic mercury

Notes:

m - metres
mbg - metres below grade
< - less than reported detection limit
'-' - sample not analyzed for parameter indicated
• formatting of cells indicates exceedances of like-formatted standards
• formatting indicates the least stringent standard/guideline exceeded
• samples collected from the same location, date and depth interval are blind field duplicate / parent sample pairs
• laboratory analytical reports detail detection limits, testing protocols and QA/QC procedures
µg/g - micrograms per gram
ns, ng - no standard or guideline listed
* - range of pH-dependent standards; value is compared to standard derived from pH of individual sample
• metals with pH-dependent standards:
Be - beryllium, Cd - cadmium, Cu - copper, Pb - lead, Ni = nickel, Zn - zinc
• water uses:
DW - drinking water, AWF - aquatic life (freshwater)
• most conservative standard of chromium(III) or (VI) applied to chromium (total)

Zn - DW
200 @ pH < 5.0
250 @ pH 5.0<5.5
300 @ pH 5.5<6.0
450 @ pH 6.0<6.5
600 @ pH 6.5<7.0
1,000 @ pH 7.0<7.5
3,000 @ pH 7.5<8.0
5,500 @ pH ≥ 8.0

Zn - AWF
150 @ pH < 6.0
250 @ pH 6.0<6.5
350 @ pH 6.5<7.0
600 @ pH 7.0<7.5
1,500 @ pH 7.5<8.0
3,000 @ pH ≥ 8.0

TABLE 5: SEDIMENT

						Particle Size				Physical Parameters		Carbon	Metals								
Site Area	Sample Location	Sample Depth (mbg)	Sample Date	Sample ID	Sample Code	% gravel (>2mm)	% sand by hydrometer	% silt by hydrometer	clay content	percent saturation	moisture	Total Organic Carbon	pH (lab)	aluminum	antimony	arsenic	barium	beryllium	bismuth	cadmium	calcium
						%	%	%	%	%	%	µg/g	pH_Units	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
BC CSR SedFS																**11**				**2.2**	
Tailings Storage	S-1	0.1	2017-Aug-23	S-1	S-1__23 Aug 17	<2	75	23	2.4	63.1	3.7	6600	7.39	12,800	1.7	9.31	117	0.52	0.24	**2.34**	5800
	S-3	0.1	2017-Aug-23	S-3	S-3__23 Aug 17	<2	78	21	<2	-	-	-	7.18	10,600	0.75	6.83	97.1	0.4	0.16	1.7	4860
	S-4	0.1	2017-Aug-23	S-4	S-4__23 Aug 17	<2	81	17	<2	63.6	3.6	7200	7.22	12,500	1.2	7.71	142	0.5	0.23	**2.33**	6520
	S-6	0.1	2017-Aug-23	S-6	S-6__23 Aug 17	8.8	77	11	2.6	61.2	24	14,000	7.91	14,800	1.78	**12.4**	148	0.62	0.24	**3.39**	6880
	S-7	0.05	2017-Aug-23	S-7	S-7__23 Aug 17	4.2	47	35	14	54.9	22	3800	7.39	23,100	0.54	10.3	195	0.74	0.38	0.877	5030
	S-8	0.1	2017-Aug-23	S-8	S-8__23 Aug 17	<2	56	43	<2	-	-	-	6.94	15,400	0.36	5.8	162	0.61	0.23	1.4	5870
	S-9	0.1	2017-Aug-23	S-9	S-9__23 Aug 17	<2	52	47	<2	95.4	7.4	10,000	7.56	12,600	2.09	**25.7**	173	0.73	0.35	**11.9**	10,100
	S-10	0.1	2017-Aug-23	S-10	S-10__23 Aug 17	<2	82	17	<2	52.6	3.5	3100	7.26	10,600	0.96	9.46	112	0.45	0.19	**2.26**	4570
				DUP A	DUP A__23 Aug 17	<2	85	15	<2	-	-	-	7.26	11,200	0.98	10.2	122	0.48	0.21	**2.64**	4420

	Metals (continued)																							Inorganics		
Sample ID	chromium (III+VI)	cobalt	copper	iron	lead	lithium	magnesium	manganese	mercury	molybdenum	nickel	potassium	selenium	silver	sodium	strontium	thallium	tin	titanium	uranium	vanadium	zinc	zirconium	chloride	phosphorus	sulfate
	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
BC CSR SedFS	**56**		**120**		**57**				**0.3**													**200**				
S-1	29.4	10.4	63.3	23,100	**94.7**	18.4	6730	754	<0.05	1.04	29.4	1690	<0.5	0.243	123	29.9	0.195	0.47	669	1.98	52.9	**732**	1.72	11.2 - 18	967	53
S-3	25.8	9.17	30.8	18,900	**69.1**	15.3	5650	482	<0.05	0.79	24.7	1330	<0.5	0.205	109	25.2	0.161	0.32	564	1.89	46.8	**635**	1.52	-	974	-
S-4	28.3	10.2	54.1	23,000	**96.4**	18.1	7090	711	<0.05	1.09	29.9	1550	<0.5	0.262	150	30.3	0.182	0.32	601	2.19	53.7	**648**	1.09	9 - 14	1070	218
S-6	34.8	14	78	27,600	**145**	19.8	7630	1510	<0.05	1.32	34	1790	<0.5	0.313	155	38	0.221	0.36	682	1.9	60.8	**1120**	1.29	9.2 - 15	1300	85
S-7	51.5	19.4	45.4	37,500	40.3	20.6	10,100	884	<0.05	1.3	37.8	3280	<0.5	0.176	167	44.8	0.268	0.54	1310	2.27	83.7	**212**	5.36	26.4 - 48	1020	107
S-8	34.8	12.6	28.2	22,800	20.1	22.4	7960	354	<0.05	1.08	36.3	1730	0.62	0.247	249	39.4	0.165	0.32	704	3.82	65.1	176	2.83	-	1340	-
S-9	29.6	13.7	42.3	29,000	**427**	16.4	8560	4580	<0.05	1.83	32.8	1960	0.5	0.687	175	38.3	0.283	0.48	590	3.12	47.9	**2280**	0.75	<9.5	1170	263
S-10	29.9	9.39	36.4	19,600	**125**	14.8	5400	1080	<0.05	1.06	25	1240	<0.5	0.257	124	23.5	0.146	0.26	478	1.65	44.7	**572**	1.11	<5.3	1070	108
DUP A	30.5	10.7	37.6	21,100	**143**	16.2	5790	1210	<0.05	1.17	27	1380	<0.5	0.301	124	24.2	0.168	0.28	500	1.92	47.4	**655**	1.47	-	1040	-

Standards / Guidelines Descriptions:

• BC CSR SedFS:BC Contaminated Sites Regulation, Schedule 3.4, Generic Numerical Sediment Standards, Freshwater Sensitive Use

Notes:

m - metres
mbg - metres below grade
< - less than reported detection limit
'-' - sample not analyzed for parameter indicated
• formatting of cells indicates exceedances of like-formatted standards
• formatting indicates the least stringent standard/guideline exceeded
• samples collected from the same location, date and depth interval are blind field duplicate / parent sample pairs
• laboratory analytical reports detail detection limits, testing protocols and QA/QC procedures
µg/g - micrograms per gram
ns, ng - no standard or guideline listed

APPENDIX B
Conceptual Site Model

Regional District of Central Kootenay
Prospective Human Health and Ecological Risk Assessment
HB Mine Tailings Management Facility
SLR Project No.: 204.03242.00004

APPENDIX B

CONCEPTUAL SITE MODEL

CSMs assist site investigators in understanding how contamination originates at a site, how the contamination is transported, where the contamination is migrating and whom the contamination may affect (Health Canada, 2012). A chart representation of the CSM is presented as Drawing 10.

The CSM for the HB Mine Tailings Facility (the site) was developed using information from the following reports:

- AMEC 2014. Five Year Hydrogeology Review, Central Landfill, Salmo, BC. Prepared for Regional District of Central Kootenay. April 2014.
- RDCK 2018. Annual Reclamation Report for 2018. Mines Act Permit Number: M-218. HB Mine Tailings Storage Facility.
- RDCK 2019. HB Mines Tailings Facility Remediation and Closure Plan. Prepared for BC Ministry of Energy, Mines and Petroleum Resources.
- CRA 2002. Revised Draft Text for Detailed Site Investigation Report. Canex Landfill Site, Salmo, British Columbia.
- CRA 2005. Southern Groundwater Flowpath. Central Landfill Site. Salmo, British Columbia.
- Canex 2000. Canex Landfill Hydrogeological Impact Assessment, prepared by Klohn-Crippen Consultants Ltd., July 31, 2000.
- SRK 2017a. Prediction of Geochemical Performance of HB Tailings Under Proposed Remediation Conditions Memo. SRK Consulting. May 23, 2017.
- SRK 2017b. HB Mine Tailings Facility Closure Design – Hydrological Analysis – DRAFT Memo. SRK Consulting. May 23, 2017.
- SRK 2017c. HB Mine Tailings Dam Seepage Assessment – Memo. SRK Consulting. September 27, 2017.
- SRK 2018. HB Mine Tailings Facility Preliminary Design Drawings dated December 2018.
- SNC 2013. Limited Risk-based Preliminary and Detailed Site Investigation and Human Health Risk Assessment. Blocks 3 and 4, District Lot 275, Plan NEP23118 and Lot A, Block 5, West Half of Block 6 and Block 7, Kootenay Land District, 6 km South of Salmo, BC.

1.0 SITE SETTING

The Site is located southwest of Salmo, British Columbia and is situated in the Columbia Mountain System between the Rocky Mountain Trench and the Interior Plateau, between the Nelson Range and the Barrington Range of the Selkirk Mountains. The site consists of the tailings deposition area (or tailings area) as well as the drainage channel (outlet ditch). The tailings area covers an approximate area of 26 hectares (ha). The outlet ditch starts at the base of the current tailing pond and seasonally flows south/southwest towards the Salmo River. The section of the outlet ditch included in this assessment is located between the end of the current tailings pond's spillway and the culvert north of Highway 3.

Currently, a tailings pond is located in the southern extremity of the tailings depositions area and is retained by an earthen dam. The pond occupies an approximate area of 2 ha with the spillway inlet in the southwest corner. Approximately 80 percent of the tailings deposition area is dry and the remaining 20 percent is submerged within the tailings pond. The tailings pond is currently fed by groundwater as well as surficial drainage channels which flow southward across the tailings area.

SRK has prepared a report detailing the design for the closure, reclamation, and the remediation of the HB Mine Tailings Facility ("SRK Closure Report"; SRK, 2018). The tailings pond will be drained and backfilled during closure to prevent pooling of water in the tailings. Under post-closure conditions, the entire tailings deposition area will be covered with 0.3 m of fill ("cap") sourced from the borrow pit area located east of the landfill to the northeast of the site. The SRK Closure Report also includes the design of lined surface water drainage channels, constructed over the tailings cover to convey surface runoff to the spillway southwest of the tailings area. Vegetation will be re-established across the entire tailings deposition area using species pre-approved by relevant stakeholders.

1.1 Site Drainage

The tailings deposition area is relatively flat with elevations ranging from 715 m (northeast corner) to 712 m (southeast corner) AMSL. The spillway inlet of the current tailings pond is 1.7 m below the crest elevation of the dam (BGC, 2002). North of the site is Sheep Creek that flows westward to the Salmo River and is located in a steeply incised bank.

Regionally, the site is located within the Pend-D'Oreille watershed. The major drainage in the area of the site is the southward flowing Salmo River, which occupies a floodplain approximately 1.2 kilometers southwest of the site. The majority of the surface water in the area of the site, including surface water from the adjacent landfill operation, currently drains through the tailing deposition area to the tailings pond. Under post-closure conditions, surface water will drain through the surface water drainage channels on an ephemeral basis across of the tailings area to the spillway. Once in the spillway drainage water will follow its current path towards the south in a narrow gulley, crosses a culvert under Highway 3, and flows through a man-made ditch system to the Salmo River.

Based on the SRK Closure report, three lined surface water drainage channels will be constructed on top of the tailings area: Main Channel and North and South Spur Channels. The Main Channel will direct surface water to the spillway from the landfill wetland area, the North and South Spur Channels will direct surface water from two streams on the east side of the impoundment (Drawing 4). The surficial drainage channels will be lined with geosynthetic and geotextile liners. SRK indicated that "*the channels are to be lined with ageosynthetic liner and covered with a 0.20 m protection layer overlain by a layer of turf-reinforcement matting (TRM*). *The objective of the TRM is to provide short term erosion protection until vegetation is established in the channel".* The spillway will also be excavated and lined with a geotextile layer. The outlet ditch is expected to remain in its current condition and continue to convey water on a seasonal basis.

1.2 Geology and Hydrogeology

On a regional scale, the Site geology is composed mainly of metamorphic rocks including highly metamorphosed schist, gneiss, amphilbolite, and quartzite as well as unaltered siltstone, sandstone, conglomerate, limestone, and dolomite (Groundwater Resources of BC). Bedrock in the vicinity of the Site belongs to the North America – basinal strata terrane, Lower Cambrian Laib Formation and consists mainly of phyllite, argillite, schist, quartzite, and minor limestone (RDCK 2019a). The majority of the Site is underlain by phyllite bedrock. Granite from the Cretaceous Anstey Pluton formation is also located within the southwestern portion of the Site property boundary, and is exposed in the west spillway cut (AMEC 2014).

The depth to bedrock is estimated to be at least 6 m at the east abutment. In select areas of the site, the overburden is absent and the bedrock surface is exposed as bedrock outcrops (RDCK 2019a). Bedrock was encountered near the surface in close proximity to both dam abutments by others. Near the center of the dam, bedrock was encountered approximately 3 to 6 m below the original ground surface (RDCK 2019a). A steep drop in bedrock occurs south of the tailings dam from approximately 663 m above meal sea level (amsl) to 587 m amsl based on stratigraphy data for MW-01-2004(D) and MW-02- 2004(D). The site is situated in an area with an irregular bedrock surface, which tends to undulate without indication of these elevation changes on the ground surface (AMEC 2014).

Stratigraphy encountered at the Site consists of overburden materials (glacial and post-glacial deposits), ranging in thickness from 0 to 47.8 m (MW-02-2004(D)) overlying the bedrock surface. The overburden generally consists of sands and gravels, overlying a silty to sandy glacial till which mantles the bedrock surface in select areas. The glacial till is occasionally absent, with the sands and gravels extending to the bedrock surface. Occasional lenses/layers of silt and/or silty clay exist within the sands and gravels. Beneath the western half of the dam, the bedrock is overlain by a dense lodgement till consisting of gravelly sand with some silt and a trace of clay. Near the center of the valley, the bedrock is overlain by the lodgement till, which is overlain by very stiff stratified glaciolacustrine consisting of sands, silts and clays. Beneath the eastern portion of the dam, the bedrock is overlain by the compact stratified glaciolacustrine material consisting primarily of sandy silt. The overburden thickness is generally shallow beneath the original dam (3 to 6 meters) and increases in thickness south of the dam (14.3 m at MW-01-2004 located approximately 140 m down valley). Approximately 1.5 m of tailings is present at the western edge of the tailings deposition area, overlying 0.6 m of silty gravel. The tailings thickness has an approximate maximum depth of 20 meters near the southcentral portion deposition area, immediately upstream of the dam. Soils beneath the tailings deposition area consist primarily of silty sand to silty sand and gravel with some clay (RDCK 2019a).

Regional surficial geology in the area is composed of colluvial and mass wasting deposits. The major rivers in the region were deeply scoured by glaciers during Pleistocene time and subsequently infilled with deposits of silt, sand, gravel, and till.

A bedrock ridge present immediately west of the tailings area forms a major hydrogeological divide that constrains groundwater flow in the area of the site to a predominantly southward flow path (CRA 2002). A landfill is located immediately north of the Site and is noted to be hydraulically connected with the Site (AMEC 2014). A groundwater flow divide is present beneath the landfill between flow from the landfill toward Sheep Creek to the north, and toward the site to the south (AMEC 2014). The groundwater flow divide occurs at another bedrock ridge located beneath the landfill oriented in an approximate east-west direction. On the southern side of the ridge, groundwater is noted to flow westward from the landfill to the tailings area at an estimated velocity of 180-290 m/year (AMEC 2014). From the site, all groundwater and surface water flow is toward the south at about 20-30 m/yr (AMEC 2014).

Groundwater monitoring data from the landfill and tailings areas indicate that groundwater flow occurs primarily within the overburden granular/sandy soils (CRA 2005). Historically, the bedrock formation was considered to be generally competent and of low permeability. With this interpretation, the bedrock surface topography would be expected to control the presence and movement of groundwater within the overburden soils; however, water levels observed in the bedrock well at MW-01-2004(D), immediately downgradient of the tailings dam, indicate that the bedrock is fractured and hydraulically connected to the shallow overburden at this location which is likely a result of the north-sound trending fault through the valley. Significant bedrock faults in the area could create preferential groundwater flowpaths. Groundwater flow beneath the tailings proceeds along the valley axis to the valley bottom aquifer.

Between the landfill and the tailings area, single-well response tests indicate that the hydraulic conductivity of the overburden is 1.8x10-5 m/s, which is typical of silty sand (CRA 2005). The calculated groundwater velocity within the tailings area is much lower (5-10 m/yr) because of the lower hydraulic gradient through the tailings deposition area and hydraulic conductivity of the tailings (RDCK 2019).

Vertical gradients at the site tend to vary based on recharge (AMEC 2014). The well pair near the tailings dam (Drawing 2), MW-01-2004 S/D, shows an average upward gradient of 0.044 m/m, but MW-02-2004 S/D, which is located further along the flowpath within the valley, shows a downward average gradient of -0.034. There is a component of groundwater flow from the site that goes downward into the fractured bedrock. This groundwater flow would ultimately be expected to discharge into the Salmo River valley bottom aquifer along with other groundwater flow from the mountainside (AMEC 2014).

Water levels within the overburden have been recorded between 0.51 to 1.86 m bg in the tailings area[1] since 2014. Downgradient of the tailings area overburden water levels drop with topography with measurements between 1.16 m bg and 3.62 m bgs at MW MW-01-2004 (S) and between 6 and 12 m bgs further downgradient at MW99-1(S) and MW-02-2004(S) respectively.

Potentiometric surfaces measured in the bedrock wells ranged from 0.33 to 1.6 m bg[2]. Monitoring well MW99-2D is reported to be artesian due to the presence of a separate gas phase below the water table (AMEC 2014). A summary of water levels measured at the site between 2014 and 2017 are presented in Table B-1.

1.3 Groundwater and Surface Water Interaction

Currently, water chemistry of the surface water within the tailings pond and the outlet ditch south of the tailings area are very similar, and are chemically distinct from the groundwater chemistry within the deep wells downgradient of the tailings dam (AMEC 2014). The elevation of the tailings ditch is unknown, but based on the water elevations and chemistry noted at MW99-1(S), AMEC noted that surface water in the ditch will recharge groundwater. Under post-closure conditions, it is expected that water within the outlet ditch will continue to recharge groundwater south of the tailings area.

1.4 Groundwater Use

SLR reviewed the BC ENV water well database and previous reports for private wells located in the area of the site. A summary of water wells identified in the area of the site is provided below:

- Two well records (75273 and 92070) were identified within 500 m of the site belonging to Central Kootenay R.D. and Ray and Stella Bernard respectively. Both wells are located to the north and upgradient of the site.
- Well records belonging to Kootenay Stone Center (82185) and Dan and Karen Bahr (105491 and 105494) are located approximately 800m to 1 km south west (i.e. trans/downgradient) of the site. Kootenay stone center's well is listed as being for commercial and industrial use whereas the Bahr wells are for private domestic use; and

[1] A measurement of 0.00 m bg was recorded at MW-01A-03 in May 2015, however based on the other water level readings at this location (between 0.74 and 1.05 m bg) this is likely a record error. MW04S-03 was also dry on all monitoring events.

[2] MW04D-03 was dry at all monitoring events.

1.5 Two private water wells not listed in the water well database are located at Ross Farm located approximately 700 metres south and southwest of the site ("Ross Property"). The wells are noted to service the residence and the barn at the Ross Property (SNC 2013).Climate Data

The general climate for the region is characterized by warm, dry to moderately moist summers and cool, snowy winters. Precipitation in the region increases from south to north, from west to east and with increasing elevation (RDCK 2019a). Snowfall typically accumulates in November with maximum accumulation typically occurring near the end of March. Snow melt occurs in April, May, and June at a maximum sustained rate of 20 to 30 mm/day based on regional snow-survey stations (RDCK 2019a). Meteorological parameters are not measured at HB Mine Tailings Facility. Mean monthly temperature range from -3.6°C in January to 19.1°C in July. Mean monthly precipitation range from 35.9 mm in July to 103.3 mm in December.

The closest active station to the Facility is Castlegar Airport, BC (Climate ID: 1141455) located approximately 36 km northwest of the Facility in an adjacent valley at an elevation of 495 m AMSL. The amount of precipitation is believed to representative of site conditions, while temperatures at site are likely to be slightly cooler than indicated at the station. Based on the Castlegar Airport climate normal data (1980 to 2000), the site is expected to be snow covered an average of 90 days per year. In addition, temperatures at the site are at or below zero degrees Celsius for an average of 120 days per year.

2.0 IDENTIFICATION OF CONTAMINATION SOURCES

The former HB Mine operated on Iron Mountain upgradient of the Site from 1912 to 1978. Commodities produced at the mine included lead, zinc, silver, cadmium, copper, gold, and talc. A tailings flume line was used to join the former HB Mine site to the tailings pond. Tailings flumes were located along the northern property boundary of Emerald Mine Road to the northern edge of the tailings deposition area (AMEC 2014).

The tailings were produced as a result of processing lead-zinc sulphide ore (SRK 2017a) and are known to contain iron, lead and zinc sulphide minerals (pyrite, galena and sphalerite, respectively) (SRK 2017a). Cadmium does not occur as a discrete sulphide mineral but is a trace component of sphalerite. Abundant calcium and magnesium carbonate minerals (calcite and dolomite, respectively) are also reportedly present in the tailings area. The tailings are thought to be non-acid generating due to the carbonate content far exceeding the sulphide content.

Based on previous investigations completed at the Site between 2016 and 2019, the following COPCs have been identified above applicable regulatory criteria in soil, groundwater, surface water and sediment at the site:

- Arsenic, cadmium, copper, iron, lead, selenium and zinc in soil;
- Ammonia-N, fluoride, sulphate, arsenic, barium, iron, lithium, manganese, molybdenum, tungsten, uranium, zinc in groundwater;
- Ammonia-N, chloride, nitrite (as N), nitrate (as N), phosphorus, aluminum, arsenic, beryllium, chromium (III + VI), cobalt, copper, iron, lead, manganese, mercury, selenium, uranium, zinc in surface water; and
- Arsenic, cadmium, lead and zinc in sediment.

3.0 PREFERENTIAL PATHWAYS

As noted previously, water levels observed in the bedrock well at MW-01-2004(D), immediately downgradient of the tailings dam, indicate that a north-south trending fault may be present at this location and may be hydraulically connected to the shallow overburden. Fractures in the bedrock may act as preferential pathways for COPCs resulting in the preferential migration of COPCs along the valley axis to the valley bottom aquifer. Insufficient information is currently available to assess the presence of this preferential pathway, however it is noted that concentrations of all COPCs met regulatory criteria at bedrock well MW-02-2004(D) located on the downgradient property line with the exception of lithium.

While discharge of mine water to the tailings pond occurred historically, the current inputs of water to the tailings pond are expected to be limited to discharge of groundwater and overland runoff from the tailings area during periods of higher precipitation and/or snowmelt. As noted previously, under post-closure conditions, surficial drainage would be directed to the spillway and outlet ditch via surficial channels over the tailings area.

Underground utilities also have the potential to act as preferential pathways for groundwater COPCs. Culverts were historically located within the tailings pond running southward to the area directly below the dam. The former culverts were in use between 1955 and 1977 and were filled with concrete once no longer in use. A historical buried pipeline alignment was also present to the southeast of the tailings pond and ran in a northeast to southwest direction from adjacent to the corner of the tailings pond to the toe of the berm. The buried pipeline alignment was reportedly removed in 2005 (SRK 2018).

4.0 CONTAMINANT FATE AND TRANSPORT

SLR relied upon data presented in previous environmental investigation reports to evaluate the distribution, migration and stability of contaminants in the tailings area. In order to understand contaminant fate and transport at the site, hydrogeological and hydrological assessments completed as part of previous investigations were reviewed to characterize groundwater and surface water migration pathways across the Site, the interaction between them, and the role of these pathways in facilitating contaminant migration.

Contaminants in the tailings may adsorb to the soil, partition to soil pore water and leach downward with infiltrating water (i.e. precipitation). Soil leachate will mix with groundwater and once in the dissolved phase, the contaminants will migrate via diffusion, advection and dispersion although these processes may be tempered by sorption of the contaminants to saturated zone materials during transport. Currently, contaminants in surficial soil may migrate via sediment transport and overland flow to the spillway and subsequently downgradient through the outlet ditch south of the site. Contaminants adsorbed to surficial soils are unlikely to transport overland via erosional processes under post-closure conditions based on the presence of the surficial cap across the tailings area and lined drainage channels. However, sediment within the outlet ditch south of the spillway will remain following closure, and may be transported downgradient with surface water or be taken up by vegetation or aquatic life. Contaminants present in the groundwater phase are expected to flow southward across the tailings area, into the drainage ditch and continue to flow south/southwest of the site to the Salmo river. Seepage of groundwater to surface water within the drainage channel is expected to be minimal under post-closure conditions based on measured groundwater depths and a seepage assessment completed by SRK in 2017 (SRK 2017c). The seepage assessment indicated that groundwater levels are expected to lower following the drainage of the tailings pond and removal of the upstream beach during closure activities. Based on the lower groundwater table and the construction of an upstream beach on the face of the dam, seepage modelling completed by SRK indicated that post-closure groundwater seepage would decrease by at least 30-60% using conservative assumptions (SRK 2017c).

Contaminants in groundwater migrating to surface water bodies may also partition to sediments or mix with the surface water. Contaminants present in the pore water-phase in subsurface soil have the potential to be taken up by the roots of vegetation and subsequently bioaccumulate through the food chain.

The gas present within the aquifer below the tailings was noted by AMEC 2014 to be the result of the oxidation of sulphide in water or metal sulphides in the mine tailings by nitrate reducing bacteria. This process would be expected to produce primarily nitrate gas with lesser amounts of nitrous oxide (N2O). The presence of a separate gas phase within the aquifer can positively or negative influence the observed water levels and can also alter several aquifer properties.

Previous geochemical analyses have demonstrated no acid rock drainage (ARD) concerns at the site. The tailings are thought to be non-acid generating in perpetuity because carbonate content far exceeds sulphide content (SLR 2018c)

5.0 IDENTIFICATION OF POTENTIAL RECEPTORS OF CONCERN AND EXPOSURE PATHWAYS

5.1 Human Health

Future land use at site is expected to consist of reclaimed wildlands. Access to the site will be restricted, with no trespassing signs posted at the entrances to the site. Human receptors on-site are likely to consist of occasional maintenance workers inspecting and maintaining the soil cap, as well as trespassers who may use the site for recreation (i.e. hikers). Human receptors are not expected to perform subsurface activities and are therefore unlikely to be exposed to subsurface soils or groundwater at the site. Although trespassers may have limited exposure to surface water at the site while hiking or camping, based on the climate information for the site as well as historical surface water observations, contact with surface water is expected to be limited based on expected dry conditions during the summer months. On-site receptors may also be exposed to sediment during dry conditions, however, based on the mobile nature of the expected on-site activities, and the limited aerial extent of exposed sediment at the site (i.e. within the outlet ditch only) human exposure to sediment would be expected to be minimal.

Plant root uptake of bioaccumulative contaminants in groundwater may also occur which could result in exposure to human receptors at the site if they ingest plant parts immediately downgradient of the site (e.g. blackberries). Based on the limited exposure for a trespasser and availability of edible plants, significant foraging on-site is not expected to occur.

Off-site human receptors of concern include residents and farmers on the surrounding lands. These receptors may potentially be exposed to contaminants in groundwater south of the site via potable groundwater use. Due to the presence of the bedrock ridge immediately west of the site, and the groundwater flow divide north of the site, groundwater flow to water wells located west and north of the site is considered an incomplete exposure pathway. Based on the direction of groundwater flow, exposure to off-Site receptors south of the site is a potentially complete exposure pathway. Results of groundwater sampling completed in 2018 indicated that all parameters met the BC CSR drinking water standards on the downgradient property boundary with the exception of lithium, which has been historically elevated at this location. Historical sampling has also been completed at the closest drinking water well locations (the Ross Property) as part of a human health risk assessment (HHRA; SNC 2013) and reclamation monitoring (RDCK 2016). The results of the HHRA and reclamation monitoring indicated that COPC concentrations in well water were below CSR drinking water standards, with the exception of iron in 2015, which failed aesthetic criteria. Drinking water wells on the Ross Property were not sampled in 2016, 2017 and 2018 as the property was noted to be vacant and condemned. Based on the results of the historical sampling, exposure via potable water use is considered an insignificant pathway based on current land uses south of the site.

A potentially complete and significant exposure pathway for potential future groundwater users immediately south of the site may be present for Lithium in groundwater. The source of the lithium in groundwater has not been confirmed. RDCK indicated that the lithium concentrations appeared to be stable downgradient, and were likely not related to groundwater quality concerns at the site (RDCK 2019b). The concentration of lithium in the downgradient wells indicated that concentrations have historically been higher than groundwater concentrations measured within the Tailings Area and lithium has been below detection limits in all soil samples collected within the tailings area, (RDCK 2019b), supporting this assessment. Uncertainty related to future groundwater use is discussed in Section 4.0 of the main text.

Should the water within the outlet ditch be used for irrigation of crops or livestock watering south of the site, off-site receptors may also be exposed to contaminants through consumption of livestock consuming surface water or produce irrigated with surface water.

5.2 Ecological Health

The site is expected to provide ecological habitat for various terrestrial species (numerous bird species, small mammals as well as deer, elk and bear). In addition, tadpoles, frogs, turtles and ducks have been observed using the tailings pond and outlet ditch (RDCK 2017). Based on ecological surveys completed at the Ross Property, downgradient of the site the outlet ditch and Salmo River provide habitat to various species of fish and aquatic life. A detailed description of ecological receptors of concern considered for the site is provided in the report text.

Based on the planned cap thickness of 30 cm, it is unlikely terrestrial wildlife or soil invertebrates will have significant exposure to contaminants in subsurface soils via direct contact or incidental ingestion. Plants with rooting depths greater than 30 cm may be exposed to COPCs in subsurface soil via root contact. Wildlife receptors of concern may also be exposed to contaminants in soil and groundwater via ingestion of plants where there is uptake of contaminants from the subsurface by plant life. It is unlikely that wildlife will utilize groundwater as a drinking water source but may be exposed to contaminants present in surface water through ingestion. Aquatic ecological receptors of concern may be exposed to contaminants in sediments and surface water through direct contact with and ingestion of these media but also through the ingestion of food and prey items where there is uptake of contaminants from sediment and surface water by organisms.

6.0 ATTACHMENTS

1. Groundwater Elevations Table
2. AMEC 2014 Groundwater Flow Map
3. AMEC 2014 Cross Section

TABLE B-1: WATER LEVELS

Monitoring Well ID	Overburden or Bedrock	TOC Elevation (m)	Date	Depth to Water (m below TOC)	Groundwater Elevation (m)
MW-01A-03	Bedrock	713.17	May-14	0.81	712.36
			Nov-14	1.05	712.12
			May-15	0.00	713.17
			Apr-16	0.80	712.37
			May-17	0.74	712.44
MW-01B-03	Overburden	713.11	May-14	0.87	712.24
			Nov-14	1.04	712.07
			May-15	1.70	711.41
			Nov-15	0.85	712.26
MW-01C-03	Overburden	713.20	May-14	0.92	712.28
			Nov-14	1.15	712.05
			May-15	1.60	711.60
			Nov-15	0.85	712.35
			Apr-16	0.93	712.27
			May-17	0.89	712.31
MW-02-05	Overburden	715.37	May-14	0.97	714.40
			Nov-14	1.21	714.16
			May-15	0.53	714.84
			Nov-15	0.91	714.46
			Apr-16	1.00	714.37
			May-17	0.85	714.53
MW-02D-03	Bedrock	714.17	May-14	1.22	712.95
			Nov-14	1.40	712.77
			May-15	1.50	712.67
			Nov-15	1.13	713.04
			Apr-16	1.24	712.94
			May-17	1.17	713.00
MW-02S-03	Overburden	714.19	May-14	1.03	713.16
			Nov-14	1.29	712.90
			May-15	1.38	712.81
			Nov-15	0.84	713.35
			Apr-16	1.08	713.11
			May-17	0.96	713.24
MW-03-05	Overburden	708.05	May-14	0.79	707.26
			Nov-14	0.98	707.07
			May-15	1.86	706.19
			Nov-15	0.96	707.09
MW-03D-03	Bedrock	712.64	May-14	0.36	712.28
			Nov-14	0.57	712.07
			May-15	0.55	712.09
			Nov-15	0.33	712.31
MW-03S-03	Overburden	712.60	May-14	0.87	711.73
			Nov-14	1.11	711.49
			May-15	1.09	711.51
			Nov-15	0.71	711.89
			Apr-16	0.89	711.71
			May-17	0.80	711.80
MW-03S-05	Overburden	708.05	Apr-16	0.90	707.15
			May-17	1.17	706.88

TABLE B-1: WATER LEVELS

Monitoring Well ID	Overburden or Bedrock	TOC Elevation (m)	Date	Depth to Water (m below TOC)	Groundwater Elevation (m)
MW-04-05	Overburden	713.24	May-14	0.79	712.45
			Nov-14	0.99	712.25
			May-15	0.93	712.31
			Nov-15	0.86	712.38
MW-04D-03	Bedrock	735.41	May-14	dry	dry
			Nov-14	dry	dry
			May-15	dry	dry
			Nov-15	dry	dry
MW-04S-03	Overburden	735.41	May-14	dry	dry
			Nov-14	dry	dry
			May-15	dry	dry
			Nov-15	dry	dry
MW-04S-05	Overburden	713.24	Apr-16	0.82	712.42
			May-17	0.81	712.44
MW-05-05	Overburden	709.88	May-14	1.04	708.84
			Nov-14	1.26	708.62
			May-15	0.51	709.37
			Nov-15	0.94	708.94
			Apr-16	1.04	708.84
			May-17	0.93	708.95
MW-06-01		714.36	May-14	1.23	713.13
			Nov-14	0.98	713.38
			May-15	0.60	713.76
			Nov-15	1.23	713.13
			Apr-16	1.15	713.21
			May-17	1.05	713.31
MW-01-2004(D)	Bedrock	682.75	Jun-05	17.64	665.11
			Dec-05	5.23	677.52
			Mar-06	3.36	679.39
			Dec-07	4.42	678.33
			Apr-08	7.84	674.91
			May-08	9.08	673.67
			Dec-08	5.19	677.56
			Apr-09	4.60	678.15
			Jun-09	5.66	677.09
			Sep-09	4.81	677.94
			Nov-09	4.16	678.59
			Apr-10	4.60	678.15
			Apr-11	3.23	679.52
			Apr-12	3.12	679.63
			May-13	2.84	679.91
			Apr-14	2.60	680.15
			May-15	1.94	680.81
			Apr-16	2.77	679.98
			May-17	2.78	679.97

TABLE B-1: WATER LEVELS

Monitoring Well ID	Overburden or Bedrock	TOC Elevation (m)	Date	Depth to Water (m below TOC)	Groundwater Elevation (m)
MW-01-2004(S)	Overburden	682.71	Jun-05	3.28	679.43
			Dec-05	3.60	679.11
			Mar-06	1.56	681.15
			Dec-07	3.24	679.47
			Apr-08	3.14	679.57
			May-08	3.47	679.24
			Dec-08	3.62	679.09
			Apr-09	3.32	679.39
			Jun-09	3.41	679.30
			Sep-09	3.62	679.09
			Nov-09	3.28	679.43
			Apr-10	3.32	679.39
			Apr-11	2.16	680.55
			Apr-12	3.46	679.25
			May-13	3.24	679.47
			Apr-14	3.00	679.71
			May-15	2.48	680.23
			Apr-16	3.20	679.51
			May-17	1.16	681.55
MW-02-2004(D)	Bedrock	638.47	Mar-05	6.98	631.49
			Jun-05	6.51	631.96
			Sep-05	7.71	630.76
			Dec-05	7.89	630.58
			Mar-06	7.06	631.41
			Dec-07	7.52	630.95
			Apr-08	6.03	632.44
			May-08	5.61	632.86
			Dec-08	7.29	631.18
			Apr-09	7.10	631.37
			Jun-09	5.94	632.53
			Sep-09	7.52	630.95
			Nov-09	7.13	631.34
			Apr-10	7.10	631.37
			Apr-11	5.23	633.24
			Apr-12	5.74	632.73
			May-13	6.10	632.37
			Jun-14	6.10	632.37
			May-15	6.60	631.87
			Apr-16	6.06	632.41
			May-17	6.83	631.64

TABLE B-1: WATER LEVELS

Monitoring Well ID	Overburden or Bedrock	TOC Elevation (m)	Date	Depth to Water (m below TOC)	Groundwater Elevation (m)
MW-02-2004(S)	Overburden	638.81	Mar-05	6.70	632.11
			Jun-05	7.16	631.65
			Sep-05	8.08	630.73
			Dec-05	7.78	631.03
			Mar-06	6.40	632.41
			Dec-07	6.86	631.95
			Apr-08	0.70	638.11
			May-08	3.92	634.89
			Dec-08	5.93	632.88
			Apr-09	3.94	634.87
			Jun-09	5.26	633.55
			Sep-09	7.51	631.30
			Nov-09	5.13	633.68
			Apr-10	3.94	634.87
			Apr-11	0.00	638.81
			Apr-12	3.35	635.46
			May-13	5.63	633.18
			Apr-14	4.51	634.30
			May-15	6.00	632.81
			Apr-16	5.45	633.36
			May-17	4.85	633.96
MW-05-01	Overburden	741.64	Apr-08	1.57	740.07
			May-08	1.59	740.05
			Dec-08	1.82	739.82
			Apr-09	1.66	739.98
			Jun-09	1.83	739.81
			Sep-09	2.61	739.03
			Nov-09	1.70	739.94
			Apr-10	1.66	739.98
			Apr-11	1.43	740.21
			Apr-12	1.47	740.17
			May-13	0.76	740.88
			Apr-14	1.49	740.15
			Nov-14	0.98	740.66
			May-15	1.12	740.52
			Apr-16	1.75	739.89
			May-17	0.63	741.01

TABLE B-1: WATER LEVELS

Monitoring Well ID	Overburden or Bedrock	TOC Elevation (m)	Date	Depth to Water (m below TOC)	Groundwater Elevation (m)
MW99-1(D)	Bedrock	645.21	Mar-05	8.15	637.06
			Jun-05	8.44	636.77
			Sep-05	8.96	636.25
			Dec-05	8.79	636.42
			Dec-07	8.56	636.65
			Apr-08	6.52	638.69
			May-08	7.37	637.84
			Dec-08	8.29	636.92
			Apr-09	7.63	637.58
			Jun-09	7.81	637.40
			Sep-09	8.80	636.41
			Nov-09	8.02	637.19
			Apr-10	7.63	637.58
			Apr-11	5.10	640.11
			Apr-12	6.88	638.33
			May-13	8.18	637.03
			Apr-14	7.94	637.27
			May-15	8.34	636.87
			Apr-16	8.14	637.07
			May-17	7.90	637.31
MW99-1(S)	Overburden	645.21	Mar-05	12.86	632.35
			Jun-05	12.84	632.37
			Sep-05	13.51	631.70
			Dec-05	13.29	631.92
			Mar-06	12.60	632.61
			Dec-07	12.62	632.59
			Apr-08	5.91	639.30
			May-08	10.27	634.94
			Dec-08	12.29	632.92
			Apr-09	12.76	632.45
			Jun-09	12.82	632.39
			Sep-09	13.07	632.14
			Nov-09	14.04	631.17
			Apr-10	12.76	632.45
			Apr-11	5.75	639.46
			Apr-12	5.81	639.40
			May-13	12.33	632.88
			Apr-14	11.41	633.80
			May-15	12.65	632.56
			Apr-16	12.12	633.09
			May-17	11.58	633.63

TABLE B-1: WATER LEVELS

Monitoring Well ID	Overburden or Bedrock	TOC Elevation (m)	Date	Depth to Water (m below TOC)	Groundwater Elevation (m)
MW99-2(D)	Bedrock	714.55	Mar-05	714.55	0.00
			Jun-05	0.43	714.12
			Sep-05	714.55	0.00
			Dec-05	714.55	0.00
			Mar-06	0.00	714.55
			Dec-07	frozen	n.c.
			Apr-08	0.00	714.55
			May-08	0.00	714.55
			Dec-08	0.18	714.37
			Apr-09	0.00	714.55
			Jun-09	0.27	714.28
			Sep-09	1.53	713.02
			Nov-09	0.00	714.55
			Apr-10	0.00	714.55
			Apr-11	0.00	714.55
			Apr-12	0.00	714.55
			May-13	0.00	714.55
			Apr-14	0.00	714.55
			Nov-14	0.00	714.55
			May-15	0.12	714.43
			Nov-15	0.00	714.55
			Apr-16	0.02	714.53
			May-17	0.00	714.55
MW99-2(S)	Overburden	714.55	Mar-05	714.55	0.00
			Jun-05	0.77	713.78
			Sep-05	714.55	0.00
			Dec-05	714.55	0.00
			Mar-06	0.70	713.85
			Dec-07	frozen	n.c.
			Apr-08	0.56	713.99
			May-08	0.57	713.98
			Dec-08	0.68	713.87
			Apr-09	0.57	713.98
			Jun-09	0.85	713.70
			Sep-09	2.39	712.16
			Nov-09	0.58	713.97
			Apr-10	0.57	713.98
			Apr-11	0.60	713.95
			Apr-12	0.61	713.94
			May-13	0.63	713.92
			Apr-14	0.57	713.98
			May-15	0.68	713.87
			Nov-15	0.98	713.57
			Apr-16	0.56	713.99
			May-17	0.56	713.99

Notes:
m - metres
n.c. -not calculated
n.m. - not measured
TOC - top of casing

0m 30 60 90 120

1 : 3000 HORIZONTAL SCALE

0m 6 12 18 24

1 : 600 VERTICAL SCALE
5X EXAGGERATION

CLIENT:

REGIONAL DISTRICT OF
CENTRAL KOOTENAY (RDCK)

AMEC Environment & Infrastructure
5681-70 STREET, EDMONTON, ALBERTA, T6B 3P6
PHONE 780-436-2152, FAX 780-435-8425

DWN BY:	CMG
CHK'D BY:	LH
DATUM:	NAD 83
PROJECTION:	UTM Zone 11
SCALE:	1:3000

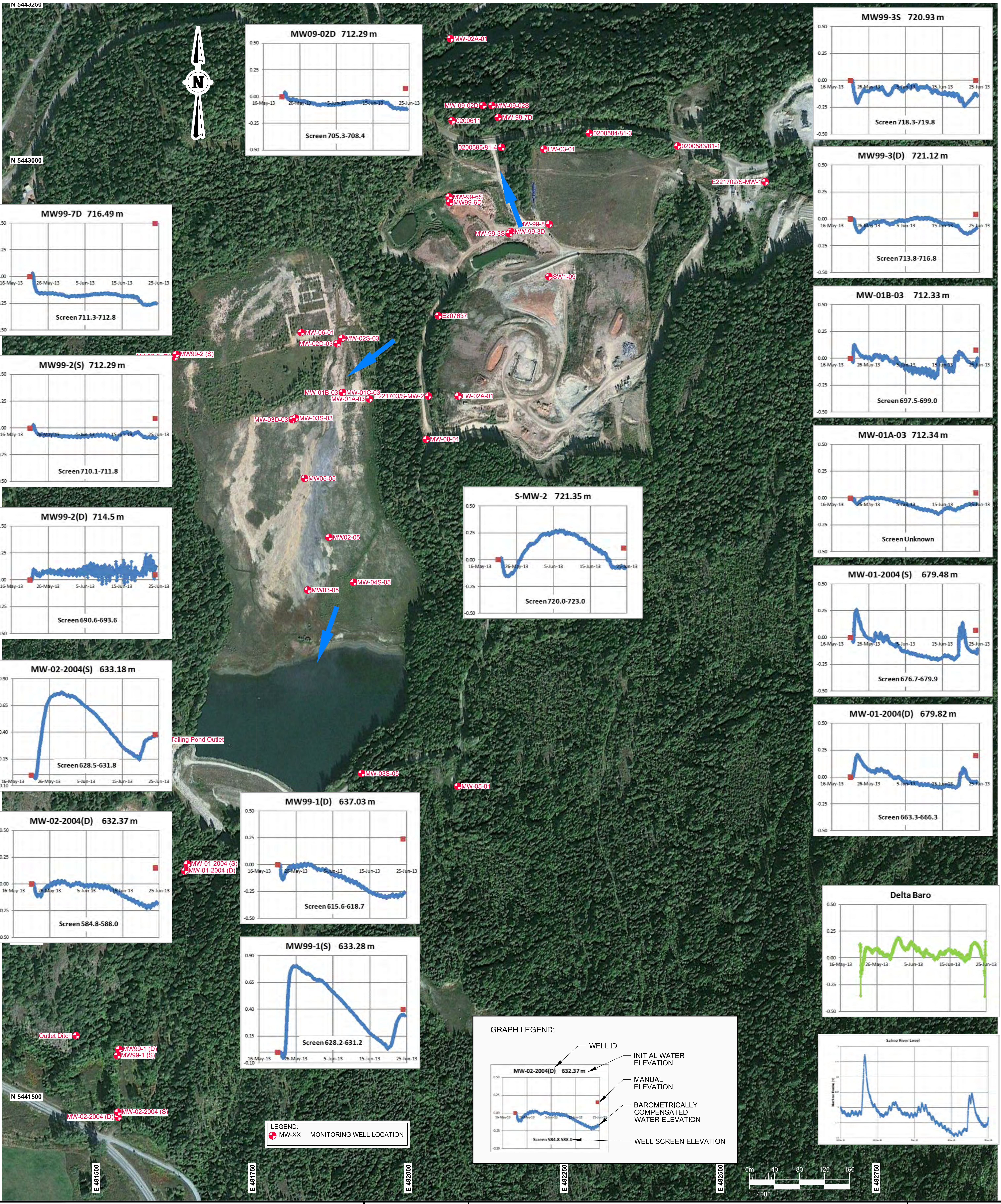
PROJECT:

CENTRAL LANDFILL
SALMO, BC

TITLE:

CROSS SECTION A-A'

DATE:	AUGUST, 2013
PROJECT No.:	CE04343
REV. No.:	A
FIGURE No.:	FIGURE 3



CLIENT: REGIONAL DISTRICT OF CENTRAL KOOTENAY (RDCK)	DWN BY: ES	PROJECT: CENTRAL LANDFILL SALMO, BC	DATE: MAY, 2014
	CHK'D BY: LH		PROJECT No.: CE04343
	DATUM: NAD 83	TITLE: SITE PLAN SHOWING GROUNDWATER ELEVATIONS	REV. No.: B
AMEC Environment & Infrastructure 5681-70 STREET, EDMONTON, ALBERTA, T6B 3P6 PHONE 780-436-2152, FAX 780-435-8425	PROJECTION: UTM Zone 11		FIGURE No.: FIGURE 4
	SCALE: 1:4000		

APPENDIX C
Food Chain Model

Regional District of Central Kootenay
Prospective Human Health and Ecological Risk Assessment
HB Mine Tailings Management Facility
SLR Project No.: 204.03242.00004

APPENDIX C

DESCRIPTION OF THE FOOD-CHAIN AND WORKED EXAMPLES

1.0 OVERVIEW OF MODEL

It is not realistic or feasible to collect tissue samples from all trophic level organisms to quantify risk to the selected receptors of concern (ROCs) thus, a food chain model was developed. The food chain model was used to calculate the daily dose of arsenic, cadmium, lead and zinc for each of the surrogate receptors. The cumulative daily dose was subsequently compared to selected toxicity reference values (TRVs).

The food chain model developed for the site considered the following routes of exposure for wildlife receptors:

- Ingestion of surface water;
- Incidental ingestion of soil during feeding (considered soil cap concentrations); and
- Ingestion of prey items (terrestrial invertebrates, plants, small mammals or birds).

Food chain models require the use of several assumptions and simplifications to predict daily dose for wildlife receptors. SLR has made the following conservative assumptions in the food chain model:

- ROCs exclusively consume prey from the Site;
- Wildlife diets were assumed to be comprised of terrestrial foods only. Aquatic prey-items were eliminated and diet proportions were readjusted to equal 100% where required. This is expected to represent the “worst-case” scenario;
- Invertebrates were assumed to be exposed to the top 30 centimetres of soil (i.e. cap soil) only;
- Exposure via inhalation and dermal absorption are negligible;
- Allometric equations in the literature are accurate proxies for food ingestion rates;
- When no information was available on incidental sediment ingestion by a given ROC, the soil ingestion rate was assumed to be 2% of the food ingestion rate, as recommended by the FCSAP Guidance (EC, 2012);
- Due to the ephemeral nature of surface water bodies on-site, 50% of drinking water was assumed to be obtained from an off-site source;
- Maximum concentration was selected for plant tissue due to the sample size;
- Although no complete and significant exposure pathways were identified for soil or surface water, the 95% UCLM concentrations were selected for each media were included to account for cumulative exposure.

Receptor characteristics (e.g., food and soil ingestion rate, body weight, home range) of the surrogate species selected to represent receptors of concern are presented in Table C-3 of this appendix. This information was generally obtained from the Wildlife Habitat Assessment completed by Gebauer & Associates Ltd. In support of the of the 2013 Ross Property ERA (Azimuth 2013) or standardized characteristics provided in the Federal Contaminated Sites Action Plan (FCSAP) ERA Guidance (Environment Canada 2012). When no information was available on the percentage of soil incidentally ingested by a given receptor, soil ingestion rates were assumed to be 2% of the food ingestion rate as recommended by Environment Canada (2012).

Uncertainties associated with each of these assumptions is discussed in the Uncertainty Analysis of the main document. The sections which follow detail the equations used in the food chain model and provide a worked example of the calculations. All concentrations in the food chain model are presented on a wet weight (ww) basis.

2.0 DAILY DOSE ESTIMATE

The daily dose is calculated by summing dosages from soil, vegetation, surface water, and prey items, and multiplying by the adjustment factor (AUF), as shown by equation 1.

(Eq. 1) $$DD_{total} = (DD_{food} + DD_{soil} + DD_{water}) \times AUF$$

where:

DD_{food} = Daily dose of COPC obtained from dietary items (mg/kg bw/day) calculated using the following equation:

(Eq. 2) $$DD_{food} = IR_{food} \times \Sigma(C_{food} \times BF \times p)$$

AUF = Site Use Factor (Area Use Factor x Seasonal Use Factor) (exposure fraction, unitless)

where: Area Use Factor = species specific foraging range (ha) divided by exposure unit area (ha) (proportion to a maximum of 100%; unitless)

IR_{food} = Species-specific food ingestion rate (kg food ww//kg bw-day) . Where a measured dry or wet weight food ingestion rate was unavailable, ingestion rates were calculated per food item using the allometric equation described in Nagy (1987).

C_{food} = Concentration (EPC) of COPC in prey or forage items (mg COPC/kg food ww)

p = Proportion of food type in the diet (%; e.g. 95% invertebrates; 5% plants)

The DD_{soil} is calculated using the following equation:

(Eq. 3) $$DD_{soil} = IR_{soil} \times C_{soil} \times BF$$

where:

DD_{soil} = Average daily dose of COPC obtained from incidental ingestion of soil or sediment (mg COPC/kg bw-day)

IR_{soil} = Species-specific incidental ingestion rate (kg soil or sediment/kg bw-day) (calculated as a proportion (*p*) of the food ingestion rate)

C_{soil} = Exposure point concentration of the COPC in soil/sediment (mg COPC/kg soil or sediment)

BF = Relative bioavailability factor of the COPC (unitless). (assumed to be 100% for water).

The **DD_{water} is** calculated using the following equation:

(Eq. 4) $$DD_{water} = IR_{water} \times C_{water} \times BF$$

where:

DD_{water} = Daily dose of COPC obtained from ingestion of surface water (mg COPC/kg bw-day)

IR_{water} = Species-specific surface water ingestion rate (mg /L-day)

C_{water} = EPC in surface water (mg /kg sediment) x 0.5 (50% on-site source)

BF = Relative bioavailability factor of the COPC (unitless) (assumed to be 100% for water)

3.0 WORKED EXAMPLE

A worked example is presented below for the calculation of HQs for exposure to lead in one avian ROC (American kestrel) and one mammalian ROC (Vagrant shrew).

3.1 ROC Characteristics

Receptor characteristics for the American Kestel and Vagrant shrew are presented below in Table A.

Table A. ROC Characteristics and TRVs

ROC	BW (kg)	AUF	Proportion of Diet (p)	Φ	TRV	TRV Source
American Kestrel	0.115	1	Prey (Mammals/ amphibians)– 32%	2%	52	LOAEL-based TRV (USEPA EcoSSL 2005)
			Invertebrates– 68%			
Vagrant Shrew	0.008	1	Invertebrates– 96%	2%	160	LOAEL-based TRV (USEPA EcoSSL 2005)
			Vegetation– 2%			
			Mushrooms - 2%			

BW – Body weight
AUF – Area Use factor
TRV – Toxicity Reference Value
Φ- Proportion of sediment ingested as a fraction of the food ingestion rate

3.2 Exposure Point Concentrations

Tables B below presents lead concentrations in soil, surface water and prey items. This worked example used the maximum tissue concentrations as the EPC in food items, and the 95% UCLM in surface water and soil.

3.2.1 Wildlife Prey

Since measured tissue concentrations were not available, prey and invertebrate tissue concentrations were calculated using the following equation:

$$Wildlife\ C_{tissue} = ADD_{total} \times BW \times BTF$$

where:

Wildlife C_{tissue}	=	Tissue concentration of COPC in given wildlife receptor (mg/kg)
ADD_{total}	=	Average daily dose of COPC obtained from all site media (mg COPC/kg bw-day)
BW	=	Species-specific body weight (kg)
BTF	=	Biotransfer Factor (d/kg)

The BTF values used to estimate wildlife tissue COPC concentrations are presented in the table below. Tissue concentrations were only modelled for potential prey items for higher-trophic organisms.

Biota Transfer Factors (BTF) (day/kg)		
Prey Item	Lead	Reference Animal (Source)
		Arsenic/Lead
Song Sparrow	0.39	Chicken (Staven et al. 2003)
American Robin	0.39	Chicken (Staven et al. 2003)
Barn Swallow	0.39	Chicken (Staven et al. 2003)
Shrew	0.39	Rabbit (Sheppard et al. 2012)
Northern Pocket Gopher	0.11	Rabbit (Sheppard et al. 2012)
Deer Mouse	0.11	Rabbit (Sheppard et al. 2012)
Gartersnake	0.39	Chicken (Staven et al. 2003)

Wildlife prey tissue EPCs were conservatively selected as the highest of all prey items

3.2.2 Summary of EPCs

Table B. EPCs for Lead

Item	Symbol	Concentration	Basis
Soil	C_{sed}	16.6 mg/kg	Measured
Surface Water	C_{water}	3.6 mg/kg ww	Measured
Vegetation	C_{food}	0.685 mg/kg ww	Measured
Invertebrates	C_{food}	0.638 mg/kg ww	Modelled from BSAF*
Small Prey	C_{food}	0.038 mg/kg ww	Modelled from BTF

*Bioaccumulation/Bioconcentration factor.

3.3 Food Ingestion Rates

Unless a measured wet weight food ingestion rate was available, dry weight values were calculated using the allometric equation described in Nagy (1987), and normalized for receptor body weight

$$\mathbf{IR = (\alpha \times BW^{b})/BW}$$

α and *b* = Constants (unitless) specific to ROCs

- α = 0.0582, and 0.0687 for avian and mammalian ROCs, respectively
- *b* is 0.651, and 0.822 for avian and mammalian ROCs respectively

ROC	Equation	IR (kg/day)
American Kestrel	N/A Value from US EPA(1993)	0.290
Vagrant Shrew	$IR = 0.0687 \times (0.008\ kg)^{0.822}$	0.0013

Ingestion rates on a food-item basis were then calculated using literature sourced diet proportions:

$$\mathbf{IR_{per\ item} = IR_{food^*}\ p}$$

The dry weight ingestion rate was then converted to wet weight where necessary:

$$\mathbf{IR_{wet\ weight} = IR_{food}\ /(1- Moisture\%)}$$

ROC	Food Item	p	$IR_{food\ per\ item}$ (kg dw food/kg-day)	$IR_{food\ per\ item}$ (kg ww food/kg-day)
American Kestrel	Prey (Mammals, amphibians)	32%	0.0928	0.290
	Insects (ground: 45%, flying: 23%)	68%	0.1972	1.2325
Vagrant Shrew	Invertebrates (Ground insects: 70%; flying: 16% earthworms: 10%)	96%	0.001248	0.0078
	Vegetation (Berries/seeds 2%)	2%	0.000026	0.000113
	Other (mushrooms)	2%	0.000026	0.000113

3.4 Soil Ingestion Rates

The soil ingestion rate (IR_{sed}; kg soil/kg-day) is determined by multiplying the fraction of incidental soil ingestion (Φ) which occurs during prey ingestion by the dry food ingestion rate (kg/kg-day). The fraction of soil ingestion is obtained from values available in the literature.

$$\mathbf{IR_{sed} = \Phi \times IR_{food}}$$

ROC	Equation	IR_{sed} (kg /kg-day)
American Kestrel	IR_s = 0.02 x (0.290 kg food/kg-day)	0.0058
Vagrant Shrew	IR_s = 0.02 x (0.0013 kg food/kg-day)	0.000026

3.5 Water Ingestion Rates

The water ingestion rate (IR_{water}; mg/L-day) is obtained from available literature values.

ROC	IR_{water} (mg/L-day)
American Kestrel	0.110
Vagrant Shrew	0.170

3.6 Dose from Food

The daily COPC intake of contaminants from food (DD_{food}; mg/kg-day) is determined from the following equation.

$$DD_{food} = \sum(IR_{food\ per\ item} \times C_{food})$$

ROC	Equation	DD_{food} (mg/kg-day)
American Kestrel	DD_{food} = (0.271 kg prey/kg-day x 0.038) + (1.2325 kg insects x 0.638)	0.797
Vagrant Shrew	DD_{food} = (0.0078 kg inverts/kg-day x 0.638) + (0.000113 kg plants/kg-day x 0.685 mg/kg) + (0.000113 kg plants/kg-day mushrooms x 0.685 mg/kg)	0.005134

3.7 Dose from Soil

The daily dose from incidental ingestion of contaminants in soil (DD_{soil} ; mg/kg-day) is given by the equation below.

$$DD_{soil} = IR_{soil} \times C_{soil} \times BF$$

ROC	Equation	DD_{soil} (mg/kg-day)
American Kestrel	DD_{soil} = (0.0058 kg/kg-day) x (16.76 mg/kg) x 1	0.0972
Vagrant Shrew	DD_{soil} = (0.000026 kg/kg-day) x (16.76 mg/kg) x 1	0.000435

3.8 Dose from Water

The daily dose from water of contaminants in soil (DD_{soil} ; mg/kg-day) is given by the equation below.

$$DD_{water} = IR_{water} \times C_{water} \times BF \times 0.5$$

ROC	Equation	DD_{soil} (mg/kg-day)
American Kestrel	DD_{water}= (0.110 kg/kg-day) x (3.624 mg/L) x 1 x 0.5	0.199
Vagrant Shrew	DD_{water} = (0.170 kg/kg-day) x (3.624 mg/L) x 1 x 0.5	0.308

3.9 Total Unadjusted Dose

The unadjusted dose (DD_{total}; mg/kg-day) is calculated by summing the doses from separate media. The equation is given below:

$$DD_{total} = DD_{food} + DD_{soil} + DD_{water}$$

ROC	Equation	DD_{total} (mg/kg-day)
American Kestrel	DD_{total} = 0.797 mg/kg-day + 0.0972 mg/kg-day + 0.199 mg/kg-day	1.09
Vagrant Shrew	DD_{total} = 0.005134 mg/kg-day + 0.000435 mg/kg-day + 0.308 mg/kg-day	0.314

3.10 Total Adjusted Dose

The adjusted dose is calculated by applying the Area Use Factor (AUF) to the unadjusted total dose, as given by the equation below. For these receptors, the AUF is 1, so the adjusted doses remain the same.

$$DD_{total} = (DD_{food} + DD_{sed}) \times AUF$$

ROC	Equation	DD_{total} (mg/kg-day)
American Kestrel	DD_{total} = (1.09 mg/kg-day) x 1.0	1.09
Vagrant Shrew	DD_{total} = (0.314 mg/kg-day) x 1.0	0.314

3.11 Hazard Quotient

The hazard quotient (HQ, unitless) is calculated following the equation below. TRVs are provided in Table A above.

$$HQ = DD_{total} / TRV$$

ROC	Equation	HQ (unitless)*
American Kestrel	HQ = (1.09 mg/kg-day) /(52 mg/kg-day)	0.021
Vagrant Shrew	HQ = (0.314 mg/kg-day)/(160 mg/kg-day)	0.002

*Rounded to 1 significant digit.

APPENDIX C, TABLE C-1. MEDIA SPECIFIC EXPOSURE POINT CONCENTRATIONS (EPCs) - FOOD CHAIN MODELLING

COPC	Cap Soil (mg/kg)	Full Depth Soil (mg/kg)	Surface Water (mg/L)	Terrestrial Plant (mg/kg)	Terrestrial Invert (mg/kg)	Terrestrial Invert - full depth (mg/kg)	Small Prey Tissue (mg/kg)
Arsenic	10.85	56	2.34	0.1	0.221	0.704	0.059
Cadmium	0.391	22	0.395	8.02	0.667	16.435	0.075
Lead	16.76	1,083	4.098	0.685	0.638	4.031	0.038
Zinc	97.42	2,140	104.9	334	65.298	179.887	22.249

Notes:
mg = milligram
kg = kilogram
L = litre
Tissue concentrations presented in wet weights
dark shade measured concentration
no shade - modelled concentration
COPC = Chemical of Potential Concern
EPC = Exposure Point Concentration

APPENDIX C, TABLE C-2A. - CHEMICAL SPECIFIC BIOACCUMULATION FACTORS

SOIL (Eco-SSL Derivation, 2005)				
		Soil Invertebrate (EcoSSL Derivation, 2005)		
COPC	**Soil EPCs**	**BAF (mg COPC/kg dw tissue)/ (mg COPC/kg dw soil)**	**Tissue Concentration (mg COPC/kg dw tissue)**	**Tissue Concentration - assuming 83% water content) (mg COPC/kg ww tissue)**
Arsenic	10.85	$\exp^{(0.706 * \ln(Cs) - 1.421}$	1.30	0.22
Cadmium	0.391	$\exp^{(0.795 * \ln(Cs) + 2.114}$	3.93	0.67
Lead	16.76	$\exp^{(0.4422 * \ln(Cs) + 0.0761}$	3.75	0.64
Zinc	97.42	$\exp^{(0.328 * \ln(Cs) + 4.449}$	384.107	65.30

Notes:
mg = milligram
kg = kilogram
L = litre
ww = wet weight
dw = dry weight
COPC = Chemical of Potential Concern
EPC = Exposure Point Concentration
BAF = Bioaccumulation Factor
[1] mercury values are for mercuric chloride
[2] sediment and water to aquatic invertebrate values are arithmetic mean of other inorganic values as per text in USEPA 1999

References:

Eco SSL Derivation, 2005. Guidance for Developing Ecological Soil Screening Levels, Attachment 4-1: Exposure Factors and Bioaccumulation Models for Derivation of Wildlife Eco-SSLs. US EPA February 2005.
US EPA 1999. Screening Level Ecological Risk Assessment Protocol, Appendic C: Media-to-receptor Bioconcentration Factors (BCFs). US EPA August 1999

APPENDIX C, TABLE C-2B. - CHEMICAL SPECIFIC BIOACCUMULATION FACTORS

SOIL (Eco-SSL Derivation, 2005)				
COPC	Soil EPCs	Soil Invertebrate (EcoSSL Derivation, 2005)		
		BAF (mg COPC/kg dw tissue)/ (mg COPC/kg dw soil)	Tissue Concentration (mg COPC/kg dw tissue)	Tissue Concentration - assuming 83% water content) (mg COPC/kg ww tissue)
Arsenic	56	$\exp^{(0.706 * \ln(Cs) - 1.421}$	4.14	0.70
Cadmium	22	$\exp^{(0.795 * \ln(Cs) + 2.114}$	96.68	16.44
Lead	1083	$\exp^{(0.4422 * \ln(Cs) + 0.0761}$	23.71	4.03
Zinc	2140	$\exp^{(0.328 * \ln(Cs) + 4.449}$	1058.161	179.89

Notes:
mg = milligram
kg = kilogram
L = litre
ww = wet weight
dw = dry weight
COPC = Chemical of Potential Concern
EPC = Exposure Point Concentration
BAF = Bioaccumulation Factor
[1] mercury values are for mercuric chloride
[2] sediment and water to aquatic invertebrate values are arithmetic mean of other inorganic values as per text in USEPA 1999

References:

Eco SSL Derivation, 2005. Guidance for Developing Ecological Soil Screening Levels, Attachment 4-1: Exposure Factors and Bioaccumulation Models for Derivation of Wildlife Eco-SSLs. US EPA February 2005.
US EPA 1999. Screening Level Ecological Risk Assessment Protocol, Appendic C: Media-to-receptor Bioconcentration Factors (BCFs). US EPA August 1999

APPENDIX C, TABLE C-3. - ECOLOGICAL RECEPTORS OF CONCERN INTAKE VALUES

Exposure Unit Area (ha) = 30

ROC Group	Representative Species	Body Weight[a] (BW)	Foraging Range[a]		Area Use Factor (AUF)	Seasonal Use Factor (SUF)	Water Ingestion Rate [a] (IR_w)	Food Ingestion Rate[a] (IR_f)		Diet: Food Item	Diet: Proportion of Diet[a] (p)	Diet: Moisture Content[b] (MC)	Food Ingestion Rate per Food Item (IR_f)		Soil Ingestion Rate (IR_S)	
		kg	m^2	ha			L/kg wet bw/day	kg dw food/ kg bw/day	kg ww food/kg bw/day				kg dw food/ kg bw/day	kg ww food/ kg bw/day	% of IR_f (dw)	kg dw/ kg bw/day
Terrestrial Receptors																
Herbivorous Bird	Song Sparrow	0.025	4000	0.4	1.0	1.0	0.070	0.2109 [g]	nr	Vegetation (berries/grass/roots)	75%	85%	0.158	1.054 [d]	2.0%	0.00422
										Insects	25%	69%	0.053	0.170 [d]		
Omnivorous Bird	American Robin	0.079	7000	0.7	1.0	1.0	0.140	0.188 [d]	1.210	Berries (Fruit)	60%	85%		0.726 [e]	4.0%	0.00750
										Invertebrates	40%	84%		0.484 [e]		
Insectivorous Bird	Barn Swallow	0.018	1000000	100	1.0	1.0	0.220	0.260	nr	Invertebrates (flying insects)	100%	84%	0.260	1.625 [e]	0.0%	0.00000
Carnivorous / Piscivorous Bird	American Kestrel	0.115	316000	31.6	1.0	1.0	0.110	0.290 [f]	nr	Mammals/amphibians	32%	68%	0.093	0.290 [d]	2.0%	0.00580
										Insects (ground: 45%, flying: 23%)	68%	84%	0.197	1.233 [d]		
Insectivorous Mammal	Vagrant Shrew	0.008	2000	0.2	1.0	1.0	0.170	0.1623 [g]	nr	Invertebrates (Ground insects: 70%; flying: 16% earthworms: 10%)	96%	84%	0.156	0.974 [d]	2.0%	0.00325
										Vegetation (Berries/seeds 2%)	2%	77%	0.003	0.014 [d]		
										Other (mushrooms)	2%	85%	0.003	0.022 [d]		
Small Herbivorous Mammal	Northern Pocket Gopher	0.15	100	0.01	1.0	1.0	0.100	0.060	nr	Vegetation (Shrubs: 20%; grasses: 80%)	100%	85%	0.060	0.400 [d]	2.4%	0.00144
Large Herbivorous Mammal	White Tailed Deer	75	1000000	100	0.3	1.0	0.100	0.060	nr	Vegetation (leaves: 80%; grasses: 15%)	95%	85%	0.057	0.380 [d]	6.3%	0.00378
										Other (mushrooms)	5%		0.003	0.003 [d]		
Small Omnivorous Mammals	Deer Mouse	0.0217	120	0.012	1.0	1.0	0.190	0.049 [c]	0.27	Invertebrates (Ground insects: 45%; earthworms: 5%)	50%	84%	0.024	0.135 [e]	2.0%	0.00097
										Berries/seeds	0%	77%	0.000	0.000 [e]		
										Vegetation (Grasses, berries, seeds)	45%	85%	0.022	0.122 [e]		
Reptiles	Gartersnake (surrogate for Rubber Boa and Western skink)	0.2	10000	1	1.0	1.0	0.060	0.008	0.030	Small mammals, amphibians	60%	84%	0.005	0.030 [d]	2.0%	0.00016
										Invertebrates	40%	69%	0.003	0.010 [d]		
Amphibian	Western Toad	0.008	250000	25	1.0	1.0	nr	0.008 [h]	nr	Insects/Spiders	70%	69%	5.68E-03	1.83E-02 [d]	2.0%	1.62E-04
										Snails/Slugs	25%	84%	2.03E-03	1.27E-02 [d]		
										Earthworms	5%	84%	4.05E-04	2.53E-03 [d]		

Notes:
kg = kilograms
m^2 = metres squared
ha = hectares
L = litre
bw = body weight
dw = dry weight
ww = wet weight
shade - "other" dietary contributions presented but not used in calculation of risk.
ROC = Receptor of Concern
AUF = Area Use Factor - Exposure Unit Area divided by Foraging Range (maximum value of 1)
SUF = Seasonal Use Factor migrating receptors assumed to use site for only 50% of year
IR_w = Water Ingestion Rate
IR_f = Food Ingestion Rate
IR_s = Soil / Sediment Ingestion Rate
p = Proportion of diet
MC = Moisture Content
[a] - From FCSAP (2012). Federal Contaminated Sites Action Plan (FCSAP) Ecological Risk Assessment guidance prepared by Azimuth Consulting Group. March 2012.
[b] From Sample and Suter (1994). Estimating Exposure of Terrestrial Wildlife to Contaminants. Oak Ridge National Library. ES/ER/TM-125.
[c] Calculated based on average of IRf (ww) and average moisture content of food items (dry weight rate needed for calculation of soil/sediment rate)
[d] Calculated based on the following: [IRf (kg dw food/kg bw/day)] / (1 - MC)
[e] Calculated based on the following: IRf (kg ww food/kg bw/day) x p
[f] From US EPA(1993). Wildlife Exposure Factors Handbook Volume I of II. December 1993.
[g] - Calculated based on Nagy (1987)
[h] - Value for insectivores from Nagy (1987)
Underline - 2.0% soil ingestion rate was used in the absence of a FCSAP 2012 value.
nr - not reported

APPENDIX C, TABLE C-4. TOXICITY REFERENCE VALUES FOR WILDLIFE

COPC	Representative Receptor	TRV	Comments
Arsenic	Song Sparrow	4.5E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	American Robin	4.5E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Barn Swallow	4.5E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	American Kestrel	4.5E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Vagrant Shrew	5.7E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Northern Pocket Gopher	5.7E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	White Tailed Deer	5.7E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Deer Mouse	5.7E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Reptiles	4.5E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
Cadmium	Song Sparrow	6.35E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	American Robin	6.35E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Barn Swallow	6.35E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	American Kestrel	6.35E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Vagrant Shrew	6.90E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Northern Pocket Gopher	6.90E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	White Tailed Deer	6.90E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Deer Mouse	6.90E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Reptiles	6.35E+00	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
Lead	Song Sparrow	4.5E+01	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	American Robin	4.5E+01	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Barn Swallow	4.5E+01	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	American Kestrel	4.5E+01	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Vagrant Shrew	1.9E+02	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Northern Pocket Gopher	1.9E+02	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	White Tailed Deer	1.9E+02	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Deer Mouse	1.9E+02	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Reptiles	4.5E+01	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
Zinc	Song Sparrow	1.7E+02	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	American Robin	1.7E+02	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Barn Swallow	1.7E+02	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	American Kestrel	1.7E+02	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Vagrant Shrew	3.0E+02	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Northern Pocket Gopher	3.0E+02	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	White Tailed Deer	3.0E+02	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Deer Mouse	3.0E+02	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)
	Reptiles	1.7E+02	Geomeans of growth and reproduction based loaels (USEPA EcoSSL 2005)

Notes:
NOAEL = No Observed Adverse Effect Level
LOAEL = Lowest Observed Adverse Effect Level
COPC = Chemical of Potential Concern
TRV = Toxicity Reference Value
SARA = Species At Risk Act
no shade - receptors with terrestrial-based diets
NS - none selected. Receptor not assessed due to insufficient intake information

References:

Sample, B.E., D.M. Opresko, and G.W. Suter II. Toxicological Benchmarks for Wildlife: 1996 Revision. Health Sciences Research Division. Oak Ridge Tennessee. Contract No. DE-AC05-84OR21400. Prepared for the United States Department of Energy. Washington, District of Columbia.

US EPA, Various Dates. http://www.epa.gov/oswer/riskassessment/ecorisk/ecossl.htm

APPENDIX C, TABLE C-5A. DERIVATION OF HAZARD QUOTIENTS FOR WILDLIFE RECEPTORS

COPC	Receptor	Exposure Medium	Soil Ingestion Rate (kg dw soil/kg bw-day)	Water Ingestion Rate (L/kg bw-day)	Individual Food Item Ingestion Rates: Terrestrial Plant Ingestion Rate (kg plant tissue/kg bw-day)	Terrestrial Invert Ingestion Rate (kg insect tissue/kg bw-day)	Prey Ingestion Rate (kg mammal tissue/kg bw-day)	Exposure Point Concentration (mg/kg): Soil	Water	Terrestrial Plant	Terrestrial Invert	Small Prey	Site Use Factor (AUF * SUF)	Daily COPC Intake (mg COPC/kg bw-day): Soil	Water	Terrestrial Plant	Terrestrial Invert	Small Prey	Average Daily Dose (mg COPC/kg bw-day)	TRV (mg/kg-day)	HQ (unitless)
Arsenic	Song Sparrow	soil + water + plants + inverts	4.22E-03	0.07	1.05	0.17	-						1.0	0.046	0.082	0.105	0.04	-	0.27	4.50E+00	6.0E-02
	American Robin	soil + water + plant + inverts	7.50E-03	0.14	0.73	0.48	-						1.0	0.081	0.164	0.073	0.11	-	0.42	4.50E+00	9.4E-02
	Barn Swallow	soil + water + inverts	0.00E+00	0.22	-	1.63	-						1.0	0.000	0.257	-	0.36	-	0.62	4.50E+00	1.4E-01
	American Kestrel	soil + water + inverts +prey	5.80E-03	0.11	-	1.23	0.29						1.0	0.063	0.129	-	0.27	-	0.46	4.50E+00	1.0E-01
	Vagrant Shrew	soil + water + plants +inverts	3.25E-03	0.17	0.01411	0.97355	-	10.9	2.3	0.1	0.2	0.1	1.0	0.035	0.199	0.001	0.22	-	0.45	5.70E+00	7.9E-02
	Northern Pocket Gopher	soil + water + plants	1.44E-03	0.10	0.40	-	-						1.0	0.016	0.117	0.040	-	-	0.17	5.70E+00	3.0E-02
	White Tailed Deer	soil + water + vegetation	3.78E-03	0.10	0.38	-	-						0.3	0.012	0.117	0.011	-	-	0.14	5.70E+00	2.5E-02
	Deer Mouse	soil + water + inverts + plants	9.72E-04	0.19	0.12	0.14	-						1.00	0.011	0.222	0.012	0.03	-	0.27	5.70E+00	4.8E-02
	Gartersnake	soil + water + prey + inverts	1.58E-04	0.06	-	0.01	0.03						1.00	0.002	0.070	-	0.00	0.00	0.08	4.50E+00	1.7E-02
Cadmium	Song Sparrow	soil + water + plants + inverts	4.22E-03	0.07	1.05	0.17	-						1.0	0.002	0.014	8.456	0.11	-	8.59	6.4E+00	**1.4E+00**
	American Robin	soil + water + plant + inverts	7.50E-03	0.14	0.73	0.48	-						1.0	0.003	0.164	5.823	0.32	-	6.31	6.4E+00	9.9E-01
	Barn Swallow	soil + water + inverts	0.00E+00	0.22	-	1.63	-						1.0	0.000	0.257	-	1.08	-	1.34	6.4E+00	2.1E-01
	American Kestrel	soil + water + inverts +prey	5.80E-03	0.11	-	1.23	0.29						1.0	0.002	0.129	-	0.82	0.02	0.98	6.4E+00	1.5E-01
	Vagrant Shrew	soil + water + plants +inverts	3.25E-03	0.17	0.01	0.97	-	0.4	0.4	8.0	0.7	0.1	1.0	0.001	0.199	0.113	0.65	-	0.96	6.9E+00	1.4E-01
	Northern Pocket Gopher	soil + water + plants	1.44E-03	0.10	0.40	-	-						1.0	0.001	0.117	3.208	-	-	3.33	6.9E+00	4.8E-01
	White Tailed Deer	soil + water + vegetation	3.78E-03	0.10	0.38	-	-						0.3	0.000	0.117	0.914	-	-	1.03	6.9E+00	1.5E-01
	Deer Mouse	soil + water + inverts + plants	9.72E-04	0.19	0.12	0.14	-						1.00	0.000	0.222	0.974	0.09	-	1.29	6.9E+00	1.9E-01
	Gartersnake	soil + water + prey + inverts	1.58E-04	0.06	-	0.01	0.03						1.00	0.000	0.070	-	0.01	0.00	0.08	6.9E+00	1.1E-02
Lead	Song Sparrow	soil + water + plants + inverts	4.22E-03	0.07	1.05	0.17	-						1.0	0.071	1E-01	0.722	0.11	-	1.04	4.5E+01	2.3E-02
	American Robin	soil + water + plant + inverts	7.50E-03	0.14	0.73	0.48	-						1.0	0.126	3E-01	0.497	0.31	-	1.22	4.5E+01	2.7E-02
	Barn Swallow	soil + water + inverts	0.00E+00	0.22	-	1.63	-						1.0	0.000	5E-01	-	1.04	-	1.49	4.5E+01	3.3E-02
	American Kestrel	soil + water + inverts +prey	5.80E-03	0.11	-	1.23	0.29						1.0	0.097	0.225	-	0.79	0.01	1.12	4.5E+01	2.5E-02
	Vagrant Shrew	soil + water + plants +inverts	3.25E-03	0.17	0.01411	0.97	-	16.8	4.1	0.7	0.6	0.0	1.0	0.054	0.348	0.010	0.62	-	1.03	1.9E+02	5.6E-03
	Northern Pocket Gopher	soil + water + plants	1.44E-03	0.10	0.40	-	-						1.0	0.024	2E-01	0.274	-	-	0.50	1.9E+02	2.7E-03
	White Tailed Deer	soil + water + vegetation	3.78E-03	0.10	0.38	-	-						0.3	0.019	6E-02	0.078	-	-	0.16	1.9E+02	8.5E-04
	Deer Mouse	soil + water + inverts + plants	9.72E-04	0.19	0.12	0.14	-						1.00	0.016	4E-01	0.083	0.09	-	0.57	1.9E+02	3.1E-03
	Gartersnake	soil + water + prey + inverts	1.58E-04	0.06	-	0.01	0.03						1.00	0.003	1E-01	-	0.01	0.00	0.13	4.5E+01	3.0E-03
Zinc	Song Sparrow	soil + water + plants + inverts	4.22E-03	0.07	1.05	0.17	-						1.0	0.4	3.7	352.175	11.11	-	367.36	1.7E+02	**2.1E+00**
	American Robin	soil + water + plant + inverts	7.50E-03	0.14	0.73	0.48	-						1.0	0.7	7.3	242.484	31.60	-	282.16	1.7E+02	**1.7E+00**
	Barn Swallow	soil + water + inverts	0.00E+00	0.22	-	1.63	-						1.0	0.0	11.5	-	106.11	-	117.65	1.7E+02	6.9E-01
	American Kestrel	soil + water + inverts +prey	5.80E-03	0.11	-	1.23	0.29						1.0	0.6	5.8	-	80.48	6.45	93.27	1.7E+02	5.5E-01
	Vagrant Shrew	soil + water + plants +inverts	3.25E-03	0.17	0.01	0.97	-	97.4	104.9	334.0	65.3	22.2	1.0	0.3	8.9	4.713	63.57	-	77.52	3.0E+02	2.6E-01
	Northern Pocket Gopher	soil + water + plants	1.44E-03	0.10	0.40	-	-						1.0	0.1	5.2	133.600	-	-	138.99	3.0E+02	4.7E-01
	White Tailed Deer	soil + water + vegetation	3.78E-03	0.10	0.38	-	-						0.3	0.1	3.1	38.076	-	-	41.33	3.0E+02	1.4E-01
	Deer Mouse	soil + water + inverts + plants	9.72E-04	0.19	0.12	0.14	-						1.00	0.1	10.0	40.581	8.82	-	59.46	1.6E+02	3.7E-01
	Gartersnake	soil + water + prey + inverts	1.58E-04	0.06	-	0.01	0.03						1.00	0.0	3.1	-	0.67	0.66	4.49	1.6E+02	2.8E-02

Notes:
mg = milligrams
kg = kilograms
L = litre
dw = dry weight
bw = body weight
COPC = Chemical of Potential Concern
AUF = Area Use Factor - Exposure Unit Area divided by Foraging Range (maximum value of 1)
SUF = Seasonal Use Factor migrating receptors assumed to use site for only 50% of year
TRV = Toxicity Reference Value
HQ = Hazard Quotient
light shade - receptors with aquatic-based diets
no shade - receptors with terrestrial-based diets
'-' = not applicable for receptor
blank = not calculated

APPENDIX C, TABLE C-5B. DERIVATION OF HAZARD QUOTIENTS FOR WILDLIFE RECEPTORS

COPC	Receptor	Exposure Medium	Soil Ingestion Rate (kg dw soil/kg bw-day)	Water Ingestion Rate (L/kg bw-day)	Individual Food Item Ingestion Rates			Exposure Point Concentration (mg/kg)					Site Use Factor (AUF * SUF)	Daily COPC Intake (mg COPC/kg bw-day)					Average Daily Dose (mg COPC/kg bw-day)	TRV (mg/kg-day)	HQ (unitless)
					Terrestrial Plant Ingestion Rate (kg plant tissue/kg bw-day)	Terrestrial Invert Ingestion Rate (kg insect tissue/kg bw-day)	Prey Ingestion Rate (kg mammal tissue/kg bw-day)	Soil	Water	Terrestrial Plant	Terrestrial Invert	Small Prey		Soil	Water	Terrestrial Plant	Terrestrial Invert	Small Prey			
Arsenic	Northern Pocket Gopher	soil + water + plants	1.44E-03	0.10	0.40	-	-	56.0	2.3	0.1	0.2	0.1	1.0	0.081	0.117	0.040	-	-	0.24	5.70E+00	4.17E-02
Cadmium			1.44E-03	0.10	0.40	-	-	22.0	0.4	8.0	0.7	0.1	1.0	0.032	0.020	3.208	-	-	3.26	6.9E+00	4.72E-01
Lead			1.44E-03	0.10	0.40	-	-	1083.0	4.1	0.7	0.6	0.0	1.0	1.560	0.205	0.274	-	-	2.04	1.9E+02	1.10E-02
Zinc			1.44E-03	0.10	0.40	-	-	2140.0	104.9	334.0	65.3	22.2	1.0	3.082	5.245	133.600	-	-	141.93	3.0E+02	4.76E-01

Notes:
mg = milligrams
kg = kilograms
L = litre
dw = dry weight
bw = body weight
COPC = Chemical of Potential Concern
AUF = Area Use Factor - Exposure Unit Area divided by Foraging Range (maximum value of 1)
SUF = Seasonal Use Factor migrating receptors assumed to use site for only 50% of year
TRV = Toxicity Reference Value
HQ = Hazard Quotient
light shade - receptors with aquatic-based diets
no shade - receptors with terrestrial-based diets
'-' = not applicable for receptor
blank = not calculated

TABLE C-6. ECOLOGICAL HEALTH - WILDLIFE TISSUE CONCENTRATIONS

Biota Transfer Factors (BTF) (day/kg)					
ROC	Arsenic	Cadmium	Lead	Zinc	Reference Animal (Source) Arsenic/Lead/Cadmium/Zinc
Song Sparrow	0.35	0.15	0.39	1	Chicken (Staven et al. 2003)
American Robin	0.35	0.15	0.39	1	Chicken (Staven et al. 2003)
Barn Swallow	0.35	0.15	0.39	1	Chicken (Staven et al. 2003)
American Kestrel	0.35	0.15	0.39	1	Chicken (Staven et al. 2003)
Shrew	0.88	0.13	0.11	1	Rabbit (Sheppard et al. 2012)
Northern Pocket Gopher	0.88	0.13	0.11	1	Rabbit (Sheppard et al. 2012)
Deer	0.016	0.0083	0.028	1	Deer (Sheppard et al. 2012)
Short-tailed Weasel	0.88	0.13	0.11	1	Rabbit (Sheppard et al. 2012)
Deer Mouse	0.88	0.13	0.11	1	Rabbit (Sheppard et al. 2012)
Black Bear	0.019	0.003	1.6	0.12	Moose (Sheppard et al. 2012)
Gartersnake	0.35	0.15	0.39	1	Chicken (Staven et al. 2003)

COPC	Wildlife Receptor	ADD_{Total} mg COPC/kg bw/day	Body Weight kg	BTF day/ kg	C tissue mg COPC/ kg ww	Tissue for Wildlife Consumption: Maximum of Sparrow, Robin, Swallow, Shrew, Gopher, Deer Mouse and snake mg COPC/kg ww
Arsenic	Song Sparrow	0.27	0.03	0.35	0.002	0.059
	American Robin	0.42	0.08	0.35	0.0117	
	Barn Swallow	0.00	0.02	0.35	0.0000	
	American Kestrel	NR	0.12	0.35	NR	
	Vagrant Shrew	0.46	0.01	0.88	0.0033	
	Northern Pocket Gopher	0.45	0.15	0.88	0.0595	
	White Tailed Deer	0.17	75.00	0.02	NR	
	Deer Mouse	0.27	0.02	0.88	0.0052	
	Black Bear	NR	68.00	0.02	NR	
	Gartersnake	0.08	0.2000	0.35	0.0052	
Cadmium	Song Sparrow	8.59	0.03	0.15	0.032	0.075
	American Robin	6.31	0.08	0.15	0.0748	
	Barn Swallow	1.34	0.02	0.15	0.0036	
	American Kestrel	NR	0.12	0.15	NR	
	Vagrant Shrew	0.96	0.01	0.13	0.0010	
	Northern Pocket Gopher	3.33	0.15	0.13	0.0648	
	White Tailed Deer	1.03	75.00	0.01	NR	
	Deer Mouse	0.25	0.02	0.13	0.0007	
	Black Bear	NR	68.00	0.00	NR	
	Gartersnake	0.08	0.2000	0.15	0.0024	
Lead	Song Sparrow	1.04	0.03	0.39	NR	0.038
	American Robin	1.22	0.08	0.39	0.0375	
	Barn Swallow	1.49	0.02	0.39	0.0104	
	American Kestrel	NR	0.12	0.39	NR	
	Vagrant Shrew	1.03	0.01	0.11	0.0009	
	Northern Pocket Gopher	0.50	0.15	0.11	0.0083	
	White Tailed Deer	0.16	75.00	0.03	0.3330	
	Deer Mouse	0.57	0.02	0.11	0.0014	
	Black Bear	NR	68	1.6	NR	
	Gartersnake	0.13	0.2	0.39	0.0104	
Zinc	Song Sparrow	367.36	0.03	1.00	9.184	22.291
	American Robin	282.16	0.08	1.00	22.3	
	Barn Swallow	117.65	0.02	1.00	2.118	
	American Kestrel	NR	0.12	1.00	NR	
	Vagrant Shrew	77.52	0.01	1.00	0.620	
	Northern Pocket Gopher	138.99	0.15	1.00	20.8	
	White Tailed Deer	41.33	75.00	1.00	NR	
	Deer Mouse	59.46	0.02	1.00	1.29	
	Black Bear	NR	68.00	0.12	NR	
	Gartersnake	4.49	0.2000	1.00	0.897	

Notes:
mg = milligram
kg = kilogram
BTF = Biota Transfer Factors
COPC = Chemical of Potential Concern
ADD_{Total} = Average Daily Dose from all food sources for the exposure area (see Table 29 for details)
NR - Not Required
C tissue = Tissue Concentration, where C tissue = ADD_{Total} * body weight * BTF

References:
Sheppard SC, Long J, and Sanipelli B. 2012. Nuclear Waste Management Organization TR-2009-35 R001: Field measurements of the transfer factors for iodine and other trace elements. ECOMatters, Updated November 2012.
Staven LH, Rhoads K, Napier BA, and Strenge DL. 2003. A Compendium of Transfer Factors for Agricultural and Animal Products. U.S. Department of Energy, June 2003.

APPENDIX D
Area Ecological Information

Regional District of Central Kootenay
Prospective Human Health and Ecological Risk Assessment
HB Mine Tailings Management Facility
SLR Project No.: 204.03242.00004

Scientific Name	Scientific Name Synonyms	English Name	English Name Synonyms	Species Code	Element Code	Global Status	Global Status Review Date	Prov Status	Prov Status Review Date
Acipenser transmontanus pop. 1		White Sturgeon (Kootenay River population)		F-ACTR-01	AFCAA01051	G4T1Q	17-Feb-06	S1	24-Apr-18
Aechmophorus occidentalis		Western Grebe		B-WEGR	ABNCA04010	G5	6-Apr-16	S1B,S2N	5-Mar-15
Asio flammeus		Short-eared Owl		B-SEOW	ABNSB13040	G5	6-Apr-16	S3B,S2N	5-Mar-15
Chrysemys picta pop. 2		Painted Turtle - Intermountain - Rocky Mountain Population	Western Painted Turtle - Intermountain - Rocky Mountain Population	R-CHPI-02	ARAAD01016	G5T2T3	2-Jan-08	S3?	30-Mar-18
Contopus cooperi		Olive-sided Flycatcher		B-OSFL	ABPAE32010	G4	7-Apr-16	S3S4B	5-Mar-15
Cottus hubbsi	*Cottus bairdi hubbsi*	Columbia Sculpin		F-COHU	AFC4E02053	G4Q	9-Nov-11	S3	11-May-10
Cypseloides niger		Black Swift		B-BLSW	ABNUA01010	G4	7-Apr-16	S2S3B	5-Mar-15
Danaus plexippus		Monarch		LE-DANPLE	IILEPP2010	G4	5-Jan-15	S3B	31-Mar-13
Dolichonyx oryzivorus		Bobolink		B-BOBO	ABPBXA9010	G5	7-Apr-16	S3B	5-Mar-15
Entosthodon fascicularis		banded cord-moss		ENTOFAS	NBMUS2P0D0	G4G5	12-Jan-01	S2S3	29-Apr-15
Gulo gulo luscus		Wolverine, *luscus* subspecies		M-GUGU-LU	AMAJF03011	G4T4	4-Apr-16	S3	3-Dec-10
Hirundo rustica		Barn Swallow		B-BASW	ABPAU09030	G5	8-Apr-16	S3S4B	5-Mar-15
Icteria virens		Yellow-breasted Chat		B-YBCH	ABPBX24010	G5	8-Apr-16	S2B	21-Mar-18
Lithobates pipiens	*Rana pipiens*	Northern Leopard Frog		A-LIPI	AAABH01170	G5	10-May-16	S1	31-Dec-16
Magnipelta mycophaga		Magnum Mantleslug		MO-MAGMYC	IMGAS61010	G3	3-Feb-06	S2S3	1-Dec-15
Megascops kennicottii macfarlanei	*Otus kennicottii macfarlanei*	Western Screech-Owl, *macfarlanei* subspecies		B-WSOW-MA	ABNSB01041	G5T4	9-Apr-16	S3	15-Mar-17
Melanerpes lewis		Lewis's Woodpecker		B-LEWO	ABNYF04010	G4	9-Apr-16	S2S3B	5-Mar-15
Numenius americanus		Long-billed Curlew		B-LBCU	ABNNF07070	G5	9-Apr-16	S3B	25-Jan-18

Scientific Name	Scientific Name Synonyms	English Name	English Name Synonyms	Species Code	Element Code	Global Status	Global Status Review Date	Prov Status	Prov Status Review Date
Oncorhynchus clarkii lewisi		Cutthroat Trout, *lewisi* subspecies	Westslope Cutthroat Trout	F-ONCL-LE	AFCHA02088	G4T4	31-May-13	S2S3	29-Mar-18
Pinus albicaulis		whitebark pine		PINUALB	PGPIN04010	G3G4	20-Mar-18	S2S3	31-Mar-13
Plestiodon skiltonianus	*Eumeces skiltonianus*	Western Skink		R-PLSK	ARACH01110	G5	2-Feb-16	S3S4	30-Mar-18
Rangifer tarandus pop. 1		Caribou (southern mountain population)		M-RATA-01	AMALC04013	G5T2Q		S1	10-Feb-17
Salvelinus confluentus		Bull Trout		F-SACO	AFCHA05020	G4	21-Dec-17	S3S4	26-Apr-18
Scouleria marginata		margined streamside moss		SCOUMAR	NBMUS6W020	G3	15-Jan-01	S1	29-Apr-15
Taxidea taxus		American Badger		M-TATA	AMAJF04010	G5	5-Apr-16	S2	15-Feb-15
Ursus arctos		Grizzly Bear		M-URAR	AMAJB01020	G4	5-Apr-16	S3?	15-Feb-15

Search Criteria
BC Conservation Status:Red (Extirpated, Endangered, or Threatened) OR Blue (Special Concern).
AND Identified Wildlife Status:True OR SARA Schedule 1 Status:True OR Provinicial Wildlife Act Status:True OR Migratory Bird Conventions Act:True OR CITES:True OR Land Use Objectives:True.
AND COSEWIC Status:Extinct OR Extirpated OR Endangered OR Threatened OR Special Concern.

AND Forest Districts:Kootenay Lake Forest District (DKL) (Restricted to Red, Blue, and Legally designated species).
AND MOE Regions:4- Kootenay (Restricted to Red, Blue, and Legally designated species).
AND Regional Districts: Central Kootenay (CKRD).
AND BGC Zone:
Sort Order:Scientific Name Ascending

Scientific Name	Prov Status Change Date	COSEWIC	COSEWIC Comments	BC List	Provincial FRPA	Land Use Objectives	Ecosection	Prov Wildlife Act	GOERT	MBCA	SARA	SARA Comments	General Status Canada	CITES
Acipenser transmontanus pop. 1	22-Nov-93	E (Nov 2012)		Red							1-E (Aug 2006)			
Aechmophorus occidentalis	29-Nov-05	SC (May 2014)		Red						Y	1-SC (Nov 2017)		4 - Secure (2005)	
Asio flammeus	1-Jun-96	SC (Mar 2008)		Blue	Y (May 2004)				Y		1-SC (Jul 2012)		3 - Sensitive (2005)	II
Chrysemys picta pop. 2	30-Mar-18	SC (Nov 2016)		Blue							1-SC (Dec 2007)			
Contopus cooperi	26-Jan-09	SC (May 2018)		Blue						Y	1-T (Feb 2010)		4 - Secure (2005)	
Cottus hubbsi	9-May-01	SC (Nov 2010)		Blue							1-SC (Jun 2003)		3 - Sensitive (2005)	
Cypseloides niger	21-Apr-15	E (May 2015)		Blue						Y			4 - Secure (2005)	
Danaus plexippus	6-Dec-99	E (Nov 2016)		Blue							1-SC (Jun 2003)		6 - Not Assessed (2000)	
Dolichonyx oryzivorus	30-Jun-98	T (Apr 2010)		Blue						Y	1-T (Nov 2017)		4 - Secure (2005)	
Entosthodon fascicularis	30-Oct-07	SC (May 2015)		Blue					Y		1-SC (Aug 2006)			
Gulo gulo luscus	30-Jun-98	SC (May 2014)		Blue	Y (May 2004)						1-SC (Jun 2018)			
Hirundo rustica	29-Nov-05	T (May 2011)		Blue						Y	1-T (Nov 2017)		4 - Secure (2005)	
Icteria virens	30-Apr-18	E (Nov 2011)		Red	Y (May 2004)					Y	1-E (Jun 2003)		4 - Secure (2005)	
Lithobates pipiens	1-Jun-96	E (Apr 2009)		Red	Y (May 2004)						1-E (Jun 2003)		4 - Secure (2005)	
Magnipelta mycophaga		SC (May 2012)		Blue							1-SC			
Megascops kennicottii macfarlanei	15-May-17	T (May 2012)		Blue	Y (May 2004)						1-T			
Melanerpes lewis	23-Apr-15	T (Apr 2010)		Blue	Y (May 2004)					Y	1-T (Jul 2012)		3 - Sensitive (2005)	
Numenius americanus	1-Jun-96	SC (May 2011)		Blue	Y (May 2004)					Y	1-SC (Jan 2005)		3 - Sensitive (2005)	

Scientific Name	Prov Status Change Date	COSEWIC	COSEWIC Comments	BC List	Provincial FRPA	Land Use Objectives	Ecosection	Prov Wildlife Act	GOERT	MBCA	SARA	SARA Comments	General Status Canada	CITES
Oncorhynchus clarkii lewisi	29-Apr-18	SC (Nov 2016)		Blue	Y (Jun 2006)						1-SC (Feb 2010)			
Pinus albicaulis	31-Mar-13	E (Apr 2010)		Blue							1-E (Jul 2012)		3 - Sensitive (2010)	
Plestiodon skiltonianus	30-Mar-18	SC (Nov 2014)		Blue							1-SC (Jan 2005)		3 - Sensitive (2005)	
Rangifer tarandus pop. 1	3-Mar-03	E (May 2014)		Red	Y (May 2004)						1-T (Jun 2003)			
Salvelinus confluentus	2-Jan-12	SC (Nov 2012)		Blue	Y (Jun 2006)								3 - Sensitive (2005)	
Scouleria marginata	8-Nov-96	E (May 2012)		Red							1-E (Jan 2005)			
Taxidea taxus	28-Apr-15	E (Nov 2012)		Red	Y (May 2004)						1-E (Jun 2018)	Ssp. *jeffersonii* only.	3 - Sensitive (2005)	
Ursus arctos	28-Apr-15	SC (May 2002)		Blue	Y (May 2004)						1-SC (Jun 2018)		3 - Sensitive (2005)	II

Search Criteria
BC Conservation Status:Red (Extirpated, Endangered, or Threatened) OR Blue (Special Concern).
AND Identified Wildlife Status:True OR SARA Schedule 1 Status:True OR Provinicial Wildlife Act Status:True OR Migratory Bird Conventions Act:True OR CITES:True OR Land Use Objectives:True.
AND COSEWIC Status:Extinct OR Extirpated OR Endangered OR Threatened OR Special Concern.

AND Forest Districts:Kootenay Lake Forest District (DKL) (Restricted to Red, Blue, and Legally designated species).
AND MOE Regions:4- Kootenay (Restricted to Red, Blue, and Legally designated species).
AND Regional Districts: Central Kootenay (CKRD).
AND BGC Zone:
Sort Order:Scientific Name Ascending

Scientific Name	Name Category	Class (English)	Species Level	Kingdom	Phylum	Class	Order	Family	Forest Dist	MOE Region	Regional Dist
Acipenser transmontanus pop. 1	Vertebrate Animal	ray-finned fishes	Population	Animalia	Craniata	Actinopterygii	Acipenseriformes	Acipenseridae	DKL	4	CKRD
Aechmophorus occidentalis	Vertebrate Animal	birds	Species	Animalia	Craniata	Aves	Podicipediformes	Podicipedidae	DCO;DKL;DOS	3;4;8	CKRD;NORD;CSRD
Asio flammeus	Vertebrate Animal	birds	Species	Animalia	Craniata	Aves	Strigiformes	Strigidae	DAB;DCC;DCH;DCK;DCO;DCR;DCS;DKA;DKL;DMH;DND;DNI;DOS;DPC;DPG;DQU;DRM;DSI;DSS_B;DSS_C	1;2;3;4;5;6;7;8;9	EKRD;MVRD;CRD;CVRD;RDN;CXRD;STRD;CKRD;TNRD;CORD;NORD;CSRD;CBRD;KSRD;KBRD;BNRD;FFRD;PRRD;SKRD;OSRD;FVRD
Chrysemys picta pop. 2	Vertebrate Animal	turtles	Population	Animalia	Craniata	Chelonia	Cryptodeira	Emydidae	DAB;DCC;DCO;DHW;DKA;DKL;DMH;DOS;DRM	3;4;5;8	EKRD;CKRD;TNRD;CORD;NORD;CSRD;CBRD;KBRD;BNRD;OSRD
Contopus cooperi	Vertebrate Animal	birds	Species	Animalia	Craniata	Aves	Passeriformes	Tyrannidae	DAB;DCC;DCH;DCK;DCO;DCR;DCS;DFN;DHW;DJA;DKA;DKL;DKM;DMH;DMK;DNC;DND;DNI;DOS;DPC;DPG;DQU;DRM;DSC;DSI;DSQ;DSS_B;DSS_C;DVA	1;2;3;4;5;6;7;8;9	EKRD;MVRD;CRD;CVRD;RDN;ACRD;CXRD;STRD;PWRD;SCRD;CKRD;SLRD;TNRD;CORD;NORD;CSRD;CBRD;MWRD;CCRD;SQCRD;KSRD;KBRD;BNRD;FFRD;PRRD;SKRD;NRRD;OSRD;FVRD
Cottus hubbsi	Vertebrate Animal	ray-finned fishes	Species	Animalia	Craniata	Actinopterygii	Scorpaeniformes	Cottidae	DAB;DCS;DKL;DOS	3;4;8	CKRD;TNRD;CORD;KBRD;OSRD
Cypseloides niger	Vertebrate Animal	birds	Species	Animalia	Craniata	Aves	Apodiformes	Apodidae	DAB;DCC;DCH;DCK;DCO;DCR;DCS;DHW;DJA;DKA;DKL;DKM;DMH;DNC;DND;DNI;DOS;DPG;DQU;DRM;DSC;DSI;DSQ;DSS_B;DSS_C;DVA	1;2;3;4;5;6;7;8	EKRD;MVRD;CRD;CVRD;RDN;ACRD;CXRD;STRD;PWRD;SCRD;CKRD;SLRD;TNRD;CORD;NORD;CSRD;CBRD;MWRD;CCRD;SQCRD;KBRD;BNRD;FFRD;OSRD;FVRD
Danaus plexippus	Invertebrate Animal	insects	Species	Animalia	Mandibulata	Insecta	Lepidoptera	Nymphalidae	DAB;DCK;DCO;DCS;DKA;DKL;DOS;DRM;DSC;DSI	1;2;3;4;8	EKRD;MVRD;CRD;CVRD;RDN;ACRD;PWRD;SCRD;CKRD;SLRD;TNRD;CORD;NORD;CSRD;KBRD;PRRD;NRRD;OSRD;FVRD
Dolichonyx oryzivorus	Vertebrate Animal	birds	Species	Animalia	Craniata	Aves	Passeriformes	Icteridae	DAB;DCC;DCO;DCS;DHW;DKA;DKL;DMH;DOS;DPG;DQU;DRM	3;4;5;7;8	EKRD;CKRD;TNRD;NORD;CSRD;CBRD;KBRD;OSRD
Entosthodon fascicularis	Nonvascular Plant		Species	Plantae	Bryophyta	Bryopsida	Funariales	Funariaceae	DCK;DKL;DSI	1;2;4	CRD;CVRD;RDN;CXRD;CKRD;FVRD
Gulo gulo luscus	Vertebrate Animal	mammals	Subspecies	Animalia	Craniata	Mammalia	Carnivora	Mustelidae	DAB;DCC;DCH;DCK;DCO;DCR;DCS;DFN;DHW;DJA;DKA;DKL;DKM;DMH;DMK;DNC;DND;DNI;DOS;DPC;DPG;DQU;DRM;DSC;DSQ;DSS_B;DSS_C;DVA	1;2;3;4;5;6;7;8;9	EKRD;MVRD;STRD;PWRD;SCRD;CKRD;SLRD;TNRD;CORD;NORD;CSRD;CBRD;MWRD;CCRD;SQCRD;KSRD;KBRD;BNRD;FFRD;PRRD;SKRD;NRRD;OSRD;FVRD
Hirundo rustica	Vertebrate Animal	birds	Species	Animalia	Craniata	Aves	Passeriformes	Hirundinidae	DAB;DCC;DCH;DCK;DCO;DCR;DCS;DFN;DHW;DJA;DKA;DKL;DKM;DMH;DMK;DNC;DND;DNI;DOS;DPC;DPG;DQC;DQU;DRM;DSC;DSI;DSQ;DSS_B;DSS_C;DVA	1;2;3;4;5;6;7;8;9	EKRD;MVRD;CRD;CVRD;RDN;ACRD;CXRD;STRD;PWRD;SCRD;CKRD;SLRD;TNRD;CORD;NORD;CSRD;CBRD;MWRD;CCRD;SQCRD;KSRD;KBRD;BNRD;FFRD;PRRD;SKRD;NRRD;OSRD;FVRD
Icteria virens	Vertebrate Animal	birds	Species	Animalia	Craniata	Aves	Passeriformes	Icteriidae	DAB;DCC;DCS;DKL;DOS	4;5;8	CKRD;CORD;NORD;CBRD;KBRD;OSRD;FVRD
Lithobates pipiens	Vertebrate Animal	amphibians	Species	Animalia	Craniata	Amphibia	Anura	Ranidae	DCO;DKL;DOS;DRM;DSI	1;4;8	EKRD;CKRD;CSRD;OSRD
Magnipelta mycophaga	Invertebrate Animal	gastropods	Species	Animalia	Mollusca	Gastropoda	Stylommatophora	Arionidae	DAB;DCC;DCO;DHW;DKA;DKL;DMH;DOS;DRM	3;4;8	EKRD;CKRD;TNRD;CORD;NORD;CSRD;CBRD;KBRD
Megascops kennicottii macfarlanei	Vertebrate Animal	birds	Subspecies	Animalia	Craniata	Aves	Strigiformes	Strigidae	DAB;DCS;DKA;DKL;DMH;DOS;DRM	3;4;8	EKRD;CKRD;SLRD;TNRD;CORD;NORD;CBRD;KBRD;OSRD
Melanerpes lewis	Vertebrate Animal	birds	Species	Animalia	Craniata	Aves	Piciformes	Picidae	DAB;DCC;DCH;DCS;DKA;DKL;DMH;DOS;DRM	3;4;5;8	EKRD;CKRD;SLRD;TNRD;CORD;NORD;CSRD;CBRD;KBRD;OSRD
Numenius americanus	Vertebrate Animal	birds	Species	Animalia	Craniata	Aves	Charadriiformes	Scolopacidae	DCC;DCH;DCO;DCS;DHW;DKA;DKL;DMH;DOS;DPG;DQU;DRM	3;4;5;7;8	EKRD;CKRD;SLRD;TNRD;NORD;CSRD;CBRD;FFRD;OSRD

Scientific Name	Name Category	Class (English)	Species Level	Kingdom	Phylum	Class	Order	Family	Forest Dist	MOE Region	Regional Dist
Oncorhynchus clarkii lewisi	Vertebrate Animal	ray-finned fishes	Subspecies	Animalia	Craniata	Actinopterygii	Salmoniformes	Salmonidae	DAB;DCO;DFN;DHW;DKL;DPC;DRM	3;4;7;8;9	EKRD;CKRD;TNRD;NORD;CSRD;KBRD;FFRD;PRRD;FVRD
Pinus albicaulis	Vascular Plant	conifers	Species	Plantae	Coniferophyta	Pinopsida	Pinales	Pinaceae	DAB;DCC;DCH;DCK;DCO;DCS;DHW;DJA;DKA;DKL;DKM;DMH;DND;DNI;DOS;DPG;DRM;DSC;DSQ;DSS	2;3;4;5;6;7;8	EKRD;STRD;CKRD;SLRD;TNRD;CSRD;MWRD;CCRD;KSRD;FFRD;OSRD;FVRD
Plestiodon skiltonianus	Vertebrate Animal	reptiles	Species	Animalia	Craniata	Reptilia	Squamata	Scincidae	DAB;DCS;DKL;DOS	3;4;8	EKRD;CKRD;TNRD;CORD;NORD;CSRD;KBRD;OSRD
Rangifer tarandus pop. 1	Vertebrate Animal	mammals	Population	Animalia	Craniata	Mammalia	Artiodactyla	Cervidae	DAB;DCC;DCO;DHW;DKL;DMH;DOS;DPC;DPG;DQU;DRM	3;4;5;7;8;9	EKRD;CKRD;TNRD;CORD;NORD;CSRD;CBRD;KBRD;FFRD;PRRD
Salvelinus confluentus	Vertebrate Animal	ray-finned fishes	Species	Animalia	Craniata	Actinopterygii	Salmoniformes	Salmonidae	DAB;DCC;DCH;DCK;DCO;DCS;DFN;DHW;DJA;DKA;DKL;DKM;DMH;DMK;DNC;DND;DNI;DOS;DPC;DPG;DQU;DRM;DSC;DSI;DSQ;DSS_B;DSS_C;DVA	1;2;3;4;5;6;7;8;9	EKRD;MVRD;STRD;SCRD;CKRD;SLRD;TNRD;CSRD;CBRD;MWRD;SQCRD;KSRD;KBRD;BNRD;FFRD;PRRD;SKRD;NRRD;OSRD;FVRD
Scouleria marginata	Nonvascular Plant		Species	Plantae	Bryophyta	Bryopsida	Grimmiales	Scouleriaceae	DKL	4	CKRD
Taxidea taxus	Vertebrate Animal	mammals	Species	Animalia	Craniata	Mammalia	Carnivora	Mustelidae	DAB;DCC;DCH;DCS;DHW;DKA;DKL;DMH;DOS;DQU;DRM	3;4;5;8	EKRD;CKRD;SLRD;TNRD;CORD;NORD;CSRD;CBRD;KBRD;OSRD
Ursus arctos	Vertebrate Animal	mammals	Species	Animalia	Craniata	Mammalia	Carnivora	Ursidae	DAB;DCC;DCH;DCK;DCO;DCR;DCS;DFN;DHW;DJA;DKA;DKL;DKM;DMH;DMK;DNC;DND;DNI;DOS;DPC;DPG;DQU;DRM;DSC;DSQ;DSS_B;DSS_C;DVA	1;2;3;4;5;6;7;8;9	EKRD;MVRD;STRD;PWRD;SCRD;CKRD;SLRD;TNRD;CORD;NORD;CSRD;CBRD;MWRD;CCRD;SQCRD;KSRD;KBRD;BNRD;FFRD;PRRD;SKRD;NRRD;OSRD;FVRD

Search Criteria

BC Conservation Status:Red (Extirpated, Endangered, or Threatened) OR Blue (Special Concern).
AND Identified Wildlife Status:True OR SARA Schedule 1 Status:True OR Provinicial Wildlife Act Status:True OR Migratory Bird Conventions Act:True OR CITES:True OR Land Use Objectives:True.
AND COSEWIC Status:Extinct OR Extirpated OR Endangered OR Threatened OR Special Concern.

AND Forest Districts:Kootenay Lake Forest District (DKL) (Restricted to Red, Blue, and Legally designated species).
AND MOE Regions:4- Kootenay (Restricted to Red, Blue, and Legally designated species).
AND Regional Districts: Central Kootenay (CKRD).
AND BGC Zone:
Sort Order:Scientific Name Ascending

Scientific Name	Municipality	BGC	Habitat Subtype	Origin	Presence	Breeding Bird	Ecosystem Group	Endemic	CDC Maps
Acipenser transmontanus pop. 1	Kaslo;Nelson	ICH	Stream/River	Native	Regularly occurring			N	Y
Aechmophorus occidentalis		BG;BWBS;CDF;CWH;ICH;IDF;MS;PP;SBPS;SBS	Estuary;Marsh;Lake;Subtidal Marine;Pond/Open Water;Sheltered Waters - Marine	Native	Regularly occurring	Y		N	Y
Asio flammeus		BG;BWBS;CDF;CWH;ICH;IDF;MS;PP;SBPS;SBS;SWB	Estuary;Marsh;Pasture/Old Field;Cultivated Field;Hedgerow;Meadow;Grassland;Urban/Suburban;Pond/Open Water;Riparian Herbaceous;Alpine/Subalpine Meadow;Alpine Grassland	Native	Regularly occurring	Y		N	Y
Chrysemys picta pop. 2	Castlegar;Cranbrook;Cache Creek;Ashcroft;Spallumcheen;Invermere;Radium Hot Springs;100 Mile House;Greenwood;Chase;Enderby;Quesnel;Vanderhoof;Clinton;Armstrong;Lumby;Salmo;Creston;Fruitvale;Grand Forks;Osoyoos;Penticton;Canal Flats;Wells;Kamloops;Kelowna;Revelstoke;Salmon Arm;Kimberley;Trail;Vernon;Summerland;Lake Country;Midway;Sicamous;Coldstream;Oliver;Williams Lake;Rossland;Montrose;Warfield;Keremeos;Merritt;Peachland;Logan Lake;Fernie;Lytton	BG;ICH;IDF;PP;SBS	Bog;Fen;Swamp;Marsh;Riparian Forest;Riparian Shrub;Lake;Urban/Suburban;Pond/Open Water;Riparian Herbaceous;Gravel Bar;Industrial	Native	Regularly occurring			N	Y
Contopus cooperi		BWBS;CDF;CWH;ESSF;ICH;IDF;MH;MS;PP;SBPS;SBS;SWB	Bog;Fen;Swamp;Riparian Forest;Conifer Forest - Mesic (average);Conifer Forest - Moist/wet;Mixed Forest (deciduous/coniferous mix);Pond/Open Water	Native	Regularly occurring	Y		N	N
Cottus hubbsi	Castlegar;Slocan;Fruitvale;Princeton;Trail;Rossland;Montrose;Keremeos	BG;ICH;IDF;PP		Native	Regularly occurring			N	Y
Cypseloides niger		BAFA;BG;CDF;CMA;CWH;ESSF;ICH;IDF;IMA;MH;MS;PP;SBPS;SBS;SWB	Bog;Fen;Swamp;Marsh;Stream/River;Lake;Cliff;Pond/Open Water	Native	Regularly occurring	Y		N	N
Danaus plexippus	Delta;Ucluelet;Tofino;Castlegar;Cranbrook;Cache Creek;Ashcroft;Lake Cowichan;Victoria;Spallumcheen;Hope;Anmore;Port Moody;Highlands;Greenwood;Chase;Enderby;Langford;Richmond;Armstrong;Kent;Kaslo;Creston;Fruitvale;Gibsons;Mission;Grand Forks;Osoyoos;Penticton;Sooke;Bowen Island;Central Saanich;Langley (City);Lantzville;Sechelt (Indian Government);West Kelowna;Pitt Meadows;Port Coquitlam;Chilliwack;Oak Bay;Langley (District);Abbotsford;Surrey;White Rock;View Royal;Colwood;Squamish;North Saanich;Sidney;Kamloops;Kelowna;Metchosin;Vancouver;Parksville;Powell River;Sechelt;North Vancouver (District);North Vancouver (City);Burnaby;Esquimalt;North Cowichan;New Westminster;Saanich;Salmon Arm;Princeton;Trail;Vernon;Summerland;Ladysmith;Nanaimo;Lake Country;Midway;Sicamous;Duncan;Coldstream;Oliver;Coquitlam;Rossland;West Vancouver;Keremeos;Merritt;Peachland;Maple Ridge;Belcarra;Lytton	BG;CDF;CWH;ESSF;ICH;IDF;MS;PP	Pasture/Old Field;Cultivated Field;Hedgerow;Meadow;Grassland;Sagebrush Steppe;Urban/Suburban	Native	Regularly occurring			N	Y
Dolichonyx oryzivorus		BG;BWBS;CDF;CWH;ICH;IDF;PP;SBS	Pasture/Old Field;Cultivated Field;Meadow;Grassland	Native	Regularly occurring	Y		N	Y
Entosthodon fascicularis		CDF;CWH;ICHdm;ICHdw	Garry Oak Maritime Meadow	Native	Regularly occurring			N	Y
Gulo gulo luscus	Telkwa;Stewart;Cranbrook;Invermere;Pemberton;Radium Hot Springs;Valemount;Terrace;Quesnel;Nakusp;Slocan;Whistler;Northern Rockies;Chetwynd;Mackenzie;Hazelton;New Hazelton;Fort St. James;Houston;Burns Lake;Fraser Lake;Vanderhoof;McBride;New Denver;Silverton;Kaslo;Granisle;Elkford;Canal Flats;Wells;Sechelt (Indian Government);Squamish;Powell River;Sechelt;Revelstoke;Prince George;Kimberley;Golden;Prince Rupert;Hudsons Hope;Williams Lake;Tumbler Ridge;Smithers;Kitimat;Sparwood;Logan Lake;Fernie;Lillooet	BAFA;BWBS;CMA;CWH;ESSF;ICH;IDF;IMA;MH;MS;SBPS;SBS;SWB	Bog;Fen;Swamp;Marsh;Riparian Forest;Stream/River;Cliff;Rock/Sparsely Vegetated Rock;Talus;Avalanche Track;Meadow;Grassland;Shrub - Natural;Deciduous/Broadleaf Forest;Conifer Forest - Mesic (average);Conifer Forest - Dry;Conifer Forest - Moist/wet;Mixed Forest (deciduous/coniferous mix);Krummholtz;Alpine/Subalpine Meadow;Alpine Grassland	Native	Regularly occurring			N	N
Hirundo rustica		BAFA;BG;BWBS;CDF;CWH;ESSF;ICH;IDF;IMA;MH;MS;PP;SBPS;SBS;SWB	Estuary;Bog;Fen;Swamp;Marsh;Riparian Forest;Riparian Shrub;Stream/River;Lake;Pasture/Old Field;Cultivated Field;Hedgerow;Meadow;Grassland;Shrub - Natural;Sagebrush Steppe;Deciduous/Broadleaf Forest;Conifer Forest - Mesic (average);Conifer Forest - Dry;Conifer Forest - Moist/wet;Mixed Forest (deciduous/coniferous mix);Urban/Suburban;Pond/Open Water;Riparian Herbaceous;Antelope-brush Steppe;Gravel Bar;Shrub - Logged;Industrial	Native	Regularly occurring	Y		N	N
Icteria virens		BG;CDF;CWH;ICH;IDF;PP;SBS	Riparian Forest;Riparian Shrub;Hedgerow;Shrub - Natural;Deciduous/Broadleaf Forest;Mixed Forest (deciduous/coniferous mix)	Native	Regularly occurring	Y		N	Y
Lithobates pipiens	Cranbrook;Invermere;Radium Hot Springs;Creston;Osoyoos;Elkford;Canal Flats;Kimberley;Golden;Oliver;Sparwood;Fernie	CDF;ICH;IDF;PP	Bog;Fen;Swamp;Marsh;Stream/River;Lake;Meadow;Pond/Open Water;Riparian Herbaceous	Native	Regularly occurring			N	Y
Magnipelta mycophaga	Castlegar;Cranbrook;Invermere;Radium Hot Springs;Greenwood;Nakusp;Slocan;New Denver;Silverton;Kaslo;Salmo;Creston;Fruitvale;Grand Forks;Elkford;Canal Flats;Kelowna;Revelstoke;Salmon Arm;Kimberley;Golden;Trail;Lake Country;Midway;Rossland;Montrose;Warfield;Peachland;Sparwood;Fernie;Nelson	ESSF;ICH;IDF;MS	Talus;Conifer Forest - Moist/wet	Native	Regularly occurring			N	Y
Megascops kennicottii macfarlanei		BG;ICH;IDF;PP	Riparian Forest;Pasture/Old Field;Cultivated Field;Hedgerow;Deciduous/Broadleaf Forest;Conifer Forest - Mesic (average);Conifer Forest - Dry;Conifer Forest - Moist/wet;Mixed Forest (deciduous/coniferous mix);Urban/Suburban	Native	Regularly occurring	Y		N	Y
Melanerpes lewis		BG;CDF;CWH;ICH;IDF;PP;SBS	Riparian Forest;Pasture/Old Field;Cultivated Field;Hedgerow;Meadow;Grassland;Sagebrush Steppe;Deciduous/Broadleaf Forest;Conifer Forest - Dry;Urban/Suburban;Antelope-brush Steppe	Native	Regularly occurring	Y		N	Y
Numenius americanus		BG;CDF;CWH;ICH;IDF;PP;SBPS;SBS	Pasture/Old Field;Cultivated Field;Intertidal Marine;Meadow;Grassland;Mudflats - Intertidal	Native	Regularly occurring	Y		N	Y

Scientific Name	Municipality	BGC	Habitat Subtype	Origin	Presence	Breeding Bird	Ecosystem Group	Endemic	CDC Maps
Oncorhynchus clarkii lewisi	Castlegar;Cranbrook;Invermere;Radium Hot Springs;Greenwood;Nakusp;Slocan;Chetwynd;New Denver;Silverton;Kaslo;Salmo;Creston;Fruitvale;Grand Forks;Elkford;Canal Flats;Revelstoke;Salmon Arm;Kimberley;Golden;Trail;Midway;Sicamous;Rossland;Montrose;Warfield;Tumbler Ridge;Sparwood;Fernie;Nelson	BWBS;ESSF;ICH;IDF;MS;SBS		Native	Regularly occurring			N	W
Pinus albicaulis		BAFAun;BAFAunp;CMAunp;CWHdm;CWHds;CWHms;CWHun;CWHvm;CWHws;ESSFdc;ESSFdcp;ESSFdcw;ESSFdk;ESSFdkp;ESSFdku;ESSFdkw;ESSFdm;ESSFdmp;ESSFdmw;ESSFdv;ESSFdvp;ESSFdvw;ESSFmc;ESSFmcp;ESSFmk;ESSFmkp;ESSFmm;ESSFmmp;ESSFmv;ESSFmvp;ESSFmw;ESSFmwp;ESSFmww;ESSFvc;ESSFvcp;ESSFvcw;ESSFwc;ESSFwcp;ESSFwcw;ESSFwk;ESSFwm;ESSFwmp;ESSFwmw;ESSFwv;ESSFwvp;ESSFxc;ESSFxcp;ESSFxcw;ESSFxv;ESSFxvp;ESSFxvw;ICHdm;ICHdw;ICHmc;ICHmk;ICHmm;ICHmw;ICHvk;ICHwk;IDFdc;IDFdk;IDFdm;IDFdw;IDFww;IDFxc;IDFxh;IMAun;IMAunp;MHmm;MHmmp;MSdc;MSdk;MSdm;MSdv;MSmw;MSxk;MSxv;SBPSxc;SBSdh;SBSmc;SBSvk;SBSwk	Cliff;Rock/Sparsely Vegetated Rock;Talus;Conifer Forest - Mesic (average);Conifer Forest - Dry	Native	Regularly occurring			N	Y
Plestiodon skiltonianus	Castlegar;Spallumcheen;Greenwood;Chase;Enderby;Nakusp;Slocan;Armstrong;Lumby;New Denver;Silverton;Kaslo;Salmo;Creston;Fruitvale;Grand Forks;Osoyoos;Penticton;Kelowna;Salmon Arm;Princeton;Trail;Vernon;Summerland;Midway;Coldstream;Oliver;Rossland;Montrose;Warfield;Keremeos;Peachland;Nelson	BG;ICH;IDF;PP	Riparian Forest;Riparian Shrub;Stream/River;Sub-soil;Rock/Sparsely Vegetated Rock;Talus;Meadow;Grassland;Sagebrush Steppe;Conifer Forest - Mesic (average);Conifer Forest - Dry;Mixed Forest (deciduous/coniferous mix);Riparian Herbaceous;Antelope-brush Steppe;Gravel Bar	Native	Regularly occurring			N	Y
Rangifer tarandus pop. 1	Cranbrook;Invermere;Nakusp;Mackenzie;McBride;Salmo;Wells;Revelstoke;Hudsons Hope;Tumbler Ridge	BAFA;ESSF;ICH;IMA	Bog;Fen;Swamp;Marsh;Riparian Forest;Cliff;Rock/Sparsely Vegetated Rock;Talus;Tundra;Avalanche Track;Meadow;Grassland;Shrub - Natural;Conifer Forest - Mesic (average);Conifer Forest - Dry;Conifer Forest - Moist/wet;Krummholtz;Alpine/Subalpine Meadow;Alpine Grassland	Native	Regularly occurring			N	Y
Salvelinus confluentus	Delta;Telkwa;Stewart;Castlegar;Cranbrook;Cache Creek;Ashcroft;Hope;Invermere;Dawson Creek;Harrison Hot Springs;Pemberton;Radium Hot Springs;100 Mile House;Valemount;Terrace;Chase;Quesnel;Nakusp;Slocan;Northern Rockies;Taylor;Chetwynd;Mackenzie;Hazelton;New Hazelton;Fort St. James;Houston;Richmond;Fraser Lake;Vanderhoof;McBride;Clinton;Kent;New Denver;Silverton;Kaslo;Salmo;Creston;Fruitvale;Mission;Granisle;Elkford;Canal Flats;Clearwater;Wells;Pitt Meadows;Port Coquitlam;Chilliwack;Langley (District);Abbotsford;Surrey;Squamish;Kamloops;Vancouver;Burnaby;Revelstoke;Prince George;New Westminster;Salmon Arm;Kimberley;Golden;Trail;Sicamous;Hudsons Hope;Williams Lake;Pouce Coupe;Coquitlam;Rossland;Montrose;Warfield;Fort St. John;Tumbler Ridge;Merritt;Maple Ridge;Smithers;Sparwood;Logan Lake;Fernie;Lytton;Lillooet;Nelson	BG;BWBS;CWH;ESSF;ICH;IDF;MS;PP;SBPS;SBS;SWB		Native	Regularly occurring			N	W
Scouleria marginata		ICH		Native	Regularly occurring			N	Y
Taxidea taxus	Castlegar;Cranbrook;Cache Creek;Ashcroft;Spallumcheen;Invermere;Radium Hot Springs;100 Mile House;Greenwood;Chase;Enderby;Clinton;Armstrong;Lumby;Creston;Fruitvale;Grand Forks;Osoyoos;Elkford;Penticton;Canal Flats;Kamloops;Kelowna;Salmon Arm;Kimberley;Princeton;Trail;Vernon;Summerland;Lake Country;Midway;Coldstream;Oliver;Williams Lake;Rossland;Montrose;Warfield;Keremeos;Merritt;Peachland;Sparwood;Logan Lake;Fernie;Lillooet;Nelson	BG;ESSF;ICH;IDF;IMA;MS;PP;SBPS	Sub-soil;Pasture/Old Field;Talus;Meadow;Grassland;Shrub - Natural;Sagebrush Steppe;Conifer Forest - Mesic (average);Conifer Forest - Dry;Krummholtz;Antelope-brush Steppe;Shrub - Logged;Alpine Grassland	Native	Regularly occurring			N	Y
Ursus arctos	Creek;Ashcroft;Spallumcheen;Hope;Invermere;Dawson Creek;Harrison Hot Springs;Pemberton;Radium Hot Springs;Anmore;Port Moody;100 Mile House;Valemount;Terrace;Greenwood;Chase;Enderby;Quesnel;Nakusp;Slocan;Whistler;Northern Rockies;Taylor;Chetwynd;Mackenzie;Hazelton;New Hazelton;Fort St. James;Houston;Burns Lake;Fraser Lake;Vanderhoof;McBride;Clinton;Armstrong;Lumby;Kent;New Denver;Silverton;Kaslo;Salmo;Creston;Fruitvale;Mission;Grand Forks;Osoyoos;Granisle;Elkford;Penticton;Canal Flats;Wells;Sechelt (Indian Government);Pitt Meadows;Port Coquitlam;Chilliwack;Abbotsford;Squamish;Kamloops;Kelowna;Powell River;Sechelt;North Vancouver (District);North Vancouver (City);Burnaby;Revelstoke;Prince George;Salmon Arm;Kimberley;Princeton;Golden;Trail;Vernon;Summerland;Lake Country;Midway;Sicamous;Prince Rupert;Hudsons	BAFA;BWBS;CMA;CWH;ESSF;ICH;IDF;IMA;MH;MS;SBPS;SBS;SWB	Estuary;Bog;Fen;Swamp;Marsh;Riparian Forest;Riparian Shrub;Stream/River;Caves;Pasture/Old Field;Talus;Tundra;Avalanche Track;Meadow;Grassland;Sagebrush Steppe;Deciduous/Broadleaf Forest;Conifer Forest - Mesic (average);Conifer Forest - Dry;Conifer Forest - Moist/wet;Mixed Forest (deciduous/coniferous mix);Beach;Urban/Suburban;Riparian Herbaceous;Gravel Bar	Native	Regularly occurring			N	N

Search Criteria
BC Conservation Status:Red (Extirpated, Endangered, or Threatened) OR Blue (Special Concern).
AND Identified Wildlife Status:True OR SARA Schedule 1 Status:True OR Provinicial Wildlife Act Status:True OR Migratory Bird Conventions Act:True OR CITES:True OR Land Use Objectives:True.
AND COSEWIC Status:Extinct OR Extirpated OR Endangered OR Threatened OR Special Concern.

AND Forest Districts:Kootenay Lake Forest District (DKL) (Restricted to Red, Blue, and Legally designated species).
AND MOE Regions:4- Kootenay (Restricted to Red, Blue, and Legally designated species).
AND Regional Districts: Central Kootenay (CKRD).
AND BGC Zone:
Sort Order:Scientific Name Ascending

Scientific Name	Mapping Status
Acipenser transmontanus pop. 1	
Aechmophorus occidentalis	
Asio flammeus	
Chrysemys picta pop. 2	Tracked and mapped at the population level.
Contopus cooperi	Currently not mapping this species as it is still wide spread and has been listed based on declining trends.
Cottus hubbsi	
Cypseloides niger	
Danaus plexippus	
Dolichonyx oryzivorus	
Entosthodon fascicularis	
Gulo gulo luscus	There are complications with defining and mapping occurrences of wide ranging carnivores; until this is resolved or a surrogate developed this species will not be mapped.
Hirundo rustica	Currently not mapping this species as it is still wide spread and has been listed based on declining trends. Partial mapping that would include large colonies may be considered in the future.
Icteria virens	
Lithobates pipiens	
Magnipelta mycophaga	
Megascops kennicottii macfarlanei	
Melanerpes lewis	
Numenius americanus	

Scientific Name	Mapping Status
Oncorhynchus clarkii lewisi	Currently the CDC is not mapping this subspecies as it is quite wide spread.
Pinus albicaulis	
Plestiodon skiltonianus	
Rangifer tarandus pop. 1	
Salvelinus confluentus	Currently the CDC is not mapping this species as it is quite wide spread.
Scouleria marginata	
Taxidea taxus	
Ursus arctos	There are complications with defining and mapping occurrences of wide ranging carnivores; until this is resolved or a surrogate developed this species will not be mapped.

Search Criteria
BC Conservation Status:Red (Extirpated, Endangered, or Threatened) OR Blue (Special Concern).
AND Identified Wildlife Status:True OR SARA Schedule 1 Status:True OR Provinicial Wildlife Act Status:True OR Migratory Bird Conventions Act:True OR CITES:True OR Land Use Objectives:True.
AND COSEWIC Status:Extinct OR Extirpated OR Endangered OR Threatened OR Special Concern.

AND Forest Districts:Kootenay Lake Forest District (DKL) (Restricted to Red, Blue, and Legally designated species).
AND MOE Regions:4- Kootenay (Restricted to Red, Blue, and Legally designated species).
AND Regional Districts: Central Kootenay (CKRD).
AND BGC Zone:
Sort Order:Scientific Name Ascending

APPENDIX E
Vegetation Metals Uptake Study

Regional District of Central Kootenay
Prospective Human Health and Ecological Risk Assessment
HB Mine Tailings Management Facility
SLR Project No.: 204.03242.00004

8 April 2019

Alayne Hamilton
Regional District of Central Kootenay
202 Lakeside Drive
Nelson, BC V1L 5R4

SLR Project No.: 204.03242.00002

Dear Ms. Hamilton,

RE: VEGETATION METALS UPTAKE STUDY, H.B. MINE TAILINGS STORAGE FACILITY, SALMO, BC

SLR was retained by the Regional District of Central Kootenay (RDCK) to undertake a preliminary investigation into whether vegetation growing atop the H.B. Mine Tailings Storage Facility (TSF) at Salmo, BC (Drawing 1) appears to be accumulating metals from soils. SLR conducted the field program on June 4, 2018.

1.0 METHODOLOGY

1.1 Sampling Locations

SLR chose four locations (Station 1 – Station 4) to collect soils and co-located plant samples at the TSF. These are shown on Drawing 2, and were selected from areas appearing to be good wildlife habitat (i.e. more vegetated areas) as well as far apart from one another to represent the TSF as a whole and possible variability in soil quality (although from our review of historic soil data the TSF tailings appear to exhibit similar metals concentrations spatially). Soil and co-located plant samples were also collected from a reference area (Reference 1 and 2) ~700 m northeast of the TSF, that was assumed to be uncontaminated as a result of historic mine operations.

1.2 Surficial Soil Sampling

Soil samples were collected from ground surface to a depth of 0.2 metres utilizing a stainless sampling tool. All soil samples collected during the sampling program were classified according to soil type, structure and colour. To prevent cross-contamination, nitrile gloves were disposed of after each sample was collected. The soil samples were placed in laboratory prepared glass jars (125 millilitres) which were labelled and stored in an ice-filled cooler. The samples and completed Chain of Custody forms were subsequently transported to Maxxam Analytics of Burnaby, BC (Maxxam) for chemical analyses. Approximately one in ten samples were duplicated to confirm field sampling techniques and laboratory analyses.

1.3 Vegetation Sampling

Vegetation sampling focussed on the dominant plant types presently growing atop the tailings, and plant types that may be preferentially consumed by wildlife as the focus was on obtaining data to allow for later evaluation of consumption risks. While metals could accumulate more in roots than upper plant parts, sampling focussed on those plant parts most likely to be consumed, which for grass and shrubs will likely be the above ground plant parts.

Vegetation samples were collected within 1.0 m radius of the soil sample locations. To prevent cross-contamination, nitrile gloves were disposed of after each sample was collected. Vegetation cuttings were collected and placed in labelled dedicated sample bags. Shrub and tree samples included leaves and twigs. Grass samples consisted of the upper half of grass blades. Following collection, the samples were stored in an ice filled cooler together with a completed Chain-of-Custody form and transported to Maxxam for analysis. Approximately one in ten samples were duplicated to confirm field sampling techniques and laboratory analyses.

RDCK had indicated that the purpose of the plant sampling was largely to evaluate whether site vegetation is accumulating metals from soil via root contact with soils (xylem translocation from roots to upper plant parts), in the event a 30 cm soil cover was placed atop the tailings as a site remedial option and plants root through that cover. Consequently, plant samples were rinsed by the laboratory of any adhered dust or soil in order to obtain true internal tissue metal concentrations, rather than tissue levels also reflecting dust or dirt adhered to the plants. The plants collected by SLR were predominantly willow and grass, both of which can root in excess of 1 m (Azimuth, 2013), with rooting depth likely dependent on species, region and soil moisture levels.

2.0 RESULTS

2.1 Soil Quality

Analytical results for the metal content of TSF and reference area soil samples collected by SLR in June, 2018 are shown in Table 1 (attached).

The Environmental Management Act and its Contaminated Sites Regulation (CSR) (BC Reg 253/2016) can apply to “core areas” (including areas where tailings are placed) of “historic mine sites”. The CSR has mandatory soil standards developed for the protection of environmental and human health for various land uses. Under the CSR, present land use at the TSF is reverted wildlands (WL_R). Following an approach used in Ecological and Human Health Risk Assessment (ENV, Protocol 13, 2017; CSAP, 2012) site soil chemistry in Table 1 was compared to the following background concentrations and mandatory CSR standards to identify contaminants of potential concern (COPCs) in soil for terrestrial biota (soil invertebrates, plants, wildlife) and humans:

- CSR Protocol 4, Table 1 Regional Estimates for Background Concentrations in Soil for Inorganic Substances, Kootenay Region;
- CSR Schedule 3.1 Part 1 Matrix Numerical Soil Standards for Environmental Protection – Toxicity to Soil Invertebrates and Plants (despite being developed based on effects to invertebrates and plants these standards are commonly used as a default to identify COPCs for wildlife);
- CSR Schedule 3.1 Part 3 Generic Numerical Soil Standards to Protect Ecological Health;

- CSR Schedule 3.1 Matrix Numerical Soil Standards for Human Health Protection – Intake of Contaminated Soil;
- CSR Schedule 3.1 Part 2 Generic Numerical Soil Standards to Protect Human Health.

Metals in TSF soils that exceed regional background concentrations and the above numerical standards, and are therefore considered to be COPCs for terrestrial biota and humans, are summarized in Table 2-1 below.

Table 2-1
TSF Soil Contaminants of Potential Concern

Receptor Group	COPC
Soil Invertebrates, Plants, Wildlife	Arsenic Cadmium Lead Zinc
Humans	Arsenic Cadmium Iron Lead

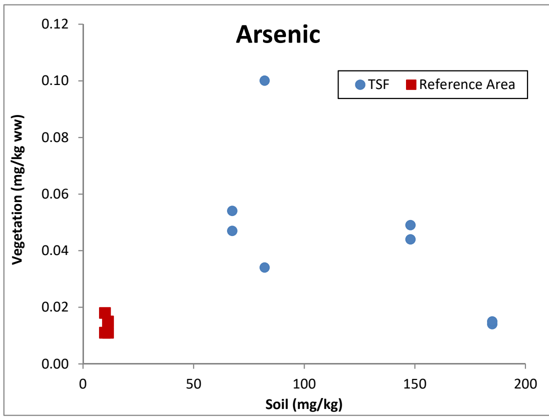
2.2 Tissue Quality

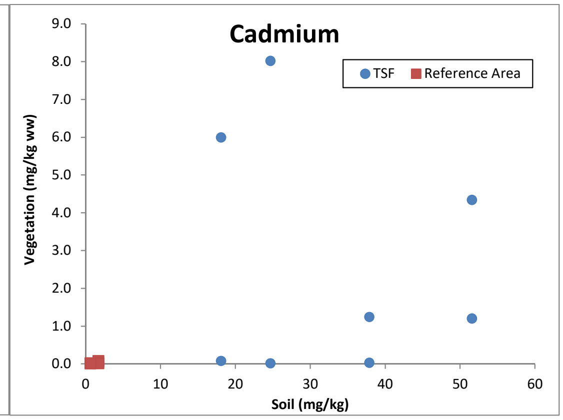
Analytical results for metals concentrations in TSF and reference area plant samples collected by SLR in June, 2018 are shown in Table 2 (attached). Results have been presented as wet weight metal content (mg metal/kg wet tissue) as this unit is more representative of plant concentrations in their natural state, as well as the concentrations that could be consumed by wildlife. Dry weight results are also presented in the attached laboratory report.

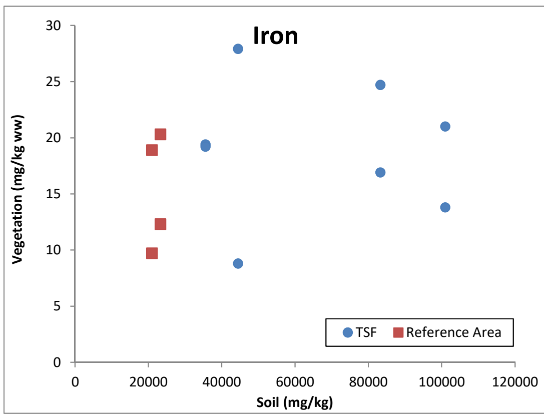
3.0 PLANT METALS UPTAKE

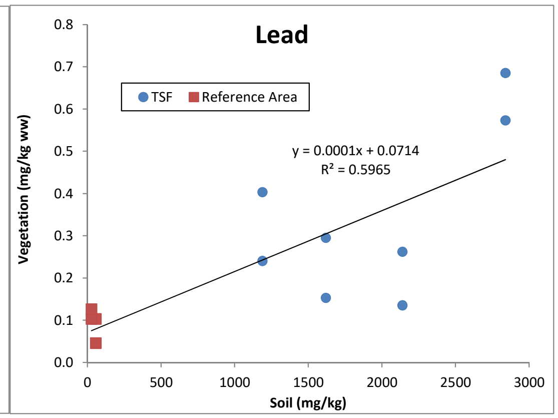
There are currently no Provincial or Federal guidelines or background levels for metals in vegetation that can be used for comparison to TSF plant metal concentrations. Plants naturally uptake metals from soil, with tissue concentrations dependent on various factors including the individual metal(s), site soil and soil porewater concentrations, soil pH, soil organic carbon content, type of plant, and part(s) of plant. Plants will normally contain detectable concentrations of many metals present in soil.

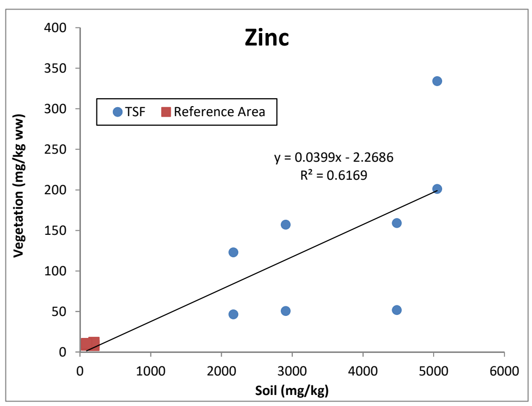
Plots are presented below depicting the concentrations of soil COPCs in plants from the TSF and reference area.











Concentrations of arsenic, cadmium, lead, and zinc were higher in vegetation samples from the TSF than plants from the reference area. Tissue iron concentrations were similar between the two areas. Tissue lead and zinc concentrations also appear to be demonstrate a reasonable correlation with soil levels, with linear regression r^2 values of 0.6 (slightly higher r^2 values using ln normalized values for soil and vegetation). A reference area willow sample was not available for side by side comparison of TSF to reference area willow concentrations; however, we suspect the TSF willow concentrations are higher than off-site willow concentrations.

The vegetation growing atop the tailings demonstrates a fairly low magnitude of metals uptake from soil. Mean site bioaccumulation factors for the soil COPCs are shown below in Table 3-1, in comparison to values from larger datasets reported on RAIS (2018).

Table 3-1
TSF Soil Contaminants of Potential Concern

Soil COPC	TSF Mean Plant BAF (ww)	RAIS (2018) BAF (ww)	TSF Mean Plant BAF (dw)	RAIS (2018) BAF (dw)
Arsenic	**0.0005**	0.01	**0.002**	0.04
Cadmium	**0.1**	0.125	**0.3**	0.5
Iron	**0.0003**	0.001	**0.001**	0.004
Lead	**0.0002**	0.0112	**0.006**	0.045
Zinc	**0.04**	0.264	**0.1**	0.99

BAFs greater than one are commonly viewed as “bioconcentration” or “bioaccumulation”; whereby tissue concentrations are higher than the soil concentrations the plant is growing in. The wet weight BAFs observed in site plants, including those reported by RAIS (2018), were all below a value of one.

Despite the TSF plants showing low BAFs, vegetation growing atop the TSF is uptaking metals. Whether or not TSF plant tissue metals concentrations could pose a risk to wildlife or human receptors may be worth further evaluation through wildlife and human health ingestion modelling and risk calculations. Additional vegetation sampling may also be worthwhile, to increase samples sizes for more definitive statistics and results interpretations, and to obtain off-site concentrations in willow.

4.0 STATEMENT OF LIMITATIONS

This report has been prepared and the work referred to in this report has been undertaken by SLR Consulting (Canada) Ltd. (SLR) for Regional District of Central Kootenay, hereafter referred to as the “Client”. It is intended for the sole and exclusive use of RDCK. The report has been prepared in accordance with the Scope of Work and agreement between SLR and the Client. Other than by the Client and as set out herein, copying or distribution of this report or use of or reliance on the information contained herein, in whole or in part, is not permitted unless payment for the work has been made in full and express written permission has been obtained from SLR.

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5.0 REFERENCES

Azimuth, 2013. CSAP Technical Guidance for Soil Sampling Depth to Characterize Ecological Exposure, MOE Policy Decision Summary Issue 11. Prepared by Azimuth Consulting Group, July, 2013.

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ENV, 2017. Protocol 13 for Contaminated Sites, Screening Level Risk Assessment, Version 3. BC Ministry of Environment and Climate Change Strategy, November 1, 2017.

RAIS, 2018. Risk Assessment Information System, RAIS Toxicity Values and Chemical Parameters. Soil-to-dry and soil-to-wet plant uptake factors. https://rais.ornl.gov/

6.0 CLOSURE

Thank you for the opportunity to assist with this simple investigation into plant tissue metal concentrations in the TSF. We would be happy to discuss the results presented above with you, as well as to provide further recommendations and any additional assistance you may wish around environmental quality, risk assessment, or remedial planning for the Salmo TSF.

Yours sincerely,
SLR Consulting (Canada) Ltd.

Michael McLeay, M.A.Sc., R.P.Bio., CSAP
Senior Scientist, Risk Assessment

Benjamin Foulger, P.Ag.
Senior Environmental Scientist

Enc Tables 1 and 2
Drawings 1 and 2
Laboratory Reports

MM/BF/mc
N:\Kamloops\Projects\General Clients\204.03242 - RDCK HB TSF\Deliverables\204.03242.Metals uptake study. April 2019

TABLE 1: SOIL ANALYTICAL RESULTS - METALS PARAMETERS (mg/kg dw)

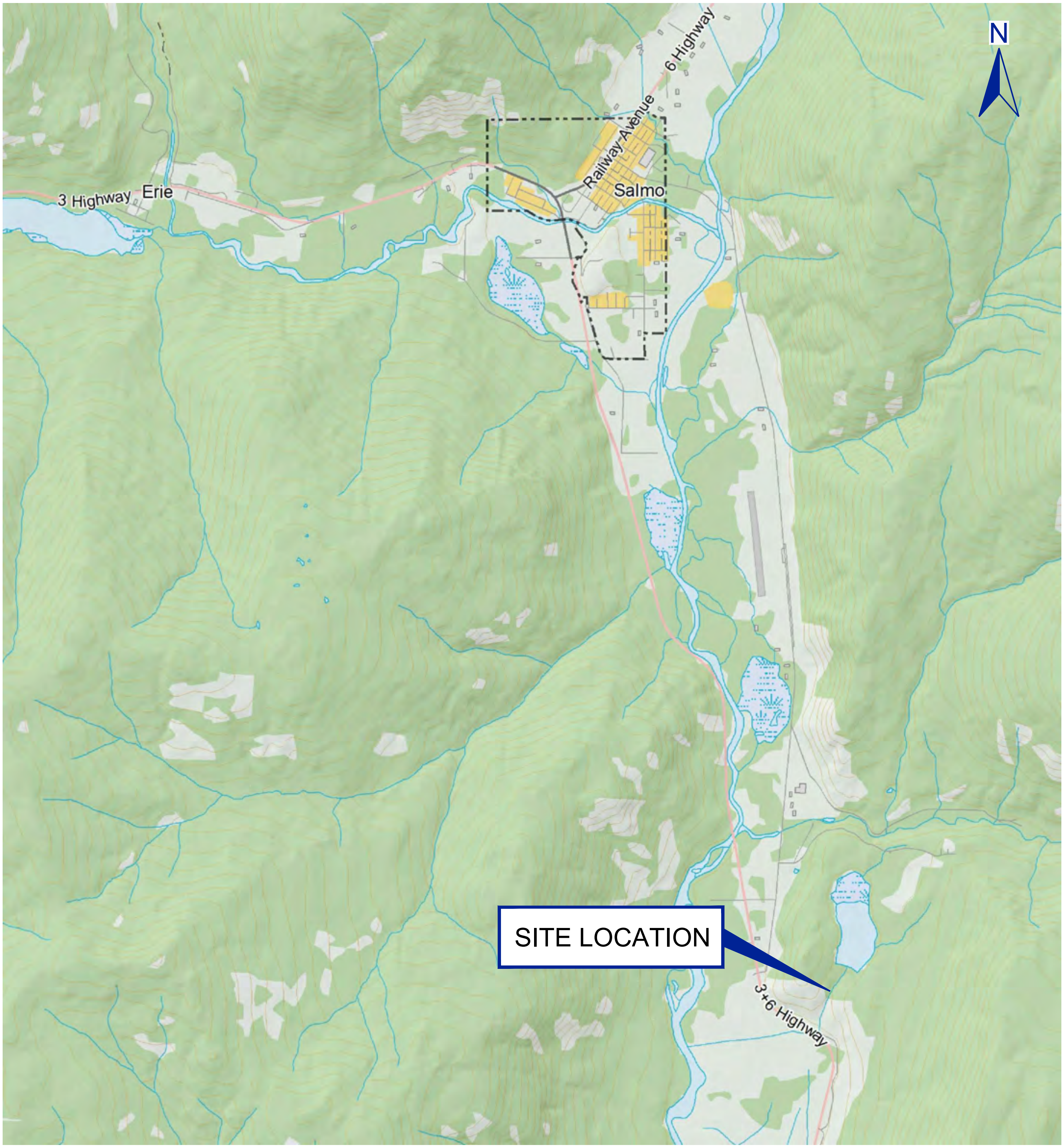
Sample ID	SSREF-1	SSREF-2	SS1-1	DUP A (SS1-1)	SS2-1	SS3-1	SS4-1	BC CSR WL_R i	BC CSR WL_R h	BC CSR WL_R t	BC CSR WL_R e	*BC P4 Kootenay*
Date	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**	**04-Jun-2018**					
Depth (m)	0 - 0.3	0 - 0.3	0 - 0.3	0 - 0.3	0 - 0.3	0 - 0.3	0 - 0.3	-	-	-	-	
pH	6.18	5.68	7.67	7.71	7.85	7.71	7.86	-	-	-	-	
Aluminum	21100	10900	3690	4100	642	592	1070	-	**40000**	-	-	*25000*
Antimony	0.63	0.39	5.64	5.39	13.0	11.5	9.64	-	**500**	-	**20**	*4*
Arsenic	11.3	9.85	**67.5**	**62.7**	**185**	**148**	**82.1**	**40**	-	**25**	-	*4*
Barium	159	99.5	71.3	74.2	19.4	20.4	43.4	**15000**	-	**700**	-	*350*
Beryllium	0.59	0.38	0.37	0.36	0.27	0.28	0.35	**150**	-	**150**	-	*0.8*
Bismuth	0.37	0.31	2.32	2.68	0.24	0.20	0.14	-	-	-	-	
Boron	1.7	< 1.0	1.4	1.4	< 1.0	< 1.0	< 1.0	-	**15000**	-	-	*1*
Cadmium	1.71	0.656	**18.1**	**17.5**	**51.6**	**37.9**	**24.7**	**40**	-	**30**	-	*0.4*
Calcium	4630	2860	126000	111000	146000	170000	236000	-	-	-	-	
Chromium (total)	31.7	34.2	12.9	14.1	3.4	2.9	5.6	**250**	-	**200**	-	*35*
Cobalt	9.92	10.7	4.06	4.55	4.76	3.86	2.09	**25**	-	**45**	-	*15*
Copper	19.9	20.3	107	121	15.8	15.1	37.0	**7500**	-	**150**	-	*35*
Iron	23300	21000	**35600**	34400	**101000**	**83300**	**44500**	-	**35000**	-	-	*30000*
Lead	58.3	27.3	**1170**	**1190**	**2840**	**2140**	**1620**	**120**		**550**	-	*120*
Lithium	17.7	11.8	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	-	**65**	-	-	
Manganese	666	337	462	467	352	344	441	**10000**	-	**2000**	-	*2000*
Mercury	< 0.050	< 0.050	< 0.050	0.057	0.112	0.079	0.060	**25**	-	**40**	-	*0.085*
Molybdenum	0.83	1.12	1.85	1.76	2.97	2.44	2.55	**400**	-	**80**	-	*1*
Nickel	28.3	28.6	18.1	18.5	23.7	19.3	11.4	**900**	-	**150**	-	*50*
Phosphorus	1130	756	467	437	373	321	301	-	-	-	-	
Potassium	1600	1760	1210	1360	216	217	436	-	-	-	-	
Selenium	< 0.50	< 0.50	0.52	0.56	1.26	0.96	0.63	**400**	-	**1.5**	-	*4*
Silver	0.352	0.296	2.91	3.26	3.46	2.57	2.21	-	**400**	-	**20**	*1*
Sodium	148	100	< 100	< 100	< 100	< 100	< 100	-	-	-	-	
Strontium	31.1	17.0	83.4	73.3	74.7	91.6	129	-	**20000**	-	-	*150*
Thallium	0.162	0.118	0.400	0.390	0.781	0.805	0.569	-	-	-	**9**	
Tin	0.66	0.37	0.73	0.81	0.27	0.32	0.23	-	**50000**	-	**50**	*4*
Tungsten	2.32	2.31	5.30	6.35	< 0.50	< 0.50	< 0.50	-	**25**	-	-	
Uranium	1.92	1.31	1.76	1.77	3.56	2.57	2.25	**250**	-	**500**	-	
Vanadium	45.3	37.3	19.7	18.4	17.6	19.0	22.3	**400**	-	**150**	-	*40*
Zinc	198	94.4	**2170**	**1920**	**5050**	**4480**	**2910**	**25000**	-	**450**	-	*200*
Zirconium	4.76	0.90	1.22	1.41	< 0.50	< 0.50	< 0.50	-	-	-	-	

Notes:
m - metres
mg/kg - milligrams per dry kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
REF - referece samples collected outside of tailings area
Exceeds Applicable Standard
BC CSR WL_R h:BC Contaminated Sites Regulation, Schedule 3.1 Part 2 Generic Numerical Soil Standards to Protect Human Health, Wildlands (Reverted)
BC CSR WL_R e:BC Contaminated Sites Regulation, Schedule 3.1 Part 3 Generic Numerical Soil Standards to Protect Ecological Health, Wildlands (Reverted)
BC CSR WL_R i:BC Contaminated Sites Regulation, Schedule 3.1 Part 1 Numerical Soil Standards, Intake of Contaminated Soil - Wildlands (Reverted)
BC CSR WL_R t:BC Contaminated Sites Regulation, Schedule 3.1 Part 1 Numerical Soil Standards,Toxicity to soil invertebrates and plants - Wildlands (Reverted)
BC P4 Region 4 Kootenay:BC CSR Protocol 4 Table 1: Regional estimates for background concentrations in soil for inorganic substances (Region 4 Kootenay)

TABLE 2: VEGETATION ANALYTICAL RESULTS - METALS PARAMETERS (mg/kg ww)

Sample ID	S1-1	DUP B	S1-2	S2-1	S2-2	S3-1	S3-2	S4-1	S4-2	REF1-1	REF1-2	REF2-1	REF2-2
Vegetation	Grass	Grass	Cottonwood	Grass	Willow	Grass	Willow	Grass	Willow	Grass	Snowberry	Grass	Rosehip
Date	04-Jun-2018	04-Jun-2018	04-Jun-2018	04-Jun-2018	04-Jun-2018	04-Jun-2018	04-Jun-2018	04-Jun-2018	04-Jun-2018	04-Jun-2018	04-Jun-2018	04-Jun-2018	04-Jun-2018
Moisture %	77	76	65	72	69	71	67	76	68	78	69	78	64
Aluminum	0.79	1.39	2.59	2.37	4.98	0.53	2.76	0.43	4.66	1.00	11.7	0.88	5.48
Antimony	0.0020	0.0019	0.0037	0.0025	0.0027	0.0020	0.0023	<0.0012	0.0036	<0.0011	0.0020	0.0014	0.0046
Arsenic	0.020	0.047	0.054	<0.014	<0.015	0.049	0.044	0.034	0.100	<0.011	<0.015	<0.011	<0.018
Barium	0.382	2.13	0.969	2.94	7.67	1.28	0.273	1.98	0.517	0.852	11.9	0.679	11.3
Beryllium	<0.023	<0.024	<0.035	<0.028	<0.031	<0.029	<0.033	<0.024	<0.032	<0.022	<0.031	<0.023	<0.036
Bismuth	<0.023	<0.024	<0.035	<0.028	<0.031	<0.029	<0.033	<0.024	<0.032	<0.022	<0.031	<0.023	<0.036
Boron	2.17	1.10	6.77	1.47	13.0	1.01	7.27	1.20	11.9	1.28	5.19	1.11	6.78
Cadmium	0.0783	0.0151	5.99	1.20	4.34	0.0271	1.24	0.0127	8.02	0.0099	0.0271	0.0089	0.0515
Calcium	1920	599	2910	1590	3280	1010	3070	576	3020	803	3110	679	4670
Chromium (total)	0.129	0.203	<0.070	0.203	<0.062	0.318	<0.065	0.281	<0.064	0.110	0.073	0.161	<0.072
Cobalt	0.0119	0.0054	0.0461	0.0094	0.0137	0.0194	0.0456	0.0056	0.0599	<0.0044	0.0111	<0.0045	0.0106
Copper	1.19	1.87	2.83	1.02	1.33	3.60	2.47	1.93	4.22	1.98	1.60	2.41	1.86
Iron	19.4	10.6	19.2	13.8	21.0	16.9	24.7	8.8	27.9	12.3	20.3	9.7	18.9
Lead	0.213	0.240	0.403	0.685	0.573	0.135	0.262	0.153	0.295	0.0457	0.103	0.103	0.126
Magnesium	549	295	635	683	784	356	1040	296	1410	270	494	254	1080
Manganese	13.8	15.5	11.2	15.7	5.68	22.2	10.7	15.4	17.7	5.81	84.9	6.18	34.6
Mercury	<0.0023	<0.0024	<0.0035	<0.0028	<0.0031	<0.0029	<0.0033	<0.0024	<0.0032	<0.0022	0.0039	<0.0023	<0.0036
Molybdenum	0.235	0.068	0.056	0.677	0.107	0.118	0.038	0.057	0.020	0.945	0.102	0.889	0.749
Nickel	0.331	0.198	0.324	0.400	0.208	0.534	0.126	0.251	0.188	0.120	0.270	0.132	0.149
Phosphorus	269	297	404	350	612	305	582	371	576	713	696	704	1330
Potassium	4570	5230	2400	4620	2080	7030	3430	6610	2820	7040	3210	7280	4300
Selenium	<0.011	<0.012	0.021	<0.014	<0.015	0.018	<0.016	<0.012	0.017	<0.011	<0.015	<0.011	<0.018
Silver	<0.0045	<0.0049	0.0105	0.0056	<0.0062	0.0129	<0.0065	<0.0049	<0.0064	<0.0044	<0.0061	<0.0045	<0.0072
Sodium	3.3	<2.4	4.0	9.2	<3.1	3.0	3.7	<2.4	<3.2	<2.2	<3.1	<2.3	<3.6
Strontium	3.88	1.85	7.71	5.23	8.58	2.82	9.24	1.82	8.26	1.85	15.3	1.73	15.4
Thallium	0.0216	0.0267	0.0152	0.0326	0.193	0.00800	0.0357	0.0226	0.0524	<0.00044	<0.00061	<0.00045	<0.00072
Tin	0.073	<0.024	0.039	0.037	0.032	0.033	0.034	<0.024	0.036	0.073	0.166	0.026	0.064
Titanium	<0.23	<0.24	<0.35	<0.28	0.39	<0.29	<0.33	<0.24	<0.32	<0.22	0.68	<0.23	<0.36
Uranium	0.00280	0.00140	0.00400	0.00450	0.00790	0.00130	0.00160	<0.00049	0.00210	<0.00044	0.00130	<0.00045	<0.00072
Vanadium	<0.045	<0.049	<0.070	<0.056	<0.062	<0.059	<0.065	<0.049	<0.064	<0.044	<0.061	<0.045	<0.072
Zinc	25.6	46.4	123	201	334	51.6	159	50.6	157	8.27	11.7	8.57	10.4

Notes:
m - metres
REF - referece area samples collected from outsite tailings area
mg/kg - milligrams per wet kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed



BASEDATA:

National Road Network, National Railway Network Geobase®, Downloaded March 2014; Aboriginal Lands, Geobase®, Downloaded March, 2014; BC regional Districts and Municipalities, GeoBC,Downloaded March 2014;Fresh Water Atlas, GeoBC®, Downloaded December 2014

- Site Location
- Rail Line
- Contour (20m)
- Municipality Boundary
- Watercourse
- Wetlands

- Buildings
- First Nations Reservation
- Wooded Area
- Developed Area
- Expressway / Highway
- Freeway
- Arterial
- Collector
- Local / Street
- Alleyway / Lane
- Resource / Recreation

0 0.5 1 2 3 km

SCALE 1:50,000
WHEN PLOTTED CORRECTLY ON A 11 x 17 PAGE LAYOUT
NAD 1983 UTM Zone 11U

THIS DRAWING IS FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY AND NOT ALL STRUCTURES ARE SHOWN.

SLR global environmental solutions

REGIONAL DISTRICT OF CENTRAL KOOTENAY
H.B. MINE TAILINGS STORAGE FACILITY

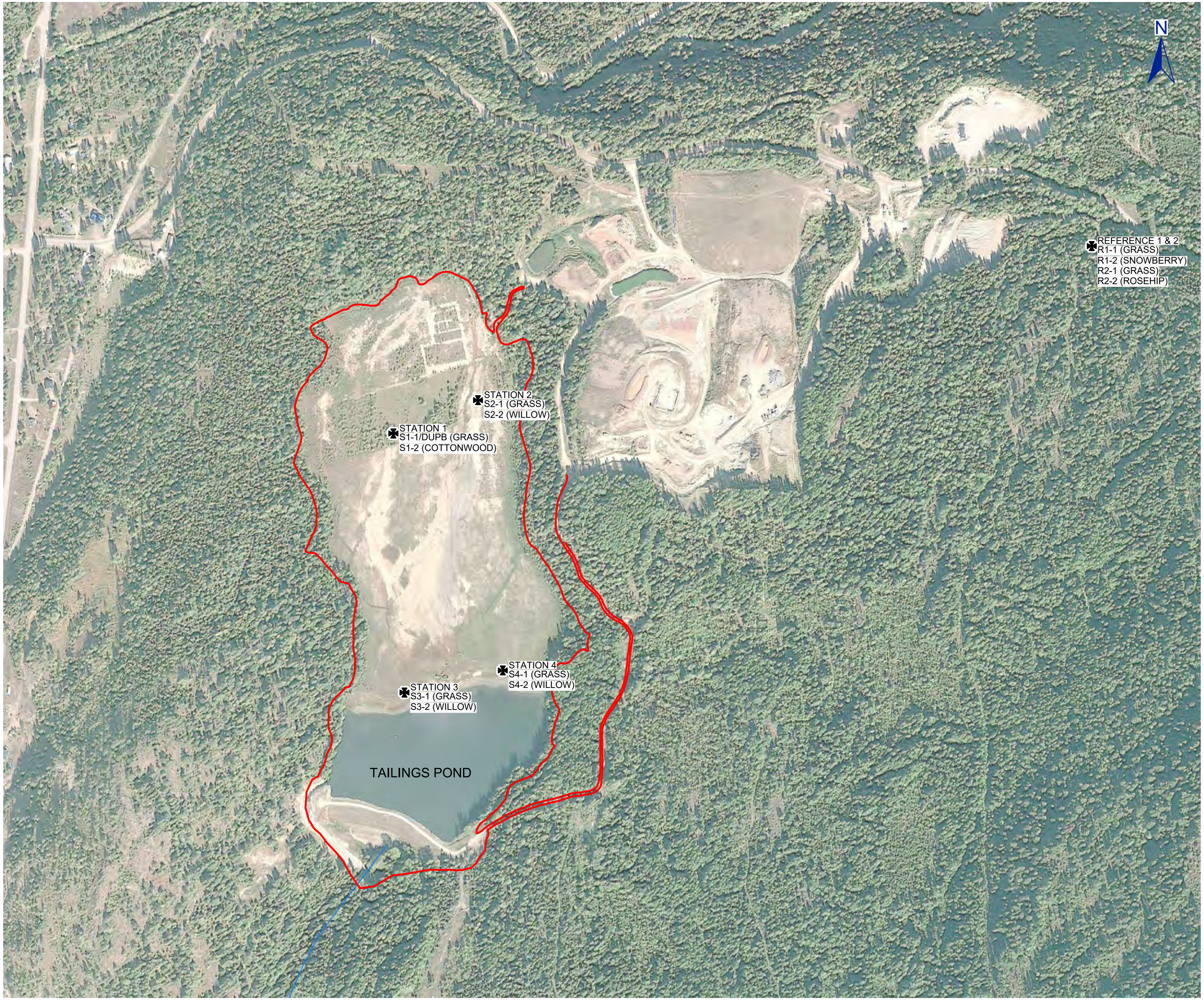
SALMO, BC

VEGETATION METALS UPTAKE STUDY

SITE LOCATION MAP

Date: June 8, 2018	Drawing No.
Project No. 204.03242.00002	1

Cadfile name: S_204-03242-00002-A1.dwg



NOTES:
NOT A LEGAL SURVEY. DO NOT USE FOR CONSTRUCTION.

REFERENCED FROM REGIONAL DISTRICT OF CENTRAL KOOTENAY ONLINE MAPPING APPLICATION AND SITE RECONNAISSANCE INFORMATION.
IMAGERY: GOOGLE EARTH (2009)

LEGEND:
PERMIT BOUNDARY
SOIL AND VEGETATION SAMPLE LOCATIONS

0 50 100 200 300 m
SCALE 1:6,000
WHEN PLOTTED CORRECTLY ON A 11 x 17 PAGE LAYOUT
NAD 1983 UTM Zone 11U

THIS DRAWING IS FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY AND NOT ALL STRUCTURES ARE SHOWN.

REGIONAL DISTRICT OF CENTRAL KOOTENAY
H.B. MINE TAILINGS STORAGE FACILITY
SALMO, BC

VEGETATION METALS UPTAKE STUDY

SITE AND SAMPLE LOCATION PLAN

Date: June 8, 2018	Drawing No. 2
Project No. 204.03242.00002	

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Cadfile name: S_204-03242-00002-A1.dwg

Maxxam
A Bureau Veritas Group Company

Success Through Science®

Your P.O. #: KAM3164
Your Project #: 204.03242.00002.0001
Site Location: HB TAILINGS
Your C.O.C. #: 523593-04-01, 523593-05-01

Attention: Ben Foulger

SLR CONSULTING (CANADA) LTD
200-1475 Ellis Street
Kelowna, BC
CANADA V1Y 2A3

Report Date: 2018/07/10
Report #: R2586374
Version: 2 - Revision

CERTIFICATE OF ANALYSIS – REVISED REPORT

MAXXAM JOB #: B844939
Received: 2018/06/07, 08:30

Sample Matrix: VEGETATION
Samples Received: 13

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Elements in Tissue by CRC ICPMS - Dry Wt	13	2018/07/03	2018/07/06	BBY7SOP-00021 BBY7SOP-00002	EPA 6020b R2 m
Elements in Tissue - Wet Wt (Calculated)	13	N/A	2018/07/10	BBY WI-00033	Auto Calc
Moisture in Tissue	13	N/A	2018/06/25	BBY8SOP-00017	BCMOE BCLM Dec2000 m

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested.
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Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Your P.O. #: KAM3164
Your Project #: 204.03242.00002.0001
Site Location: HB TAILINGS
Your C.O.C. #: 523593-04-01, 523593-05-01

Attention: Ben Foulger

SLR CONSULTING (CANADA) LTD
200-1475 Ellis Street
Kelowna, BC
CANADA V1Y 2A3

Report Date: 2018/07/10
Report #: R2586374
Version: 2 - Revision

CERTIFICATE OF ANALYSIS – REVISED REPORT

MAXXAM JOB #: B844939
Received: 2018/06/07, 08:30

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Letitia Prefontaine, B.Sc., Senior Project Manager
Email: LPrefontaine@maxxam.ca
Phone# (604)639-2616
==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B844939
Report Date: 2018/07/10

SLR CONSULTING (CANADA) LTD
Client Project #: 204.03242.00002.0001
Site Location: HB TAILINGS
Your P.O. #: KAM3164
Sampler Initials: BF

ELEMENTS BY ATOMIC SPECTROSCOPY - DRY WT (VEGETATION)

Maxxam ID		TP1145	TP1146	TP1147	TP1148	TP1149	TP1150		
Sampling Date		2018/06/04 12:15	2018/06/04 12:30	2018/06/04 13:45	2018/06/04 13:50	2018/06/04 14:55	2018/06/04 15:10		
COC Number		523593-04-01	523593-04-01	523593-04-01	523593-04-01	523593-04-01	523593-04-01		
	UNITS	**S1-1**	**S1-2**	**S2-1**	**S2-2**	**S3-1**	**S3-2**	**RDL**	**QC Batch**
Total Metals by ICPMS									
Total Aluminum (Al)	mg/kg	3.5	7.4	8.4	16.2	1.8	8.5	1.0	9047921
Total Antimony (Sb)	mg/kg	0.0087	0.0105	0.0088	0.0087	0.0067	0.0072	0.0050	9047921
Total Arsenic (As)	mg/kg	0.089	0.155	<0.050	<0.050	0.167	0.134	0.050	9047921
Total Barium (Ba)	mg/kg	1.68	2.76	10.5	24.9	4.37	0.84	0.10	9047921
Total Beryllium (Be)	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.10	9047921
Total Bismuth (Bi)	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.10	9047921
Total Boron (B)	mg/kg	9.6	19.3	5.2	42.2	3.4	22.2	2.0	9047921
Total Cadmium (Cd)	mg/kg	0.345	17.1	4.28	14.1	0.092	3.78	0.010	9047921
Total Calcium (Ca)	mg/kg	8450	8300	5640	10600	3440	9400	10	9047921
Total Chromium (Cr)	mg/kg	0.57	<0.20	0.72	<0.20	1.08	<0.20	0.20	9047921
Total Cobalt (Co)	mg/kg	0.053	0.131	0.033	0.044	0.066	0.140	0.020	9047921
Total Copper (Cu)	mg/kg	5.24	8.07	3.63	4.30	12.2	7.55	0.050	9047921
Total Iron (Fe)	mg/kg	85	55	49	68	58	76	10	9047921
Total Lead (Pb)	mg/kg	0.938	1.15	2.44	1.86	0.458	0.802	0.010	9047921
Total Magnesium (Mg)	mg/kg	2420	1810	2430	2540	1210	3200	10	9047921
Total Manganese (Mn)	mg/kg	60.7	32.0	55.7	18.4	75.6	32.8	0.10	9047921
Total Mercury (Hg)	mg/kg	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.010	9047921
Total Molybdenum (Mo)	mg/kg	1.04	0.159	2.41	0.348	0.402	0.116	0.050	9047921
Total Nickel (Ni)	mg/kg	1.46	0.923	1.42	0.677	1.82	0.384	0.050	9047921
Total Phosphorus (P)	mg/kg	1190	1150	1240	1990	1040	1780	10	9047921
Total Potassium (K)	mg/kg	20100	6850	16400	6750	23900	10500	10	9047921
Total Selenium (Se)	mg/kg	<0.050	0.060	<0.050	<0.050	0.061	<0.050	0.050	9047921
Total Silver (Ag)	mg/kg	<0.020	0.030	0.020	<0.020	0.044	<0.020	0.020	9047921
Total Sodium (Na)	mg/kg	15	11	33	<10	10	11	10	9047921
Total Strontium (Sr)	mg/kg	17.1	22.0	18.6	27.8	9.61	28.3	0.10	9047921
Total Thallium (Tl)	mg/kg	0.0951	0.0434	0.116	0.627	0.0271	0.109	0.0020	9047921
Total Tin (Sn)	mg/kg	0.32	0.11	0.13	0.10	0.11	0.10	0.10	9047921
Total Titanium (Ti)	mg/kg	<1.0	<1.0	<1.0	1.3	<1.0	<1.0	1.0	9047921
Total Uranium (U)	mg/kg	0.0123	0.0114	0.0162	0.0257	0.0043	0.0050	0.0020	9047921
Total Vanadium (V)	mg/kg	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.20	9047921
RDL = Reportable Detection Limit									

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Maxxam Job #: B844939
Report Date: 2018/07/10

SLR CONSULTING (CANADA) LTD
Client Project #: 204.03242.00002.0001
Site Location: HB TAILINGS
Your P.O. #: KAM3164
Sampler Initials: BF

ELEMENTS BY ATOMIC SPECTROSCOPY - DRY WT (VEGETATION)

Maxxam ID		TP1145	TP1146	TP1147	TP1148	TP1149	TP1150		
Sampling Date		2018/06/04 12:15	2018/06/04 12:30	2018/06/04 13:45	2018/06/04 13:50	2018/06/04 14:55	2018/06/04 15:10		
COC Number		523593-04-01	523593-04-01	523593-04-01	523593-04-01	523593-04-01	523593-04-01		
	UNITS	S1-1	S1-2	S2-1	S2-2	S3-1	S3-2	RDL	QC Batch
Total Zinc (Zn)	mg/kg	113	352	717	1090	176	486	0.20	9047921
RDL = Reportable Detection Limit									

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Maxxam Job #: B844939
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SLR CONSULTING (CANADA) LTD
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Site Location: HB TAILINGS
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Sampler Initials: BF

ELEMENTS BY ATOMIC SPECTROSCOPY - DRY WT (VEGETATION)

Maxxam ID		TP1151	TP1152	TP1162	TP1163	TP1164	TP1165		
Sampling Date		2018/06/04 16:55	2018/06/04 17:10	2018/06/04 18:35	2018/06/04 18:40	2018/06/04 18:50	2018/06/04 18:55		
COC Number		523593-04-01	523593-04-01	523593-05-01	523593-05-01	523593-05-01	523593-05-01		
	UNITS	**S4-1**	**S4-2**	**REF1-1**	**REF1-2**	**REF2-1**	**REF2-2**	**RDL**	**QC Batch**
Total Metals by ICPMS									
Total Aluminum (Al)	mg/kg	1.8	14.5	4.6	38.3	3.9	15.2	1.0	9047921
Total Antimony (Sb)	mg/kg	<0.0050	0.0112	<0.0050	0.0065	0.0061	0.0128	0.0050	9047921
Total Arsenic (As)	mg/kg	0.138	0.311	<0.050	<0.050	<0.050	<0.050	0.050	9047921
Total Barium (Ba)	mg/kg	8.12	1.61	3.91	38.8	3.02	31.4	0.10	9047921
Total Beryllium (Be)	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.10	9047921
Total Bismuth (Bi)	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.10	9047921
Total Boron (B)	mg/kg	4.9	37.0	5.9	17.0	4.9	18.8	2.0	9047921
Total Cadmium (Cd)	mg/kg	0.052	24.9	0.046	0.089	0.039	0.143	0.010	9047921
Total Calcium (Ca)	mg/kg	2360	9380	3680	10200	3020	13000	10	9047921
Total Chromium (Cr)	mg/kg	1.15	<0.20	0.50	0.24	0.72	<0.20	0.20	9047921
Total Cobalt (Co)	mg/kg	0.023	0.186	<0.020	0.036	<0.020	0.029	0.020	9047921
Total Copper (Cu)	mg/kg	7.92	13.1	9.06	5.23	10.7	5.18	0.050	9047921
Total Iron (Fe)	mg/kg	36	87	56	66	43	53	10	9047921
Total Lead (Pb)	mg/kg	0.627	0.915	0.210	0.336	0.459	0.351	0.010	9047921
Total Magnesium (Mg)	mg/kg	1210	4370	1240	1610	1130	3000	10	9047921
Total Manganese (Mn)	mg/kg	63.2	55.0	26.7	278	27.5	96.2	0.10	9047921
Total Mercury (Hg)	mg/kg	<0.010	<0.010	<0.010	0.013	<0.010	<0.010	0.010	9047921
Total Molybdenum (Mo)	mg/kg	0.234	0.062	4.33	0.332	3.95	2.08	0.050	9047921
Total Nickel (Ni)	mg/kg	1.03	0.585	0.551	0.882	0.587	0.413	0.050	9047921
Total Phosphorus (P)	mg/kg	1520	1790	3270	2270	3130	3700	10	9047921
Total Potassium (K)	mg/kg	27100	8760	32300	10500	32400	11900	10	9047921
Total Selenium (Se)	mg/kg	<0.050	0.054	<0.050	<0.050	<0.050	<0.050	0.050	9047921
Total Silver (Ag)	mg/kg	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.020	9047921
Total Sodium (Na)	mg/kg	<10	<10	<10	<10	<10	<10	10	9047921
Total Strontium (Sr)	mg/kg	7.47	25.6	8.51	50.0	7.67	42.8	0.10	9047921
Total Thallium (Tl)	mg/kg	0.0927	0.163	<0.0020	<0.0020	<0.0020	<0.0020	0.0020	9047921
Total Tin (Sn)	mg/kg	<0.10	0.11	0.33	0.54	0.12	0.18	0.10	9047921
Total Titanium (Ti)	mg/kg	<1.0	<1.0	<1.0	2.2	<1.0	<1.0	1.0	9047921
Total Uranium (U)	mg/kg	<0.0020	0.0065	<0.0020	0.0042	<0.0020	<0.0020	0.0020	9047921
Total Vanadium (V)	mg/kg	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.20	9047921
RDL = Reportable Detection Limit									

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SLR CONSULTING (CANADA) LTD
Client Project #: 204.03242.00002.0001
Site Location: HB TAILINGS
Your P.O. #: KAM3164
Sampler Initials: BF

ELEMENTS BY ATOMIC SPECTROSCOPY - DRY WT (VEGETATION)

Maxxam ID		TP1151	TP1152	TP1162	TP1163	TP1164	TP1165		
Sampling Date		2018/06/04 16:55	2018/06/04 17:10	2018/06/04 18:35	2018/06/04 18:40	2018/06/04 18:50	2018/06/04 18:55		
COC Number		523593-04-01	523593-04-01	523593-05-01	523593-05-01	523593-05-01	523593-05-01		
	UNITS	**S4-1**	**S4-2**	**REF1-1**	**REF1-2**	**REF2-1**	**REF2-2**	**RDL**	**QC Batch**
Total Zinc (Zn)	mg/kg	207	488	37.9	38.3	38.1	28.9	0.20	9047921
RDL = Reportable Detection Limit									

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Sampler Initials: BF

ELEMENTS BY ATOMIC SPECTROSCOPY - DRY WT (VEGETATION)

Maxxam ID		TP1166		
Sampling Date		2018/06/04 16:55		
COC Number		523593-05-01		
	UNITS	**DUP B**	**RDL**	**QC Batch**
Total Metals by ICPMS				
Total Aluminum (Al)	mg/kg	5.7	1.0	9047921
Total Antimony (Sb)	mg/kg	0.0078	0.0050	9047921
Total Arsenic (As)	mg/kg	0.194	0.050	9047921
Total Barium (Ba)	mg/kg	8.75	0.10	9047921
Total Beryllium (Be)	mg/kg	<0.10	0.10	9047921
Total Bismuth (Bi)	mg/kg	<0.10	0.10	9047921
Total Boron (B)	mg/kg	4.5	2.0	9047921
Total Cadmium (Cd)	mg/kg	0.062	0.010	9047921
Total Calcium (Ca)	mg/kg	2460	10	9047921
Total Chromium (Cr)	mg/kg	0.84	0.20	9047921
Total Cobalt (Co)	mg/kg	0.022	0.020	9047921
Total Copper (Cu)	mg/kg	7.69	0.050	9047921
Total Iron (Fe)	mg/kg	43	10	9047921
Total Lead (Pb)	mg/kg	0.988	0.010	9047921
Total Magnesium (Mg)	mg/kg	1220	10	9047921
Total Manganese (Mn)	mg/kg	63.8	0.10	9047921
Total Mercury (Hg)	mg/kg	<0.010	0.010	9047921
Total Molybdenum (Mo)	mg/kg	0.279	0.050	9047921
Total Nickel (Ni)	mg/kg	0.815	0.050	9047921
Total Phosphorus (P)	mg/kg	1220	10	9047921
Total Potassium (K)	mg/kg	21500	10	9047921
Total Selenium (Se)	mg/kg	<0.050	0.050	9047921
Total Silver (Ag)	mg/kg	<0.020	0.020	9047921
Total Sodium (Na)	mg/kg	<10	10	9047921
Total Strontium (Sr)	mg/kg	7.63	0.10	9047921
Total Thallium (Tl)	mg/kg	0.110	0.0020	9047921
Total Tin (Sn)	mg/kg	<0.10	0.10	9047921
Total Titanium (Ti)	mg/kg	<1.0	1.0	9047921
Total Uranium (U)	mg/kg	0.0057	0.0020	9047921
Total Vanadium (V)	mg/kg	<0.20	0.20	9047921
RDL = Reportable Detection Limit				

Maxxam Job #: B844939
Report Date: 2018/07/10

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Sampler Initials: BF

ELEMENTS BY ATOMIC SPECTROSCOPY - DRY WT (VEGETATION)

Maxxam ID		TP1166		
Sampling Date		2018/06/04 16:55		
COC Number		523593-05-01		
	UNITS	DUP B	RDL	QC Batch
Total Zinc (Zn)	mg/kg	191	0.20	9047921
RDL = Reportable Detection Limit				

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ELEMENTS BY ATOMIC SPECTROSCOPY - WET WT (VEGETATION)

Maxxam ID		TP1145		TP1146		TP1147		TP1148		
Sampling Date		2018/06/04 12:15		2018/06/04 12:30		2018/06/04 13:45		2018/06/04 13:50		
COC Number		523593-04-01		523593-04-01		523593-04-01		523593-04-01		
	UNITS	S1-1	RDL	S1-2	RDL	S2-1	RDL	S2-2	RDL	QC Batch
Calculated Parameters										
Total Aluminum (Al)	mg/kg	0.79	0.23	2.59	0.35	2.37	0.28	4.98	0.31	9057735
Total Antimony (Sb)	mg/kg	0.0020	0.0011	0.0037	0.0018	0.0025	0.0014	0.0027	0.0015	9057735
Total Arsenic (As)	mg/kg	0.020	0.011	0.054	0.018	<0.014	0.014	<0.015	0.015	9057735
Total Barium (Ba)	mg/kg	0.382	0.023	0.969	0.035	2.94	0.028	7.67	0.031	9057735
Total Beryllium (Be)	mg/kg	<0.023	0.023	<0.035	0.035	<0.028	0.028	<0.031	0.031	9057735
Total Bismuth (Bi)	mg/kg	<0.023	0.023	<0.035	0.035	<0.028	0.028	<0.031	0.031	9057735
Total Boron (B)	mg/kg	2.17	0.45	6.77	0.70	1.47	0.56	13.0	0.62	9057735
Total Cadmium (Cd)	mg/kg	0.0783	0.0023	5.99	0.0035	1.20	0.0028	4.34	0.0031	9057735
Total Calcium (Ca)	mg/kg	1920	2.3	2910	3.5	1590	2.8	3280	3.1	9057735
Total Chromium (Cr)	mg/kg	0.129	0.045	<0.070	0.070	0.203	0.056	<0.062	0.062	9057735
Total Cobalt (Co)	mg/kg	0.0119	0.0045	0.0461	0.0070	0.0094	0.0056	0.0137	0.0062	9057735
Total Copper (Cu)	mg/kg	1.19	0.011	2.83	0.018	1.02	0.014	1.33	0.015	9057735
Total Iron (Fe)	mg/kg	19.4	2.3	19.2	3.5	13.8	2.8	21.0	3.1	9057735
Total Lead (Pb)	mg/kg	0.213	0.0023	0.403	0.0035	0.685	0.0028	0.573	0.0031	9057735
Total Magnesium (Mg)	mg/kg	549	2.3	635	3.5	683	2.8	784	3.1	9057735
Total Manganese (Mn)	mg/kg	13.8	0.023	11.2	0.035	15.7	0.028	5.68	0.031	9057735
Total Mercury (Hg)	mg/kg	<0.0023	0.0023	<0.0035	0.0035	<0.0028	0.0028	<0.0031	0.0031	9057735
Total Molybdenum (Mo)	mg/kg	0.235	0.011	0.056	0.018	0.677	0.014	0.107	0.015	9057735
Total Nickel (Ni)	mg/kg	0.331	0.011	0.324	0.018	0.400	0.014	0.208	0.015	9057735
Total Phosphorus (P)	mg/kg	269	2.3	404	3.5	350	2.8	612	3.1	9057735
Total Potassium (K)	mg/kg	4570	2.3	2400	3.5	4620	2.8	2080	3.1	9057735
Total Selenium (Se)	mg/kg	<0.011	0.011	0.021	0.018	<0.014	0.014	<0.015	0.015	9057735
Total Silver (Ag)	mg/kg	<0.0045	0.0045	0.0105	0.0070	0.0056	0.0056	<0.0062	0.0062	9057735
Total Sodium (Na)	mg/kg	3.3	2.3	4.0	3.5	9.2	2.8	<3.1	3.1	9057735
Total Strontium (Sr)	mg/kg	3.88	0.023	7.71	0.035	5.23	0.028	8.58	0.031	9057735
Total Thallium (Tl)	mg/kg	0.0216	0.00045	0.0152	0.00070	0.0326	0.00056	0.193	0.00062	9057735
Total Tin (Sn)	mg/kg	0.073	0.023	0.039	0.035	0.037	0.028	0.032	0.031	9057735
Total Titanium (Ti)	mg/kg	<0.23	0.23	<0.35	0.35	<0.28	0.28	0.39	0.31	9057735
Total Uranium (U)	mg/kg	0.00280	0.00045	0.00400	0.00070	0.00450	0.00056	0.00790	0.00062	9057735
Total Vanadium (V)	mg/kg	<0.045	0.045	<0.070	0.070	<0.056	0.056	<0.062	0.062	9057735
RDL = Reportable Detection Limit										

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Maxxam Job #: B844939
Report Date: 2018/07/10

SLR CONSULTING (CANADA) LTD
Client Project #: 204.03242.00002.0001
Site Location: HB TAILINGS
Your P.O. #: KAM3164
Sampler Initials: BF

ELEMENTS BY ATOMIC SPECTROSCOPY - WET WT (VEGETATION)

Maxxam ID		TP1145		TP1146		TP1147		TP1148		
Sampling Date		2018/06/04 12:15		2018/06/04 12:30		2018/06/04 13:45		2018/06/04 13:50		
COC Number		523593-04-01		523593-04-01		523593-04-01		523593-04-01		
	UNITS	**S1-1**	**RDL**	**S1-2**	**RDL**	**S2-1**	**RDL**	**S2-2**	**RDL**	**QC Batch**
Total Zinc (Zn)	mg/kg	25.6	0.045	123	0.070	201	0.056	334	0.062	9057735
RDL = Reportable Detection Limit										

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Maxxam Job #: B844939
Report Date: 2018/07/10

SLR CONSULTING (CANADA) LTD
Client Project #: 204.03242.00002.0001
Site Location: HB TAILINGS
Your P.O. #: KAM3164
Sampler Initials: BF

ELEMENTS BY ATOMIC SPECTROSCOPY - WET WT (VEGETATION)

Maxxam ID		TP1149		TP1150		TP1151		TP1152		
Sampling Date		2018/06/04 14:55		2018/06/04 15:10		2018/06/04 16:55		2018/06/04 17:10		
COC Number		523593-04-01		523593-04-01		523593-04-01		523593-04-01		
	UNITS	**S3-1**	**RDL**	**S3-2**	**RDL**	**S4-1**	**RDL**	**S4-2**	**RDL**	**QC Batch**
Calculated Parameters										
Total Aluminum (Al)	mg/kg	0.53	0.29	2.76	0.33	0.43	0.24	4.66	0.32	9057735
Total Antimony (Sb)	mg/kg	0.0020	0.0015	0.0023	0.0016	<0.0012	0.0012	0.0036	0.0016	9057735
Total Arsenic (As)	mg/kg	0.049	0.015	0.044	0.016	0.034	0.012	0.100	0.016	9057735
Total Barium (Ba)	mg/kg	1.28	0.029	0.273	0.033	1.98	0.024	0.517	0.032	9057735
Total Beryllium (Be)	mg/kg	<0.029	0.029	<0.033	0.033	<0.024	0.024	<0.032	0.032	9057735
Total Bismuth (Bi)	mg/kg	<0.029	0.029	<0.033	0.033	<0.024	0.024	<0.032	0.032	9057735
Total Boron (B)	mg/kg	1.01	0.59	7.27	0.65	1.20	0.49	11.9	0.64	9057735
Total Cadmium (Cd)	mg/kg	0.0271	0.0029	1.24	0.0033	0.0127	0.0024	8.02	0.0032	9057735
Total Calcium (Ca)	mg/kg	1010	2.9	3070	3.3	576	2.4	3020	3.2	9057735
Total Chromium (Cr)	mg/kg	0.318	0.059	<0.065	0.065	0.281	0.049	<0.064	0.064	9057735
Total Cobalt (Co)	mg/kg	0.0194	0.0059	0.0456	0.0065	0.0056	0.0049	0.0599	0.0064	9057735
Total Copper (Cu)	mg/kg	3.60	0.015	2.47	0.016	1.93	0.012	4.22	0.016	9057735
Total Iron (Fe)	mg/kg	16.9	2.9	24.7	3.3	8.8	2.4	27.9	3.2	9057735
Total Lead (Pb)	mg/kg	0.135	0.0029	0.262	0.0033	0.153	0.0024	0.295	0.0032	9057735
Total Magnesium (Mg)	mg/kg	356	2.9	1040	3.3	296	2.4	1410	3.2	9057735
Total Manganese (Mn)	mg/kg	22.2	0.029	10.7	0.033	15.4	0.024	17.7	0.032	9057735
Total Mercury (Hg)	mg/kg	<0.0029	0.0029	<0.0033	0.0033	<0.0024	0.0024	<0.0032	0.0032	9057735
Total Molybdenum (Mo)	mg/kg	0.118	0.015	0.038	0.016	0.057	0.012	0.020	0.016	9057735
Total Nickel (Ni)	mg/kg	0.534	0.015	0.126	0.016	0.251	0.012	0.188	0.016	9057735
Total Phosphorus (P)	mg/kg	305	2.9	582	3.3	371	2.4	576	3.2	9057735
Total Potassium (K)	mg/kg	7030	2.9	3430	3.3	6610	2.4	2820	3.2	9057735
Total Selenium (Se)	mg/kg	0.018	0.015	<0.016	0.016	<0.012	0.012	0.017	0.016	9057735
Total Silver (Ag)	mg/kg	0.0129	0.0059	<0.0065	0.0065	<0.0049	0.0049	<0.0064	0.0064	9057735
Total Sodium (Na)	mg/kg	3.0	2.9	3.7	3.3	<2.4	2.4	<3.2	3.2	9057735
Total Strontium (Sr)	mg/kg	2.82	0.029	9.24	0.033	1.82	0.024	8.26	0.032	9057735
Total Thallium (Tl)	mg/kg	0.00800	0.00059	0.0357	0.00065	0.0226	0.00049	0.0524	0.00064	9057735
Total Tin (Sn)	mg/kg	0.033	0.029	0.034	0.033	<0.024	0.024	0.036	0.032	9057735
Total Titanium (Ti)	mg/kg	<0.29	0.29	<0.33	0.33	<0.24	0.24	<0.32	0.32	9057735
Total Uranium (U)	mg/kg	0.00130	0.00059	0.00160	0.00065	<0.00049	0.00049	0.00210	0.00064	9057735
Total Vanadium (V)	mg/kg	<0.059	0.059	<0.065	0.065	<0.049	0.049	<0.064	0.064	9057735
RDL = Reportable Detection Limit										

Maxxam Job #: B844939
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Sampler Initials: BF

ELEMENTS BY ATOMIC SPECTROSCOPY - WET WT (VEGETATION)

Maxxam ID		TP1149		TP1150		TP1151		TP1152		
Sampling Date		2018/06/04 14:55		2018/06/04 15:10		2018/06/04 16:55		2018/06/04 17:10		
COC Number		523593-04-01		523593-04-01		523593-04-01		523593-04-01		
	UNITS	**S3-1**	**RDL**	**S3-2**	**RDL**	**S4-1**	**RDL**	**S4-2**	**RDL**	**QC Batch**
Total Zinc (Zn)	mg/kg	51.6	0.059	159	0.065	50.6	0.049	157	0.064	9057735
RDL = Reportable Detection Limit										

Maxxam Job #: B844939
Report Date: 2018/07/10

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Sampler Initials: BF

ELEMENTS BY ATOMIC SPECTROSCOPY - WET WT (VEGETATION)

Maxxam ID		TP1162		TP1163		TP1164		TP1165		
Sampling Date		2018/06/04 18:35		2018/06/04 18:40		2018/06/04 18:50		2018/06/04 18:55		
COC Number		523593-05-01		523593-05-01		523593-05-01		523593-05-01		
	UNITS	**REF1-1**	**RDL**	**REF1-2**	**RDL**	**REF2-1**	**RDL**	**REF2-2**	**RDL**	**QC Batch**
Calculated Parameters										
Total Aluminum (Al)	mg/kg	1.00	0.22	11.7	0.31	0.88	0.23	5.48	0.36	9057735
Total Antimony (Sb)	mg/kg	<0.0011	0.0011	0.0020	0.0015	0.0014	0.0011	0.0046	0.0018	9057735
Total Arsenic (As)	mg/kg	<0.011	0.011	<0.015	0.015	<0.011	0.011	<0.018	0.018	9057735
Total Barium (Ba)	mg/kg	0.852	0.022	11.9	0.031	0.679	0.023	11.3	0.036	9057735
Total Beryllium (Be)	mg/kg	<0.022	0.022	<0.031	0.031	<0.023	0.023	<0.036	0.036	9057735
Total Bismuth (Bi)	mg/kg	<0.022	0.022	<0.031	0.031	<0.023	0.023	<0.036	0.036	9057735
Total Boron (B)	mg/kg	1.28	0.44	5.19	0.61	1.11	0.45	6.78	0.72	9057735
Total Cadmium (Cd)	mg/kg	0.0099	0.0022	0.0271	0.0031	0.0089	0.0023	0.0515	0.0036	9057735
Total Calcium (Ca)	mg/kg	803	2.2	3110	3.1	679	2.3	4670	3.6	9057735
Total Chromium (Cr)	mg/kg	0.110	0.044	0.073	0.061	0.161	0.045	<0.072	0.072	9057735
Total Cobalt (Co)	mg/kg	<0.0044	0.0044	0.0111	0.0061	<0.0045	0.0045	0.0106	0.0072	9057735
Total Copper (Cu)	mg/kg	1.98	0.011	1.60	0.015	2.41	0.011	1.86	0.018	9057735
Total Iron (Fe)	mg/kg	12.3	2.2	20.3	3.1	9.7	2.3	18.9	3.6	9057735
Total Lead (Pb)	mg/kg	0.0457	0.0022	0.103	0.0031	0.103	0.0023	0.126	0.0036	9057735
Total Magnesium (Mg)	mg/kg	270	2.2	494	3.1	254	2.3	1080	3.6	9057735
Total Manganese (Mn)	mg/kg	5.81	0.022	84.9	0.031	6.18	0.023	34.6	0.036	9057735
Total Mercury (Hg)	mg/kg	<0.0022	0.0022	0.0039	0.0031	<0.0023	0.0023	<0.0036	0.0036	9057735
Total Molybdenum (Mo)	mg/kg	0.945	0.011	0.102	0.015	0.889	0.011	0.749	0.018	9057735
Total Nickel (Ni)	mg/kg	0.120	0.011	0.270	0.015	0.132	0.011	0.149	0.018	9057735
Total Phosphorus (P)	mg/kg	713	2.2	696	3.1	704	2.3	1330	3.6	9057735
Total Potassium (K)	mg/kg	7040	2.2	3210	3.1	7280	2.3	4300	3.6	9057735
Total Selenium (Se)	mg/kg	<0.011	0.011	<0.015	0.015	<0.011	0.011	<0.018	0.018	9057735
Total Silver (Ag)	mg/kg	<0.0044	0.0044	<0.0061	0.0061	<0.0045	0.0045	<0.0072	0.0072	9057735
Total Sodium (Na)	mg/kg	<2.2	2.2	<3.1	3.1	<2.3	2.3	<3.6	3.6	9057735
Total Strontium (Sr)	mg/kg	1.85	0.022	15.3	0.031	1.73	0.023	15.4	0.036	9057735
Total Thallium (Tl)	mg/kg	<0.00044	0.00044	<0.00061	0.00061	<0.00045	0.00045	<0.00072	0.00072	9057735
Total Tin (Sn)	mg/kg	0.073	0.022	0.166	0.031	0.026	0.023	0.064	0.036	9057735
Total Titanium (Ti)	mg/kg	<0.22	0.22	0.68	0.31	<0.23	0.23	<0.36	0.36	9057735
Total Uranium (U)	mg/kg	<0.00044	0.00044	0.00130	0.00061	<0.00045	0.00045	<0.00072	0.00072	9057735
Total Vanadium (V)	mg/kg	<0.044	0.044	<0.061	0.061	<0.045	0.045	<0.072	0.072	9057735
RDL = Reportable Detection Limit										

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Client Project #: 204.03242.00002.0001
Site Location: HB TAILINGS
Your P.O. #: KAM3164
Sampler Initials: BF

ELEMENTS BY ATOMIC SPECTROSCOPY - WET WT (VEGETATION)

Maxxam ID		TP1162		TP1163		TP1164		TP1165		
Sampling Date		2018/06/04 18:35		2018/06/04 18:40		2018/06/04 18:50		2018/06/04 18:55		
COC Number		523593-05-01		523593-05-01		523593-05-01		523593-05-01		
	UNITS	**REF1-1**	**RDL**	**REF1-2**	**RDL**	**REF2-1**	**RDL**	**REF2-2**	**RDL**	**QC Batch**
Total Zinc (Zn)	mg/kg	8.27	0.044	11.7	0.061	8.57	0.045	10.4	0.072	9057735
RDL = Reportable Detection Limit										

Maxxam Job #: B844939
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SLR CONSULTING (CANADA) LTD
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Sampler Initials: BF

ELEMENTS BY ATOMIC SPECTROSCOPY - WET WT (VEGETATION)

Maxxam ID		TP1166		
Sampling Date		2018/06/04 16:55		
COC Number		523593-05-01		
	UNITS	**DUP B**	**RDL**	**QC Batch**
Calculated Parameters				
Total Aluminum (Al)	mg/kg	1.39	0.24	9057735
Total Antimony (Sb)	mg/kg	0.0019	0.0012	9057735
Total Arsenic (As)	mg/kg	0.047	0.012	9057735
Total Barium (Ba)	mg/kg	2.13	0.024	9057735
Total Beryllium (Be)	mg/kg	<0.024	0.024	9057735
Total Bismuth (Bi)	mg/kg	<0.024	0.024	9057735
Total Boron (B)	mg/kg	1.10	0.49	9057735
Total Cadmium (Cd)	mg/kg	0.0151	0.0024	9057735
Total Calcium (Ca)	mg/kg	599	2.4	9057735
Total Chromium (Cr)	mg/kg	0.203	0.049	9057735
Total Cobalt (Co)	mg/kg	0.0054	0.0049	9057735
Total Copper (Cu)	mg/kg	1.87	0.012	9057735
Total Iron (Fe)	mg/kg	10.6	2.4	9057735
Total Lead (Pb)	mg/kg	0.240	0.0024	9057735
Total Magnesium (Mg)	mg/kg	295	2.4	9057735
Total Manganese (Mn)	mg/kg	15.5	0.024	9057735
Total Mercury (Hg)	mg/kg	<0.0024	0.0024	9057735
Total Molybdenum (Mo)	mg/kg	0.068	0.012	9057735
Total Nickel (Ni)	mg/kg	0.198	0.012	9057735
Total Phosphorus (P)	mg/kg	297	2.4	9057735
Total Potassium (K)	mg/kg	5230	2.4	9057735
Total Selenium (Se)	mg/kg	<0.012	0.012	9057735
Total Silver (Ag)	mg/kg	<0.0049	0.0049	9057735
Total Sodium (Na)	mg/kg	<2.4	2.4	9057735
Total Strontium (Sr)	mg/kg	1.85	0.024	9057735
Total Thallium (Tl)	mg/kg	0.0267	0.00049	9057735
Total Tin (Sn)	mg/kg	<0.024	0.024	9057735
Total Titanium (Ti)	mg/kg	<0.24	0.24	9057735
Total Uranium (U)	mg/kg	0.00140	0.00049	9057735
Total Vanadium (V)	mg/kg	<0.049	0.049	9057735
RDL = Reportable Detection Limit				

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ELEMENTS BY ATOMIC SPECTROSCOPY - WET WT (VEGETATION)

Maxxam ID		TP1166		
Sampling Date		2018/06/04 16:55		
COC Number		523593-05-01		
	UNITS	**DUP B**	**RDL**	**QC Batch**
Total Zinc (Zn)	mg/kg	46.4	0.049	9057735
RDL = Reportable Detection Limit				

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PHYSICAL TESTING (VEGETATION)

Maxxam ID		TP1145	TP1146	TP1147	TP1148	TP1149	TP1150		
Sampling Date		2018/06/04 12:15	2018/06/04 12:30	2018/06/04 13:45	2018/06/04 13:50	2018/06/04 14:55	2018/06/04 15:10		
COC Number		523593-04-01	523593-04-01	523593-04-01	523593-04-01	523593-04-01	523593-04-01		
	UNITS	**S1-1**	**S1-2**	**S2-1**	**S2-2**	**S3-1**	**S3-2**	**RDL**	**QC Batch**
Physical Properties									
Moisture	%	77	65	72	69	71	67	0.30	9035880
RDL = Reportable Detection Limit									

Maxxam ID		TP1151	TP1152	TP1162	TP1163	TP1164	TP1165		
Sampling Date		2018/06/04 16:55	2018/06/04 17:10	2018/06/04 18:35	2018/06/04 18:40	2018/06/04 18:50	2018/06/04 18:55		
COC Number		523593-04-01	523593-04-01	523593-05-01	523593-05-01	523593-05-01	523593-05-01		
	UNITS	**S4-1**	**S4-2**	**REF1-1**	**REF1-2**	**REF2-1**	**REF2-2**	**RDL**	**QC Batch**
Physical Properties									
Moisture	%	76	68	78	69	78	64	0.30	9035880
RDL = Reportable Detection Limit									

Maxxam ID		TP1166		
Sampling Date		2018/06/04 16:55		
COC Number		523593-05-01		
	UNITS	**DUP B**	**RDL**	**QC Batch**
Physical Properties				
Moisture	%	76	0.30	9035880
RDL = Reportable Detection Limit				

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GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	5.3°C

Version 2: Report reissued to include results in wet weight as per Ben Foulger on 2018/07/10.

Results relate only to the items tested.

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QUALITY ASSURANCE REPORT

SLR CONSULTING (CANADA) LTD
Client Project #: 204.03242.00002.0001
Site Location: HB TAILINGS
Your P.O. #: KAM3164
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			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
9035880	Moisture	2018/06/25					<0.30	%	0.75	20		
9047921	Total Aluminum (Al)	2018/07/06					<1.0	mg/kg	5.4	35	38	17 - 93
9047921	Total Antimony (Sb)	2018/07/06	94	75 - 125	101	75 - 125	<0.0050	mg/kg	19	35		
9047921	Total Arsenic (As)	2018/07/06	100	75 - 125	101	75 - 125	<0.050	mg/kg	NC	35	96	42 - 199
9047921	Total Barium (Ba)	2018/07/06	NC	75 - 125	118	75 - 125	<0.10	mg/kg	2.7	35		
9047921	Total Beryllium (Be)	2018/07/06	98	75 - 125	103	75 - 125	<0.10	mg/kg	NC	35		
9047921	Total Bismuth (Bi)	2018/07/06					<0.10	mg/kg	NC	35		
9047921	Total Boron (B)	2018/07/06					<2.0	mg/kg	0.0043	35	124	75 - 125
9047921	Total Cadmium (Cd)	2018/07/06	NC	75 - 125	101	75 - 125	<0.010	mg/kg	1.3	35	101	75 - 125
9047921	Total Calcium (Ca)	2018/07/06					<10	mg/kg	2.2	35	98	75 - 125
9047921	Total Chromium (Cr)	2018/07/06	93	75 - 125	107	75 - 125	<0.20	mg/kg	NC	35		
9047921	Total Cobalt (Co)	2018/07/06	93	75 - 125	108	75 - 125	<0.020	mg/kg	0.95	35	93	75 - 125
9047921	Total Copper (Cu)	2018/07/06	83	75 - 125	105	75 - 125	<0.050	mg/kg	5.1	35	98	75 - 125
9047921	Total Iron (Fe)	2018/07/06					<10	mg/kg	0.22	35		
9047921	Total Lead (Pb)	2018/07/06	95	75 - 125	108	75 - 125	<0.010	mg/kg	3.1	35		
9047921	Total Magnesium (Mg)	2018/07/06					<10	mg/kg	4.7	35		
9047921	Total Manganese (Mn)	2018/07/06	NC	75 - 125	111	75 - 125	<0.10	mg/kg	6.2	35	104	75 - 125
9047921	Total Mercury (Hg)	2018/07/06	94	75 - 125	108	75 - 125	<0.010	mg/kg	NC	35	105	75 - 125
9047921	Total Molybdenum (Mo)	2018/07/06	95	75 - 125	103	75 - 125	<0.050	mg/kg	2.3	35		
9047921	Total Nickel (Ni)	2018/07/06	93	75 - 125	108	75 - 125	<0.050	mg/kg	2.1	35	92	75 - 125
9047921	Total Phosphorus (P)	2018/07/06					<10	mg/kg	4.2	35	110	75 - 125
9047921	Total Potassium (K)	2018/07/06					<10	mg/kg	5.5	35	100	75 - 125
9047921	Total Selenium (Se)	2018/07/06	92	75 - 125	103	75 - 125	<0.050	mg/kg	NC	35	105	75 - 125
9047921	Total Silver (Ag)	2018/07/06	86	75 - 125	89	75 - 125	<0.020	mg/kg	NC	35		
9047921	Total Sodium (Na)	2018/07/06					<10	mg/kg	NC	35	97	75 - 125
9047921	Total Strontium (Sr)	2018/07/06	NC	75 - 125	106	75 - 125	<0.10	mg/kg	0.061	35	104	75 - 125
9047921	Total Thallium (Tl)	2018/07/06	NC	75 - 125	107	75 - 125	<0.0020	mg/kg	2.3	35		
9047921	Total Tin (Sn)	2018/07/06	93	75 - 125	104	75 - 125	<0.10	mg/kg	0.0096	35		
9047921	Total Titanium (Ti)	2018/07/06	91	75 - 125	107	75 - 125	<1.0	mg/kg	24	35		
9047921	Total Uranium (U)	2018/07/06	101	75 - 125	108	75 - 125	<0.0020	mg/kg	2.6	35		

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QUALITY ASSURANCE REPORT(CONT'D)

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
9047921	Total Vanadium (V)	2018/07/06	98	75 - 125	109	75 - 125	<0.20	mg/kg	NC	35		
9047921	Total Zinc (Zn)	2018/07/06	NC	75 - 125	107	75 - 125	<0.20	mg/kg	5.2	35	98	75 - 125

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference <= 2x RDL).

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Client Project #: 204.03242.00002.0001
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VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Andy Lu, Ph.D., P.Chem., Scientific Specialist

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

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Maxxam

Maxxam Analytics International Corporation o/a Maxxam Analytics
4606 Canada Way, Burnaby, British Columbia Canada V5G 1K5 Tel (604) 734 7276 Toll-free 800-563-6266 Fax (604) 731 2386 www.maxxam.ca

Chain Of Custody Record

Page 1 of 2

INVOICE TO:		Report Information		Project Information	
Company Name	#17775 SLR CONSULTING (CANADA) LTD	Company Name	SLR CONSULTING (CANADA) LTD.	Quotation #	B51186
Contact Name	Ben Foulger	Contact Name	Ben Foulger	P.O. #	~~[illegible]~~ KAM3164
Address	200-1475 Ellis Street	Address	1024 GILKER STREET	Project #	~~[illegible]~~ 204.03242.00002.0001
	Kelowna BC V1Y 2A3		NELSON BC V1L 5V4	Project Name	HB TAILINGS
Phone	(250) 762-7202 x Fax (250) 374-8656 x	Phone	~~[illegible]~~ 250-777-7144 Fax	Site #	~~[illegible]~~
Email	bfoulger@slrconsulting.com, analytical@slrconsulting.c	Email	bfoulger@slrconsulting.com, analytical@slrconsulting.c	Sampled By	B. FOULGER

Laboratory Use Only	
Maxxam Job #	Bottle Order #: 523593
Chain Of Custody Record: C#523593-04-01	Project Manager: Letitia Prefontaine

Regulatory Criteria

- [x] CSR DW
- [ ] CCME
- [ ] BC Water Quality
- [ ] Other ________

Special Instructions

SAMPLES MUST BE KEPT COOL (< 10°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

ANALYSIS REQUESTED (PLEASE BE SPECIFIC)

Turnaround Time (TAT) Required

Please provide advance notice for rush projects

Regular (Standard) TAT: [x]
(will be applied if Rush TAT is not specified)
Standard TAT = 5-7 Working days for most tests.
Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.

Job Specific Rush TAT (if applies to entire submission)
1 DAY [ ] 2 Day [ ] 3 Day [ ] Date Required: ______ Time Required: [ ]
Rush Confirmation Number: RAG (call lab for #)

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Metals Field Filtered ? (Y / N)	RINSED TOTAL METALS (~~CSR BTEX/VPH/MTBE in Water~~)	MOISTURE CONTENT (~~[illegible]~~)	LEPH & HEPH with CSR/CCME PAH in Water	CSR Dissolved Metals in Water with CV Hg	1,3,5-trimethylbenzene, 1,3-butadiene, 1,2-dibromoethane, 1,2-dichloroethane	1,2,4-trimethylbenzene, n-hexane, n-decane, naphthalene,	methylcyclohexane, isopropylbenzene	CSR VOC + VPH in Water + Acetone	Glycols in Water		# of Bottles	Comments
1		S1-1	JUNE 4, 2018	12:15	VEGETATION		X	X									1	* LAB TO RINSE SAMPLES PRIOR TO ANALYSIS
2		S1-2	↓	12:30	↓		X	X									1	
3		S2-1		1:45			X	X									1	
4		S2-2		1:50			X	X									1	
5		S3-1		2:55			X	X									1	
6		S3-2		3:10			X	X									1	B844939_COC
7		S4-1		4:55			X	X									1	
8		S4-2		5:10			X	X									1	
9																		
10																		

* RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted	Lab Use Only		
B. FOULGER	18/06/05	4:00 pm	BILLO PUNI	2018/06/07	08:30		Time Sensitive [ ]	Temperature (°C) on Receipt: 5, 5, 6	Custody Seal Intact on Cooler? Yes [ ] No [ ] N/A

* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO MAXXAM'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.MAXXAM.CA/TERMS.

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

White: Maxxam Yellow: Client

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Chain Of Custody Record Page 2 of 2

INVOICE TO		Report Information		Project Information		Laboratory Use Only	
Company Name	#17775 SLR CONSULTING (CANADA) LTD	Company Name	SLR CONSULTING (CANADA) LTD	Quotation #	B51185	Maxxam Job #	Bottle Order #
Contact Name	Ben Foulger	Contact Name	Ben Foulger	P.O. #	~~[illegible]~~ KAM 3164		301593
Address	200-1475 Ellis Street	Address	1024 GILKER STREET	Project #	~~[illegible]~~ 204.03242.00002.0001	Chain Of Custody Record	Project Manager
	Kelowna BC V1Y 2A3		NELSON, BC	Project Name	HB TAILINGS	C#523993-05-01	Lorna Pretorius
Phone	(250) 762-7202 x / Fax (250) 374-8656 x	Phone	~~[illegible]~~ 250-777-9144	Site #	~~[illegible]~~		
Email	bfoulger@slrconsulting.com, analytical@slrconsulting.c	Email	bfoulger@slrconsulting.com, analytical@slrconsulting.c	Sampled By	B. FOULGER		

Regulatory Criteria

- [x] CSR DW
- [ ] CCME
- [ ] BC Water Quality
- [ ] Other ________

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ANALYSIS REQUESTED (PLEASE BE SPECIFIC)

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Job Specific Rush TAT (if applies to entire submission)
1 DAY [ ] 2 Day [ ] 3 Day [ ] Date Required: ______ [ ]
Rush Confirmation Number: ______ (call lab for #)

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Metals Field Filtered ? (Y / N)	*RINSED ~~CSR Dissolved Metals in Water~~ TOTAL METALS	~~[illegible]~~ MOISTURE CONTENT	LEPH & HEPH with CSR/CCME PAH in Water	CSR Dissolved Metals in Water with CV Hg	1,3,5-trimethylbenzene, 1,3-butadiene, 1,2-dibromoethane, 1,2-dichloroethane	1,2,4-trimethylbenzene, n-hexane, n-decane, naphthalene	methylcyclohexane, isopropylbenzene	CSR VOC + VPH in Water + Acetone	Glycols in Water		# of Bottles	Comments
1		REF1-1	JUNE 4, 2018	6:35 pm	[illegible]		X	X									1	*LAB TO RINSE SAMPLES
2		REF1-2	↓	6:40 pm	↓		X	X									1	PRIOR TO ANALYSIS
3		REF2-1		6:50 pm			X	X									1	
4		REF2-2	↓	6:55 pm	↓		X	X									1	
5		DUP B	JUNE 4, 2018	4:55 pm	↓		X	X									1	
6																		
7																		
8																		
9																		
10																		

B844939_COC

* RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted	Lab Use Only		
B. FOULGER	18/06/04	4:00 pm	BILLO PUM	2018/06/07	08:30		Time Sensitive [ ]	Temperature (°C) on Receipt: 5, 5, 6	Custody Seal Intact on Cooler? Yes [ ] No [ ] N/A

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White: Maxxam Yellow: Client

Maxxam Analytics International Corporation o/a Maxxam Analytics

SLR CONSULTING (CANADA) LTD.

Review of Field and Lab Quality Assurance / Quality Control Data (QA/QC)

Laboratory **Maxxam Analytics**
SLR Project No. **204.03242.00002**

Analytical Certificate No. B844939 Date Certificate Issued 2018/07/09

Medium	Soil	Water	Air	Other:
No. of Samples	0	0	0	13 (Vegetation)

SLR CONSULTING (CANADA) LTD. Field QA/QC

arrival temperature **5.3** °C

travel blank (Y/N) N contaminant detected? (Y/N) N/A

Total number of blind field duplicates analyzed: 1

Sample ID	Duplicate ID	RPD Acceptable (Y/N)
S4-1	DUPB	Y

Notes

Laboratory QA/QC

	Completed (Y/N)	Acceptable (Y/N)
Method Blank	Y	Y
Lab Duplicates	Y	Y
Matrix Spike	Y	Y
Surrogate Recovery	Y	Y
Spiked Blank	Y	Y

Laboratory data acceptable (Y/N) Y
If no, has a data quality waiver been supplied? (Y/N)
Date of waiver:

Notes

Date: July 10, 2018
Reviewed by: B. Foulger

Maxxam
A Bureau Veritas Group Company

Success Through Science®

Your P.O. #: KAM3164
Your Project #: 204.03242.00002.0001
Site Location: HB-TAILINGS
Your C.O.C. #: 521505-07-01

Attention: Ben Foulger

SLR CONSULTING (CANADA) LTD
200-1475 Ellis Street
Kelowna, BC
CANADA V1Y 2A3

Report Date: 2018/06/12
Report #: R2570274
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B844942
Received: 2018/06/07, 08:30

Sample Matrix: Soil
Samples Received: 7

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Elements by ICPMS (total)	7	2018/06/11	2018/06/11	BBY7SOP-00004 / BBY7SOP-00001	EPA 6020b R2 m
pH (2:1 DI Water Extract)	7	2018/06/11	2018/06/11	BBY6SOP-00028	BCMOE BCLM Mar2005 m

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Letitia Prefontaine, B.Sc., Senior Project Manager
Email: LPrefontaine@maxxam.ca
Phone# (604)639-2616
==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B844942
Report Date: 2018/06/12

SLR CONSULTING (CANADA) LTD
Client Project #: 204.03242.00002.0001
Site Location: HB-TAILINGS
Your P.O. #: KAM3164
Sampler Initials: BF

CSR/CCME METALS IN SOIL WITH HG (SOIL)

Maxxam ID		TP1169	TP1170	TP1171	TP1172	TP1173	TP1174		
Sampling Date		2018/06/04 12:00	2018/06/04 13:30	2018/06/04 14:45	2018/06/04 16:45	2018/06/04 18:30	2018/06/04 18:45		
COC Number		521505-07-01	521505-07-01	521505-07-01	521505-07-01	521505-07-01	521505-07-01		
	UNITS	**SS1-1**	**SS2-1**	**SS3-1**	**SS4-1**	**SSREF-1**	**SSREF-2**	**RDL**	**QC Batch**
Physical Properties									
Soluble (2:1) pH	pH	7.67	7.85	7.71	7.86	6.18	5.68	N/A	9020085
Total Metals by ICPMS									
Total Aluminum (Al)	mg/kg	3690	642	592	1070	21100	10900	100	9020083
Total Antimony (Sb)	mg/kg	5.64	13.0	11.5	9.64	0.63	0.39	0.10	9020083
Total Arsenic (As)	mg/kg	67.5	185	148	82.1	11.3	9.85	0.50	9020083
Total Barium (Ba)	mg/kg	71.3	19.4	20.4	43.4	159	99.5	0.10	9020083
Total Beryllium (Be)	mg/kg	0.37	0.27	0.28	0.35	0.59	0.38	0.20	9020083
Total Bismuth (Bi)	mg/kg	2.32	0.24	0.20	0.14	0.37	0.31	0.10	9020083
Total Boron (B)	mg/kg	1.4	<1.0	<1.0	<1.0	1.7	<1.0	1.0	9020083
Total Cadmium (Cd)	mg/kg	18.1	51.6	37.9	24.7	1.71	0.656	0.050	9020083
Total Calcium (Ca)	mg/kg	126000	146000	170000	236000	4630	2860	100	9020083
Total Chromium (Cr)	mg/kg	12.9	3.4	2.9	5.6	31.7	34.2	1.0	9020083
Total Cobalt (Co)	mg/kg	4.06	4.76	3.86	2.09	9.92	10.7	0.30	9020083
Total Copper (Cu)	mg/kg	107	15.8	15.1	37.0	19.9	20.3	0.50	9020083
Total Iron (Fe)	mg/kg	35600	101000	83300	44500	23300	21000	100	9020083
Total Lead (Pb)	mg/kg	1170	2840	2140	1620	58.3	27.3	0.10	9020083
Total Lithium (Li)	mg/kg	<5.0	<5.0	<5.0	<5.0	17.7	11.8	5.0	9020083
Total Manganese (Mn)	mg/kg	462	352	344	441	666	337	0.20	9020083
Total Mercury (Hg)	mg/kg	<0.050	0.112	0.079	0.060	<0.050	<0.050	0.050	9020083
Total Molybdenum (Mo)	mg/kg	1.85	2.97	2.44	2.55	0.83	1.12	0.10	9020083
Total Nickel (Ni)	mg/kg	18.1	23.7	19.3	11.4	28.3	28.6	0.80	9020083
Total Phosphorus (P)	mg/kg	467	373	321	301	1130	756	10	9020083
Total Potassium (K)	mg/kg	1210	216	217	436	1600	1760	100	9020083
Total Selenium (Se)	mg/kg	0.52	1.26	0.96	0.63	<0.50	<0.50	0.50	9020083
Total Silver (Ag)	mg/kg	2.91	3.46	2.57	2.21	0.352	0.296	0.050	9020083
Total Sodium (Na)	mg/kg	<100	<100	<100	<100	148	100	100	9020083
Total Strontium (Sr)	mg/kg	83.4	74.7	91.6	129	31.1	17.0	0.10	9020083
Total Thallium (Tl)	mg/kg	0.400	0.781	0.805	0.569	0.162	0.118	0.050	9020083
Total Tin (Sn)	mg/kg	0.73	0.27	0.32	0.23	0.66	0.37	0.10	9020083
Total Tungsten (W)	mg/kg	5.30	<0.50	<0.50	<0.50	2.32	2.31	0.50	9020083

RDL = Reportable Detection Limit
N/A = Not Applicable

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Maxxam Job #: B844942
Report Date: 2018/06/12

SLR CONSULTING (CANADA) LTD
Client Project #: 204.03242.00002.0001
Site Location: HB-TAILINGS
Your P.O. #: KAM3164
Sampler Initials: BF

CSR/CCME METALS IN SOIL WITH HG (SOIL)

Maxxam ID		TP1169	TP1170	TP1171	TP1172	TP1173	TP1174		
Sampling Date		2018/06/04 12:00	2018/06/04 13:30	2018/06/04 14:45	2018/06/04 16:45	2018/06/04 18:30	2018/06/04 18:45		
COC Number		521505-07-01	521505-07-01	521505-07-01	521505-07-01	521505-07-01	521505-07-01		
	UNITS	**SS1-1**	**SS2-1**	**SS3-1**	**SS4-1**	**SSREF-1**	**SSREF-2**	**RDL**	**QC Batch**
Total Uranium (U)	mg/kg	1.76	3.56	2.57	2.25	1.92	1.31	0.050	9020083
Total Vanadium (V)	mg/kg	19.7	17.6	19.0	22.3	45.3	37.3	2.0	9020083
Total Zinc (Zn)	mg/kg	2170	5050	4480	2910	198	94.4	1.0	9020083
Total Zirconium (Zr)	mg/kg	1.22	<0.50	<0.50	<0.50	4.76	0.90	0.50	9020083

RDL = Reportable Detection Limit

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Maxxam Job #: B844942
Report Date: 2018/06/12

SLR CONSULTING (CANADA) LTD
Client Project #: 204.03242.00002.0001
Site Location: HB-TAILINGS
Your P.O. #: KAM3164
Sampler Initials: BF

CSR/CCME METALS IN SOIL WITH HG (SOIL)

Maxxam ID		TP1175		
Sampling Date		2018/06/04 12:00		
COC Number		521505-07-01		
	UNITS	**DUP A**	**RDL**	**QC Batch**
Physical Properties				
Soluble (2:1) pH	pH	7.71	N/A	9020085
Total Metals by ICPMS				
Total Aluminum (Al)	mg/kg	4100	100	9020083
Total Antimony (Sb)	mg/kg	5.39	0.10	9020083
Total Arsenic (As)	mg/kg	62.7	0.50	9020083
Total Barium (Ba)	mg/kg	74.2	0.10	9020083
Total Beryllium (Be)	mg/kg	0.36	0.20	9020083
Total Bismuth (Bi)	mg/kg	2.68	0.10	9020083
Total Boron (B)	mg/kg	1.4	1.0	9020083
Total Cadmium (Cd)	mg/kg	17.5	0.050	9020083
Total Calcium (Ca)	mg/kg	111000	100	9020083
Total Chromium (Cr)	mg/kg	14.1	1.0	9020083
Total Cobalt (Co)	mg/kg	4.55	0.30	9020083
Total Copper (Cu)	mg/kg	121	0.50	9020083
Total Iron (Fe)	mg/kg	34400	100	9020083
Total Lead (Pb)	mg/kg	1190	0.10	9020083
Total Lithium (Li)	mg/kg	<5.0	5.0	9020083
Total Manganese (Mn)	mg/kg	467	0.20	9020083
Total Mercury (Hg)	mg/kg	0.057	0.050	9020083
Total Molybdenum (Mo)	mg/kg	1.76	0.10	9020083
Total Nickel (Ni)	mg/kg	18.5	0.80	9020083
Total Phosphorus (P)	mg/kg	437	10	9020083
Total Potassium (K)	mg/kg	1360	100	9020083
Total Selenium (Se)	mg/kg	0.56	0.50	9020083
Total Silver (Ag)	mg/kg	3.26	0.050	9020083
Total Sodium (Na)	mg/kg	<100	100	9020083
Total Strontium (Sr)	mg/kg	73.3	0.10	9020083
Total Thallium (Tl)	mg/kg	0.390	0.050	9020083
Total Tin (Sn)	mg/kg	0.81	0.10	9020083
Total Tungsten (W)	mg/kg	6.35	0.50	9020083

RDL = Reportable Detection Limit
N/A = Not Applicable

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Maxxam Job #: B844942
Report Date: 2018/06/12

SLR CONSULTING (CANADA) LTD
Client Project #: 204.03242.00002.0001
Site Location: HB-TAILINGS
Your P.O. #: KAM3164
Sampler Initials: BF

CSR/CCME METALS IN SOIL WITH HG (SOIL)

Maxxam ID		TP1175		
Sampling Date		2018/06/04 12:00		
COC Number		521505-07-01		
	UNITS	**DUP A**	**RDL**	**QC Batch**
Total Uranium (U)	mg/kg	1.77	0.050	9020083
Total Vanadium (V)	mg/kg	18.4	2.0	9020083
Total Zinc (Zn)	mg/kg	1920	1.0	9020083
Total Zirconium (Zr)	mg/kg	1.41	0.50	9020083
RDL = Reportable Detection Limit				

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GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	5.3°C

Results relate only to the items tested.

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Maxxam Job #: B844942
Report Date: 2018/06/12

QUALITY ASSURANCE REPORT

SLR CONSULTING (CANADA) LTD
Client Project #: 204.03242.00002.0001
Site Location: HB-TAILINGS
Your P.O. #: KAM3164
Sampler Initials: BF

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
9020083	Total Aluminum (Al)	2018/06/11					<100	mg/kg			111	70 - 130
9020083	Total Antimony (Sb)	2018/06/11	86	75 - 125	98	75 - 125	<0.10	mg/kg			136 (1)	70 - 130
9020083	Total Arsenic (As)	2018/06/11	90	75 - 125	94	75 - 125	<0.50	mg/kg	1.1	30	94	70 - 130
9020083	Total Barium (Ba)	2018/06/11	NC	75 - 125	94	75 - 125	<0.10	mg/kg			106	70 - 130
9020083	Total Beryllium (Be)	2018/06/11	95	75 - 125	98	75 - 125	<0.20	mg/kg			111	70 - 130
9020083	Total Bismuth (Bi)	2018/06/11					<0.10	mg/kg				
9020083	Total Boron (B)	2018/06/11					<1.0	mg/kg				
9020083	Total Cadmium (Cd)	2018/06/11	91	75 - 125	95	75 - 125	<0.050	mg/kg			104	70 - 130
9020083	Total Calcium (Ca)	2018/06/11					<100	mg/kg			107	70 - 130
9020083	Total Chromium (Cr)	2018/06/11	97	75 - 125	96	75 - 125	<1.0	mg/kg			109	70 - 130
9020083	Total Cobalt (Co)	2018/06/11	88	75 - 125	95	75 - 125	<0.30	mg/kg			102	70 - 130
9020083	Total Copper (Cu)	2018/06/11	94	75 - 125	96	75 - 125	<0.50	mg/kg			103	70 - 130
9020083	Total Iron (Fe)	2018/06/11					<100	mg/kg			106	70 - 130
9020083	Total Lead (Pb)	2018/06/11	94	75 - 125	101	75 - 125	<0.10	mg/kg			123	70 - 130
9020083	Total Lithium (Li)	2018/06/11	96	75 - 125	99	75 - 125	<5.0	mg/kg			114	70 - 130
9020083	Total Manganese (Mn)	2018/06/11	NC	75 - 125	93	75 - 125	<0.20	mg/kg			106	70 - 130
9020083	Total Mercury (Hg)	2018/06/11	94	75 - 125	96	75 - 125	<0.050	mg/kg			101	70 - 130
9020083	Total Molybdenum (Mo)	2018/06/11	92	75 - 125	97	75 - 125	<0.10	mg/kg			105	70 - 130
9020083	Total Nickel (Ni)	2018/06/11	95	75 - 125	96	75 - 125	<0.80	mg/kg			110	70 - 130
9020083	Total Phosphorus (P)	2018/06/11					<10	mg/kg			103	70 - 130
9020083	Total Potassium (K)	2018/06/11					<100	mg/kg			96	70 - 130
9020083	Total Selenium (Se)	2018/06/11	82	75 - 125	96	75 - 125	<0.50	mg/kg				
9020083	Total Silver (Ag)	2018/06/11	89	75 - 125	94	75 - 125	<0.050	mg/kg			118	70 - 130
9020083	Total Sodium (Na)	2018/06/11					<100	mg/kg			104	70 - 130
9020083	Total Strontium (Sr)	2018/06/11	92	75 - 125	96	75 - 125	<0.10	mg/kg			111	70 - 130
9020083	Total Thallium (Tl)	2018/06/11	94	75 - 125	96	75 - 125	<0.050	mg/kg			89	70 - 130
9020083	Total Tin (Sn)	2018/06/11	92	75 - 125	98	75 - 125	<0.10	mg/kg			99	70 - 130
9020083	Total Tungsten (W)	2018/06/11					<0.50	mg/kg				
9020083	Total Uranium (U)	2018/06/11	98	75 - 125	101	75 - 125	<0.050	mg/kg			104	70 - 130
9020083	Total Vanadium (V)	2018/06/11	NC	75 - 125	95	75 - 125	<2.0	mg/kg			110	70 - 130

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QUALITY ASSURANCE REPORT(CONT'D)

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
9020083	Total Zinc (Zn)	2018/06/11	93	75 - 125	97	75 - 125	<1.0	mg/kg			109	70 - 130
9020083	Total Zirconium (Zr)	2018/06/11					<0.50	mg/kg				
9020085	Soluble (2:1) pH	2018/06/11			101	97 - 103			0.31	20		

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

(1) Reference Material exceeds acceptance criteria for Sb. 10% of analytes failure in multielement scan is allowed.

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Maxxam Job #: B844942
Report Date: 2018/06/12

SLR CONSULTING (CANADA) LTD
Client Project #: 204.03242.00002.0001
Site Location: HB-TAILINGS
Your P.O. #: KAM3164
Sampler Initials: BF

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Rob Reinert, B.Sc., Scientific Specialist

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

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Maxxam

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Chain Of Custody Record

Page 1 of 1

INVOICE TO:		Report Information		Project Information	
Company Name	#17775 SLR CONSULTING (CANADA) LTD	Company Name	SLR CONSULTING (CANADA) LTD.	Quotation #	B51186
Contact Name	Ben Foulger	Contact Name	Ben Foulger	P.O. #	~~[illegible]~~ KAM 3164
Address	200-1475 Ellis Street	Address		Project #	~~[illegible]~~ 204.03242.00002.0001
	Kelowna BC V1Y 2A3			Project Name	HB-TAILINGS
Phone	(250) 762-7202 x / Fax: (250) 374-8656 x	Phone	Fax:	Site #	~~[illegible]~~
Email	bfoulger@slrconsulting.com, analytical@slrconsulting.c	Email	bfoulger@slrconsulting.com, analytical@slrconsulting.c	Sampled By	B. FOULGER

Laboratory Use Only

Maxxam Job #	Bottle Order #:
	521505
Chain Of Custody Record	**Project Manager**
C#521505-07-01	Letitia Profontaine

Regulatory Criteria:

- [x] CSR DW
- [ ] CCME
- [ ] BC Water Quality
- [ ] Other ______

Special Instructions

SAMPLES MUST BE KEPT COOL (< 10°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

ANALYSIS REQUESTED (PLEASE BE SPECIFIC)

Turnaround Time (TAT) Required

Please provide advance notice for rush projects

Regular (Standard) TAT: [X]

(will be applied if Rush TAT is not specified)

Standard TAT = 5-7 Working days for most tests.

Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.

Job Specific Rush TAT (if applies to entire submission)

1 DAY [ ] 2 Day [ ] 3 Day [ ] Date Required: ______ [ ]

Rush Confirmation Number: ______ *(call lab for #)*

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Metals Field Filtered ? (Y / N)	CSR BTEX/VPH/MTBE in Soil - Field Preserved	EPH in Soil	CSR PAH in Soil	CSR/CCME Metals in Soil with pH	Soluble Sodium and Chloride in Soil						# of Bottles	Comments
1		SS1-1	June 4, 2018	12:00	SOIL					X							2	
2		SS2-1		1:30 pm						X							2	
3		SS3-1		2:45 pm						X							2	
4		SS4-1		4:45 pm						X							2	
5		SS REF-1		6:30 pm						X							2	
6		SS REF-2		6:45 pm						X							2	
7		DUP A	June 4, 2018	12:00	SOIL					X							2	B844942_COC
8																		
9																		
10																		

* RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted	Lab Use Only: Time Sensitive	Temperature (°C) on Receipt	Custody Seal Intact on Cooler?
/ B. FOULGER	18/06/05	4:00pm	BILLOPUN	2018/06/07	08:30		[ ]	5, 5, 6	[ ] Yes [ ] No

* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO MAXXAM'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.MAXXAM.CA/TERMS.

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

White: Maxxam Yellow: Client

0018

Maxxam Analytics International Corporation o/a Maxxam Analytics

SLR CONSULTING (CANADA) LTD.

Review of Field and Lab Quality Assurance / Quality Control Data (QA/QC)

Laboratory **Maxxam Analytics**
SLR Project No. **204.03242.00002**

Analytical Certificate No. B844942 Date Certificate Issued 2018/06/12

Medium	Soil	Water	Air	Other:
No. of Samples	7	0	0	0

SLR CONSULTING (CANADA) LTD. Field QA/QC

arrival temperature **5.3** °C

travel blank (Y/N) N contaminant detected? (Y/N) N/A

Total number of blind field duplicates analyzed: 1

Sample ID	Duplicate ID	RPD Acceptable (Y/N)
SS1-1	DUPA	Y

Notes

Laboratory QA/QC

	Completed (Y/N)	Acceptable (Y/N)
Method Blank	Y	Y
Lab Duplicates	Y	Y
Matrix Spike	Y	Y
Surrogate Recovery	Y	Y (see notes)
Spiked Blank	Y	Y

Laboratory data acceptable (Y/N) Y
If no, has a data quality waiver been supplied? (Y/N)
Date of waiver:

Notes
Surrogate recovery for Antimony exceeded the laboratory QAQC limits however the overall data set was deemed reliable.

Date: July 10, 2018
Reviewed by: B. Foulger

APPENDIX F
TRVs

Regional District of Central Kootenay
Prospective Human Health and Ecological Risk Assessment
HB Mine Tailings Management Facility
SLR Project No.: 204.03242.00004

APPENDIX F

SURFACE WATER TOXICITY REFERENCE VALUES - HB MINE TAILINGS MANAGEMENT FACILITY PROSPECTIVE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

This appendix presents the surface water toxicity reference values (TRVs) used as part of the effects assessment section for aquatic life.

The selection of TRVs for aquatic life included a review of direct contact ecotoxicity values from the following sources:

- Technical supporting documents published by BC MOE as part of the BC AWQG, and WWQG;
- Technical supporting documents published by CCME as part of the Canadian Environmental Quality Guidelines for the protection of aquatic life;
- Technical supporting documents published by the USEPA to support the Ambient Water Quality Guidelines;
- Technical supporting document published by the Ontario Ministry of Energy and Environment as part of the provincial sediment quality standards; and
- Publications of peer reviewed toxicology literature, accessed from Web of Science citation indexing service.

Preference was given to chronic toxicity data for reproduction, growth and survival endpoints, when selecting TRVs. EC_{20} values were considered appropriate TRVs where available, which is in keeping with the BC CSR Protocol 1 (BC ENV 1998) protection goal for aquatic organisms. ENV's risk-based approach to managing sites is not to protect each individual from a toxic effect, but rather to protect enough individuals so that a viable population and community of organisms can be maintained.

The proposed TRVs are outlined in Table A and discussed below the table.

Table A: Surface Water TRVs for Aquatic Life (µg/L)

COPC	Receptor Groups			
	Aquatic Plant	Aquatic Invertebrates	Fish	Amphibians
Aluminum	500	320	500	320
Beryllium	5.3	5.3	-	5.3
Cadmium	23.3	Long term average BC WQG	0.76	209
Chromium	10	10	10	10
Copper	Long term average BC WQG			
Iron	1740	1740	-	1740
Lead	Long term average BC WQG			
Zinc	1113	41.59	90	107.7
Nitrite	Long term average BC WQG		-	Long term average BC WQG

"-" Not a COPC for fish

Aluminum

BC ENV has not published a guideline for total aluminum but selected a maximum concentration of 100 µg/L for dissolved aluminum as a concentration considered safe for sensitive aquatic life (at pH ≥ 6.5) (Butcher, 1988). The BC ENV guideline is based on the CCME guideline for waters with pH greater than 6.5 but is expressed in terms of dissolved aluminum. The 30 day-average guideline (50 µg/L) was set arbitrarily by BC ENV at 50% of the maximum dissolved aluminum guideline of 100 µg/L. The original CCME guideline for total aluminum of 100 µg/L was based on the UE EPA 1973 proposed guideline for water with pH equal or greater than 6.5.

Chronic toxicity data for aluminum reviewed by BC ENV ranged from 10 µg/L (95% survival of brook trout after 14 days exposure at pH 4.4 to 6,700 µg/L for chronic effects to midge larvae at pH 6.6 (endpoint not described). The lowest chronic toxicity value reviewed by BC MOE for pH ≥ 6.5 was 320 µg/L for Daphnia Magna (16% reproductive impairment at pH 7.7). The lowest chronic value for pH ≥ 6.5 for fish was a LC50 of 500 µg/L for rainbow trout obtained after 44 days exposure at pH ranging from 6.5 to 7.4 (Butcher, 1988). A LC20 of 1000 µg/L was reported for brook trout for eyed eggs mortality after 8 days of exposure at pH 6.5 (Butcher, 1988). CCME (1997) indicates that aquatic plants appear to be less sensitive than some invertebrates and reported a 50% reduction in root growth observed at 2500 µg/L at circumneutral pH for the eurasian milfoil *(Myriophyllum spicatum* L). BC ENV reported a 96-hour EC50 of 570 µg/L for biomass reduction (growth endpoint) for *Selenastrum carpicornutum* at pH 7.6 and of 460 µg/L at pH 8.2. Chronic toxicity values for aquatic plants obtained at pH higher than 6.5 were higher than the reported acute values. BC ENV also reported that aquatic macrophytes may be relatively tolerant to aluminum and reported that frond production in *Lemna minor* was not significantly affected after 96-hour exposure in water with aluminum ranging from 300 to 46,000 µg/L aluminum. BC ENV reported non-effect level for embryos of wood frog at total aluminum concentration of 200 µg/L and pH 5.57.

Species-specific TRVs were selected for aluminum. Based on the pH of the receiving environment, the lowest chronic value of 500 µg/L obtained at pH > 6.5 (Butcher, 1988) was selected as the fish TRV. This value was also selected as a TRV for aquatic plants. The lowest chronic toxicity value of 320 µg/L for Daphnia Magna obtained at pH 7.7 was selected as the TRV for invertebrates and amphibians.

Beryllium

BC ENV and CCME have not derived a WQG for beryllium for the protection of aquatic life. The beryllium working WQG adopted by BC ENV was developed by the Australia and New Zealand Environment and Conservation Council (ANZECC, 2000). The ANZECC supporting document provides limited rationale to support the derivation of the beryllium guideline. ANZEEC indicated that the toxicity of beryllium decreased with in function of increasing hardness. ANZEEC reported that acute toxicity in soft water (hardness of 23 mg/L) for the most sensitive species, the guppy, ranged from 130 µg/L to 450 µg/L (Slonim 1973). ANZEEC added that acute toxicity to the crustacean *Daphnia magna* was comparable to the acute toxicity to fish. ANZEEC did not identify chronic tests with freshwater fish; but reported chronic effects of beryllium on *Daphna magna* reproduction at concentrations of 5.3 µg/L. CCME (1997) reported that available toxicity data for a green alga (*Chlorella vannielii*) indicates that this species was resistant. ANZEEC guidelines is based on the acute toxicity of 130 µg/L in soft water divided by a safety factor or 100.

Based on the above information the TRV was set at 5.3 µg/L, the lowest value for a chronic study with aquatic invertebrates cited by ANZEEC. This TRV was also selected for aquatic plants and amphibians based on the lack of information for these receptors.

Cadmium

BC ENV recently developed a WQG for dissolved cadmium (BC ENV 2015). BC ENV indicates that the "*guideline applies to the dissolved cadmium fraction only as this is the more bioavailable form however there is still the potential for toxicity due to particulate-associated cadmium*". As dissolved cadmium data was not available the BC ENV WQG was conservatively applied to total cadmium.

The guideline is based on 20 short-term and 28 long-term primary studies. The long-term studies included toxicity data on one BC resident aquatic plant species, one resident algal species, thirteen resident fish species (including 8 salmonids), eleven resident invertebrate species, and one resident amphibian species (BC ENV, 2015). BC ENV noted that invertebrate species were generally found to be the group most sensitive to chronic exposures of cadmium. The minimum effect concentration from a primary invertebrate study (0.253 µg/L; IC20 for *H. azteca* biomass) normalized to a harness of 50 mg/L was used to support the derivation of the long-term average water quality guideline. An uncertainty factor of 2 was applied to this value to derive the guideline.

The studies used to develop the long-term water quality guidelines indicated that toxicity value (normalized to 50 mg/L) for non salmonid fish species ranged from 0.764 to 13 µg/L. The lowest value was obtained for sculpin and was a 21-day LOEC (endpoint: biomass). Toxicity values (normalized to 50 mg/L) for salmonid fish species ranged from 1.13 to 13.3 µg/L. The lowest EC20 (endpoint: biomass; duration 30 days) was 1.29 µg/L.

An EC20 (endpoint: growth rate) for aquatic plants of 23.2 µg/L was provided. Finally, a LOEC (endpoint: growth rate) of 209 µg/L for amphibian was provided.

Based on the above information the following TRVs were selected: 0.25 µg/L for invertebrates, 0.764 for fish, 23.2 for aquatic plants and 209 µg/L for amphibians.

The long-term average BC WQG varies in function of the receiving water hardness. Based on the sample-specific hardness, the BC long-term average WQG for cadmium ranges from 0.16 to 0.54 µg/L. Because some of the WQG values are actually higher than the selected TRV for invertebrates (0.25 µg/L), the long-term average BC WQG was selected as the TRV for invertebrates.

Chromium

The BC ENV Working WQG guideline for chromium is expressed in terms of trivalent chromium (8.9 µg/L) and hexavalent chromium (1 µg/L). BC ENV adopted the CCME (1999) chromium WQG.

The surface water dataset does not include chromium speciation data. Total chromium concentrations were conservatively compared to the guideline for Cr(VI) as it is the principal chromium species found in surface waters.

Estimates of chronic toxicity of hexavalent chromium to freshwater fish presented in CCME (1999) range from 10 µg/L for *Salmo salar* (360-h increase in hatching time) to 74900 µg/L- for *Anaba scandens* (30-d LC50). CCME noted that among the more than 30 fish species studied, salmonids seemed to be the most sensitive group. Invertebrates were identified as the most sensitive organisms to hexavalent chromium. Chronic toxicity for 40 invertebrate species ranged from 10 µg/L for *Ceriodaphnia dubia* (14-d LOEC) to 1000000 µg/L-for *Chironomus tentans* (decrease in rest time). Chromium concentrations of 600 µg/L were noted to inhibit the growth of aquatic plants.

The CCME WQG for hexavalent chromium for the protection of 1.0 µg/L was derived by multiplying the 14-d LOEC of 10 µg/L by a safety factor of 0.1 (CCME 1999).

Based on the above information a TRV of 10 µg/L was selected for this HHERA.

Copper

Copper was selected as a COPC based on comparison to the BC long-term average WQG conservatively calculated using the minimum hardness value of 66 mg/L. The BC long-term average WQG was also selected as the TRV for copper. In the evaluation of risk, the sample specific hardness value was considered.

Iron

The BCWQ guideline had previously been 300 µg/L (adopted from CCME, 1987), however, the guideline was updated in 2008. The new water quality guideline for the protection of aquatic life is 1000 µg/L for total iron and 350 µg/L for dissolved iron (Phibben *et al.*, 2008).

The guideline for total iron is based on recent field-based research of Linton *et al.* (2007). Linton *et al.* (2007) derived two benchmarks of change in community structure to establish the guideline. The first benchmark of 210 µg/L corresponds to no or minimal changes in aquatic community structure and function. The second benchmark of 1740 µg/L allows for a slight to moderate changes in community population (i.e., loss of some rare species and/or replacement of sensitive ubiquitous taxa with more tolerant taxa). Phibben et al (2008) selected 1000 µg/L as the value for the BC guideline based on the precautionary principle and noted that this value may be overprotective in some instances. They indicated that other recent research has recommended 1700 µg/L as a guideline for total iron.

The BCWQ guideline for dissolved iron is based toxicity tests conducted by the Pacific Environmental Science Center (PESC) for the BC MOE. The test species included rainbow trout, the amphipod *Hyalella azteca*, the chironomid *Chironomus tentans*, *Daphnia magna*, and *Selanastrum capricornutum.* The lowest toxicity value obtained with the above species was the acute LC_{50} of 3500 µg/L reported for *Hyalella* in soft water. The EC_{50} for *Hyalella* was divided by a safety factor of 10 and rounded down to 350 µg/L to derive the BC dissolved iron guideline (Phibben *et al.*, 2008). The LC50 for rainbow trout in soft water was >6400 µg/L and the LC50 for *selenastrum capricornatum* was 3600 µg/L.

Based on the above information the benchmark of 1740 µg/L for total iron proposed by Linton et al (2007) was adopted as the TRV.

Lead

Lead was selected as a COPC based on comparison to the BC long-term average WQG conservatively calculated using the minimum hardness value of 66 mg/L. The BC long-term average WQG was also selected as the TRV for lead. In the evaluation of risk, the sample specific hardness value was considered.

Zinc

Zinc was retained as a COPC based on the concentrations exceeding the BC long-term WQG of 7.5 µg/L for waters with hardness less than 90 mg/L. The BC ENV guideline, developed in 1999 was based on the lowest observed effect level (LOEL) of 15 µg/L for copepod divided by a safety factor of 2. As zinc toxicity decrease with hardness an equation was provided to calculate the WQG based on various hardness. The slope in the equation was obtained from two LOELs at different hardness: 15 µg/L at a hardness of 90 mg/L and 180 µg/L at a hardness of 200 mg/L. BC ENV indicated that the zinc guidelines were characterized as interim because the minimum requirement for primary data were not met.

The CCME recently updated the WQG for zinc CCME (2018). The CCME updated zinc guideline was derived using a species sensitive distribution (SSD). Long-term toxicity data for zinc provided by the CCME were reviewed in selecting a TRV for zinc. The toxicity data provided in the CCME supporting document are normalized by the CCME to 50 mg/L hardness, pH 7.5 and 0.5 mg/L DOC. These toxicity data were normalized to a hardness of 145 mg/L to select the zinc TRVs for aquatic plants, aquatic invertebrates and amphibians. This represented the average hardness for the downstream channel and the drainage channel over the tailings. Hardness data for location SW1-07 were conservatively not used in averaging the hardness because hardness at this location was significantly higher (254 to 353 mg/L). Toxicity data for fish were normalized using the average hardness for the downstream channel only (152 mg/L). The toxicity data is discussed below and provided in a Table F-1 after the text.

CCME (2018) included two aquatic plant species in the long-term SSD. The more sensitive endpoint was an adjusted 7-d EC10 for growth of 1113 µg/L for *Lemna minor*. The less sensitive endpoint was for *Ceratophyllum demersum* (hornwort), with an adjusted 15-d LOEC of 3000 µg/L. The 7-d EC10 for *Lemna minor* was selected as the TRV for aquatic plant.

The CCME (2018) included acceptable long-term toxicity data for eleven invertebrate species in deriving the SSD. These toxicity endpoints were normalized to a hardness of 145 mg/L. This represented the average hardness for the downstream channel and the drainage channel over the tailings. Hardness data for location SW1-07 were conservatively not used in averaging the hardness because hardness at this location was higher. The geomean of the hardness normalized EC10s of 41.59 µg/L (endpoint: reproduction, duration 21 day) was selected as the TRV for zinc.

The CCME (2018) included acceptable long-term zinc toxicity values in the SSD for nine fish species obtained in tests with durations of 21 days or longer for adult or juvenile life stages, and seven days or longer for tests involving fish eggs or larvae for nine fish species. The most sensitive fish species in the long-term SSD was *Jordanella floridae* (flagfish), with a 100-d MATC of 27.9 µg Zn/L for larval growth. The least sensitive species included in the SSD was *Oncorhynchus clarkii pleuriticus* (Colorado River cutthroat trout), with an adjusted 30-d MATC of 169.3 µg/L for swim-up fry survival, which was a geometric mean of two individual MATC values (CCME, 2018). The data point for *Jordanella floridae* was not included in the dataset to derive the TRV as this species is not relevant to the area. The toxicity data for the remaining eight species were adjusted (using CCME equation) to the average predicted hardness on 152 mg/L (Table F-2). The lowest value was an EC10 of 90 µg/L (endpoint: mortality, duration 30 days) obtained for mottled sculpin. This value was selected as the TRV for fish.

The CCME identified only one chronic toxicity data for amphibians, an adjusted four-week MATC value of 107.6 µg/L (dissolved zinc) for development of *B. boreas* eggs (CCME, 2018). The CCME also identified four acute toxicity value for amphibians for inclusion in the short-term SSD. These short-term values ranged from 840 µg/L (96h LC50 for the western toad) to 34500 (4-days LC50 for the African clawed frog). The chronic value of 107.6 µg/L was selected as the TRV for amphibians.

Nitrite

Nitrite was selected as a COPC based on comparison to the BC long-term average WQG conservatively calculated using the minimum chloride value of 0.8 mg/L. The BC long-term average WQG was also selected as the TRV for nitrite. In the evaluation of risk, the sample specific hardness value was considered.

Table F-1: Toxicity Reference Value Selection - Terrestrial Plants

Plants - Root Contact with Groundwater		
Parameter	TRV (µg/L)	Reference
Manganese	200	BCWQG for acidic soils
	1000	BCWQG for neutral or alkaline soils
Molybdenum	30	BCWQG for non-forage crops
Fluoride	1000	BCWQG 30 day average, CCME guideline
Uranium	10	BC CSR IW
Zinc	5,000	BCWQG soil pH greater than or equal to 7
Plants - Root Contact with Soil		
Parameter	TRV (µg/g)	Reference
Arsenic	25	BC plant & invert guideline
	18	ECO SSL for plants
Cadmium	30	BC plant & invert guideline
	32	ECO SSL for plants
Lead	550	BC plant & invert guideline
	120	ECO SSL for plants
Zinc	450	BC soil & invert guideline
	160	ECO SSL for plants

TRV selected.

*Reviewed TRVs are lower than the most conservative Ecological CSR standard.
CSR plants and invertebrates standard selected as TRV.

References

USEPA EcoSSLs 2005.
BC Water Quality Guidelines for manganese, molybdenum, fluoride and zinc (BC ENV).

Family	Species Latin name	Species common name	Life stage	Exposure duration	Endpoint	Observed effect	Measured effect concentration	Variation	Adjusted effect concentration (µg/L)	Total/dissolved	Conversion: total to dissolved (µg/L)
Amphibians	*Bufo boreas*	western toad	egg	4 w	MATC	development	264		299.0515546	not reported	294.8648329
Fish	*Cottus bairdi*	mottled sculpin	less than 2 mo	30 d	EC10	mortality	155.7		90.39793218	dissolved	N/A
Fish	*Phoxinus phoxinus*	Eurasian minnow	yearling	150 d	LC10	mortality	102		148.3749261	not reported	146.2976772
Fish	*Pimephales promelas*	fathead minnow	larva	7 d	IC10	growth	83.9		198.1267703	not reported	195.3529955
Fish	*Prosopium williamsoni*	mountain whitefish	eyed egg to fry	90 d	IC10	biomass	380		380.7078948	dissolved	N/A
Fish	*Salmo trutta*	brown trout	early life stage	58 d	MATC	weight	196		371.5409378	dissolved	N/A
Fish	*Salvelinus fontinalis*	brook trout	egg	24 w	IC10	egg fragility	200		469.2162382	total	462.6472109
Invertebrates	*Brachionus havanaensis*	rotifer	adults and juveniles	18 d	EC10	population growth	78.2		101.49	not reported	100.0710904
Invertebrates	*Ceriodaphnia dubia*	water flea	neonate	7 d	MATC	reproduction	18.1		30.91	dissolved	N/A
Invertebrates	*Chironomus riparius*	harlequin fly	1st instar	11 w	LOEC	development	100		27.49	total	27.10527346
Invertebrates	*Dreissena polymorpha*	zebra mussel	adult	10 w	LC10	mortality	517		142.18	not reported	140.1853823
Invertebrates	*Lampsilis siliquoidea*	fatmucket clam	juvenile	28 d	IC10	length	55	95% CI 24–181	288.61	total	284.5708784
Invertebrates	*Physa gyrina*	snail	adult	30 d	NOEC/L	mortality	570		955.47	total	942.0947246
Invertebrates	*Potamopyrgus jenkinsi*	New Zealand mud snail	juvenile	12 w	MATC	growth	91		53.23	not reported	52.48743459
Invertebrates	*Rhithrogena hageni*	mayfly	nymph	10 d	EC10	mortality	2069.2		4648.99	dissolved	N/A
Plants	*Ceratophyllum demersum*	hornwort		15 d	LOEC	chlorophyll content and	3000		3101.37	total	3057.950267
Plants	*Lemna minor*	duckweed	not reported	7 d	EC10	growth	1379.05		1113.13	not reported	1097.546243
Fish	*Oncorhynchus clarkii pleuriticus*	Colorado River cutthroat trout	swim-up fry	30 d	MATC	biomass	1343		786.404742	dissolved	N/A
Fish	*Oncorhynchus clarkii pleuriticus*	Colorado River cutthroat trout	swim-up fry	30 d	MATC	biomass	134		273.8390225	dissolved	N/A
Fish	*Oncorhynchus clarkii pleuriticus*	Colorado River cutthroat trout	swim-up fry	30 d	MATC	biomass	Geomean		464.0563606	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	171	95% CI 91–324	303.6661029	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	337	95% CI 25.5–83.6	183.5104702	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	290	95% CI 96–880	371.3079269	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	312	95% CI 184–531	382.7947187	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	34.5	95% CI 14.5–82.4	204.0581494	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	38.4	95% CI 19.7–74.58	5436.692361	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	46.1	95% CI 25.5–83.6	281.7044933	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	73.6	95% CI 23.4–231.7	424.8094439	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	99.1	95% CI 30.3–324.3	8751.781306	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	219	111–432	330.7271739	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	185	99–346	217.2193581	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	259	123–548	206.8838593	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	578	322–1,038	294.30144	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	902	483–1,683	334.2582182	dissolved	N/A
Fish	*Oncorhynchus mykiss*	rainbow trout	juvenile	30 d	LC10	mortality	Geomean		448.8118133	dissolved	N/A
Invertebrates	*Brachionus calyciflorus*	rotifer	less than 2 h	48 h	EC10	intrinsic rate of population	550	95% CI 359–844	127.44	dissolved	N/A
Invertebrates	*Brachionus calyciflorus*	rotifer	less than 2 h	48 h	EC10	intrinsic rate of population	197	95% CI 171–226	271.85	dissolved	N/A
Invertebrates	*Brachionus calyciflorus*	rotifer	less than 2 h	48 h	EC10	intrinsic rate of population	142	95% CI 122–165	178.72	dissolved	N/A
Invertebrates	*Brachionus calyciflorus*	rotifer	less than 2 h	48 h	EC10	intrinsic rate of population	66	95% CI 26–166	212.98	dissolved	N/A
Invertebrates	*Brachionus calyciflorus*	rotifer	less than 2 h	48 h	EC10	intrinsic rate of population	453	95% CI 293–703	243.86	dissolved	N/A
Invertebrates	*Brachionus calyciflorus*	rotifer	less than 2 h	48 h	EC10	intrinsic rate of population	Geomean		200.20	dissolved	N/A
Invertebrates	*Daphnia magna*	cladoceran	newborn juvenile	21 d	EC10	reproduction	179	95% CI 158–194	52.18	total	51.4491283
Invertebrates	*Daphnia magna*	cladoceran	newborn juvenile	21 d	EC10	reproduction	114	95% CI 87–130	6.38	total	6.295281292
Invertebrates	*Daphnia magna*	cladoceran	newborn juvenile	21 d	EC10	reproduction	233	95% CI 182–269	139.77	total	137.8095689
Invertebrates	*Daphnia magna*	cladoceran	newborn juvenile	21 d	EC10	reproduction	277	95% CI 255–294	48.93	total	48.24787808
Invertebrates	*Daphnia magna*	cladoceran	newborn juvenile	21 d	EC10	reproduction	90	95% CL 62–115	17.12	total	16.87632198
Invertebrates	*Daphnia magna*	cladoceran	newborn juvenile	21 d	EC10	reproduction	328	95% CI 278–358	232.23	total	228.9776535
Invertebrates	*Daphnia magna*	cladoceran	newborn juvenile	21 d	EC10	reproduction	331	95% CI 290–369	37.85	total	37.31811019
Invertebrates	*Daphnia magna*	cladoceran	newborn juvenile	21 d	EC10	reproduction	394	95% CI 337–438	45.05	total	44.42095291
Invertebrates	*Daphnia magna*	cladoceran	newborn juvenile	21 d	EC10	reproduction	423	95% CI 368–452	17.46	total	17.2184682
Invertebrates	*Daphnia magna*	cladoceran	newborn juvenile	21 d	EC10	reproduction	502	95% CI 11–625	57.40	total	56.59725472
Invertebrates	*Daphnia magna*	cladoceran	newborn juvenile	21 d	EC10	reproduction	Geomean		41.59	total	41.00642466
Invertebrates	*Lymnaea stagnalis*	great pond snail	21 d	28 d	EC10	growth	1629	95% CI 1,034–2,566	337.86	dissolved	N/A
Invertebrates	*Lymnaea stagnalis*	great pond snail	21 d	28 d	EC10	growth	910	95% CI 763–1,086	278.36	dissolved	N/A
Invertebrates	*Lymnaea stagnalis*	great pond snail	21 d	28 d	EC10	growth	200	95% CI 139–289	333.77	dissolved	N/A
Invertebrates	*Lymnaea stagnalis*	great pond snail	21 d	28 d	EC10	growth	244	95% CI 195–306	288.15	dissolved	N/A
Invertebrates	*Lymnaea stagnalis*	*great pond snail*	*21 d*	28 d	EC10	growth	Geomean		308.39	dissolved	N/A

Source: Canadian Council of Ministers of the Environment. 2018. Scientific criteria document for the development of the Canadian water quality guidelines for the protection of aquatic life: zinc. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Family	Included in SSD?	Experimental design	Test conditions	Toxicity methods	Water type used in test	Analytical methods	Statistical analyses	Replications	Toxicant concentrations	Control mortality	Alkalinity (mg/L)	Conductivity (μS/cm)
Amphibians	Yes. Most preferred endpoint.	lab	flow-through	usual	Fort Collins, CO, tap water	standard	appropriate	adequate	measured repeatedly	less than 10%	35.9	103
Fish	Yes. Most preferred endpoint.	lab	flow-through	usual	dechlorinated Fort Collins municipal tap water	standard	appropriate	adequate	measured directly	less than 10%	110 (95–118)	254 (229–284)
Fish	Yes. Most preferred endpoint.	lab	flow-through	usual	dechlorinated Umea, Sweden, tap water	standard	appropriate	inadequate	measured at beginning and	less than 10%	49–79	745–1010
Fish	Yes. Most preferred endpoint.	lab	renewal	standard	Lake Superior water	not specified	appropriate	adequate	not reported	done but not reported		
Fish	Yes. Most preferred endpoint.	lab	flow-through	standard	dechlorinated Fort Collins municipal tap water	standard	appropriate	adequate	measured repeatedly	less than 10%	35.9 (6.2) mg/L	77.0 (4.4) uS/cm
Fish	Yes. Most preferred and sensitive endpoint. Geomean	lab	flow-through	usual	dechlorinated Fort Collins tap water	standard	appropriate	adequate	measured repeatedly	less than 10%	33.6	94.8
Fish	Yes. Most preferred and sensitive endpoint.	lab	flow-through	standard	Lake Superior UV sterilization	standard	appropriate	inadequate	measured at beginning and	less than 10%	41.3 (39.0–43.3)	
Invertebrates	Yes. Most preferred endpoint.	lab	renewal	not specified	reconstituted moderately hard water	standard	appropriate	adequate	nominal	not needed		
Invertebrates	Yes. Most preferred and sensitive endpoint. Geomean	lab	renewal	standard	US EPA formulated moderately hard water	standard	appropriate	adequate	measured directly	less than 10%		350.2
Invertebrates	Yes	lab	renewal	usual	Lake Maarsseveen I, Netherlands, water	standard	appropriate	inadequate	measured at beginning and	less than 20%		
Invertebrates	Yes. Most preferred endpoint.	lab	renewal	novel	filtered Lake Markermeer, Netherlands, water	standard	appropriate	inadequate	measured at beginning and	less than 10%		
Invertebrates	Yes. Most preferred endpoint and most sensitive effect.	lab	flow-through	standard	ASTM reconstituted soft water	standard	appropriate	adequate	measured repeatedly	less than 20%	47	198
Invertebrates	Yes	lab	flow-through	standard	WFTS well water	standard	appropriate	inadequate	measured at beginning and	done but not reported	29	
Invertebrates	Yes. Most preferred endpoint.	lab	renewal	usual	Lake Maarsseveen water	standard	appropriate	inadequate	measured at beginning and	not needed		
Invertebrates	Yes. Most preferred endpoint.	lab	flow-through	usual	Fort Collins well water mixed with reverse	standard	appropriate	adequate	measured at beginning and	less than 10%	39.9 (SD 1.3)	
Plants	Yes	lab	not reported	not specified	distilled water and one-fifth strength Hoagland's	not specified	appropriate	adequate	nominal			
Plants	Yes. Most preferred endpoint.	lab	static	usual	deionized water	not specified	appropriate	adequate	nominal	not needed		
Fish	Part of geometric mean.	lab	flow-through	usual	on-site well water mixed with Fort Collins tap water	standard	appropriate	adequate	measured directly	less than 10%	104.5	262
Fish	Part of geometric mean.	lab	flow-through	usual	dechlorinated Fort Collins tap water and reverse	standard	appropriate	adequate	measured directly	less than 10%	23.5	59.5
Fish	Yes. Next most preferred endpoint.											
Fish	Part of geometric mean.	lab	flow-through	usual	carbon-filtered deionized water	standard	appropriate	adequate	measured directly	less than 10%		<2
Fish	Part of geometric mean.	lab	flow-through	usual	carbon-filtered deionized water	standard	appropriate	adequate	measured directly	less than 10%		<2
Fish	Part of geometric mean.	lab	flow-through	usual	carbon-filtered deionized water	standard	appropriate	adequate	measured directly	less than 10%		<2
Fish	Part of geometric mean.	lab	flow-through	usual	carbon-filtered deionized water	standard	appropriate	adequate	measured directly	less than 10%		<2
Fish	Part of geometric mean.	lab	flow-through	usual	carbon-filtered deionized water	standard	appropriate	adequate	measured directly	less than 10%		<2
Fish	Part of geometric mean.	lab	flow-through	usual	carbon-filtered deionized water	standard	appropriate	adequate	measured directly	less than 10%		<2
Fish	Part of geometric mean.	lab	flow-through	usual	carbon-filtered deionized water	standard	appropriate	adequate	measured directly	less than 10%		<2
Fish	Part of geometric mean.	lab	flow-through	usual	carbon-filtered deionized water	standard	appropriate	adequate	measured directly	less than 10%		<2
Fish	Part of geometric mean.	lab	flow-through	usual	carbon-filtered deionized water	standard	appropriate	adequate	measured directly	less than 10%		<2
Fish	Part of geometric mean.	lab	flow-through	standard	Brisy: surface water	standard	appropriate	adequate	measured at beginning and	done but not reported	14.3	
Fish	Part of geometric mean.	lab	flow-through	standard	Voyon: surface water	standard	appropriate	adequate	measured at beginning and	done but not reported	17.1	
Fish	Part of geometric mean.	lab	flow-through	standard	Bihain: surface water	standard	appropriate	adequate	measured at beginning and	done but not reported	1.7	
Fish	Part of geometric mean.	lab	flow-through	standard	Markermeer: surface water	standard	appropriate	adequate	measured at beginning and	done but not reported	68.5	
Fish	Part of geometric mean.	lab	flow-through	standard	Ankeveen: surface water	standard	appropriate	adequate	measured at beginning and	done but not reported	41.1	
Fish	Yes.											
Invertebrates	Part of geometric mean.	lab	static	standard	Ankeveen: natural (Ankeveensche	standard	appropriate	yes	measured	appropriate		
Invertebrates	Part of geometric mean.	lab	static	standard	Voyon: natural (Le Voyon, France)	standard	appropriate	yes	measured	appropriate		
Invertebrates	Part of geometric mean.	lab	static	standard	Brisy: natural (L'Ourthe Orientale, Belgium)	standard	appropriate	yes	measured	appropriate		
Invertebrates	Part of geometric mean.	lab	static	standard	Brisy: high pH (added NaHC03)	standard	appropriate	yes	measured	appropriate		
Invertebrates	Part of geometric mean.	lab	static	standard	Brisy: high pH, high Ca (added NaHC03 and	standard	appropriate	yes	measured	appropriate		
Invertebrates	Yes. Considered life cycle for this species and therefore long-											
Invertebrates	Part of geometric mean.	lab	renewal	standard	deionized water	standard	appropriate	adequate	measured at beginning and	less than 10%		
Invertebrates	Part of geometric mean.	lab	renewal	standard	deionized water	standard	appropriate	adequate	measured at beginning and	less than 10%		
Invertebrates	Part of geometric mean.	lab	renewal	standard	deionized water	standard	appropriate	adequate	measured at beginning and	less than 10%		
Invertebrates	Part of geometric mean.	lab	renewal	standard	deionized water	standard	appropriate	adequate	measured at beginning and	less than 10%		
Invertebrates	Part of geometric mean.	lab	renewal	standard	deionized water	standard	appropriate	adequate	measured at beginning and	less than 10%		
Invertebrates	Part of geometric mean.	lab	renewal	standard	deionized water	standard	appropriate	adequate	measured at beginning and	less than 10%		
Invertebrates	Part of geometric mean.	lab	renewal	standard	deionized water	standard	appropriate	adequate	measured at beginning and	less than 10%		
Invertebrates	Part of geometric mean.	lab	renewal	standard	deionized water	standard	appropriate	adequate	measured at beginning and	less than 10%		
Invertebrates	Part of geometric mean.	lab	renewal	standard	deionized water	standard	appropriate	adequate	measured at beginning and	less than 10%		
Invertebrates	Part of geometric mean.	lab	renewal	standard	deionized water	standard	appropriate	adequate	measured at beginning and	less than 10%		
Invertebrates	Yes. Most sensitive geomean of comparable values.											
Invertebrates	Part of geometric mean.	lab	renewal	usual	Ankeveen: natural (Ankeveensche	standard	appropriate	adequate	measured	appropriate		
Invertebrates	Part of geometric mean.	lab	renewal	usual	Markermeer: natural (Marken, Netherlands)	standard	appropriate	adequate	measured	appropriate		
Invertebrates	Part of geometric mean.	lab	renewal	usual	Voyon: natural (Le Voyon, France)	standard	appropriate	adequate	measured	appropriate		
Invertebrates	Part of geometric mean.	lab	renewal	usual	Brisy: natural (L'Ourthe Orientale, Belgium)	standard	appropriate	adequate	measured	appropriate		
Invertebrates	Yes. Geomean of most preferred endpoints within MLR											

Source: Canadian Council of Ministers of the Environment. 2018. Scientific criteria document for the development of the Canadian water quality guidelines for the protection of aquatic life: zinc. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Family	Measured pH	Average or estimated pH	Temperature (ºC)	O2	Measured hardness (mg/L)	Average or estimated hardness (mg/L)	Measured DOC (mg/L)	Average or estimated DOC (mg/L)	Notes on estimated water chemistry	Salinity	Formulation	Habitat
Amphibians	7.22	7.22	19.4	8.6 mg/L	57	57		1.90	DOC estimate based on measurements in		ZnSO4	freshwater
Fish	7.5 (7.4–7.7)	7.50	12.4 (11.7–13.1)	8.2 (7.6– 8.8)	154 (138–167)	154		1.90	DOC estimated from other tests conducted		ZnSO4	freshwater
Fish	7.1–8.2	7.63	11.6	9.8	64–77	70.2		1.60	DOC estimate is default DOC value for		Zn(NO3)2 x 4H2O	freshwater
Fish		7.60	25		48	48		1.10	DOC estimate is recommended DOC			freshwater
Fish	6.81 (0.18)	6.81	9.0 (0.2)	DO 9.2 (0.6) mg/L	47.8 (6.2) mg/L Ca and Mg	47.8	1.9	1.90			ZnSO4	freshwater
Fish	7.59	7.59	11.7	8.52 mg/L	47.7	47.7		1.90	DOC estimated from other tests conducted		ZnSO4	freshwater
Fish	7.2–7.9	7.54	9	10.9–12.2	45.9 (45.0–48.0)	45.9		1.10	DOC estimate is recommended DOC		ZnSO4 x 7H2O	freshwater
Invertebrates	7.1–7.3	7.20	23	7–8		85		0.50	Hardness estimate is expected hardness for		ZnCl2	freshwater
Invertebrates	7.5	7.50	25.3	88.3%	82.4	82.4		0.50	DOC estimate is default DOC value for		ZnSO4	freshwater
Invertebrates	7.3–7.7	7.50	20	aerated		229	4.3	4.3	Hardness estimated from Ca concentration			freshwater
Invertebrates	7.9	7.9	15	aerated	268	268		6.74	Hardness calculated. DOC estimate based		ZnCl2	freshwater
Invertebrates	8	8	20		48	48		0.30	DOC estimate from author			freshwater
Invertebrates	6.9	6.90	15	near saturation	36	36		1.10	DOC estimate is from US EPA's 2007 Cu		ZnCl2	freshwater
Invertebrates	7.8–8.2	8.00	15		159	159	4.3	4.3			ZnCl2	freshwater
Invertebrates	7.77 (SD 0.07)	7.77	11.9 (SD 0.1)		44.4 (SD 1.1)	44.4		1.90	DOC estimated from other tests conducted		ZnSO4 salt	freshwater
Plants		7.50	20–29		140 mg/L (see notes)	140		0.50	Hardness estimated based on one-fifth-			freshwater
Plants	6	6.00	25–27			50		0.50	Estimates of hardness and DOC not possible,		ZnCl2/ ZnNO3	freshwater
Fish	7.53	7.53	12	7.54	149.4	149.4		1.90	DOC estimate based on measurements in		ZnSO4	freshwater
Fish	7.24	7.24	12.1	7.46	31.1	31.1		1.90	DOC estimate based on measurements in		ZnSO4	freshwater
Fish												
Fish	7.58	7.58	15		104.99	104.99	0.3	0.3	Hardness calculated.		not reported	freshwater
Fish	7.68	7.68	15		398.68	398.68	0.3	0.3	Hardness calculated.		not reported	freshwater
Fish	7.87	7.87	15		190.35	190.35	0.3	0.3	Hardness calculated.		not reported	freshwater
Fish	5.68	5.68	15		30.24	30.24	0.3	0.3	Hardness calculated.		not reported	freshwater
Fish	7.61	7.61	15		30.24	30.24	0.3	0.3	Hardness calculated.		not reported	freshwater
Fish	7.45	7.45	15		32.7	32.7	0.3	0.3	Hardness calculated.		not reported	freshwater
Fish	7.65	7.65	15		30.24	30.24	0.3	0.3	Hardness calculated.		not reported	freshwater
Fish	7.58	7.58	15		30.24	30.24	0.3	0.3	Hardness calculated.		not reported	freshwater
Fish	6.78	6.78	15		30.24	30.24	0.3	0.3	Hardness calculated.		not reported	freshwater
Fish	7.08	7.08	15	>90%	31.5	31.5	2.84	2.84	Hardness calculated from Mg and Ca		dissolved	freshwater
Fish	6.8	6.8	15	>90%	28.2	28.2	3.92	3.92	Hardness calculated from Mg and Ca		dissolved	freshwater
Fish	6.15	6.15	15	>90%	23.4	23.4	4.25	4.25	Hardness calculated from Mg and Ca		dissolved	freshwater
Fish	8.13	8.13	15	>90%	176.3	176.3	6.22	6.22	Hardness calculated from Mg and Ca		dissolved	freshwater
Fish	7.76	7.76	15	>90%	103.7	103.7	22.9	22.9	Hardness calculated from Mg and Ca		dissolved	freshwater
Fish												
Invertebrates	7.77	7.77	25		Ca 79.2 mg/L; Mg 13.9 mg/L	255	8.94	8.94	Hardness estimated from = 2.5 (Ca) + 4.1			freshwater
Invertebrates	7.4	7.4	25		Ca 11.4 mg/L; Mg 4.2 mg/L	45.7	2.83	2.83	Hardness estimated from = 2.5 (Ca) + 4.1			freshwater
Invertebrates	6.89	6.89	25		Ca 10.9 mg/L; Mg 4.8 mg/L	46.9	1.18	1.18	Hardness estimated from = 2.5 (Ca) + 4.1			freshwater
Invertebrates	8.09	8.09	25		Ca 10.2 mg/L; mg 3.9 mg/L	41.5	1.73	1.73	Hardness estimated from = 2.5 (Ca) + 4.1			freshwater
Invertebrates	8.16	8.16	25		Ca 118 mg/L; Mg 3.9 mg/L	311	1.49	1.49	Hardness estimated from = 2.5 (Ca) + 4.1			freshwater
Invertebrates												
Invertebrates	7.25	7.25			240	240	2	2			ZnCl2	freshwater
Invertebrates	6.5	6.5			370	370	9.7	9.7			ZnCl2	freshwater
Invertebrates	8	8			110	110	9.7	9.7			ZnCl2	freshwater
Invertebrates	6.5	6.5			110	110	9.7	9.7			ZnCl2	freshwater
Invertebrates	8	8			370	370	9.7	9.7			ZnCl2	freshwater
Invertebrates	7.25	7.25			35	35	21	21			ZnCl2	freshwater
Invertebrates	7.25	7.25			240	240	21	21			ZnCl2	freshwater
Invertebrates	7.25	7.25			240	240	21	21			ZnCl2	freshwater
Invertebrates	6	6			240	240	21	21			ZnCl2	freshwater
Invertebrates	7.25	7.25			240	240	21	21			ZnCl2	freshwater
Invertebrates												
Invertebrates	7.81	7.81	20		Ca 79.4 mg/L; Mg 14 mg/L	256	12.7	12.7	Hardness calculated. as 2.5 (Ca) + 4.1 (Mg).			freshwater
Invertebrates	7.9	7.9	20		Ca 64.4 mg/L; Mg 15.7 mg/L	225	7.82	7.82	Hardness calculated. as 2.5 (Ca) + 4.1 (Mg).			freshwater
Invertebrates	7.41	7.41	20		Ca 8.8 mg/L; Mg 3.8 mg/L	37.6	2.85	2.85	Hardness calculated. as 2.5 (Ca) + 4.1 (Mg).			freshwater
Invertebrates	6.77	6.77	20		Ca 9.8 mg/L; Mg 4.0 mg/L	40.9	1.5	1.5	Hardness calculated. as 2.5 (Ca) + 4.1 (Mg).			freshwater
Invertebrates												

Source: Canadian Council of Ministers of the Environment. 2018. Scientific criteria document for the development of the Canadian water quality guidelines for the protection of aquatic life: zinc. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Family	Exposure	Resident species?	Surrogate species?	Ranking	Additional details/rationale for ranking	Authors	Year	Journal	Volume	Pages	Other Reference
Amphibians	long-term	yes	no	primary		Davies and Brinkman	1999				Pollution Studies #F-
Fish	long-term	yes	no	primary	Calculated from raw data.	Brinkman and Woodling	2005	Environmental Toxicology and	24	1515–1517	
Fish	long-term	no	yes	secondary	Calculated from given mortality in Figure 1 (in the associated journal article) from 3 points.	Bengtsson	1974	OIKOS	25	370–373	
Fish	long-term	yes	no	secondary	Estimated with the probit method based on values given in Table 3 (in the associated	Norberg and Mount	1985	Environmental Toxicology and	4	711–718	
Fish	long-term	yes	no	primary	Calculated from data.	Brinkman and Vieira	2008			10–20	Job Progress Report for
Fish	long-term	yes	no	primary		Davies et al.	2002				Pollution Studies,
Fish	long-term	yes	no	secondary	Estimated with the probit method from values given in Table 2 (in the associated journal	Holcombe et al.	1979	Transactions of the	108	76–87	
Invertebrates	long-term	no	yes	secondary	Calculated from raw data. Analytical methods and abiotic factors reported through author	Juárez-Franco et al.	2007	Journal of Environment	42	1489–1493	
Invertebrates	long-term	yes	no	primary	Concentration reported for bioavailable metal concentration.	Cooper et al.	2009	and Environmental	72	1523–1528	
Invertebrates	long-term	no	yes	secondary	Only two tested concentrations, no replication, hardness not reported.	Timmermans et al.	1992	Hydrobiologia	241	119–134	
Invertebrates	long-term	yes	no	secondary	Calculated with the mortality data from Table 2 (in the associated journal article).	Kraak et al.	1994b	Aquatic Toxicology	30	77–89	
Invertebrates	long-term	yes	no	primary		Wang et al.	2010	Toxicology and Chemistry	29 (9)	2053–2063	
Invertebrates	long-term	yes	no	secondary	Concentrations not mentioned, no CI, control quality missing. Number of replicates not	Nebeker et al.	1986	Environmental Toxicology and	5	807–811	
Invertebrates	long-term	no	yes	secondary	Calculated by the geometric mean of the given NOEC and LOEC. Water hardness calculated.	Dorgelo et al.	1995	Hydrobiologia	316	199–210	
Invertebrates	long-term	no	yes	primary	Calculated from raw data, supplied through author correspondence.	Brinkman and Johnston	2008	Archives of Environmental	54	466–472	
Plants	long-term	yes	no	secondary		Umebese and Motajo	2008	Journal of Environmental	29	197–200	
Plants	long-term	yes	no	secondary	Calculated from raw data.	Ince et al.	1999	Archives of Environmental	36	365–372	
Fish	long-term	yes	no	primary		Brinkman and Hansen	2004			22–35	Pollution Studies,
Fish	long-term	yes	no	primary		Brinkman and Hansen	2004			22–35	Pollution Studies,
Fish											
Fish	long-term	yes	no	primary	Control mortality and toxicant concentrations from author communication.	De Schamphelaer	2004	Environmental Science and	38	6201–6209	
Fish	long-term	yes	no	primary	Control mortality and toxicant concentrations from author communication.	De Schamphelaer	2004	Environmental Science and	38	6201–6209	
Fish	long-term	yes	no	primary	Control mortality and toxicant concentrations from author communication.	De Schamphelaer	2004	Environmental Science and	38	6201–6209	
Fish	long-term	yes	no	primary	Control mortality and toxicant concentrations from author communication.	De Schamphelaer	2004	Environmental Science and	38	6201–6209	
Fish	long-term	yes	no	primary	Control mortality and toxicant concentrations from author communication.	De Schamphelaer	2004	Environmental Science and	38	6201–6209	
Fish	long-term	yes	no	primary	Control mortality and concentration values from author communication.	De Schamphelaer	2004	Environmental Science and	38	6201–6209	
Fish	long-term	yes	no	primary	Control mortality and toxicant concentrations from author communication.	De Schamphelaer	2004	Environmental Science and	38	6201–6209	
Fish	long-term	yes	no	primary	Control mortality and toxicant concentrations from author communication.	De Schamphelaer	2004	Environmental Science and	38	6201–6209	
Fish	long-term	yes	no	primary	Control mortality and toxicant concentrations from author communication.	De Schamphelaer	2004	Environmental Science and	38	6201–6209	
Fish	long-term	yes	no	secondary	Control quality, tested concentrations and form of Zn not reported.	De Schamphelaer	2005	Environmental Toxicology and	24	1190–1197	
Fish	long-term	yes	no	secondary	Control quality, tested concentrations and form of Zn not reported.	De Schamphelaer	2005	Environmental Toxicology and	24	1190–1197	
Fish	long-term	yes	no	secondary	Control quality, tested concentrations and form of Zn not reported.	De Schamphelaer	2005	Environmental Toxicology and	24	1190–1197	
Fish	long-term	yes	no	secondary	Control quality, tested concentrations and form of Zn not reported.	De Schamphelaer	2005	Environmental Toxicology and	24	1190–1197	
Fish	long-term	yes	no	secondary	Control quality, tested concentrations and form of Zn not reported.	De Schamphelaer	2005	Environmental Toxicology and	24	1190–1197	
Fish											
Invertebrates	long-term	no	yes	primary	48 hours is life cycle test for this species, therefore considered chronic. Additional	De Schamphelaer	2010	Science of the Total	408.00	5414–5422	
Invertebrates	long-term	no	yes	primary	48 hours is life cycle test for this species, therefore considered chronic. Hormesis model	De Schamphelaer	2010	Science of the Total	408.00	5414–5422	
Invertebrates	long-term	no	yes	primary	48 hours is life cycle test for this species, therefore considered chronic. Additional	De Schamphelaer	2010	Science of the Total	408.00	5414–5422	
Invertebrates	long-term	no	yes	primary	48 hours is life cycle test for this species, therefore considered chronic. Additional	De Schamphelaer	2010	Science of the Total	408.00	5414–5422	
Invertebrates	long-term	no	yes	primary	48 hours is life cycle test for this species, therefore considered chronic. Additional	De Schamphelaer	2010	Science of the Total	408.00	5414–5422	
Invertebrates											
Invertebrates	long-term	yes	no	primary	Toxicant concentrations not reported but stated that effect concentrations were within	Heijerick et al.	2003	Archives of Environmental	44	210–217	
Invertebrates	long-term	yes	no	primary	Toxicant concentrations not reported but stated that effect concentrations were within	Heijerick et al.	2003	Archives of Environmental	44	210–217	
Invertebrates	long-term	yes	no	primary	Toxicant concentrations not reported but stated that effect concentrations were within	Heijerick et al.	2003	Archives of Environmental	44	210–217	
Invertebrates	long-term	yes	no	primary	Toxicant concentrations not reported but stated that effect concentrations were within	Heijerick et al.	2003	Archives of Environmental	44	210–217	
Invertebrates	long-term	yes	no	primary	Toxicant concentrations not reported but stated that effect concentrations were within	Heijerick et al.	2003	Archives of Environmental	44	210–217	
Invertebrates	long-term	yes	no	primary	Toxicant concentrations not reported but stated that effect concentrations were within	Heijerick et al.	2003	Archives of Environmental	44	210–217	
Invertebrates	long-term	yes	no	primary	Toxicant concentrations not reported but stated that effect concentrations were within	Heijerick et al.	2003	Archives of Environmental	44	210–217	
Invertebrates	long-term	yes	no	primary	Toxicant concentrations not reported but stated that effect concentrations were within	Heijerick et al.	2003	Archives of Environmental	44	210–217	
Invertebrates	long-term	yes	no	primary	Toxicant concentrations not reported but stated that effect concentrations were within	Heijerick et al.	2003	Archives of Environmental	44	210–217	
Invertebrates	long-term	yes	no	primary	Toxicant concentrations not reported but stated that effect concentrations were within	Heijerick et al.	2003	Archives of Environmental	44	210–217	
Invertebrates											
Invertebrates	long-term	yes	no	primary	Additional information (e.g., control response) available from supplementary material.	De Schamphelaer	2010	Science of the Total	408	5414–5422	
Invertebrates	long-term	yes	no	primary	Additional information (e.g., control response) available from supplementary material.	De Schamphelaer	2010	Science of the Total	408	5414–5422	
Invertebrates	long-term	yes	no	primary	Additional information (e.g., control response) available from supplementary material.	De Schamphelaer	2010	Science of the Total	408	5414–5422	
Invertebrates	long-term	yes	no	primary	Additional information (e.g., control response) available from supplementary material.	De Schamphelaer	2010	Science of the Total	408	5414–5422	
Invertebrates											

Source: Canadian Council of Ministers of the Environment. 2018. Scientific criteria document for the development of the Canadian water quality guidelines for the protection of aquatic life: zinc. Canadian Council of Ministers of the Environment, Winnipeg, MB.

APPENDIX G
Well Search

Regional District of Central Kootenay
Prospective Human Health and Ecological Risk Assessment
HB Mine Tailings Management Facility
SLR Project No.: 204.03242.00004

Groundwater Wells and Aquifers

Well Summary

Well Tag Number: 75273
Well Identification Plate Number:
Owner Name: CENTRAL KOOTENAY R D
Licensed Status: Unlicensed

Well Status: New
Well Class: Unknown
Well Subclass:
Intended Water Use:

Observation Well Number:
Observation Well Status:
Environmental Monitoring System (EMS) ID:
Aquifer Number:
Alternative specs submitted (if required): No

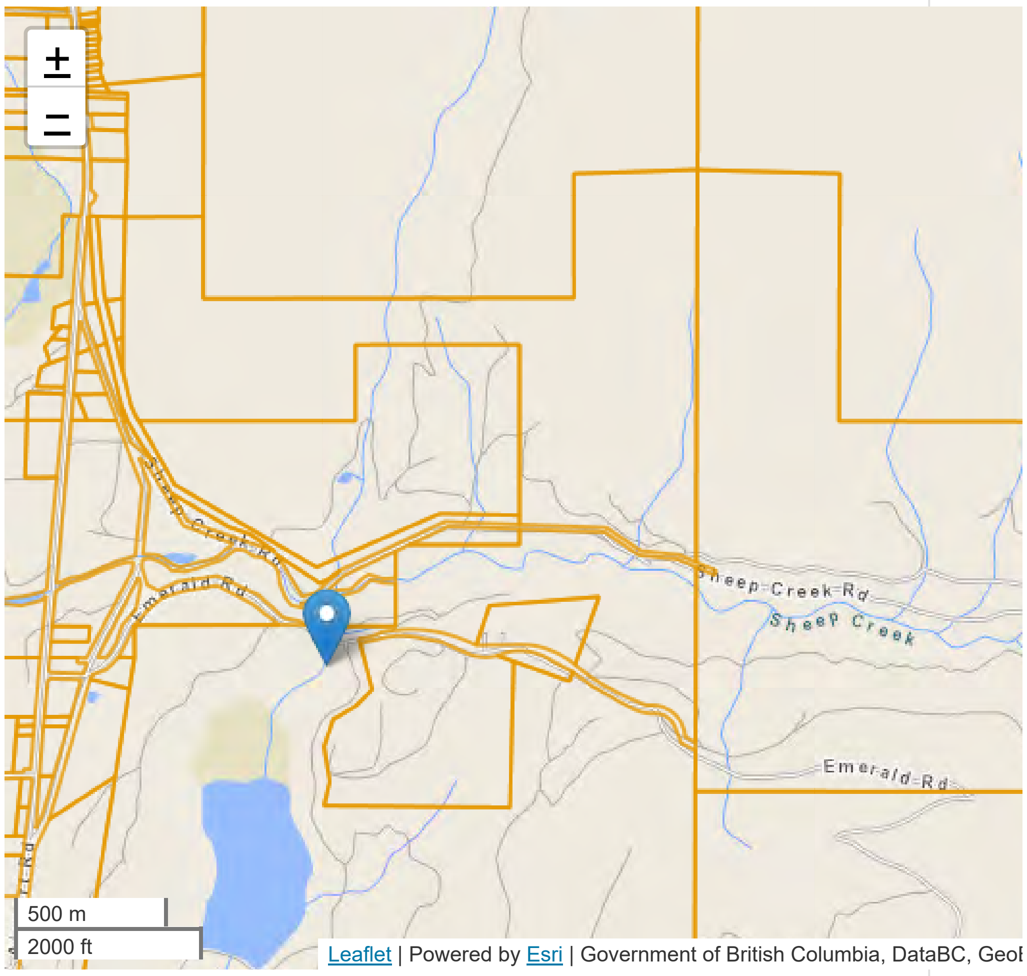
Location Information

Street Address: SALMO DUMP
Town/City: SALMO

Legal Description:

Lot	A
Plan	14234
District Lot	1236
Block	
Section	
Township	
Range	
Land District	26
Property Identification Description (PID)	

Description of Well Location:



Geographic Coordinates - North American Datum of 1983 (NAD 83)
Latitude: 49.139233
Longitude: -117.245947
UTM Easting: 482061
UTM Northing: 5442963
Zone: 11
Location Accuracy Code:

Well Activity

Activity Type	Work Start Date	Work End Date	Drilling Company
There are no records to show			

Well Completion Data

Total Depth Drilled:
Finished Well Depth: 20.00 feet
Final Casing Stick Up:
Depth to Bedrock:
Ground elevation: 0.00

Static Water Level (BTOC):
Estimated Well Yield:
Artesian Flow:
Artesian Pressure:
Method of determining elevation:

Well Cap:
Well Disinfected: No
Drilling Method:
Orientation of Well: vertical

Lithology

From (ft bgl)	To (ft bgl)	Raw Data	Description	Moisture	Colour	Hardness	Observations	Water Bearing Flow Estimate (USGPM)
0.00	3.00	clay						
3.00	5.00	gravel						
5.00	20.00	bedrock						

Casing Details

From (ft)	To (ft)	Casing Type	Casing Material	Diameter	Wall Thickness	Drive Shoe
There are no records to show						

Surface Seal and Backfill Details

Surface Seal Material:
Surface Seal Installation Method:
Surface Seal Thickness:
Surface Seal Depth:

Backfill Material Above Surface Seal:
Backfill Depth:

Liner Details

Liner Material:
Liner Diameter:
Liner from:

Liner Thickness:
Liner to:

Liner perforations

From	To
There are no records to show	

Screen Details

Intake Method:
Type:
Material:
Opening:
Bottom:

Installed Screens

From	To	Internal Diameter	Assembly Type	Slot Size
There are no records to show				

Well Development

Developed by:

Development Total Duration:

Well Yield

No well yield data available.

Well Decommission Information

Finished Well Depth: 20.00 feet
Reason for Decommission:
Method of Decommission:

Sealant Material:
Backfill Material:
Decommission Details:

Comments

DRY HOLE METHOD OF DRILLING = DRILLED

Alternative Specs Submitted: No

Documents

- WTN 75273_Well Record.pdf

Disclaimer

Groundwater Wells and Aquifers

Well Summary

Well Tag Number: 82185
Well Identification Plate Number:
Owner Name: KOOTENAY STONE CENTRE
Licensed Status: Unlicensed

Well Status: New
Well Class: Water Supply
Well Subclass:
Intended Water Use: Commercial and Industrial

Observation Well Number:
Observation Well Status:
Environmental Monitoring System (EMS) ID:
Aquifer Number:
Alternative specs submitted (if required): No

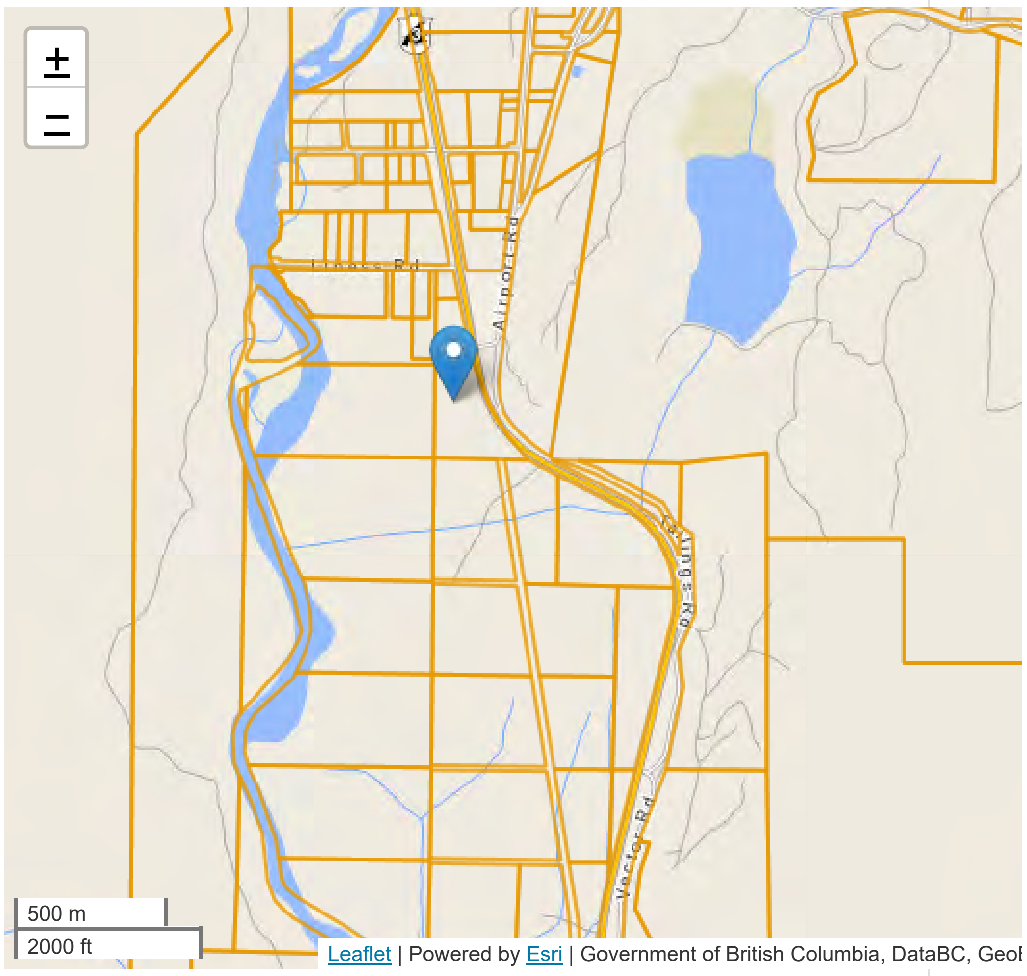
Location Information

Street Address: 8048 HIGHWAY 3
Town/City: SOUTH SALMO

Legal Description:

Lot	2
Plan	11 847
District Lot	1236
Block	
Section	
Township	
Range	
Land District	
Property Identification Description (PID)	12652954

Description of Well Location: Hwy 3, South of Salmo; Folio #24707 05557 04311



Geographic Coordinates - North American Datum of 1983 (NAD 83)
Latitude: 49.128629 **Longitude:** -117.261864
UTM Easting: 480896 **UTM Northing:** 5441788
Zone: 11 **Location Accuracy Code:**

Well Activity

Activity Type	Work Start Date	Work End Date	Drilling Company
There are no records to show			

Well Completion Data

Total Depth Drilled:
Finished Well Depth: 40.00 feet
Final Casing Stick Up:
Depth to Bedrock:
Ground elevation:

Static Water Level (BTOC):
Estimated Well Yield: 25.000 USGPM
Artesian Flow:
Artesian Pressure:
Method of determining elevation:

Well Cap:
Well Disinfected: No
Drilling Method:
Orientation of Well: vertical

Lithology

From (ft bgl)	To (ft bgl)	Raw Data	Description	Moisture	Colour	Hardness	Observations	Water Bearing Flow Estimate (USGPM)
0.00	40.00	Coarse gravel with coarse to medium sand						

Casing Details

From (ft)	To (ft)	Casing Type	Casing Material	Diameter	Wall Thickness	Drive Shoe
20.00	0.00		Steel	6.250		Yes
40.00	20.00		Steel	6.120		Yes

Surface Seal and Backfill Details

Surface Seal Material:
Surface Seal Installation Method:
Surface Seal Thickness:
Surface Seal Depth:

Backfill Material Above Surface Seal:
Backfill Depth:

Liner Details

Liner Material:
Liner Diameter:
Liner from:

Liner Thickness:
Liner to:

Liner perforations

From	To
There are no records to show	

Screen Details

Intake Method:
Type:
Material:
Opening:
Bottom:

Installed Screens

From	To	Internal Diameter	Assembly Type	Slot Size
There are no records to show				

Well Development

Developed by:

Development Total Duration:

Well Yield

No well yield data available.

Well Decommission Information

Finished Well Depth: 40.00 feet
Reason for Decommission:
Method of Decommission:

Sealant Material:
Backfill Material:
Decommission Details:

Comments

Water is fresh and clear with no color, smell or gas MEASUREMENTS TAKEN AT GROUND LEVEL

Alternative Specs Submitted: No

Documents

- WTN 82185_Well Record.pdf

Disclaimer

Groundwater Wells and Aquifers

Well Summary

Well Tag Number: 92070
Well Identification Plate Number:
Owner Name: RAY & STELLA BERNARD
Licensed Status: Unlicensed

Well Status: New
Well Class: Water Supply
Well Subclass:
Intended Water Use: Private Domestic

Observation Well Number:
Observation Well Status:
Environmental Monitoring System (EMS) ID:
Aquifer Number:
Alternative specs submitted (if required): No

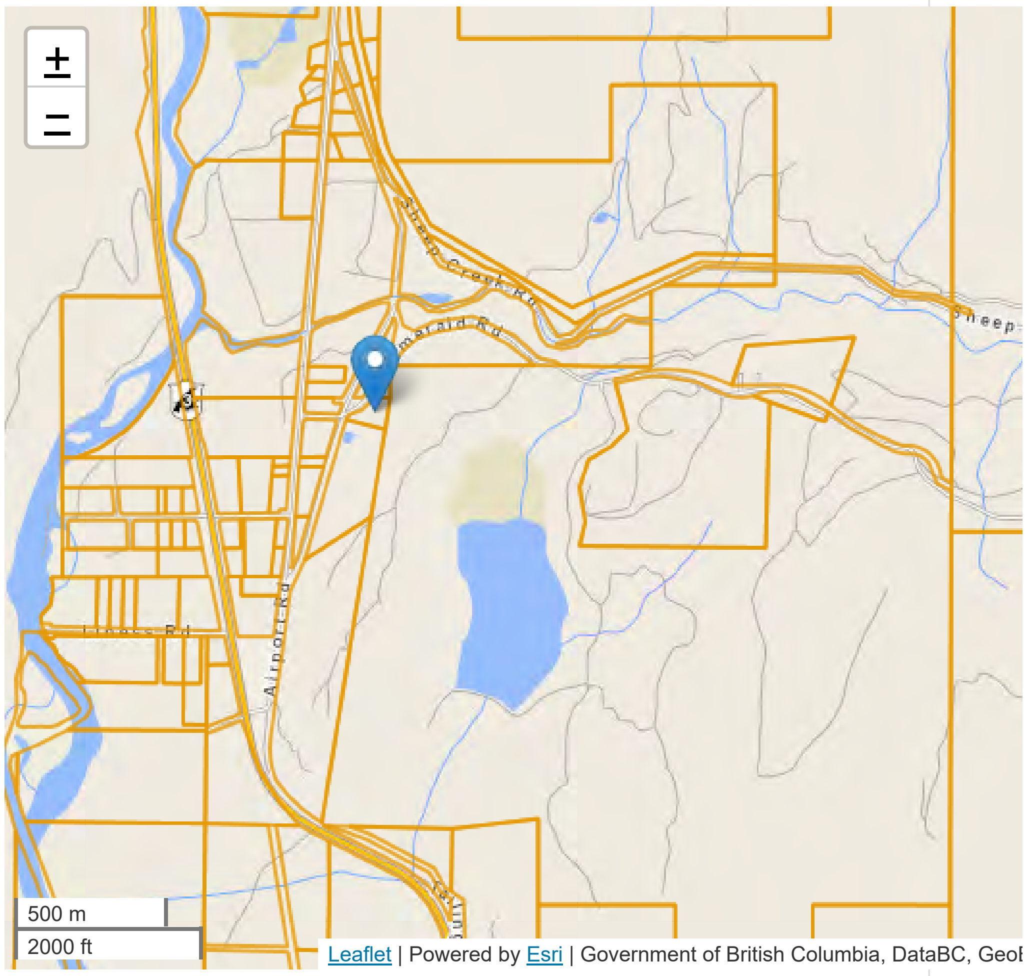
Location Information

Street Address:
Town/City:

Legal Description:

Lot	1
Plan	11981
District Lot	1236
Block	
Section	
Township	
Range	
Land District	26
Property Identification Description (PID)	12617768

Description of Well Location: SALMO



Geographic Coordinates - North American Datum of 1983 (NAD 83)
Latitude: 49.139042 **Longitude:** -117.255214
UTM Easting: 481385 **UTM Northing:** 5442944
Zone: 11 **Location Accuracy Code:**

Well Activity

Activity Type	Work Start Date	Work End Date	Drilling Company
There are no records to show			

Well Completion Data

Total Depth Drilled: 195.00 feet
Finished Well Depth: 195.00 feet
Final Casing Stick Up: 6.000 inches
Depth to Bedrock: 6.00 feet
Ground elevation:

Static Water Level (BTOC): 80.00 feet
Estimated Well Yield: 5.000 USGPM
Artesian Flow:
Artesian Pressure:
Method of determining elevation:

Well Cap: WELDED CAP
Well Disinfected: No
Drilling Method:
Orientation of Well: vertical

Lithology

From (ft bgl)	To (ft bgl)	Raw Data	Description	Moisture	Colour	Hardness	Observations	Water Bearing Flow Estimate (USGPM)
0.00	6.00	SAND, GRAVEL						
6.00	20.00	BROKEN BEDROCK						
20.00	35.00	BEDROCK CASED						
35.00	195.00							

Casing Details

From (ft)	To (ft)	Casing Type	Casing Material	Diameter	Wall Thickness	Drive Shoe
0.00	35.00		Steel	6.000	0.219	Yes
35.00	195.00		Open hole	6.000		No

Surface Seal and Backfill Details

Surface Seal Material:
Surface Seal Installation Method:
Surface Seal Thickness:
Surface Seal Depth:

Backfill Material Above Surface Seal:
Backfill Depth:

Liner Details

Liner Material:
Liner Diameter:
Liner from:

Liner Thickness:
Liner to:

Liner perforations

From	To
There are no records to show	

Screen Details

Intake Method:
Type:
Material:
Opening:
Bottom:

Installed Screens

From	To	Internal Diameter	Assembly Type	Slot Size
There are no records to show				

Well Development

Developed by:

Development Total Duration:

Well Yield

No well yield data available.

Well Decommission Information

Finished Well Depth: 195.00 feet
Reason for Decommission:
Method of Decommission:

Sealant Material:
Backfill Material:
Decommission Details:

Comments

MEASUREMENTS FROM GROUND LEVEL. SHOE: 1X6" CARBIDE BUTTON. RECOMMENDED PUMP TYPE: SUB. RECOMMENDED PUMPING RATE: 5 USGPM.

Alternative Specs Submitted: No

Documents

- WTN 92070_Well Record.pdf

Disclaimer

Groundwater Wells and Aquifers

Well Summary

Well Tag Number: 105491
Well Identification Plate Number: 32850
Owner Name: DAN & KAREN BAHR
Licensed Status: Unlicensed

Well Status: New
Well Class: Injection
Well Subclass:
Intended Water Use: Private Domestic

Observation Well Number:
Observation Well Status:
Environmental Monitoring System (EMS) ID:
Aquifer Number:
Alternative specs submitted (if required): No

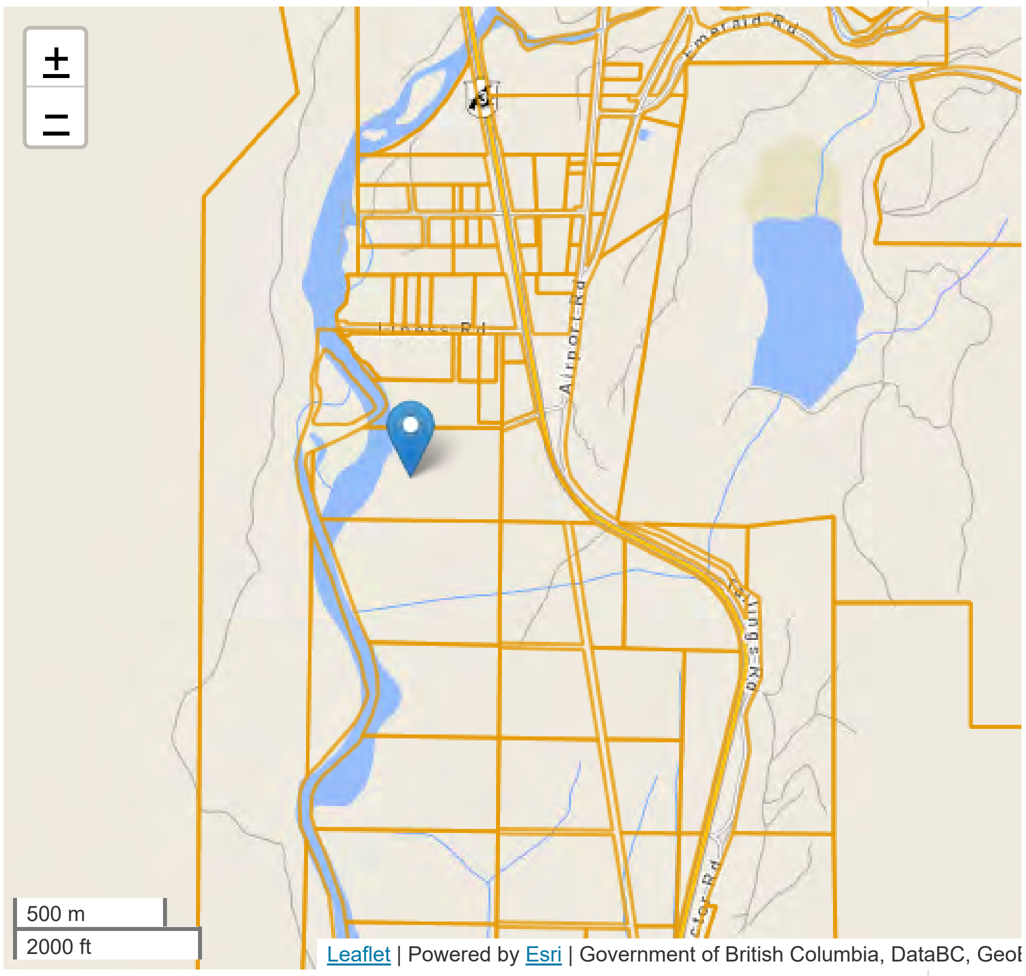
Location Information

Street Address: 110 MURTON ROAD
Town/City: SALMO

Legal Description:

Lot	
Plan	
District Lot	
Block	
Section	
Township	
Range	
Land District	26
Property Identification Description (PID)	6069011

Description of Well Location: NOT PROVIDED.



Geographic Coordinates - North American Datum of 1983 (NAD 83)
Latitude: 49.12833 **Longitude:** -117.266756
UTM Easting: 480539 **UTM Northing:** 5441756
Zone: 11 **Location Accuracy Code:**

Well Activity

Activity Type	Work Start Date	Work End Date	Drilling Company
There are no records to show			

Well Completion Data

Total Depth Drilled: 40.00 feet
Finished Well Depth: 40.00 feet
Final Casing Stick Up: 30.000 inches
Depth to Bedrock:
Ground elevation: 2152.00

Static Water Level (BTOC): 11.00 feet
Estimated Well Yield: 80.000 USGPM
Artesian Flow:
Artesian Pressure:
Method of determining elevation:

Well Cap: PLATE
Well Disinfected: No
Drilling Method:
Orientation of Well: vertical

Lithology

From (ft bgl)	To (ft bgl)	Raw Data	Description	Moisture	Colour	Hardness	Observations	Water Bearing Flow Estimate (USGPM)
0.00	3.00	CLAY & TOPSOIL			brown	Loose	MOIST	
3.00	26.00	SAND W/ GRAVEL			brown	Hard	WET @ 8'	
26.00	29.00	ORANGE SAND W/ GRAVEL				Loose	HIGH PRODUCTION	
29.00	34.00	SAND W/ CLAY/SILT	dark-coloured		grey	Loose	WET	
34.00	40.00	SAND W/ GRAVEL			brown	Loose	HIGH PRODUCTION	

Casing Details

From (ft)	To (ft)	Casing Type	Casing Material	Diameter	Wall Thickness	Drive Shoe
0.00	35.00		Steel	6.630	0.219	Yes

Surface Seal and Backfill Details

Surface Seal Material: Bentonite clay and cement mixture
Surface Seal Installation Method: Pumped
Surface Seal Thickness: 1.65
Surface Seal Depth:

Backfill Material Above Surface Seal:
Backfill Depth:

Liner Details

Liner Material:
Liner Diameter:
Liner Thickness:
Liner from:
Liner to:

Liner perforations

From	To
There are no records to show	

Screen Details

Intake Method: Screen
Type: Telescope
Material: Stainless Steel
Opening: Continuous Slot
Bottom: Bail

Installed Screens

From	To	Internal Diameter	Assembly Type	Slot Size
34.50 ft	35.00 ft	6.00	K_PACKER	
35.00 ft	40.00 ft	6.00	SCREEN	40.00

Well Development

Developed by:
Development Total Duration: 2.00 hours

Well Yield

No well yield data available.

Well Decommission Information

Finished Well Depth: 40.00 feet
Reason for Decommission:
Method of Decommission:

Sealant Material:
Backfill Material:
Decommission Details:

Comments

DRIVE SHOE: REG. FILTER PACK TYPE OF MATERIAL: NATURAL.

Alternative Specs Submitted: No

Documents

- WTN 105491_Well Construction.pdf

Disclaimer

Groundwater Wells and Aquifers

Well Summary

Well Tag Number: 105494
Well Identification Plate Number: 32849
Owner Name: DAN & KAREN BAHR
Licensed Status: Unlicensed

Well Status: New
Well Class: Water Supply
Well Subclass:
Intended Water Use: Private Domestic

Observation Well Number:
Observation Well Status:
Environmental Monitoring System (EMS) ID:
Aquifer Number:
Alternative specs submitted (if required): No

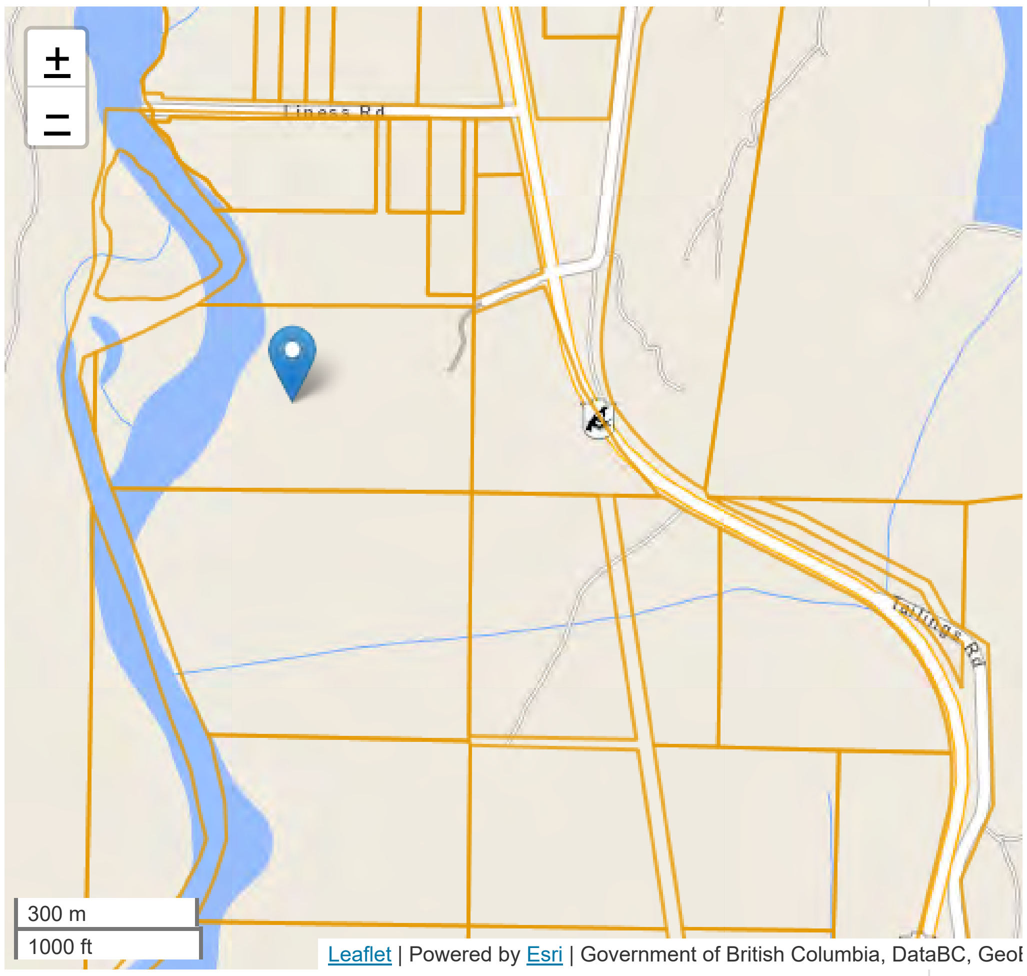
Location Information

Street Address: 110 MURTON ROAD
Town/City: SALMO

Legal Description:

Lot	
Plan	
District Lot	
Block	
Section	
Township	
Range	
Land District	26
Property Identification Description (PID)	6069011

Description of Well Location: NOT PROVIDED.



Geographic Coordinates - North American Datum of 1983 (NAD 83)
Latitude: 49.128384
Longitude: -117.266756
UTM Easting: 480539
UTM Northing: 5441762
Zone: 11
Location Accuracy Code:

Well Activity

Activity Type	Work Start Date	Work End Date	Drilling Company
There are no records to show			

Well Completion Data

Total Depth Drilled: 40.00 feet
Finished Well Depth: 40.00 feet
Final Casing Stick Up: 30.000 inches
Depth to Bedrock:
Ground elevation: 2152.00

Static Water Level (BTOC): 11.00 feet
Estimated Well Yield: 60.000 USGPM
Artesian Flow:
Artesian Pressure:
Method of determining elevation:

Well Cap: PLATE
Well Disinfected: No
Drilling Method:
Orientation of Well: vertical

Lithology

From (ft bgl)	To (ft bgl)	Raw Data	Description	Moisture	Colour	Hardness	Observations	Water Bearing Flow Estimate (USGPM)
0.00	1.00				brown	Loose	MOIST	
1.00	30.00	SAND W/ GRAVEL			brown	Hard	WET @ 8' ON	
30.00	32.00	ORANGE SAND W/ GRAVEL				Loose	HIGH PRODUCTION	
32.00	35.00	SAND W/ CLAY/SILT			brown	Loose	WET	
35.00	40.00	SAND W/ GRAVEL			brown	Loose	HIGH PRODUCTION	

Casing Details

From (ft)	To (ft)	Casing Type	Casing Material	Diameter	Wall Thickness	Drive Shoe
0.00	36.00		Steel	6.000	0.219	Yes

Surface Seal and Backfill Details

Surface Seal Material: Bentonite clay and cement mixture
Surface Seal Installation Method: Pumped
Surface Seal Thickness: 1.65
Surface Seal Depth:

Backfill Material Above Surface Seal:
Backfill Depth:

Liner Details

Liner Material:
Liner Diameter:
Liner Thickness:
Liner from:
Liner to:

Liner perforations

From	To
There are no records to show	

Screen Details

Intake Method: Screen
Type: Telescope
Material: Stainless Steel
Opening: Continuous Slot
Bottom: Bail

Installed Screens

From	To	Internal Diameter	Assembly Type	Slot Size
35.50 ft	36.00 ft	6.00	K_PACKER	
36.00 ft	40.00 ft	6.00	SCREEN	20.00

Well Development

Developed by:
Development Total Duration: 2.00 hours

Well Yield

No well yield data available.

Well Decommission Information

Finished Well Depth: 40.00 feet
Reason for Decommission:
Method of Decommission:
Sealant Material:
Backfill Material:
Decommission Details:

Comments

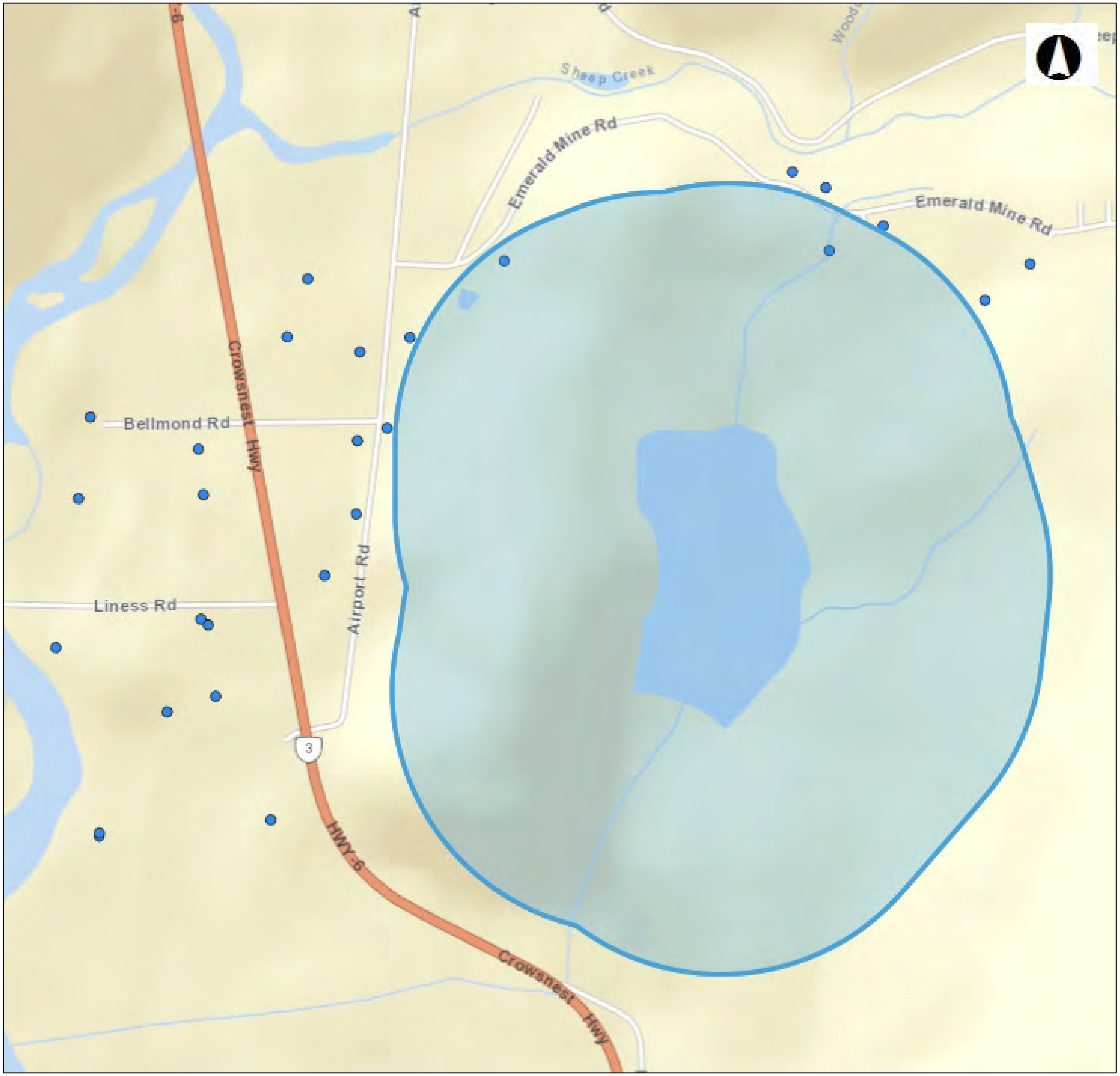
DRIVE SHOE: REG. FILTER PACK TYPE OF MATERIAL: NATURAL. ESTIMATED WELL YIELD: 60-70 USGPM.

Alternative Specs Submitted: No

Documents

- WTN 105494_Well Construction.pdf

Disclaimer



BRITISH COLUMBIA

Water Wells Within 500m

Legend

- Water Wells - All

0 0.37 0.73 km

1: 18,056

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CAUTION: Maps obtained using this site are not designed to assist in navigation. These maps may be generalized and may not reflect current conditions. Uncharted hazards may exist. DO NOT USE THESE MAPS FOR NAVIGATIONAL PURPOSES.

Datum: NAD83
Projection: BC Albers

Key Map of British Columbia

global environmental solutions

Calgary, AB
1185-10201 Southport Rd SW
Calgary, AB T2W 4X9
Canada
Tel: (403) 266-2030
Fax: (403) 263-7906

Edmonton, AB
6940 Roper Road
Edmonton, AB T6B 3H9
Canada
Tel: (780) 490-7893
Fax: (780) 490-7819

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Energy   Waste Management   Planning & Development   Industry   Mining & Minerals   Infrastructure

Appendix F – Borrow Source Investigations

Appendix F-1 – 2017 Test Pit Investigation

HB Mine Tailings Facility – 2017 Test Pit Investigation

Prepared for

Regional District of Central Kootenay

Prepared by

SRK Consulting (Canada) Inc.
1CR012.004
December 2019

HB Mine Tailings Facility – 2017 Test Pit Investigation

December 2019

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File Name: HB_TestPit_Report_1CR012-004_20191213.docx

srk consulting

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1 Introduction

1.1 General

The Regional District of Central Kootenay (RDCK) retained SRK Consulting (Canada) Ltd. to carry out the design for the closure and remediation of the HB Mine Tailings Facility. The preliminary closure design is described in SRK (2017). As part of the proposed closure and remediation, the dam is proposed to be upgraded by raising of the dam's filter layer to the dam crest to mitigate the risk of internal erosion and piping. In addition, a new spillway at the eastern abutment is proposed to be constructed to eliminate the existing pond upstream of the HB Dam.

A test pit investigation was undertaken in December 2017 in support of this closure / remediation design. The key objectives of the investigation were:

1. Characterize two potential sand and gravel borrow sources and evaluate their suitability as the dam filter material;
2. Investigate for the presence of bedrock at the east dam abutment; and,
3. Complete additional testing of the glaciolacustrine unit within the vicinity of the HB Dam to verify previous test results (Thurber 2016).

The additional testing of the glaciolacustrine silt was undertaken as a result of the Independent Tailings Board review of the draft Preliminary Design Report (SRK 2017) that questioned the assumption that the glaciolacustrine was overconsolidated, based on the known surficial geological history of the area. The glaciolacustrine was assumed to be overconsolidated based on a single consolidation test completed as part of the 2015 Thurber geotechnical investigation (Thurber 2016) that estimated the preconsolidation pressure to be 600 kPa (from a sample collected 1.5 m below surface).

This report provides a summary of the test pit program, samples collected, and laboratory results.

1.2 Roles and Responsibilities

This field program involved several parties as detailed below:

- The excavator (Deere 120C) and operator for the test pits was provided by Custom Dozing Ltd. under contract to the RDCK;
- Field supervision, sample collection, and test pit logging was carried out by Peter Mikes, PEng. of SRK;
- Soil index testing of the sand and gravel materials was conducted by Artech Consulting Ltd., out of their Cranbrook BC laboratory; and,
- Advanced Geotechnical tested was conducted by Tetra Tech (Canada) Ltd, (formerly MEG Technical Services), out of their Richmond BC laboratory.

2 Field Program

2.1 Overview

The test pit investigation occurred on November 16 and 17, 2017. Weather was mostly cloudy with temperatures ranging between -5 and 5 °C with periods of light snowfall. Fifteen test pits were excavated at two potential sand and gravel borrow sources, and six test pits were excavated within the vicinity of the HB Dam east abutment and potential spillway alignment. Test pits were excavated with a John Deere 120C excavator with a maximum reach of approximately 4 m. SRK field engineer Peter Mikes was present during the test pit excavations to log and collect samples.

Logging was completed as per the Unified Soil Classification System (ASTM D-2487). Grab samples were collected from representative soil units from within the test pits, and were placed in Zip-Loc bags to aid in preserving moisture contents. An undisturbed block sample of the glaciolacustrine unit was wrapped in cling wrap to preserve moisture, stored in a small cooler stuffed with bubble-wrap, and maintained in the truck to avoid freezing.

2.2 Test Pit Locations

The RDCK has identified two potential borrow sources for sand and gravel that are available for use:

- North Sand and Gravel Borrow (NSGB) is located on the north side of Emerald Road, and west of the Emerald Pit that is owned by the Ministry of Transportation.
- The Landfill Sand and Gravel Borrow (LSGB) is located near the northeast corner of the Central Landfill area and was used during the operation of the landfill.

Test Pit locations at each borrow were planned to characterize spatial variability. Seven test pits were excavated at the NSGB, and eight test pits were excavated at the LSGB.

Six pits were excavated in the vicinity of the HB Dam east abutment and spillway. The objective of each of these test pits, except for SRK17-TP-20, was to find bedrock. The objective of SRK17-TP-20 was to obtain an undisturbed sample of glaciolacustrine material at a location along the proposed spillway alignment.

Table 1 lists the test pit locations excavated during the program. The locations of the test pits are provided in Figures 1 to 4, with the logs provided in Appendix A.

Table 1: Test Pit Locations

Area	Hole ID	Easting	Northing	Total Depth (m)
North Sand and Gravel borrow	SRK17-TP-01	482,465.5	5,443,053.5	3.0
	SRK17-TP-02	482,458.3	5,443,071.0	3.2
	SRK17-TP-03	482,465.7	5,443,090.0	2.8
	SRK17-TP-04	482,444.5	5,443,085.9	3.2
	SRK17-TP-05	482,478.6	5,443,117.6	0.2
	SRK17-TP-06	482,455.6	5,443,103.4	3.3
	SRK17-TP-07	482,428.0	5,443,072.0	2.8
Landfill Sand and Gravel Borrow	SRK17-TP-08	482,693.3	5,442,937.9	2.6
	SRK17-TP-09	482,690.0	5,442,903.4	2.6
	SRK17-TP-10	482,673.4	5,442,871.2	2.8
	SRK17-TP-11	482,658.3	5,442,935.0	2.0
	SRK17-TP-12	482,659.0	5,442,914.1	1.7
	SRK17-TP-13	482,627.1	5,442,895.8	2.0
	SRK17-TP-14	482,617.9	5,442,945.4	3.0
	SRK17-TP-15	482,678.7	5,442,929.5	0.3
East Abutment/ Spillway	SRK17-TP-16	481,886.2	5,441,959.1	0.2
	SRK17-TP-17	481,857.3	5,441,952.4	0.3
	SRK17-TP-18	481,840.7	5,441,951.9	4.0
	SRK17-TP-19	481,853.3	5,441,978.9	2.0
	SRK17-TP-20	481,792.0	5,441,928.4	4.3
	SRK17-TP-21	481,851.8	5,441,940.6	0.2

2.3 Sample Collection and Testing Programs

Sand and Gravel Borrow Testing Program

All samples were sent to the Artech Consulting Laboratory in Cranbrook BC. Particle size distributions and gravimetric moisture content tests were completed on all samples, with hydrometer testing undertaken as required such that the D_{10} particle diameter[1] could be determined.

HB Dam East Abutment Testing Program

Three samples were collected from the HB Dam east abutment area: two till samples collected from SRK17-TP18 were sent to the Artech laboratory for particle size distribution testing; and one undisturbed block sample of glaciolacustrine material collected from SRK17-TP-20 was sent to the Tetra Tech (formerly MEG) laboratory in Richmond, BC.

[1] The D10 particle diameter of a soil is the diameter where 10% of the particles are smaller by mass.

The testing program for the undisturbed glaciolacustrine sample consisted of soil index tests (moisture content, particle size distribution, Atterberg Limits, and specific gravity), one dimensional consolidation testing (ASTM D2435), and direct simple shear tests (ASTM D6528). Parameters for the consolidation and shear tests were selected to replicate the previous testing (Thurber 2016) to assess the material variability.

3 Sand and Gravel Borrow Results

3.1 Field Results

North Sand and Gravel Borrow Area

Seven test pits were excavated within the NSGB (Figure 2). Six test pits completed to the maximum reach of the excavator, and one test pit (SRK17-TP-05) was terminated near surface due to the presence of large cobbles and boulders that would be unsuitable as filter material. The borrow area generally consisted of dry sand and some gravel and a trace of fines (generally less than 5%). Fine-grained silt was encountered in SRK17-TP-04 at a depth of 2.7 m. No groundwater was observed.

Landfill Sand and Gravel Borrow Area

Eight test pits were excavated within the LSGB (Figure 3). All test pits were completed to the maximum reach of the excavator, except for SRK17-TP-15, which was a shallow hand-dug test pit. The LSGB borrow material was more variable compared to the NSGB, and ranged from well graded gravel with some cobbles (SRK17-TP-09) to silt with sand (SRK-17-TP-10, 11, 13, and 14). Sand material suitable as filter material was encountered in test pits SRK17-TP-08, 12, and 15. No groundwater was observed.

3.2 Laboratory Results

Gravimetric moisture content and particle size distribution tests (wash sieves and hydrometer as required) were carried out on 19 samples. The results are summarized in Table 2, and the complete laboratory test certificates are provided in Appendix B.

Table 2: Water Content and Particle Size Distribution Results

Borrow Area	Sample ID	Depth (m)	Water Content (%)	Gravel (%)	Sand (%)	Fines (%)
North S&G Borrow Area	SRK17-TP01-1	1.4 – 1.5	5.0	36.4	59.1	4.5
	SRK17-TP01-2	2.0 – 2.1	1.1	53.7	44.7	1.6
	SRK17-TP01-3	2.9 – 3.0	1.5	31.6	65.6	2.8
	SRK17-TP02-1	1.2 - 1.3	4.0	32.9	64.0	3.1
	SRK17-TP02-1	3.0 – 3.2	8.4	14.4	81.2	4.4
	SRK17-TP04-1	2.3 - 2.5	7.0	28.5	61.7	9.8
	SRK17-TP04-2	3.0 - 3.2	30.1	0.4	18.4	81.2
	SRK17-TP06-1	1.5 - 1.6	2.4	43.9	54.0	2.1
	SRK17-TP06-2	3.0 - 3.2	3.0	35.6	62.0	2.4
	SRK17-TP07-1	1.5 - 1.6	3.1	37	60.3	2.7
Landfill S&G Borrow Area	SRK17-TP08-1	1.2 - 1.3	9.0	14.8	74.5	10.7
	SRK17-TP08-2	2.2 - 2.3	1.7	9.7	88.6	1.7
	SRK17-TP09-1	0.0 - 1.3	3.4	66	28.0	6
	SRK17-TP09-2	2.0 - 2.1	1.9	68	28.2	3.8
	SRK17-TP10-1	1.6 - 1.7	14.3	2.6	17.1	80.3
	SRK17-TP11-1	0.3 - 0.5	16.6	0.6	40.2	59.2
	SRK17-TP12-1	0.0 – 0.0	4.1	25.4	70.5	4.1
	SRK17-TP13-1	0.0 – 2.0	23.0	0.0	8.7	91.3
	SRK17-TP14-1	0.0 - 0.5	5.6	31.4	61.6	7.0
	SRK17-TP14-2	1.0 - 1.2	27.3	0.1	34.5	65.4
	SRK17-TP15-1	0.0 - 0.3	9.4	11.6	83.5	4.9

Figure 5 presents the particle size distribution results for from each borrow area. The figure also includes the particle size distribution envelope for the HB Dam filter (SRK 2017). The filter compatibility is further discussed in the following section.

3.3 Filter Compatibility

Table 3 presents the filter particle size requirements from the preliminary design report (SRK 2017). Approximately 5,1000 m^3 of filter material is required. The particle size distribution results provided in Figure 5 indicate that screening of the borrow materials is required to remove the size fraction with a diameter greater than 33 mm.

Table 3: Filter Particle Size Requirements

Diameter (% passing)	Minimum Diameter (mm)	Maximum Diameter (mm)
D_{15}	0.05	0.70
D_{50}	0.17	2.50
D_{85}	0.55	14.00
D_{100}	-	33.00

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North Sand and Gravel Borrow Area

Figure 6 presents the NSGB screened particle size distributions compared to the filter gradation envelope. Removal of particle diameters greater than 25 mm results in all particle size distributions meeting the filter requirements, except for the silt encountered in SRK17-TP-04 at a depth of 2.7 m. The screening would remove approximately 17% of the run-of-borrow material based on a weighted average of the test pit logs and particle size distribution results, with a range between 2 and 32%. Allowing for an additional wastage factor of 5%, approximately 6,540 m^3 of material would require to be screened to produce the 5,100 m^3 of filter material required for the dam.

Figure 6 also provides an outline of the area of the existing NSGB that may be further developed to produce the filter material. With an area of 2,600 m^2 and an estimated average excavation depth of 3 m, an estimated volume of 7,8000 m^3 is available, which is likely to meet the project requirements. In addition, the borrow area appears to have expansion potential to the west towards the Emerald Pit (Figure 1) based on a visual assessment of the western pit face and a comparison to previous borrow test pit results completed by SRK at the Emerald Pit on a past project. Expansion of the borrow area may be preferential to deepening the existing borrow as it would reduce the potential for of pooling water, and a shallower borrow would be easier to regrade and reclaim once no longer needed.

Landfill Sand and Gravel Borrow

Figure 7 presents the LSGB screened particle size distributions compared to the filter gradation envelope. Removal of particle diameters greater than 25 mm results in one half of the particle size distributions meeting filter requirements. The suitable material is located on test pits SRK17-TP08, 12, 14 (to a depth of 0.5 m), and 15.

Figure 7 also provides and outline of the area where suitable filter material is available. Based on an assumed average excavation depth of 0.5 m within the current floor of the borrow area and 3 m within the face of the borrow area, an estimated volume of 4,300 m^3 is available. It is estimated that screening of this material would remove approximately 11% of the run-of-borrow material, resulting in approximately 3,900 m^3 of filter material. The results indicate the borrow area does not appear to contain sufficient volume for the filter. In addition, due to the variability of the material and presence of areas with high silt contents, use of this borrow area is not recommended.

4 HB Dam East Abutment Results

4.1 Field Results

The objectives the test pits near the east abutment of the HB Dam were to find bedrock, and to complete additional testing of the glaciolacustrine unit to verify previous test results completed in 2015 (Thurber 2016).

Five test pits were excavated near the east abutment, with an additional test pit (SRK17-TP-20) excavated downstream of the dam to collect the undisturbed glaciolacustrine sample (Figure 4). Test pits SRK17-TP-16, -17, and -21 encountered suspected bedrock near surface (within 0.2 m), with no bedrock encountered in the remaining test pits. In addition, two bedrock outcrops were observed at the locations noted in Figure 4.

4.2 Laboratory Results

4.2.1 Soil Index Test Results

Soil index test results for the samples collected from HB Dam East Abutment area are summarized in Table 4, with the particle size distribution curves provided in Figure 8. The glaciolacustrine sample is non-plastic and has a specific gravity of 2.72[2]. The complete laboratory test certificates are provided in Appendix C.

Table 4: East Abutment Soil Index Test Results

Sample ID	Depth (m)	Material Description	Water Content (%)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
SRK17-TP18-1	1.4 – 1.5	Till	7.2	35.8	32.6	24.6	7
SRK17-TP18-2	2.0 – 2.1	Till	16.2	7.8	33.3	41.3	17.6
SRK17-TP20-1	0.8 – 0.9	Glaciolacustrine	24.3	0	53	41	6

4.2.2 Consolidation

A one-dimensional consolidation test (ASTM D2435) was completed on the undisturbed glaciolacustrine sample with the complete results provided in Appendix C. Figure 9a plots a summary of the compression curve and coefficient of consolidation results. The coefficient of consolidation values was estimated using the square root fitting method as per ASTM D2435 (2011).

Figure 9a also provides a comparison with the previous test results completed by Thurber in 2015 (Thurber 2016). The compression curves of the two tests are similar, with the 2017 sample having lower void ratios. The pre-consolidation pressure of the 2017 sample is estimated to be approximately 500 kPa based on the Casagrande method (ASTM 2011).

[2] Specific gravity is the ratio of the density of the solids to the density of water.

The 2017 test result supports the Thurber (2016) conclusion that the glaciolacustrine material below the Dam remains in an overconsolidated condition, as the estimated stress within the glaciolacustrine silt and clay below the dam crest is approximately 300 kPa.

4.2.3 Strength Testing

Direct simple shear tests were completed on the undisturbed glaciolacustrine sample at initial confining stresses of 150kPa and 300 kPa. The laboratory test results are provided in Appendix C and are summarized in Figure 10.

Figure 10 also includes the two direct simple shear test results completed by Thurber (2016). Both laboratory programs were completed using the same test parameters and at the same laboratory[3]. The friction angles for the four tests range between 28 and 36°. The stress paths for each test indicates that the material is behaving as normally consolidated or lightly overconsolidated soil. This is evident due to the reduction in the effective vertical stress as the material is sheared (and increase in pore pressure) indicating the sample is contracting.

The test completed at a 150 kPa confining stress resulted in a similar friction angle as the Thurber test result, while the test completed at a confining stress of 300 kPA resulted in lower friction angle. The difference is suspected to be due to differences in the material consistency, as well as sample variability. The Thurber (2016) sample was described in the test pit log as a “firm to stiff, brown, moist silty clay” with medium plasticity (ML), while the 2017 glaciolacustrine sample is a non-plastic, dry, firm to hard, bedded sand with silt (SM).

[3] The friction angles reported in Figure 10 for the TP15-6 sample are slightly higher than reported in Thurber (2016). The Thurber results are believed to be angle α as opposed to Φ’.

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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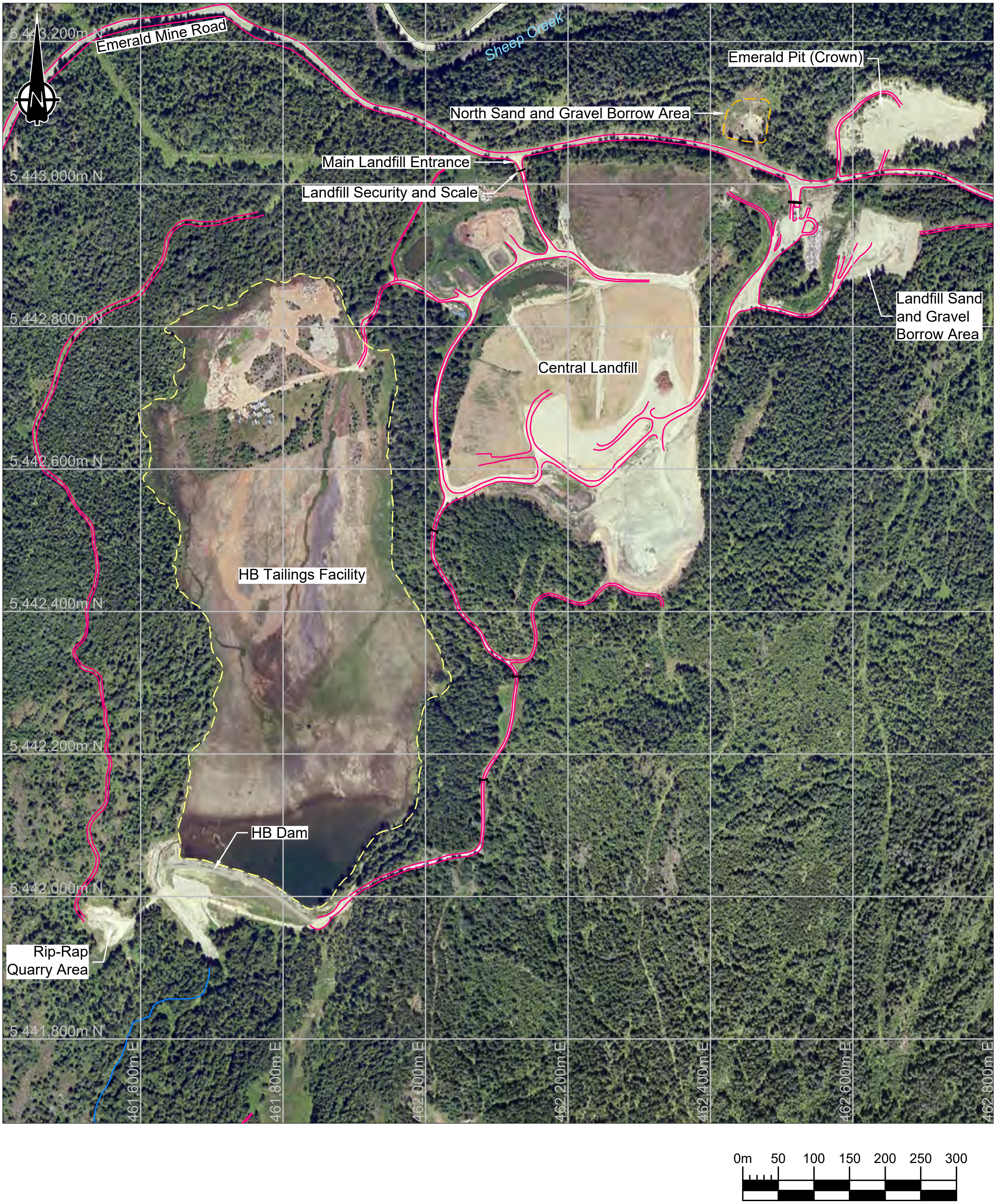
Figures



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REGIONAL DISTRICT CENTRAL KOOTENAY

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FILE NAME: 1CR012.004 - GA.dwg		General Arrangement
		DATE: February 2018
		APPROVED: PHM
		FIGURE: 1

LEGEND

Test Pit Location

0m 10 20 30 40

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FILE NAME: 1CR012.004 - TP locs.dwg

HB Mine Tailings Facility

2017 Borrow Investigation

Test Pit Locations
North Sand and Gravel Borrow Area

DATE: February 2018

APPROVED: PHM

FIGURE: 2

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LEGEND

Test Pit Location

0m 10 20 30 40

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HB Mine Tailings Facility

2017 Borrow Investigation

Test Pit Locations
Landfill Sand and Gravel Borrow Area

DATE:	APPROVED:	FIGURE:
February 2018	PHM	3

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NOTE

1. Spillway alignment obtained from the Preliminary Design Report (SRK 2017).

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HB Mine Tailings Facility

2017 Borrow Investigation

Test Pit Locations
HB Dam East Abutment

SRK JOB NO.:	1CR012.004	DATE: February 2018	APPROVED: PHM	FIGURE: 4
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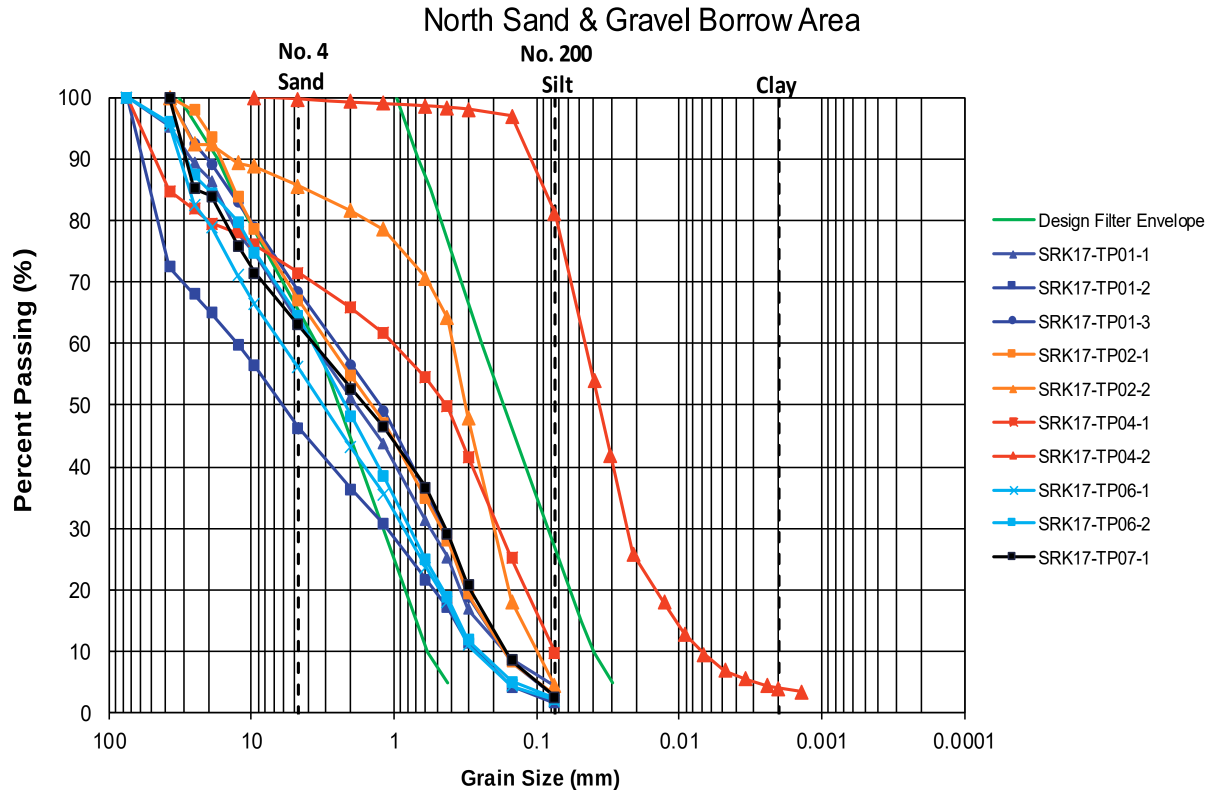

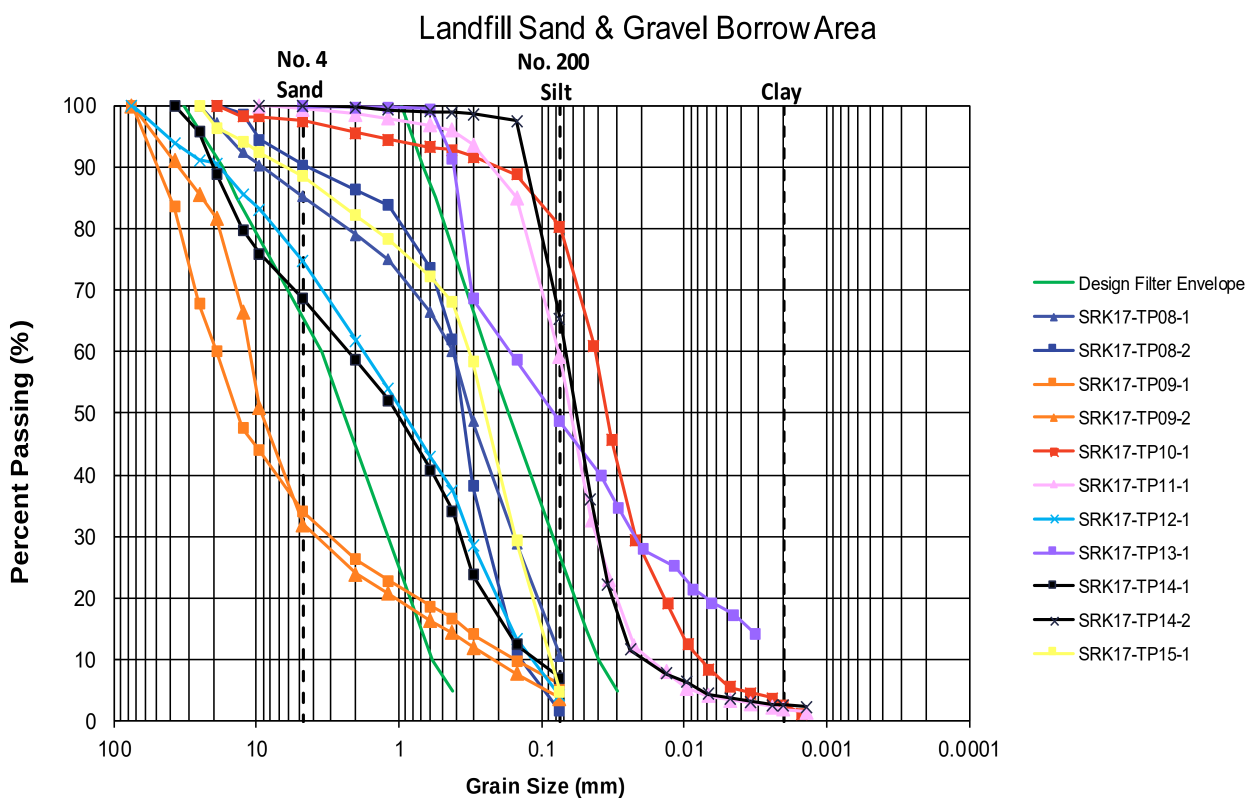

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REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

2017 Test Pit Investigation

Sand and Gravel Borrow Area Particle Size Distributions

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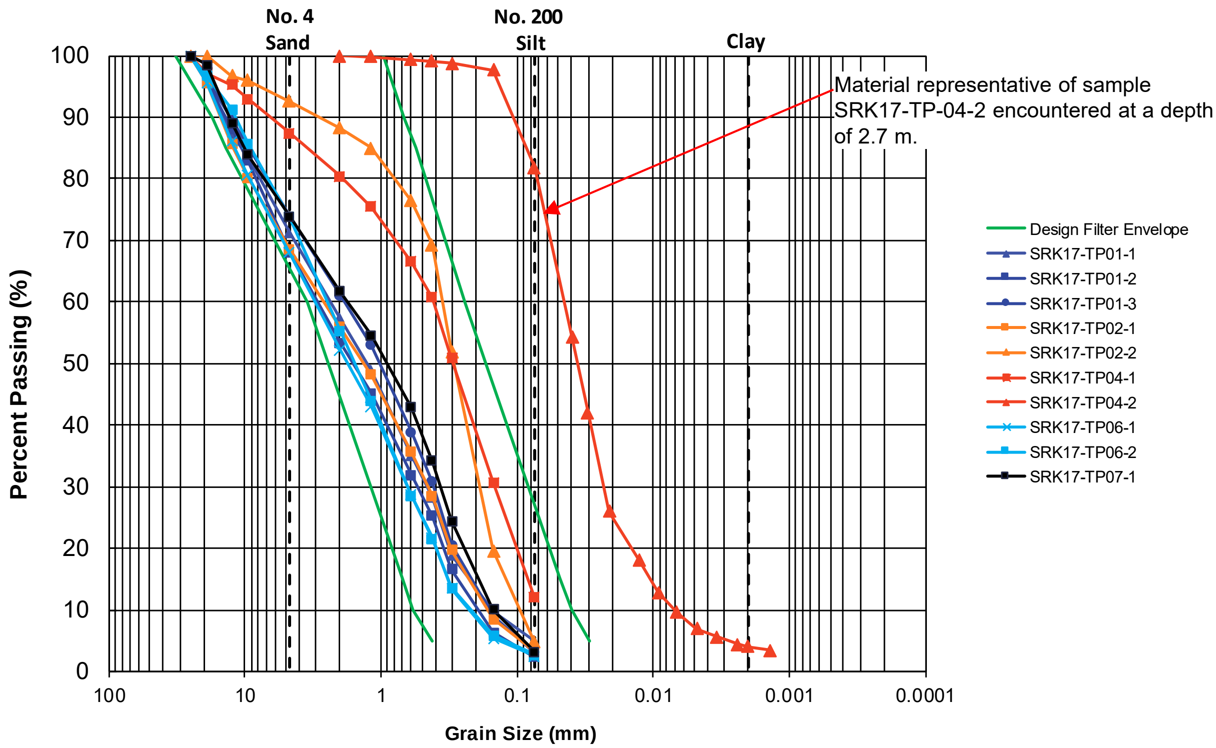
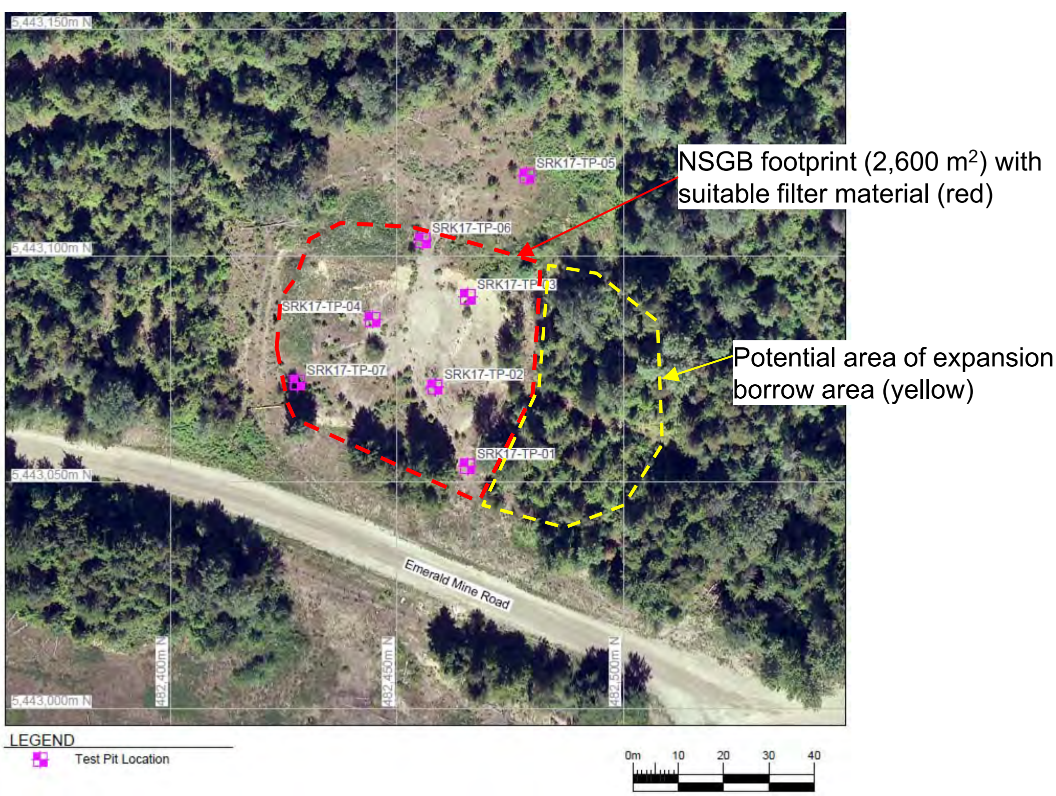
February 2018	phm	5

North Sand & Gravel Borrow Area - Screened @ 25 mm





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REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

2017 Test Pit Investigation

NSGB Screened Particle Size Distributions and Potential Development Area

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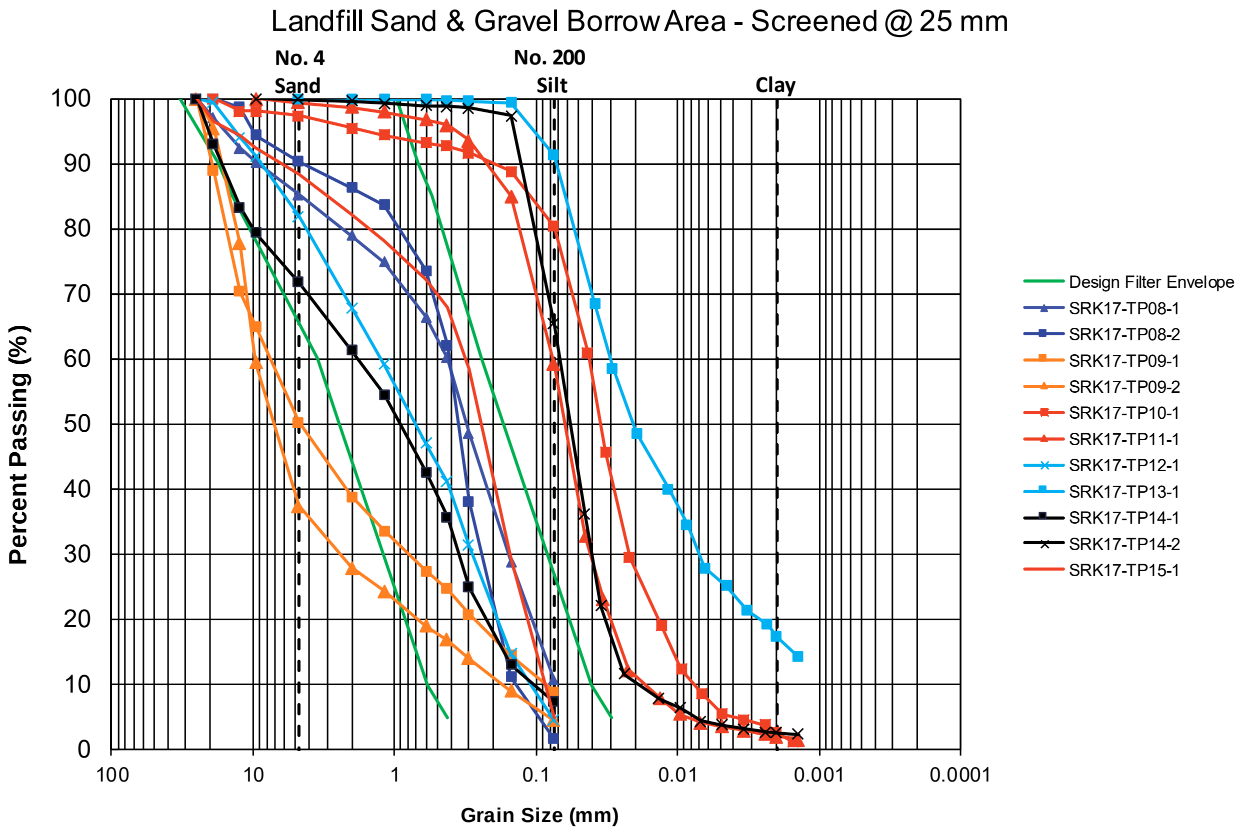

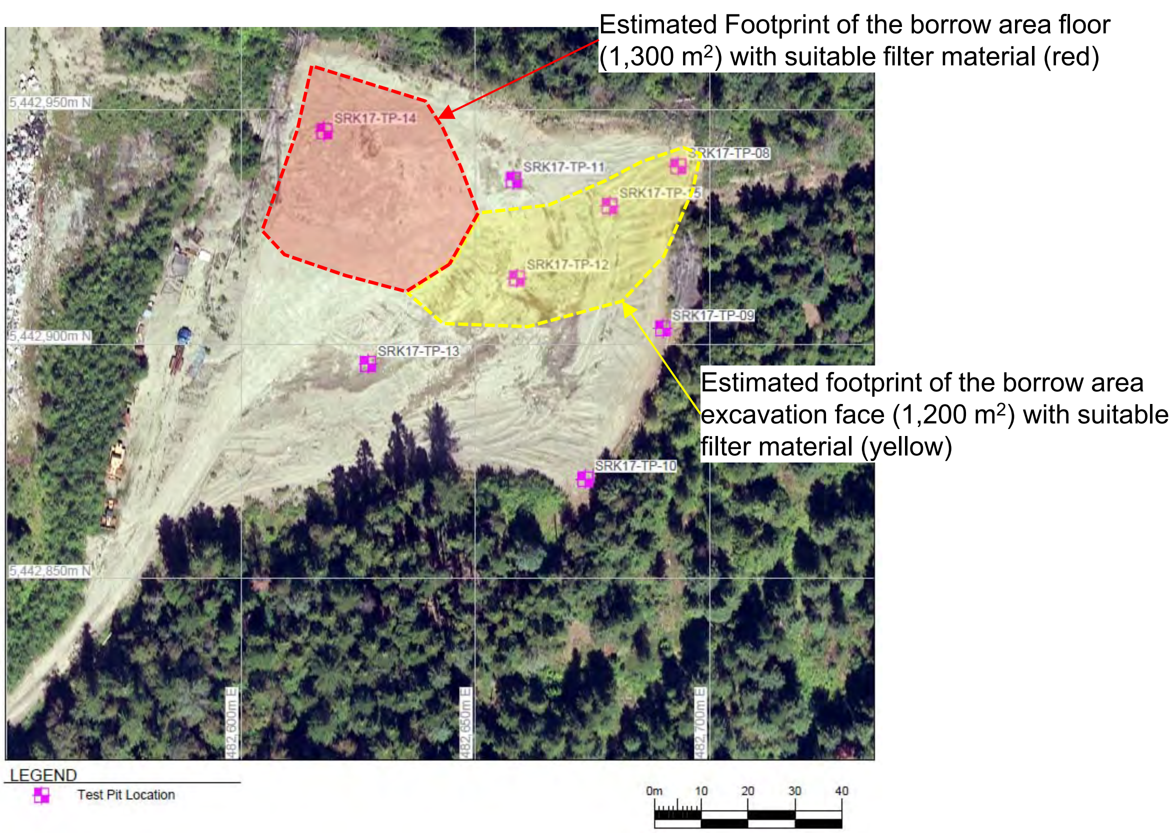

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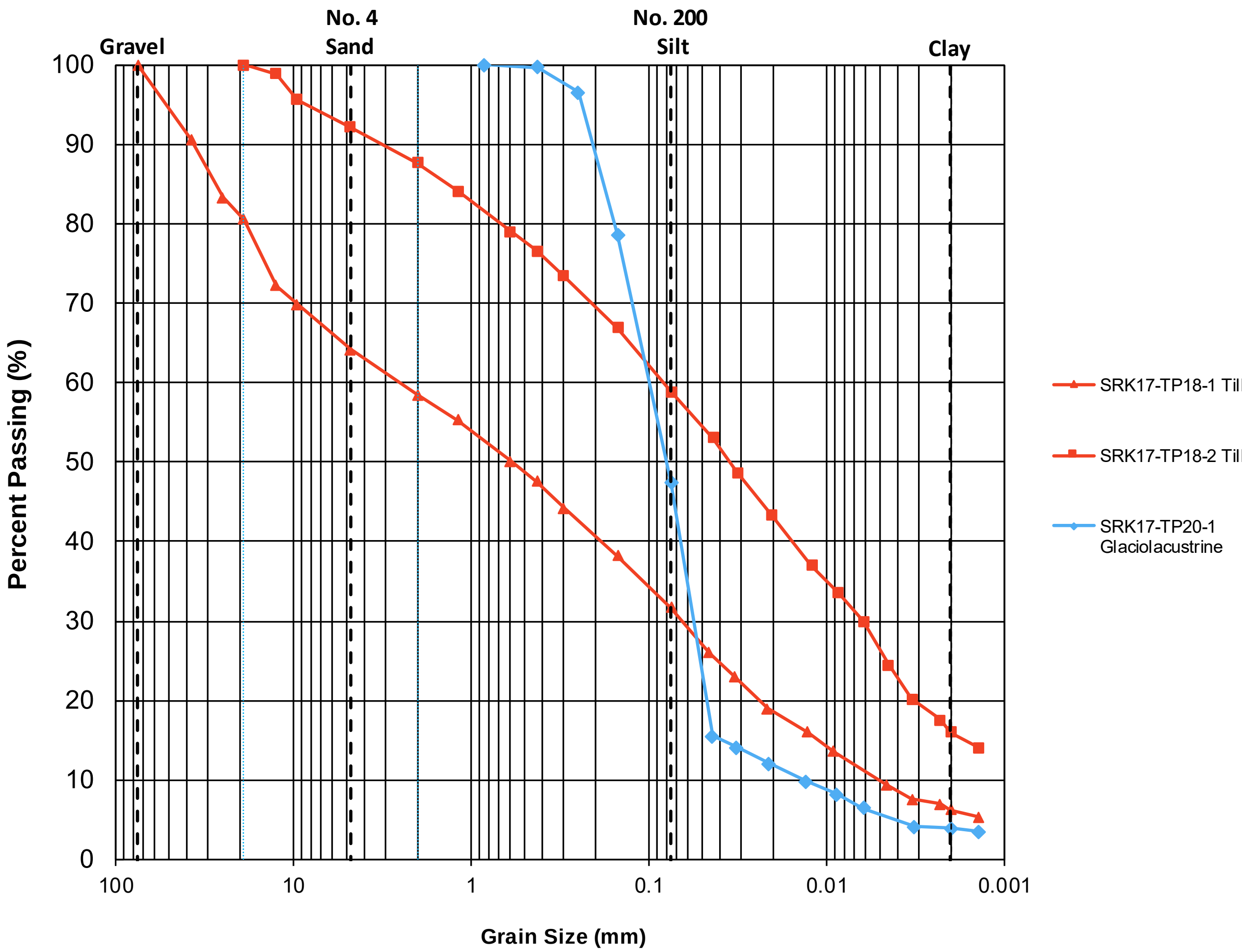
srk consulting

Job No: 1CR012.004.600 Filename: FigureHBTestPit_Portrait.pptx	HB Mine Tailings Facility	2017 Test Pit Investigation **LSGB Screened Particle Size Distributions and Potential Development Areas** Date: February 2018 / Approved: phm / Figure: 7



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srk consulting

Job No: 1CR012.004.600

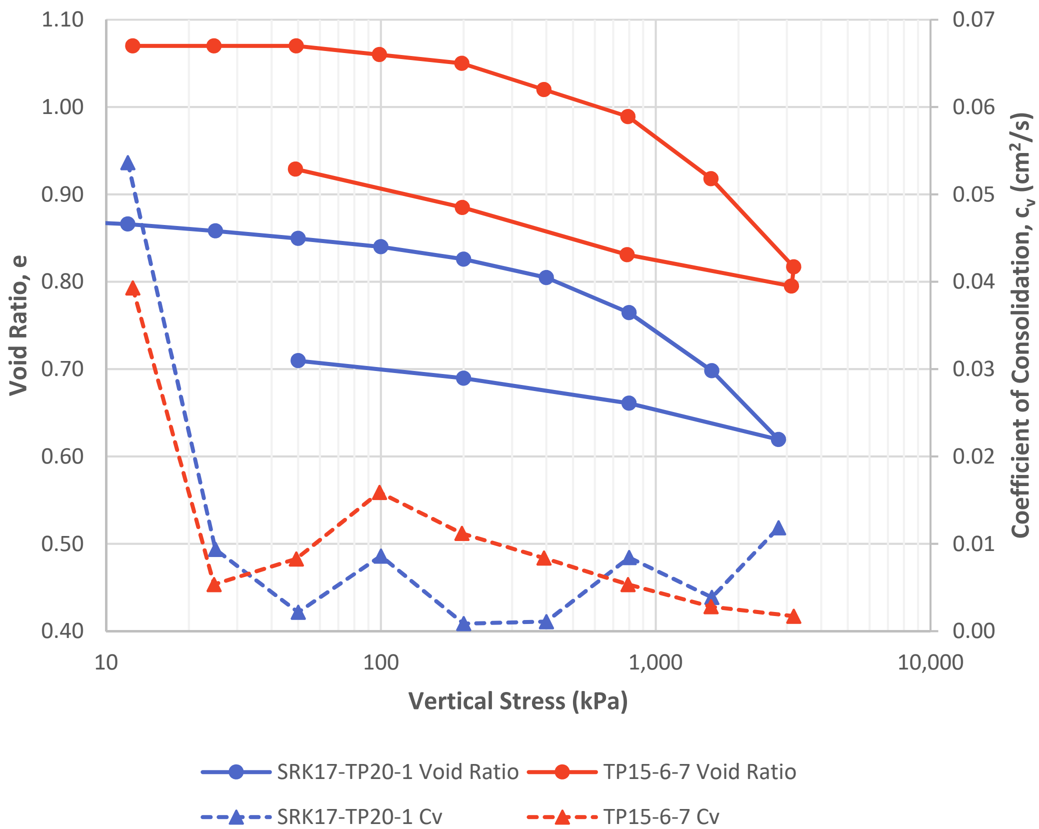
Filename: FigureHBTestPit_Portrait.pptx

HB Mine Tailings Facility

2017 Test Pit Investigation

East Dam Abutment Area
Particle Size Distributions

Date:	Approved:	Figure:
February 2018	phm	8



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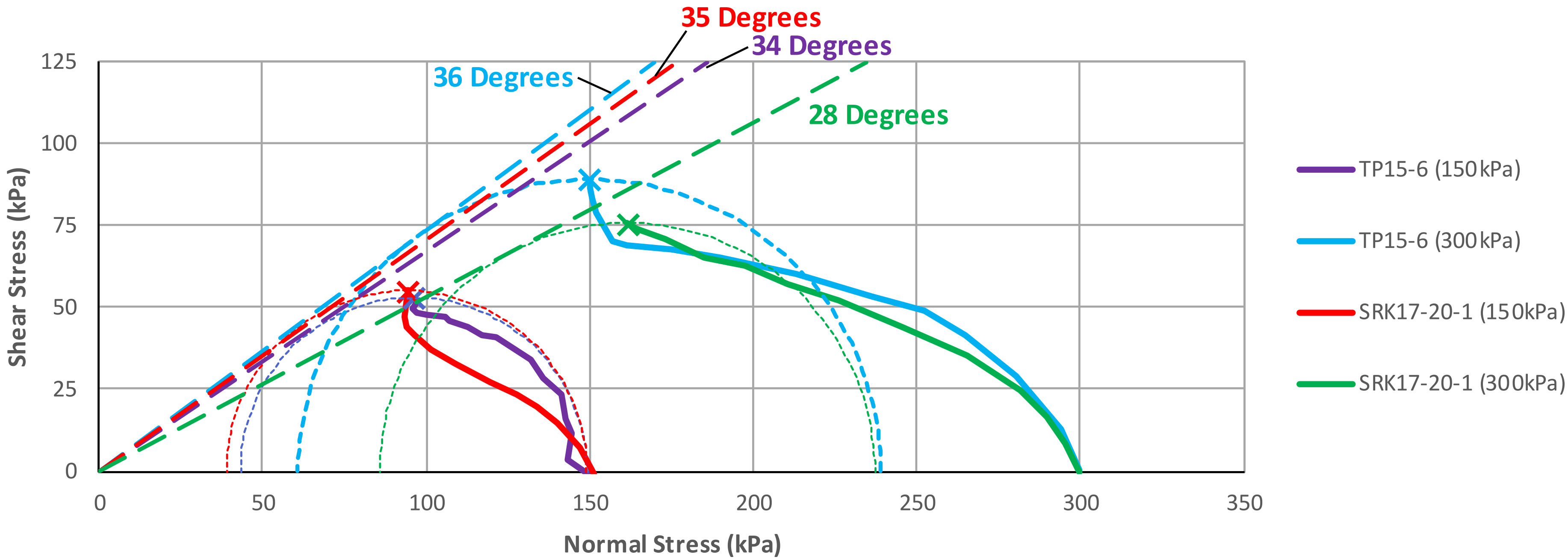
srk consulting		2017 Test Pit Investigation **Glaciolacustrine Consolidation Results**
Job No: 1CR012.004.600 Filename: FigureHBTestPit_Portrait.pptx	HB Mine Tailings Facility	Date: February 2018 · Approved: phm · Figure: **9**



Notes

1. TP15-6 test results were digitized from laboratory results provided in Thurber (2016)
2. The ‘X’ for each test denotes the point of maximum shear stress.

srk consulting

Job No: 1CR012.004.600	HB Mine Tailings Facility	2017 Test Pit Investigation
Filename: FigureHBTestPit_Landscape.pptx		**Glaciolacustrine Direct Simple Shear Test Results**
		Date: March 2018 / Approved: phm / Figure: **10**

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Appendix A – Test Pit Logs

SITE:	HB Mine Tailings Facility	HOLE ID:	**SRK17-TP-01**
PROJECT NO:	1CR012.004.600	LOCATION DESCRIPTION:	North S&G Borrow, SE corner crest
CONTRACTOR:	Custom Dozing		
EXCAVATOR:	John Deere 120C	COORDINATES:	482465.454 E 5443053.525 N
LOGGED BY:	P. Mikes	DATUM:	UTM Zone 11
DATE:	16-Nov-17	GROUND ELEV (m):	752.5
		TOTAL DEPTH (m):	3

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol: GW, GC, SM, CL, CH, GP, SW, SC, OL, OH, GM, SP, ML, MH, Fill

Sample Type: Grab, Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel, Sand, Silt, Clay, Fines (%) 0 20 40 60 80 100

Depth (m)	Symbol	Soil Description	Sample Type
0 – 0.2		ORGANICS, roots/grasses	
0.2 – 1.2		Poorly-graded SAND with gravel some silt, little organics at top of zone, moist, non-cohesive. Gravel rounded, trace of cobbles up to 20 cm.	
1.2 – 2.1		Poorly-graded GRAVEL with sand, some silt, moist, non-cohesive. Gravel rounded, trace of cobbles	SRK17-TP01-1 (1.4); SRK17-TP01-2 (2.0)
2.1 – 3.0		Poorly-graded SAND and GRAVEL, trace silt, light brown, dry, non-cohesive, massive. Material similar as above but dry, less gravel	SRK17-TP01-3 (2.9)

Test Pit Photograph

SITE:	HB Mine Tailings Facility
PROJECT NO:	1CR012.004.600
CONTRACTOR:	Custom Dozing
EXCAVATOR:	John Deere 120C
LOGGED BY:	P. Mikes
DATE:	16-Nov-17

HOLE ID:	**SRK17-TP-02**
LOCATION DESCRIPTION:	North S&G Borrow, SE corner floor
COORDINATES:	482458.257 E 5443071.037 N
DATUM:	UTM Zone 11
GROUND ELEV (m):	745
TOTAL DEPTH (m):	3.2

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol

GW, GC, SM, CL, CH
GP, SW, SC, OL, OH
GM, SP, ML, MH, Fill

Sample Type: Grab; Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content; Liquid Limit; Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel; Sand; Silt; Clay; Fines (%) 0 20 40 60 80 100

Depth (m)	Symbol	Soil Description	Sample Type	Tests Completed
0	SP	Poorly-graded SAND with gravel, brown, trace fines, moist, non-cohesive		
1		Material dry below 1m		
1.2			SRK17-TP02-1	
2		Few cobbles up to 20cm in diameter		
2.8	SP	Poorly-graded SAND, medium to fine, little gravel, brown, dry.		
3			SRK17-TP02-2	

Test Pit Photograph

SITE:	HB Mine Tailings Facility	HOLE ID:	**SRK17-TP-03**
PROJECT NO:	1CR012.004.600	LOCATION DESCRIPTION:	North S&G Borrow, NE corner floor
CONTRACTOR:	Custom Dozing	COORDINATES:	482465.54 E 5443090.92 N
EXCAVATOR:	John Deere 120C	DATUM:	UTM Zone 11
LOGGED BY:	P. Mikes	GROUND ELEV (m):	745
DATE:	16-Nov-17	TOTAL DEPTH (m):	2.8

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol: GW, GC, SM, CL, CH, GP, SW, SC, OL, OH, GM, SP, ML, MH, Fill

Sample Type: Grab, Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel, Sand, Silt, Clay, Fines (%) 0 20 40 60 80 100

Depth (m)	Symbol	Soil Description
0	SP	Poorly-graded GRAVEL with sand, brown, moist, some cobbles.
1		Material is more bony compared to last two holes, harder digging.
2		No sample was collected from this hole as the PSD result would likely be biased towards being finer.

Depth scale: 0, 0.2, 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6, 1.8, 2, 2.2, 2.4, 2.6

Test Pit Photograph

SITE:	HB Mine Tailings Facility	HOLE ID:	**SRK17-TP-04**
PROJECT NO:	1CR012.004.600	LOCATION DESCRIPTION:	North S&G Borrow, SW corner floor
CONTRACTOR:	Custom Dozing	COORDINATES:	482444.55 E 5443085.92 N
EXCAVATOR:	John Deere 120C	DATUM:	UTM Zone 11
LOGGED BY:	P. Mikes	GROUND ELEV (m):	745
DATE:	16-Nov-17	TOTAL DEPTH (m):	3.2

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol

GW GC SM CL CH
GP SW SC OL OH
GM SP ML MH Fill

Sample Type: Grab, Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel, Sand, Silt, Clay, Fines (%) 0 20 40 60 80 100

Depth (m)	Symbol	Soil Description	Sample Type	Tests Completed
0 – 2.7	SP	Poorly-graded SAND with gravel, little fines, light brown, dry, non-cohesive, massive. The excavator also dug into the face at the NE corner of the borrow - material was the sam as noted between 0 and 2.7m.	SRK17-TP04-1 (2.3–2.5)	
2.7 – 3.2	ML	SILT with sand. Fine sand, compact, non cohesive, massive. Hard digging.	SRK17-TP04-2 (3.0–3.2)	

Depth scale: 0, 0.2, 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6, 1.8, 2, 2.2, 2.4, 2.6, 2.8, 3

Test Pit Photograph

SITE:	HB Mine Tailings Facility
PROJECT NO:	1CR012.004.600
CONTRACTOR:	Custom Dozing
EXCAVATOR:	John Deere 120C
LOGGED BY:	P. Mikes
DATE:	16-Nov-17
HOLE ID:	**SRK17-TP-05**
LOCATION DESCRIPTION:	North S&G Borrow, NE of the borrow area
COORDINATES:	482478.648 E 5443117.576 N
DATUM:	UTM Zone 11
GROUND ELEV (m):	743.5
TOTAL DEPTH (m):	0.2

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol

GW GC SM CL CH
GP SW SC OL OH
GM SP ML MH Fill

Sample Type: Grab, Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel, Sand, Silt, Clay, Fines (%) 0 20 40 60 80 100

Depth (m)	Symbol	Soil Description	Sample Type	Tests Completed	Moisture Contents & Atterberg Limits	Particle Size Distribution
0 – 0.2 (0, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.11, 0.12, 0.13, 0.14, 0.15, 0.16, 0.17, 0.18, 0.19)	GW	Well graded GRAVEL with sand, orange, some cobbles and boulders. Hole abandoned as material is too coarse for use as filter material.				

Test Pit Photograph

SITE: HB Mine Tailings Facility
PROJECT NO: 1CR012.004.600
CONTRACTOR: Custom Dozing
EXCAVATOR: John Deere 120C
LOGGED BY: P. Mikes
DATE: 16-Nov-17

HOLE ID: **SRK17-TP-06**
LOCATION DESCRIPTION: North S&G Borrow, north of borrow area along road
COORDINATES: 482455.618 E 5443103.422 N
DATUM: UTM Zone 11
GROUND ELEV (m): 743
TOTAL DEPTH (m): 3.3

CLIENT: Regional District of Central Kootenay
PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol

GW, GC, SM, CL, CH, GP, SW, SC, OL, OH, GM, SP, ML, MH, Fill

Sample Type: Grab, Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel, Sand, Silt, Clay, Fines (%) 0 20 40 60 80 100

Depth (m)	Symbol	Soil Description	Sample Type
0 – 1.2	SP	Pooly-graded SAND and gravel, brown, moist, some cobbles (up to 25 cm) Material not as good compared to the south east corner of the pit	
1.2 – 2.5	SP	Poorly-graded SAND and gravel, brown, moist, trace cobbles Material getting better with depth, i.e. less coarse.	SRK17-TP06-1
2.5 – 3.3	SP	Poorly-graded SAND and gravel, brown, dry	SRK17-TP06-2

Test Pit Photograph

SITE:	HB Mine Tailings Facility	HOLE ID:	**SRK17-TP-07**
PROJECT NO:	1CR012.004.600	LOCATION DESCRIPTION:	North S&G Borrow, SW corner crest
CONTRACTOR:	Custom Dozing	COORDINATES:	482428.031 E 5443071.997 N
EXCAVATOR:	John Deere 120C	DATUM:	UTM Zone 11
LOGGED BY:	P. Mikes	GROUND ELEV (m):	748.5
DATE:	16-Nov-17	TOTAL DEPTH (m):	2.8

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol: GW, GC, SM, CL, CH, GP, SW, SC, OL, OH, GM, SP, ML, MH, Fill

Sample Type: Grab, Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel, Sand, Silt, Clay, Fines (%) 0 20 40 60 80 100

Depth (m)	Symbol	Soil Description	Sample Type	Tests Completed
0	ML	Sandy organic soil		
0.1 – 2.8	SP	Poorly-graded SAND with gravel, trace silt, light brown, dry, non-cohesive		
1.5 – 1.6			SRK17-TP07-1 (Grab)	

Depth scale: 0, 0.2, 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6, 1.8, 2, 2.2, 2.4, 2.6

Test Pit Photograph

SITE:	HB Mine Tailings Facility	HOLE ID:	**SRK17-TP-08**
PROJECT NO:	1CR012.004.600	LOCATION DESCRIPTION:	Landfill S&G Borrow, NE corner crest
CONTRACTOR:	Custom Dozing		
EXCAVATOR:	John Deere 120C	COORDINATES:	482693.349 E 5442937.898 N
LOGGED BY:	P. Mikes	DATUM:	UTM Zone 11
DATE:	16-Nov-17	GROUND ELEV (m):	798
		TOTAL DEPTH (m):	2.6

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol: GW, GC, SM, CL, CH, GP, SW, SC, OL, OH, GM, SP, ML, MH, Fill

Sample Type: Grab, Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel, Sand, Silt, Clay, Fines (%) 0 20 40 60 80 100

Depth (m)	Soil Description	Sample
0 – 1.0	Poorly-graded GRAVEL with sand (~30%), brown, moist. Gravel rounded trace fo cobbles up to 30 cm diameter.	
1.0 – 1.6	Poorly-graded SAND with gravel (~15%) and trace silt, light brown, dry	SRK17-TP08-1 (~1.25)
1.6 – 2.6	Poorly-graded SAND with silt, trace gravel. Fine to medium sand, non cohesive, dry.	
~2.25	Clean sand layer not holding up in the hole - lots of sloughing	SRK17-TP08-2 (~2.25)

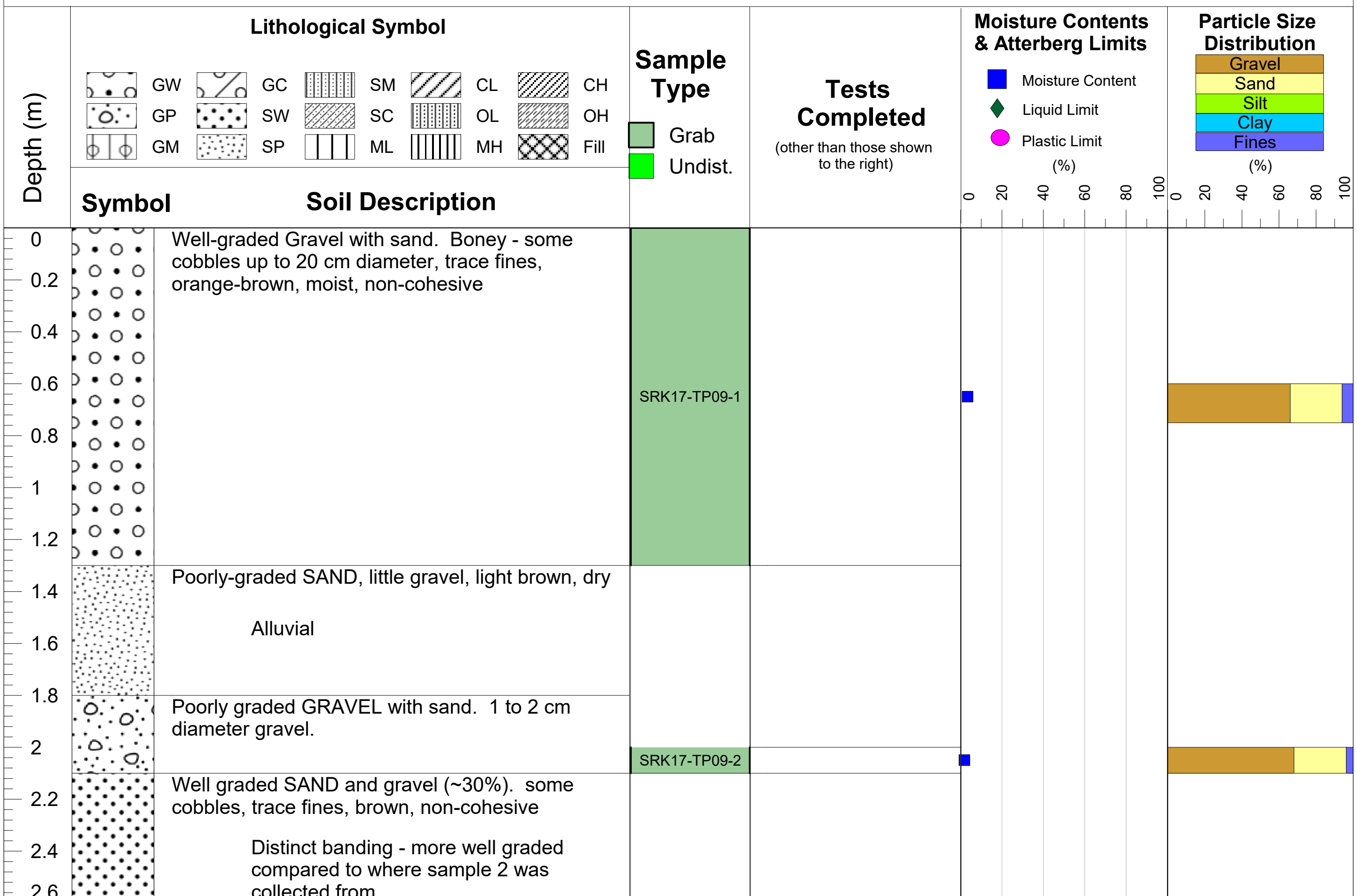
Depth (m): 0, 0.2, 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6, 1.8, 2, 2.2, 2.4, 2.6

Test Pit Photograph

SITE:	HB Mine Tailings Facility
PROJECT NO:	1CR012.004.600
CONTRACTOR:	Custom Dozing
EXCAVATOR:	John Deere 120C
LOGGED BY:	P. Mikes
DATE:	16-Nov-17
HOLE ID:	SRK17-TP-09
LOCATION DESCRIPTION:	Landfill S&G Borrow, middle crest
COORDINATES:	482689.99 E 5442903.354 N
DATUM:	UTM Zone 11
GROUND ELEV (m):	798
TOTAL DEPTH (m):	2.6

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program



Test Pit Photograph

SITE:	HB Mine Tailings Facility	HOLE ID:	**SRK17-TP-10**
PROJECT NO:	1CR012.004.600	LOCATION DESCRIPTION:	Landfill S&G Borrow, SE corner crest
CONTRACTOR:	Custom Dozing		
EXCAVATOR:	John Deere 120C	COORDINATES:	482673.438 E 5442871.209 N
LOGGED BY:	P. Mikes	DATUM:	UTM Zone 11
DATE:	16-Nov-17	GROUND ELEV (m):	797.5
		TOTAL DEPTH (m):	2.8

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol

GW GC SM CL CH
GP SW SC OL OH
GM SP ML MH Fill

Sample Type: Grab; Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content; Liquid Limit; Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel; Sand; Silt; Clay; Fines (%) 0 20 40 60 80 100

Depth (m)	Symbol	Soil Description	Sample Type	Tests Completed
0 – 0.8	SP	Poorly-graded SAND and gravel (~40%). Boney - some cobbles up to 20cm diameter, trace fines, orange-brown, moist, non-cohesive		
0.8 – 1.2	SP	Poorly-graded SAND, little gravel, light brown, dry, non-cohesive		
1.2 – 2.8	ML	SILT with sand, light brown, non-cohesive, dry. Sand is fine to medium.	SRK17-TP10-1 (at ~1.6 m)	
2.8		Hole ended at 2.8 due to excessive sloughing of the fine sand.		

Test Pit Photograph

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

SITE:	HB Mine Tailings Facility	HOLE ID:	**SRK17-TP-11**
PROJECT NO:	1CR012.004.600	LOCATION DESCRIPTION:	Landfill S&G Borrow, NE corner floor
CONTRACTOR:	Custom Dozing	COORDINATES:	482658.325 E 5442935.02 N
EXCAVATOR:	John Deere 120C	DATUM:	UTM Zone 11
LOGGED BY:	P. Mikes	GROUND ELEV (m):	783
DATE:	16-Nov-17	TOTAL DEPTH (m):	2

Lithological Symbol

GW GC SM CL CH
GP SW SC OL OH
GM SP ML MH Fill

Sample Type: Grab; Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content; Liquid Limit; Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel; Sand; Silt; Clay; Fines (%) 0 20 40 60 80 100

Depth (m)	Symbol	Soil Description	Sample Type	Tests Completed
0 – 2	ML	SILT with sand, light brown, sand is fine to medium grained, dry, non-cohesive	SRK17-TP11-1 (Grab, 0.3–0.5)	

Depth (m): 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9

Test Pit Photograph

SITE:	HB Mine Tailings Facility	HOLE ID:	**SRK17-TP-12**
PROJECT NO:	1CR012.004.600	LOCATION DESCRIPTION:	Landfill S&G Borrow, mid-east floor
CONTRACTOR:	Custom Dozing		
EXCAVATOR:	John Deere 120C	COORDINATES:	482659.045 E 5442914.149 N
LOGGED BY:	P. Mikes	DATUM:	UTM Zone 11
DATE:	16-Nov-17	GROUND ELEV (m):	783.5
		TOTAL DEPTH (m):	1.7

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol: GW, GC, SM, CL, CH, GP, SW, SC, OL, OH, GM, SP, ML, MH, Fill

Sample Type: Grab, Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel, Sand, Silt, Clay, Fines (%) 0 20 40 60 80 100

Depth (m)	Symbol	Soil Description	Sample Type	Tests Completed
0 – 0.1	SP	Poorly-graded SAND with gravel, trace silt, light brown, dry, non-cohesive	SRK17-TP12-1	
0.3 – 0.5		Sample for this hole was collected approximetely 3 m up from the borrow floor, material same as that described for hole.		
1.6 – 1.7		Bedrock? Excavator hitting rocks, unable to advance		

Depth scale (m): 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6

Test Pit Photograph

SITE:	HB Mine Tailings Facility	HOLE ID:	SRK17-TP-13
PROJECT NO:	1CR012.004.600	LOCATION DESCRIPTION:	Landfill S&G Borrow, SE corner floor
CONTRACTOR:	Custom Dozing		
EXCAVATOR:	John Deere 120C	COORDINATES:	482627.101 E 5442895.799 N
LOGGED BY:	P. Mikes	DATUM:	UTM Zone 11
DATE:	16-Nov-17	GROUND ELEV (m):	781
		TOTAL DEPTH (m):	2

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol: GW, GC, SM, CL, CH, GP, SW, SC, OL, OH, GM, SP, ML, MH, Fill

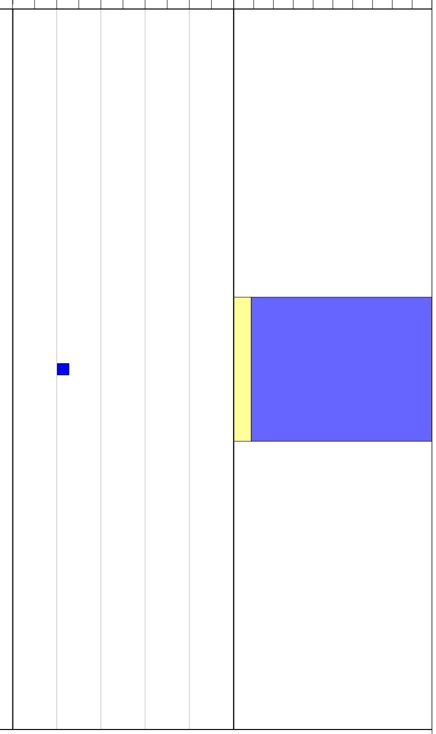
Sample Type: Grab, Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content, Liquid Limit, Plastic Limit (%)

Particle Size Distribution: Gravel, Sand, Silt, Clay, Fines (%)

Depth (m)	Symbol	Soil Description	Sample
0	ML	SILT, some sand, firm, brown with some grey banding, moist, low plasticity.	Grab
1			SRK17-TP13-1
1.9		Hold ended at 2 m as material is likely too fine for use as filter material at dam.	



Test Pit Photograph

SITE:	HB Mine Tailings Facility	HOLE ID:	**SRK17-TP-14**
PROJECT NO:	1CR012.004.600	LOCATION DESCRIPTION:	Landfill S&G Borrow, NW corner floor
CONTRACTOR:	Custom Dozing		
EXCAVATOR:	John Deere 120C	COORDINATES:	482617.85 E 5442945.424 N
LOGGED BY:	P. Mikes	DATUM:	UTM Zone 11
DATE:	16-Nov-17	GROUND ELEV (m):	778.5
		TOTAL DEPTH (m):	3

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol

GW GC SM CL CH
GP SW SC OL OH
GM SP ML MH Fill

Sample Type: Grab, Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel, Sand, Silt, Clay, Fines (%) 0 20 40 60 80 100

Depth (m)	Symbol	Soil Description	Sample Type	Tests Completed
0 – 0.5	SP	Poorly-graded SAND with silt and gravel, brown, damp, non-cohesive.	SRK17-TP14-1	
0.5 – 3	ML	Sandy SILT, sand is fine-grained, brown, non-cohesive.	SRK17-TP14-2 (1.0 – 1.2)	
		Wet near the bottom of the hole, sloughing.		

Depth scale: 0, 0.2, 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6, 1.8, 2, 2.2, 2.4, 2.6, 2.8

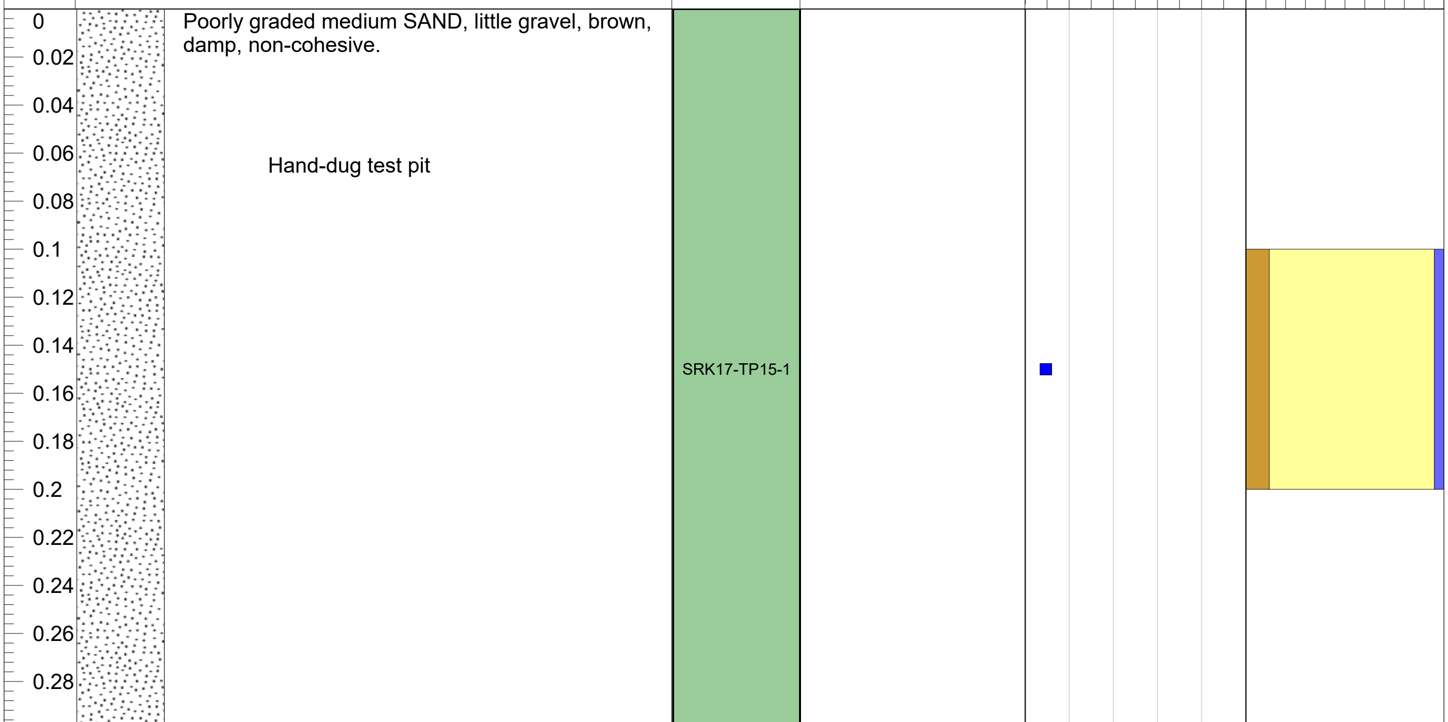
Test Pit Photograph

SITE:	HB Mine Tailings Facility	HOLE ID:	**SRK17-TP-15**
PROJECT NO:	1CR012.004.600	LOCATION DESCRIPTION:	Landfill S&G Borrow, mid-slope north end
CONTRACTOR:	Custom Dozing	COORDINATES:	482678.67 E 5442929.48 N
EXCAVATOR:	John Deere 120C	DATUM:	UTM Zone 11
LOGGED BY:	P. Mikes	GROUND ELEV (m):	792
DATE:	16-Nov-17	TOTAL DEPTH (m):	0.3

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Depth (m)	Lithological Symbol: GW, GP, GM, GC, SW, SP, SM, SC, ML, CL, OL, MH, CH, OH, Fill — Symbol / Soil Description	Sample Type: Grab, Undist.	Tests Completed (other than those shown to the right)	Moisture Contents & Atterberg Limits: Moisture Content, Liquid Limit, Plastic Limit (%)	Particle Size Distribution: Gravel, Sand, Silt, Clay, Fines (%)
0 – 0.3	Poorly graded medium SAND, little gravel, brown, damp, non-cohesive. Hand-dug test pit	SRK17-TP15-1			



Test Pit Photograph

SITE: HB Mine Tailings Facility
PROJECT NO: 1CR012.004.600
CONTRACTOR: Custom Dozing
EXCAVATOR: John Deere 120C
LOGGED BY: P. Mikes
DATE: 16-Nov-17

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

HOLE ID: **SRK17-TP-16**
LOCATION DESCRIPTION: Approx. 50 m east of dam, near control point 6785
COORDINATES: 481886.178 E 5441959.07 N
DATUM: UTM Zone 11
GROUND ELEV (m): 718
TOTAL DEPTH (m): 0.2

Lithological Symbol

GW, GC, SM, CL, CH
GP, SW, SC, OL, OH
GM, SP, ML, MH, Fill

Sample Type
Grab
Undist.

Tests Completed
(other than those shown to the right)

Moisture Contents & Atterberg Limits
Moisture Content
Liquid Limit
Plastic Limit
(%)
0 20 40 60 80 100

Particle Size Distribution
Gravel
Sand
Silt
Clay
Fines
(%)
0 20 40 60 80 100

Depth (m)	Symbol	Soil Description	Sample Type	Tests Completed	Moisture Contents & Atterberg Limits	Particle Size Distribution
0	SM	Organic soil - silty SAND with gravel				
0.01						
0.02						
0.03						
0.04						
0.05						
0.06						
0.07						
0.08						
0.09						
0.1						
0.11						
0.12						
0.13						
0.14						
0.15						
0.16						
0.17						
0.18		Excavator unable to advance - rocks				
0.19						
		Weathered bedrock?				

Test Pit Photograph

SITE: HB Mine Tailings Facility
PROJECT NO: 1CR012.004.600
CONTRACTOR: Custom Dozing
EXCAVATOR: John Deere 120C
LOGGED BY: P. Mikes
DATE: 16-Nov-17

HOLE ID: **SRK17-TP-17**
LOCATION DESCRIPTION: Approx. 25m east of dam along centerlin, near where 'old ditch" goes into woods.
COORDINATES: 481857.341 E 5441952.381 N
DATUM: UTM Zone 11
GROUND ELEV (m): 712.5
TOTAL DEPTH (m): 0.3

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol: GW, GC, SM, CL, CH, GP, SW, SC, OL, OH, GM, SP, ML, MH, Fill

Sample Type: Grab, Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel, Sand, Silt, Clay, Fines (%) 0 20 40 60 80 100

Depth (m)	Symbol	Soil Description	Sample Type	Tests Completed
0 – 0.2	SM	Silty SAND with gravel, some organics, brown, moist Excavator unable to advance - rocks		
0.2		Weathered bedrock?		

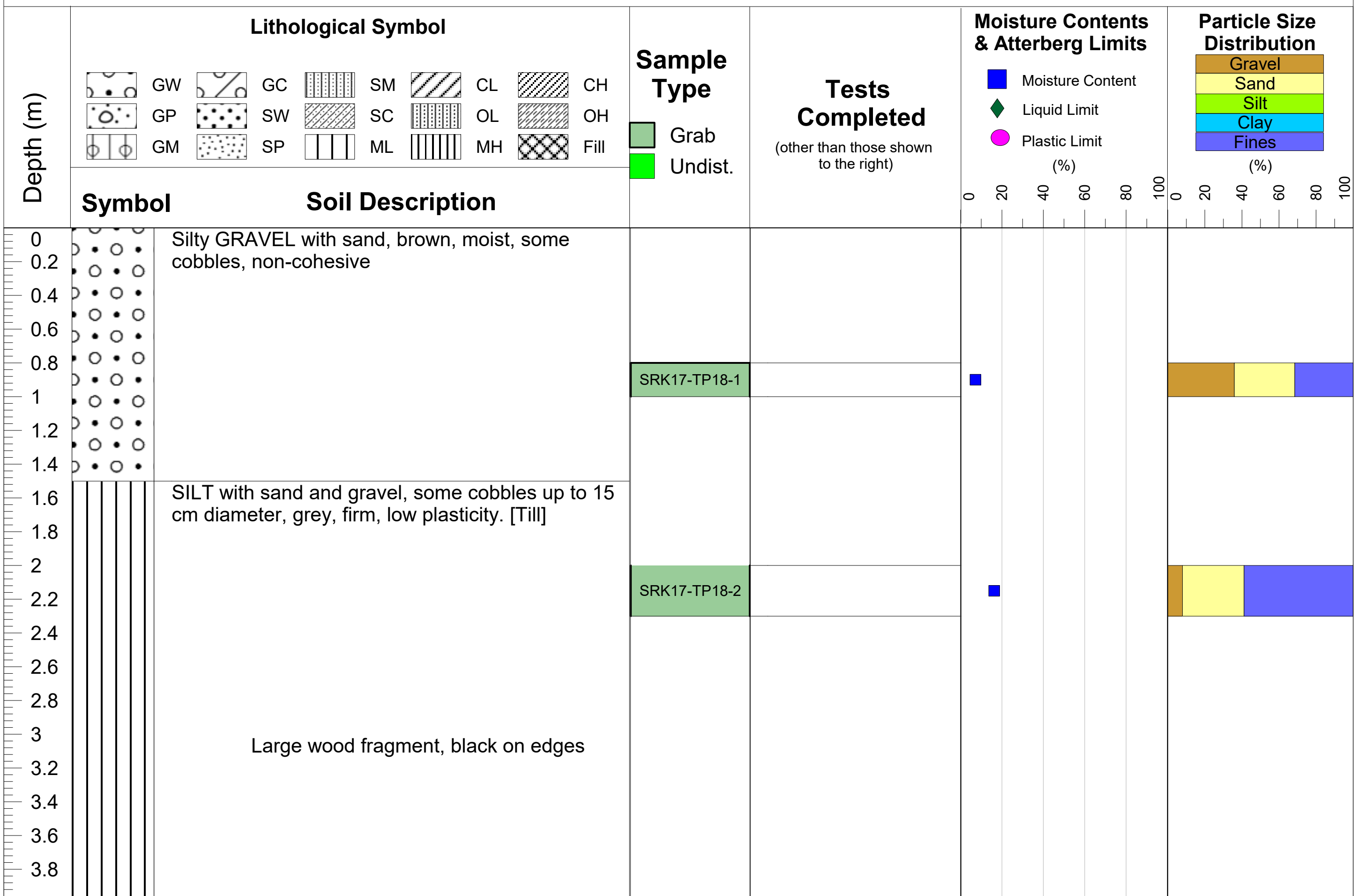
Depth scale: 0, 0.02, 0.04, 0.06, 0.08, 0.1, 0.12, 0.14, 0.16, 0.18, 0.2, 0.22, 0.24, 0.26, 0.28

Test Pit Photograph

SITE:	HB Mine Tailings Facility	HOLE ID:	**SRK17-TP-18**
PROJECT NO:	1CR012.004.600	LOCATION DESCRIPTION:	East abutment; on turnaroud side of barricade near the ditch
CONTRACTOR:	Custom Dozing	COORDINATES:	481840.674 E 5441951.892 N
EXCAVATOR:	John Deere 120C	DATUM:	UTM Zone 11
LOGGED BY:	P. Mikes	GROUND ELEV (m):	711
DATE:	16-Nov-17	TOTAL DEPTH (m):	4

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program



Test Pit Photograph

SITE:	HB Mine Tailings Facility
PROJECT NO:	1CR012.004.600
CONTRACTOR:	Custom Dozing
EXCAVATOR:	John Deere 120C
LOGGED BY:	P. Mikes
DATE:	17-Nov-17

HOLE ID:	**SRK17-TP-19**
LOCATION DESCRIPTION:	East abutment near the pump location
COORDINATES:	481853.304 E 5441978.852 N
DATUM:	UTM Zone 11
GROUND ELEV (m):	710
TOTAL DEPTH (m):	2

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol: GW, GC, SM, CL, CH, GP, SW, SC, OL, OH, GM, SP, ML, MH, Fill

Sample Type: Grab, Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel, Sand, Silt, Clay, Fines (%) 0 20 40 60 80 100

Depth (m)	Symbol	Soil Description	Sample Type	Tests Completed
0 – 0.95	GP	Silty GRAVEL with sand, some cobbles up to 15 cm diameter, brown, moist. [Fill]		
0.95 – 2	ML	SILT with sand and gravel, little cobbles, grey, low plasticity [Till] Woody debris - original ground surface, some organics Excavator unable to proceed due to steepness of road and engineer's decision not to further disturb the road area due to the proximety to the pump and dam.		

Test Pit Photograph

SITE: HB Mine Tailings Facility

PROJECT NO: 1CR012.004.600

CONTRACTOR: Custom Dozing

EXCAVATOR: John Deere 120C

LOGGED BY: P. Mikes

DATE: 17-Nov-17

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

HOLE ID: **SRK17-TP-20**

LOCATION DESCRIPTION: Near proposed east spillway, approx. 8m south of 'gulley' along road to stilling basin

COORDINATES: 481792.017 E 5441928.437 N

DATUM: UTM Zone 11

GROUND ELEV (m): 701.5

TOTAL DEPTH (m): 4.3

Lithological Symbol: GW, GC, SM, CL, CH, GP, SW, SC, OL, OH, GM, SP, ML, MH, Fill

Sample Type: Grab, Undist.

Moisture Contents & Atterberg Limits (%): Moisture Content, Liquid Limit, Plastic Limit

Particle Size Distribution (%): Gravel, Sand, Silt, Clay, Fines

Depth (m)	Symbol	Soil Description	Sample Type	Tests Completed (other than those shown to the right)
0 – 0.6	ML	Sandy SILT with gravel, brown, moist, cohesive, non plastic.		
0.6 – 4.3	ML	SILT and SAND, grey, cohesive, non-plastic, dry, bedded. [Lacustrine]	SRK17-TP20-1 (Undist., at 0.85)	Specific gravity (2.72); 1D consolidation; direct shear (@150kPa and 300kPa)

Test Pit Photograph

SITE:	HB Mine Tailings Facility	HOLE ID:	**SRK17-TP-21**
PROJECT NO:	1CR012.004.600	LOCATION DESCRIPTION:	East abutment area, up the bank, south of the dam.
CONTRACTOR:	Custom Dozing		
EXCAVATOR:	John Deere 120C	COORDINATES:	481851.844 E 5441940.588 N
LOGGED BY:	P. Mikes	DATUM:	UTM Zone 11
DATE:	17-Nov-17	GROUND ELEV (m):	714
		TOTAL DEPTH (m):	0.2

CLIENT: Regional District of Central Kootenay

PROJECT: 2017 Borrow and East Abut. Test Pit Program

Lithological Symbol: GW, GC, SM, CL, CH, GP, SW, SC, OL, OH, GM, SP, ML, MH, Fill

Sample Type: Grab, Undist.

Tests Completed (other than those shown to the right)

Moisture Contents & Atterberg Limits: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

Particle Size Distribution: Gravel, Sand, Silt, Clay, Fines (%) 0 20 40 60 80 100

Depth (m)	Symbol	Soil Description	Sample Type	Tests Completed
0 – 0.19	SM	Organic soil - silty SAND and gravel, broken angular rock		
0.2		Weathered bedrock?		

Depth scale: 0, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.11, 0.12, 0.13, 0.14, 0.15, 0.16, 0.17, 0.18, 0.19

Test Pit Photograph

Appendix B – Sand and Gravel Test Results

PHONE: 250-489-1940 FAX: 250-489-1667 EMAIL: info@artechconsulting.ca
229 Industrial Rd F, Cranbrook, BC V1C 6N4 www.artechconsulting.ca

ARTECH
CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18001

Client Project: HB Tailings Facility

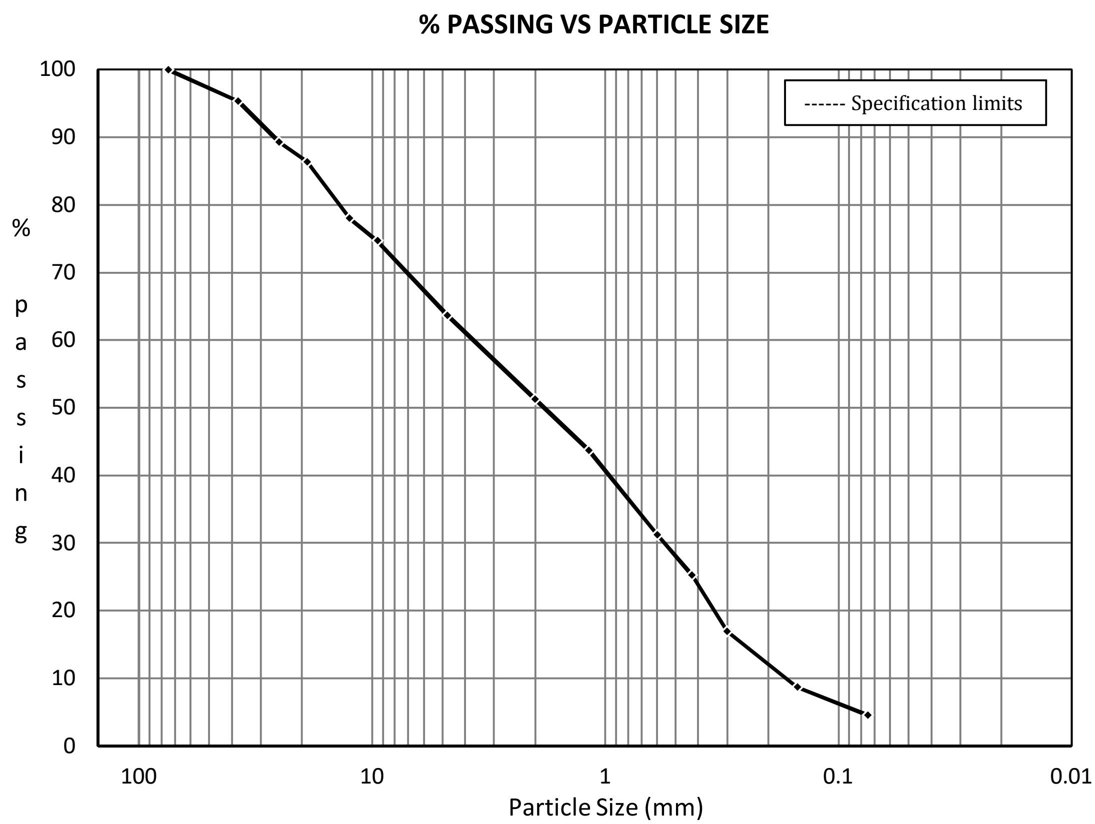
Date Received: January 8, 2018

Sample Description: GRAVEL and SAND, trace silt/clay
Sample ID: SRK17-TP01-1
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0	100.0	
37.5	95.3	
25.0	89.3	
19.0	86.4	
12.5	78.0	
9.5	74.7	
4.75	63.6	
2.00	51.2	
1.18	43.7	
0.600	31.3	
0.425	25.3	
0.300	16.9	
0.150	8.7	
0.075	4.5	



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	36.4 %
Sand :	< 4.75mm and > 0.075mm	59.1 %
Silt/Clay :	< 0.075mm	4.5 %

Moisture Content: 5.0%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:
Bryan Morrison, BSc.

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229 Industrial Rd F, Cranbrook, BC V1C 6N4 www.artechconsulting.ca

ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18002
Client Project: HB Tailings Facility
Date Received: January 8, 2018

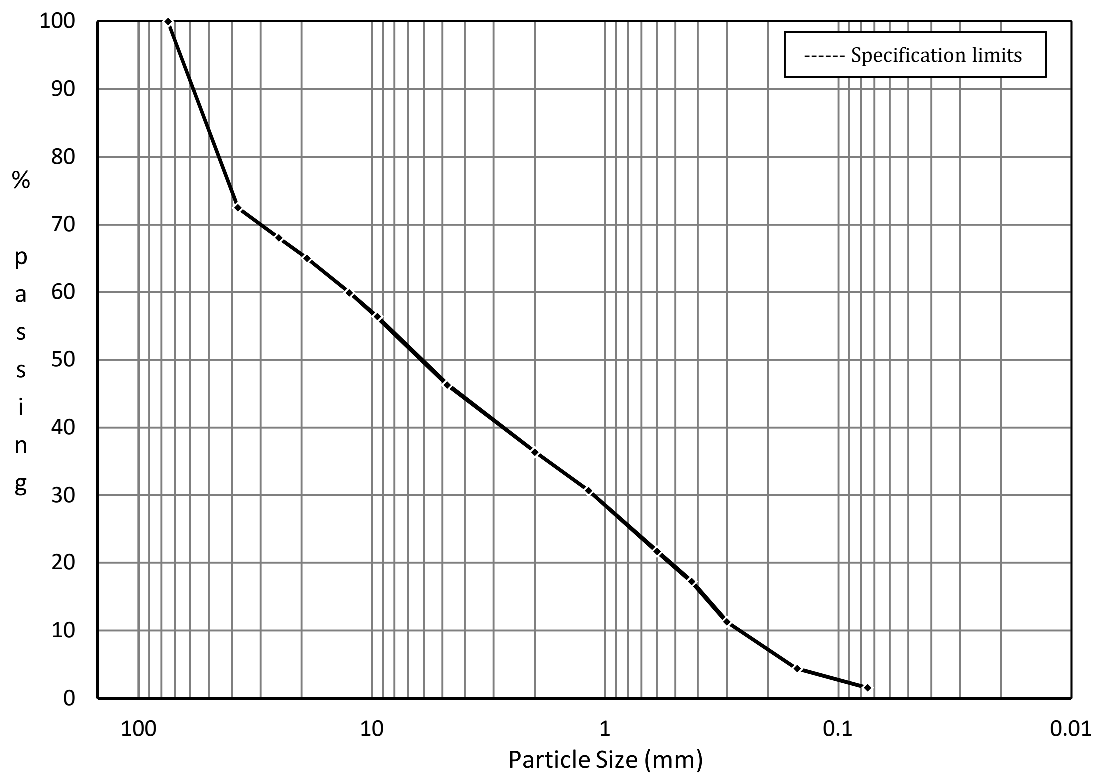
Sample Description: GRAVEL and SAND, trace silt/clay
Sample ID: SRK17-TP01-2
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0	100.0	
37.5	72.4	
25.0	68.0	
19.0	65.0	
12.5	59.9	
9.5	56.4	
4.75	46.3	
2.00	36.3	
1.18	30.7	
0.600	21.7	
0.425	17.2	
0.300	11.3	
0.150	4.3	
0.075	1.6	

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	53.7 %
Sand :	< 4.75mm and > 0.075mm	44.7 %
Silt/Clay :	< 0.075mm	1.6 %

Moisture Content: 1.1%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:

Bryan Morrison, BSc.

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ARTECH
CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18003

Client Project: HB Tailings Facility

Date Received: January 8, 2018

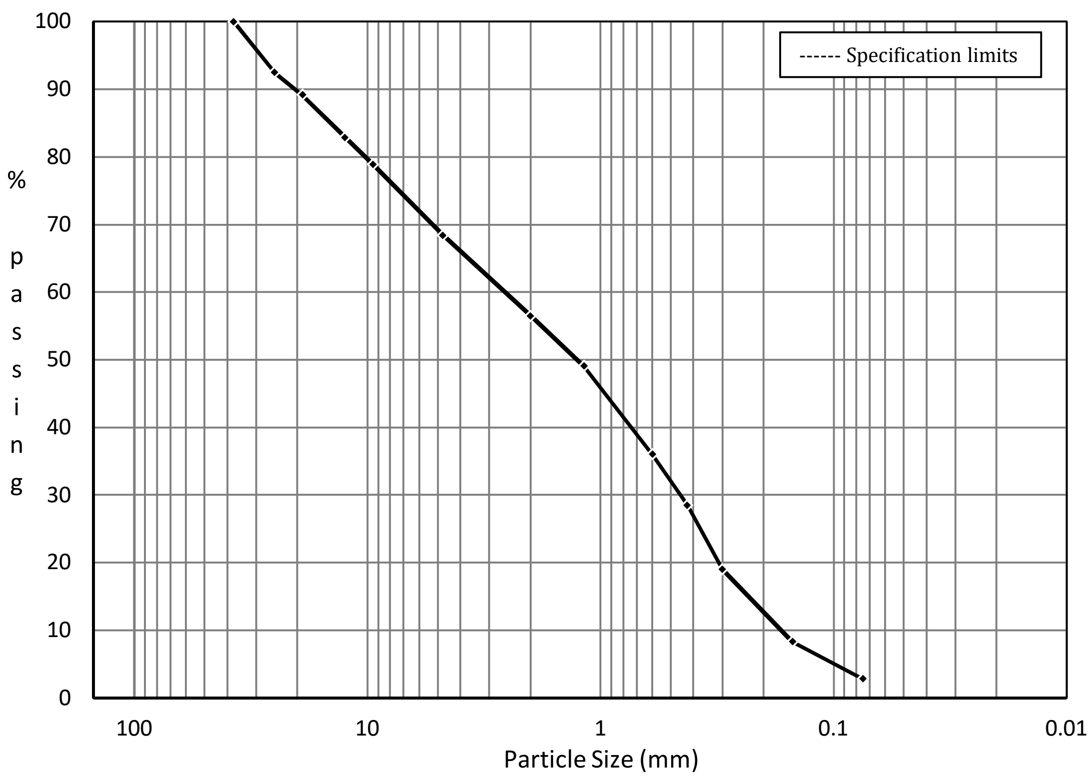
Sample Description: Gravelly SAND, trace silt/clay
Sample ID: SRK17-TP01-3
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0		
37.5	100.0	
25.0	92.5	
19.0	89.2	
12.5	82.9	
9.5	78.9	
4.75	68.4	
2.00	56.5	
1.18	49.1	
0.600	36.0	
0.425	28.5	
0.300	19.0	
0.150	8.3	
0.075	2.8	

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	31.6 %
Sand :	< 4.75mm and > 0.075mm	65.6 %
Silt/Clay :	< 0.075mm	2.8 %

Moisture Content: 1.5%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:
Bryan Morrison, BSc.

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ARTECH
CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18004

Client Project: HB Tailings Facility

Date Received: January 8, 2018

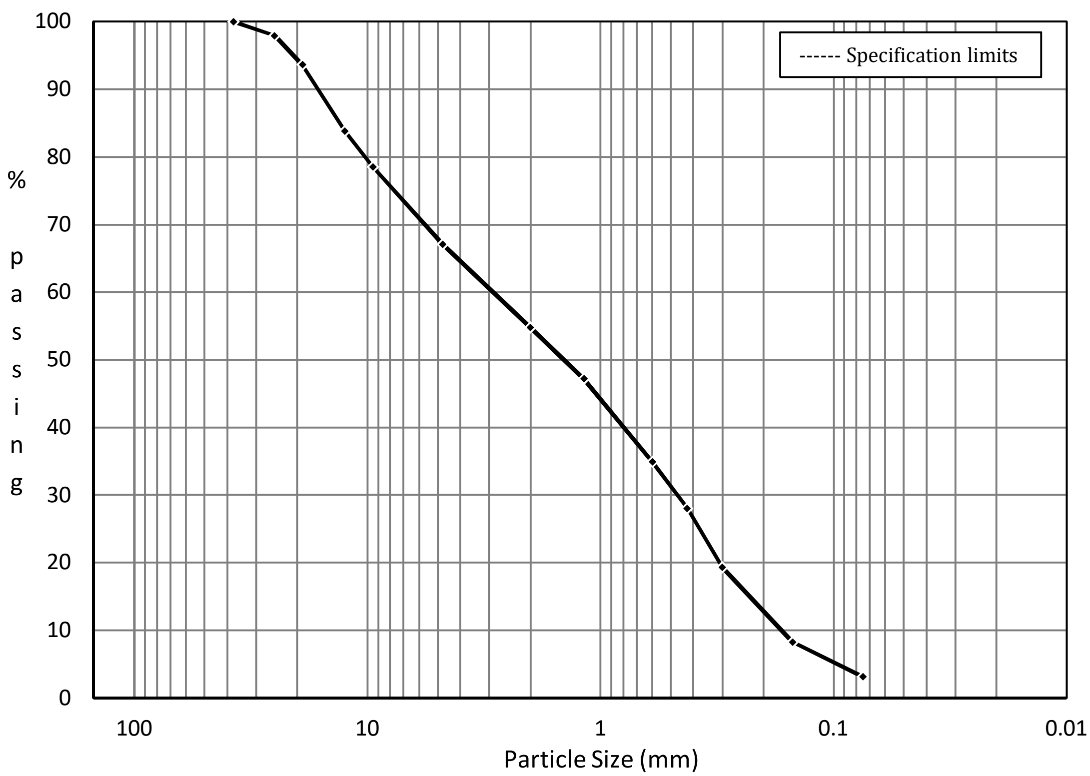
Sample Description: Gravelly SAND, trace silt/clay
Sample ID: SRK17-TP02-1
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0		
37.5	100.0	
25.0	97.9	
19.0	93.6	
12.5	83.8	
9.5	78.5	
4.75	67.1	
2.00	54.7	
1.18	47.2	
0.600	34.9	
0.425	28.0	
0.300	19.3	
0.150	8.3	
0.075	3.1	

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	32.9 %
Sand :	< 4.75mm and > 0.075mm	63.9 %
Silt/Clay :	< 0.075mm	3.1 %

Moisture Content: 4.0%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:
Bryan Morrison, BSc.

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ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Lab ID: S18005

Client Project: HB Tailings Facility

Attn: Peter Mikes
CC: -

Date Received: January 8, 2018

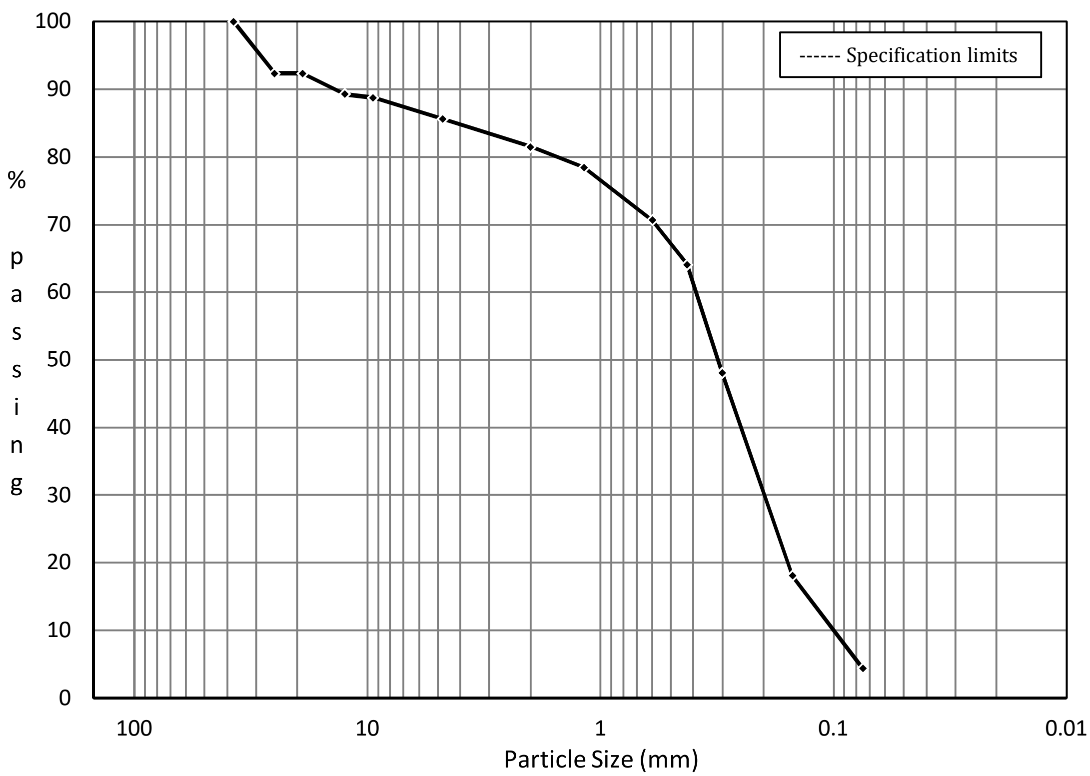
Sample Description: SAND, some gravel, trace silt/clay
Sample ID: SRK17-TP02-2
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0		
37.5	100.0	
25.0	92.4	
19.0	92.4	
12.5	89.3	
9.5	88.7	
4.75	85.6	
2.00	81.5	
1.18	78.5	
0.600	70.6	
0.425	64.1	
0.300	48.0	
0.150	18.1	
0.075	4.4	

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	14.4 %
Sand :	< 4.75mm and > 0.075mm	81.2 %
Silt/Clay :	< 0.075mm	4.4 %

Moisture Content: 8.4%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:

Bryan Morrison, BSc.

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ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Lab ID: S18006
Client Project: HB Tailings Facility

Attn: Peter Mikes
CC: -

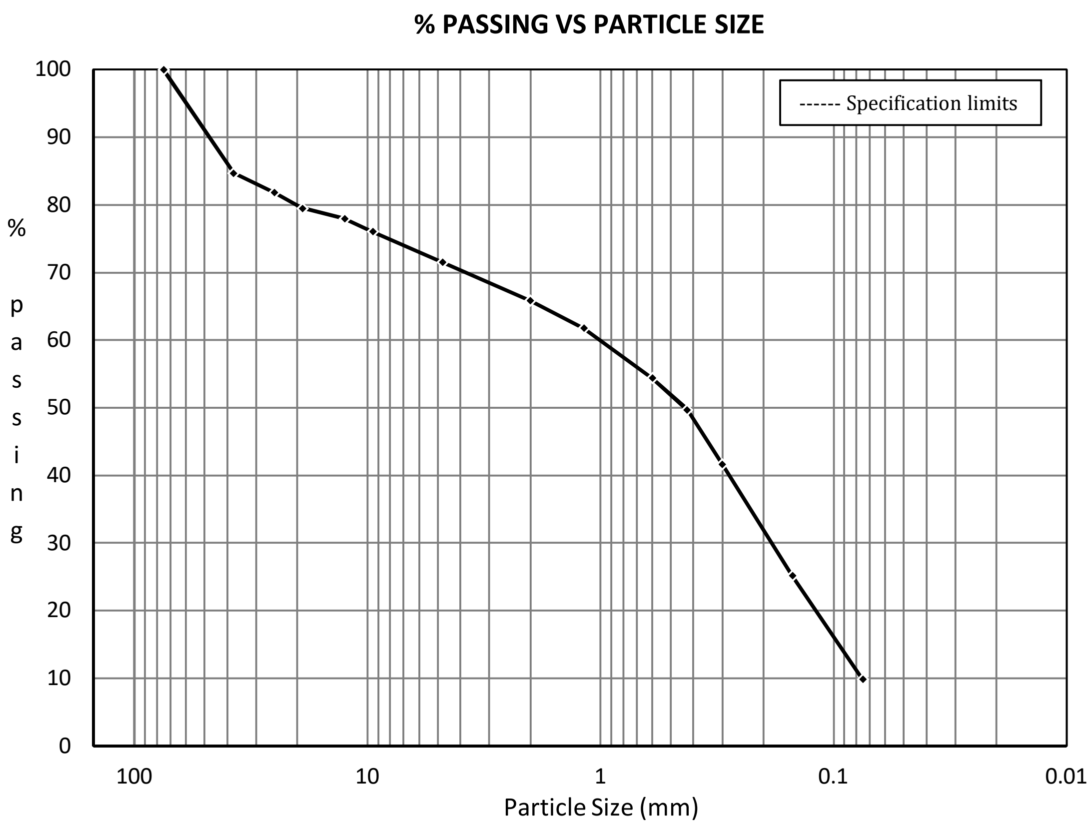
Date Received: January 8, 2018

Sample Description: Gravelly SAND, trace silt/clay
Sample ID: SRK17-TP04-1
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0	100.0	
37.5	84.7	
25.0	81.8	
19.0	79.5	
12.5	77.9	
9.5	76.0	
4.75	71.5	
2.00	65.8	
1.18	61.7	
0.600	54.4	
0.425	49.7	
0.300	41.6	
0.150	25.1	
0.075	9.8	



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	28.5 %
Sand :	< 4.75mm and > 0.075mm	61.7 %
Silt/Clay :	< 0.075mm	9.8 %

Moisture Content: 7.0%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:
Bryan Morrison, BSc.

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229 Industrial Rd F, Cranbrook, BC V1C 6N4 www.artechconsulting.ca

ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS (HYDROMETER)

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18007
Client Project: HB Tailings Facility
Date Received: January 8, 2018

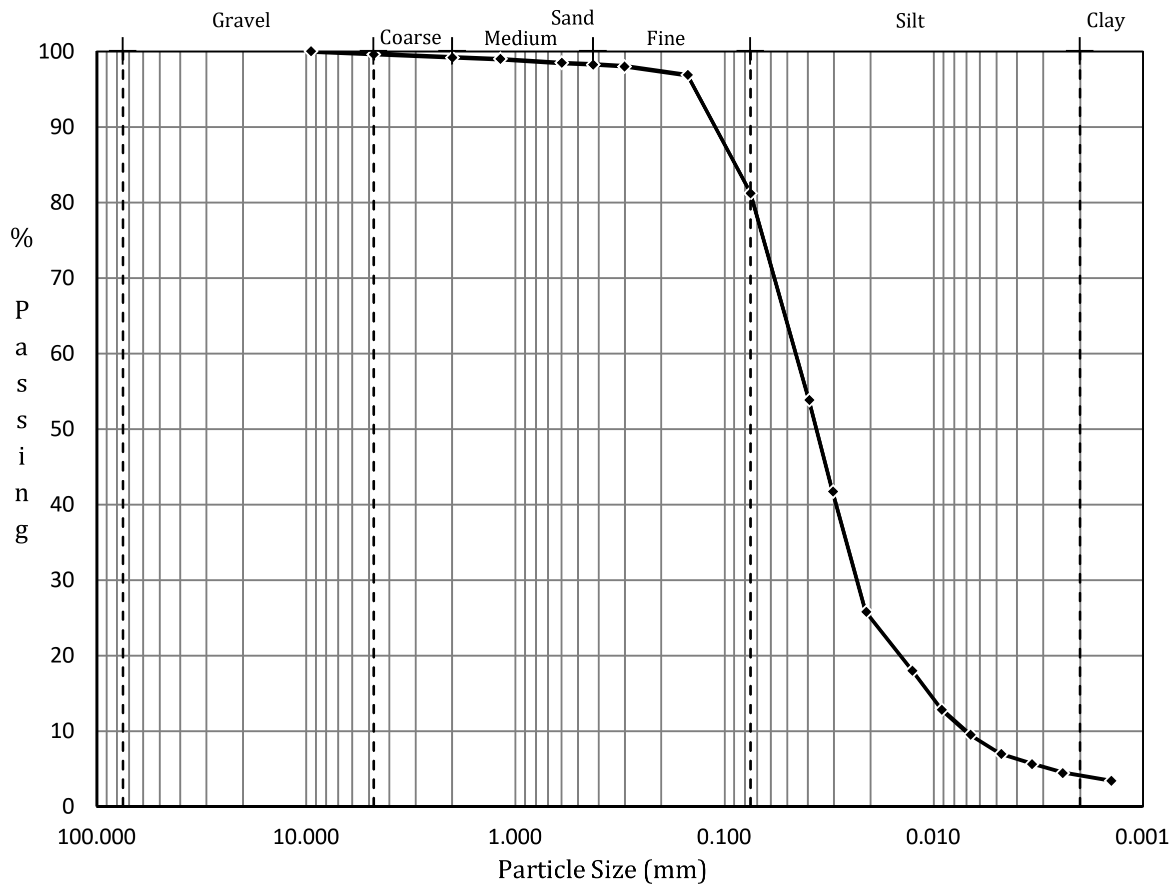
Sample Description: SILT, some sand, trace gravel, trace clay
Sample ID SRK17-TP04-2
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Sieve Analysis	
Sieve Size (mm)	% Passing
75	
37.5	
25	
19	
12.5	
9.5	100.0
4.75	99.6
2.00	99.2
1.18	99.0
0.600	98.5
0.425	98.3
0.300	98.0
0.150	96.9
0.075	81.2

Hydrometer Analysis	
Diameter of particle (mm)	% of soil in suspension
0.0393	53.9
0.0304	41.7
0.0211	25.8
0.0127	18.0
0.0092	12.8
0.0067	9.5
0.0048	6.9
0.0034	5.6
0.0024	4.4
0.0014	3.4

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	0.4 %
Sand :	< 4.75mm and > 0.075mm	18.5 %
Silt :	< 0.075mm and > 0.002mm	76.8 %
Clay :	< 0.002mm	4.4 %

Moisture Content : 30.1 %

Tested in accordance with AASHTO T88 Particle Size Analysis of Soils (modified)

Report Date: January 15, 2018

Reviewed By:
Bryan Morrison, BSc.

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ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18008

Client Project: HB Tailings Facility

Date Received: January 8, 2018

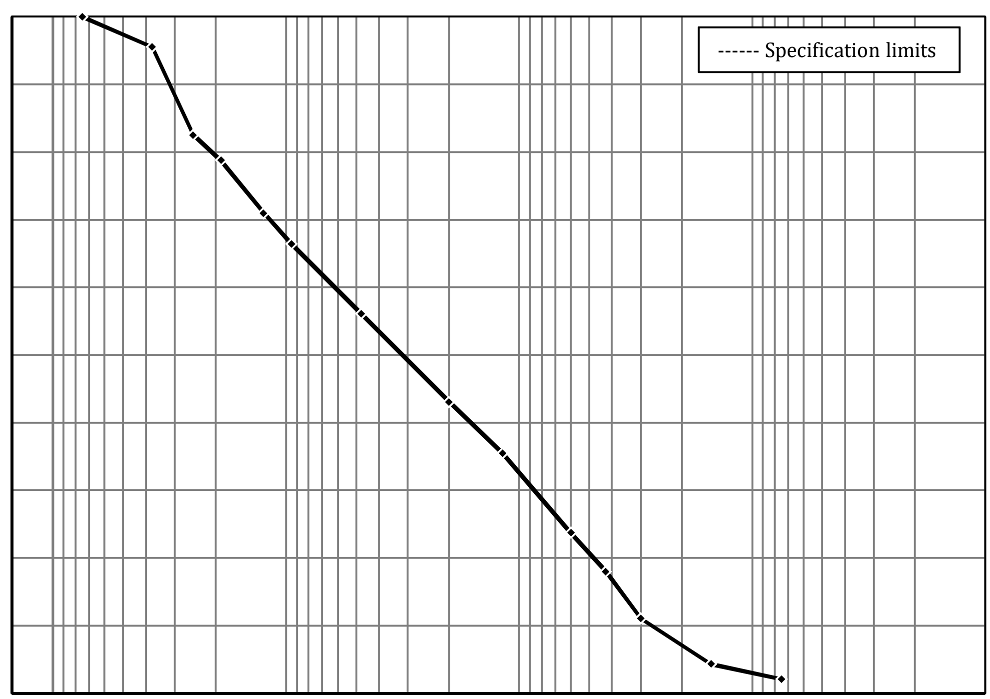
Sample Description: GRAVEL and SAND, trace silt/clay
Sample ID: SRK17-TP06-1
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0	100.0	
37.5	95.5	
25.0	82.5	
19.0	78.8	
12.5	71.0	
9.5	66.4	
4.75	56.1	
2.00	43.1	
1.18	35.5	
0.600	23.7	
0.425	18.0	
0.300	11.1	
0.150	4.4	
0.075	2.1	

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	43.9 %
Sand :	< 4.75mm and > 0.075mm	54.0 %
Silt/Clay :	< 0.075mm	2.1 %

Moisture Content: 2.4%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:

Bryan Morrison, BSc.

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229 Industrial Rd F, Cranbrook, BC V1C 6N4 www.artechconsulting.ca

ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Lab ID: S18009
Client Project: HB Tailings Facility

Attn: Peter Mikes
CC: -

Date Received: January 8, 2018

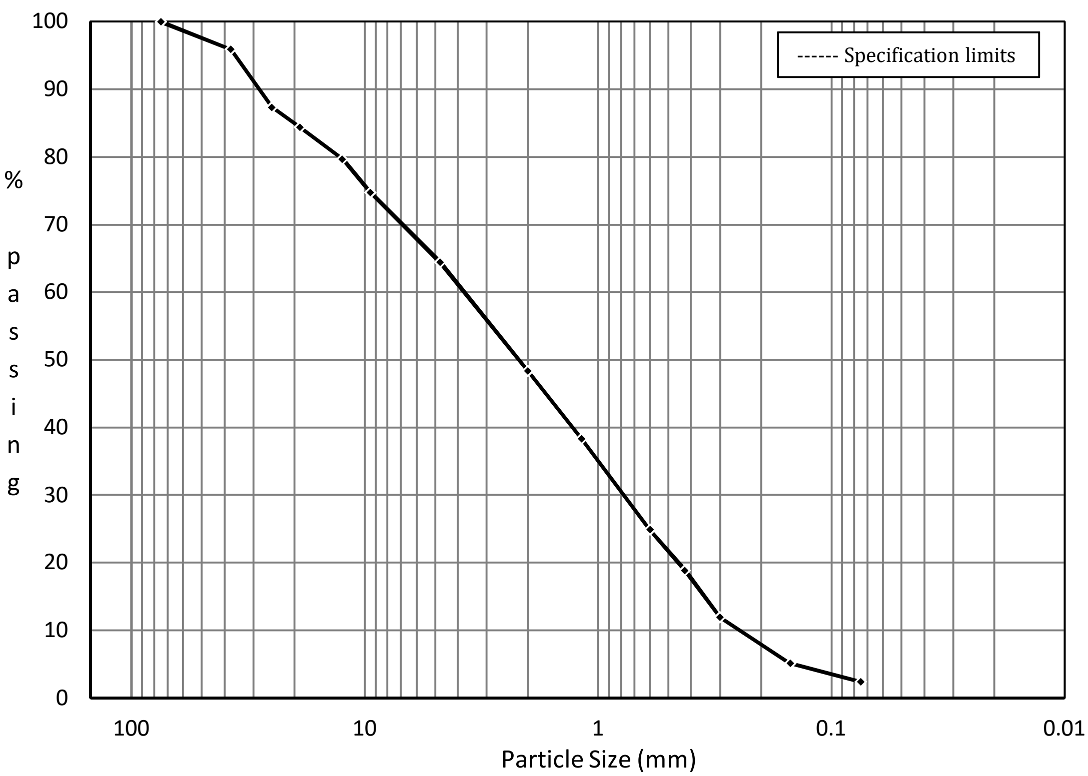
Sample Description: GRAVEL and SAND, trace silt/clay
Sample ID: SRK17-TP06-2
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0	100.0	
37.5	95.9	
25.0	87.3	
19.0	84.4	
12.5	79.7	
9.5	74.8	
4.75	64.4	
2.00	48.3	
1.18	38.4	
0.600	24.9	
0.425	18.8	
0.300	11.9	
0.150	5.1	
0.075	2.4	

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	35.6 %
Sand :	< 4.75mm and > 0.075mm	62.0 %
Silt/Clay :	< 0.075mm	2.4 %

Moisture Content: 3.0%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:

Bryan Morrison, BSc.

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ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Lab ID: S18010
Client Project: HB Tailings Facility

Attn: Peter Mikes
CC: -

Date Received: January 8, 2018

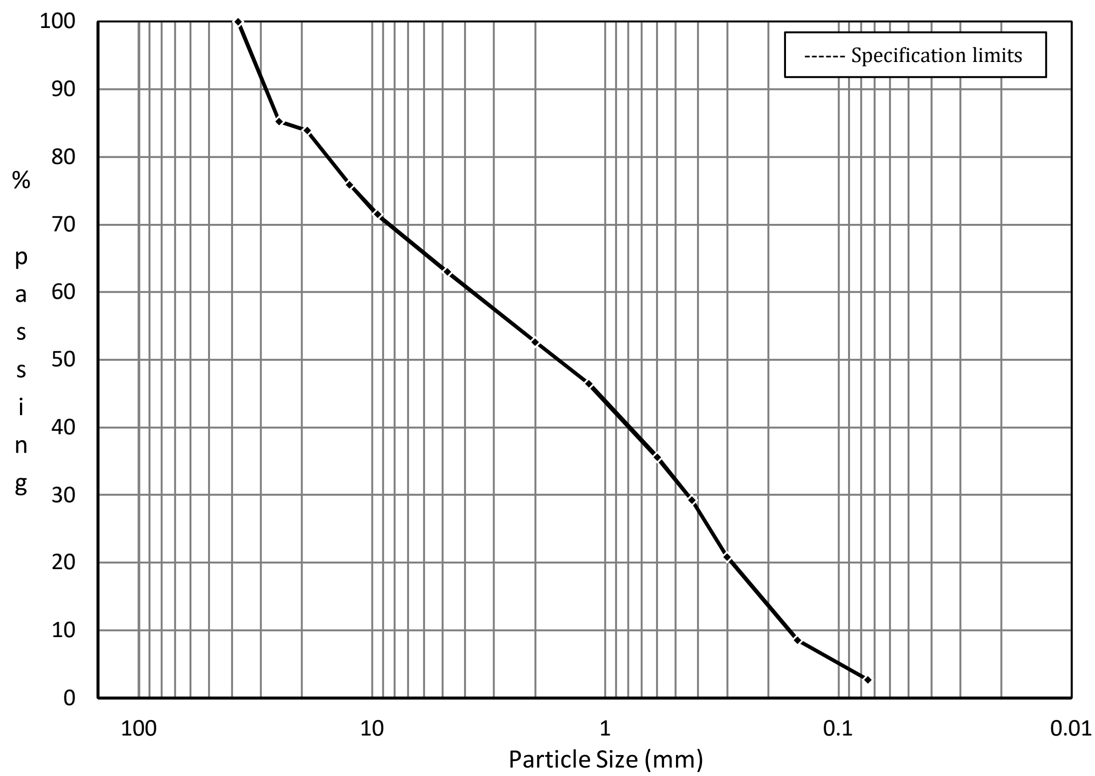
Sample Description: GRAVEL and SAND, trace silt/clay
Sample ID: SRK17-TP07-1
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0		
37.5	100.0	
25.0	85.2	
19.0	83.9	
12.5	75.9	
9.5	71.5	
4.75	63.0	
2.00	52.6	
1.18	46.5	
0.600	35.6	
0.425	29.2	
0.300	20.8	
0.150	8.6	
0.075	2.7	

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	37.0 %
Sand :	< 4.75mm and > 0.075mm	60.3 %
Silt/Clay :	< 0.075mm	2.7 %

Moisture Content: 3.1%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:

Bryan Morrison, BSc.

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ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18011
Client Project: HB Tailings Facility
Date Received: January 8, 2018

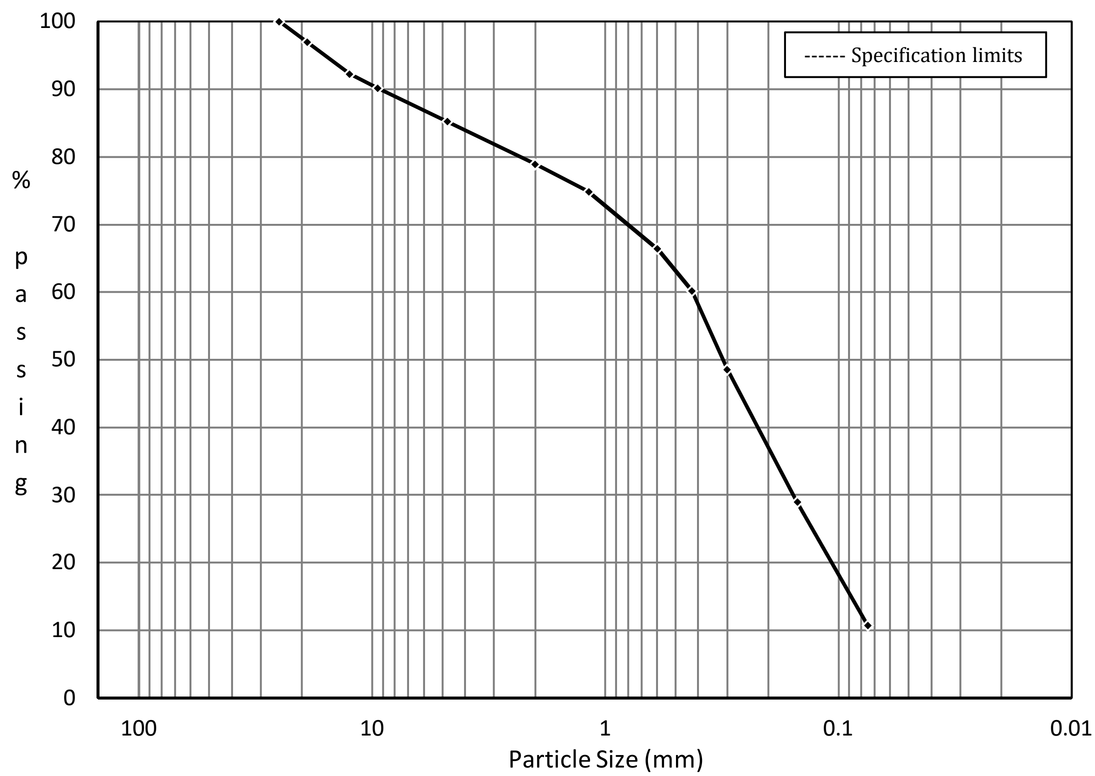
Sample Description: SAND, some gravel, some silt/clay
Sample ID: SRK17-TP08-1
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0		
37.5		
25.0	100.0	
19.0	97.0	
12.5	92.3	
9.5	90.2	
4.75	85.2	
2.00	78.9	
1.18	74.9	
0.600	66.4	
0.425	60.1	
0.300	48.6	
0.150	28.9	
0.075	10.7	

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	14.8 %
Sand :	< 4.75mm and > 0.075mm	74.5 %
Silt/Clay :	< 0.075mm	10.7 %

Moisture Content: 9.0%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By: Bryan Morrison, BSc.

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ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Lab ID: S18012
Client Project: HB Tailings Facility

Attn: Peter Mikes
CC: -

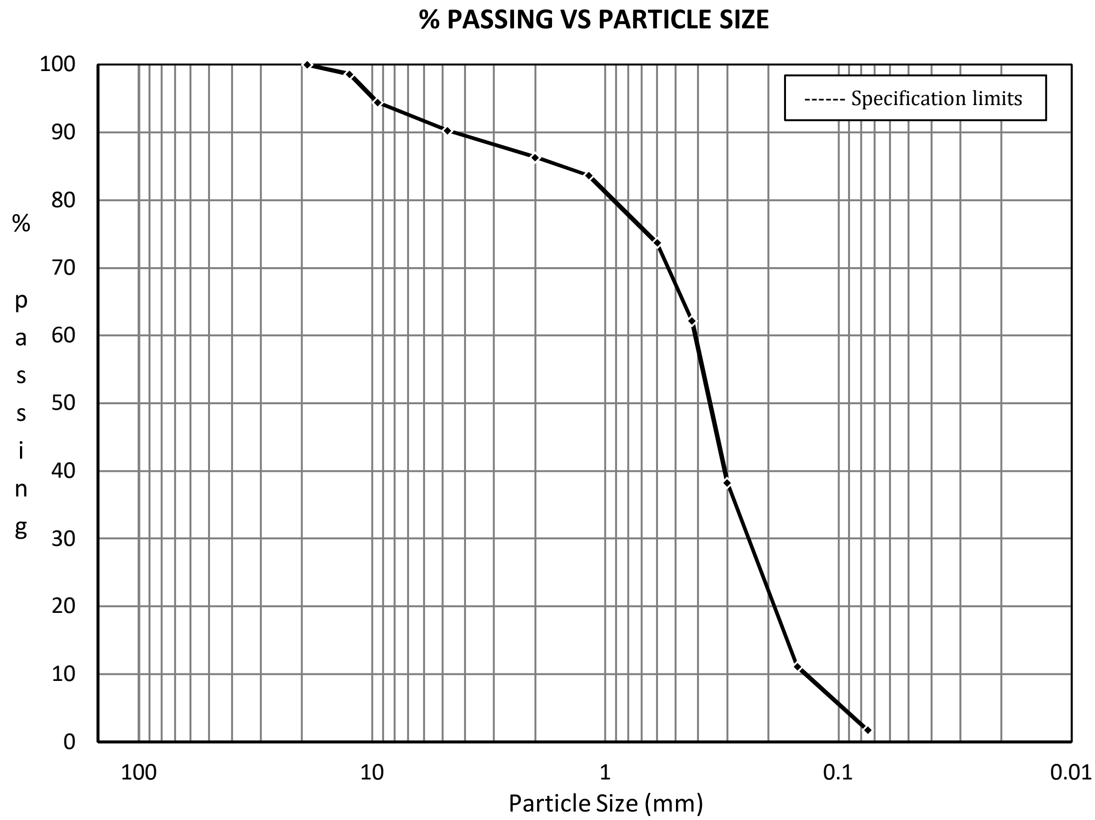
Date Received: January 8, 2018

Sample Description: SAND, trace gravel, trace silt/clay
Sample ID: SRK17-TP08-2
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0		
37.5		
25.0		
19.0	100.0	
12.5	98.6	
9.5	94.4	
4.75	90.3	
2.00	86.3	
1.18	83.7	
0.600	73.6	
0.425	62.1	
0.300	38.2	
0.150	11.1	
0.075	1.7	



Summary

Cobble :	>75mm		%
Gravel :	< 75mm and > 4.75mm	9.7	%
Sand :	< 4.75mm and > 0.075mm	88.6	%
Silt/Clay :	< 0.075mm	1.7	%

Moisture Content: 1.7%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:

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ARTECH
CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18013

Client Project: HB Tailings Facility

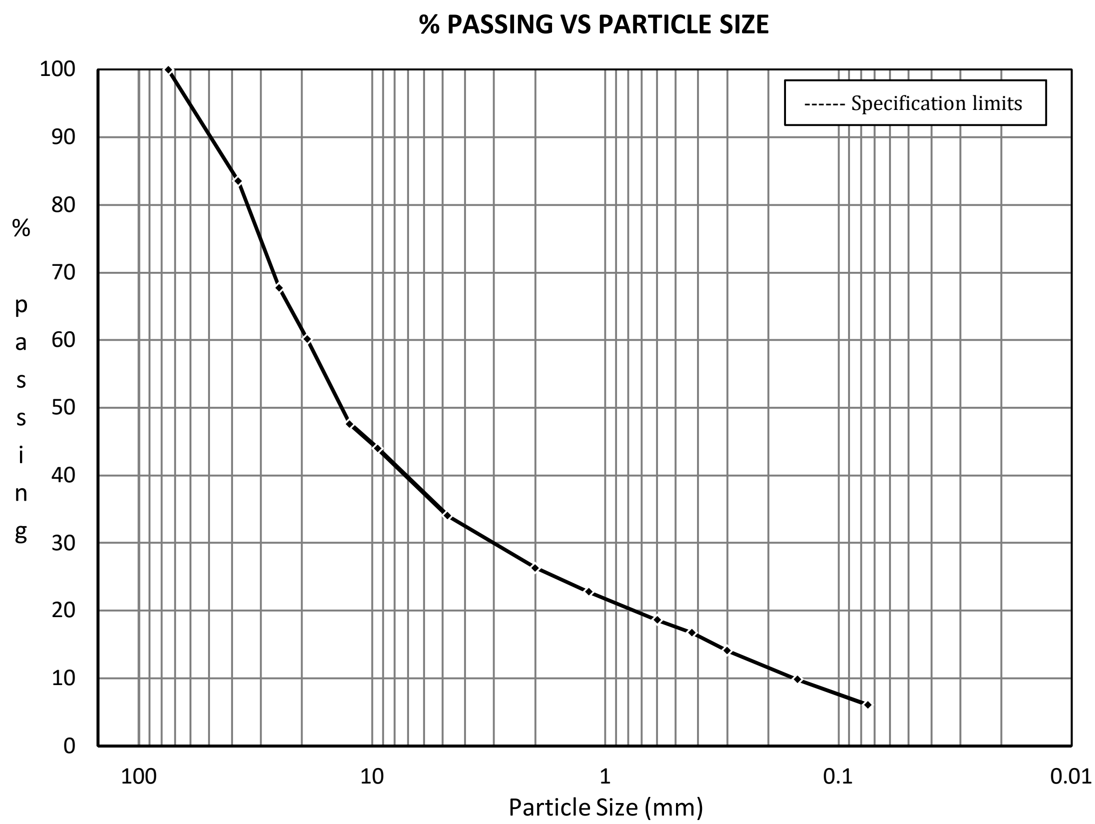
Date Received: January 8, 2018

Sample Description: Sandy GRAVEL, trace silt/clay
Sample ID: SRK17-TP09-1
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0	100.0	
37.5	83.5	
25.0	67.7	
19.0	60.2	
12.5	47.6	
9.5	44.0	
4.75	34.0	
2.00	26.3	
1.18	22.8	
0.600	18.6	
0.425	16.7	
0.300	14.1	
0.150	9.8	
0.075	6.0	



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	66.0 %
Sand :	< 4.75mm and > 0.075mm	28.0 %
Silt/Clay :	< 0.075mm	6.0 %

Moisture Content: 3.4%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:
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ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18014

Client Project: HB Tailings Facility

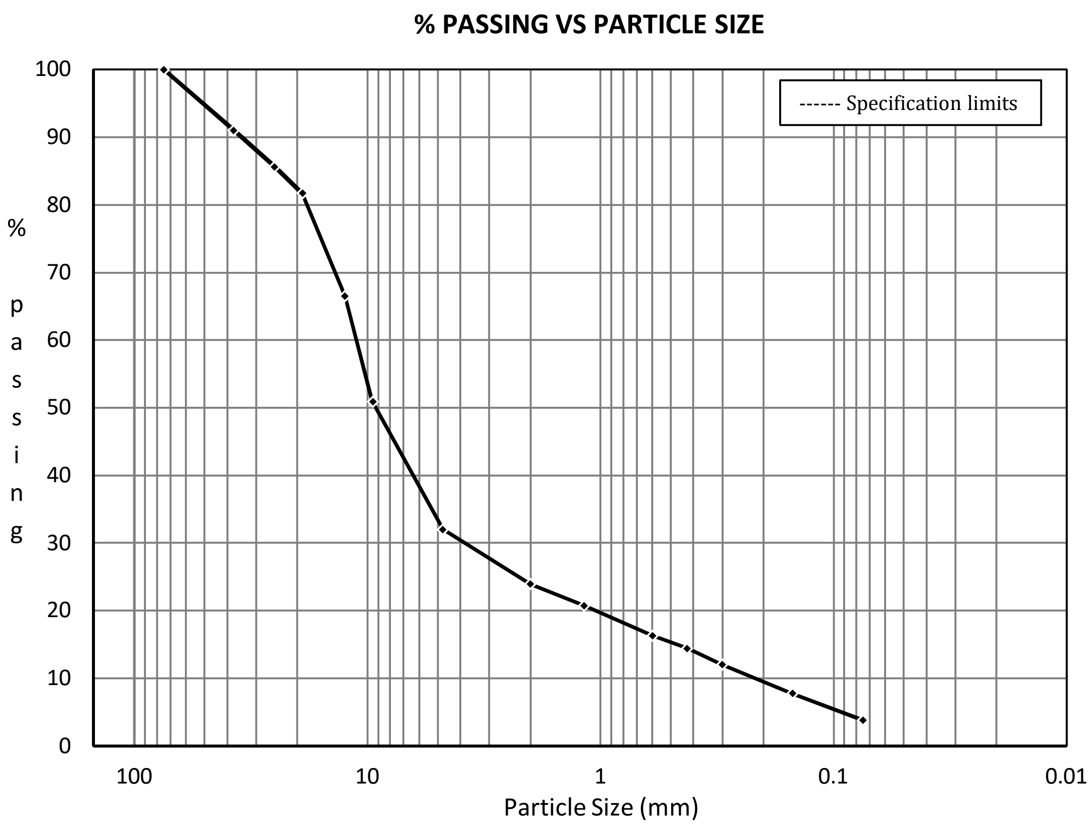
Date Received: January 8, 2018

Sample Description: Sandy GRAVEL, trace silt/clay
Sample ID: SRK17-TP09-2
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0	100.0	
37.5	91.0	
25.0	85.6	
19.0	81.7	
12.5	66.5	
9.5	50.9	
4.75	32.0	
2.00	23.9	
1.18	20.8	
0.600	16.3	
0.425	14.4	
0.300	12.0	
0.150	7.7	
0.075	3.8	



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	68.0 %
Sand :	< 4.75mm and > 0.075mm	28.2 %
Silt/Clay :	< 0.075mm	3.8 %

Moisture Content: 1.9%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:
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ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS (HYDROMETER)

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18015
Client Project: HB Tailings Facility
Date Received: January 8, 2018

Sample Description: SILT, some sand, trace gravel, trace clay
Sample ID SRK17-TP10-1
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

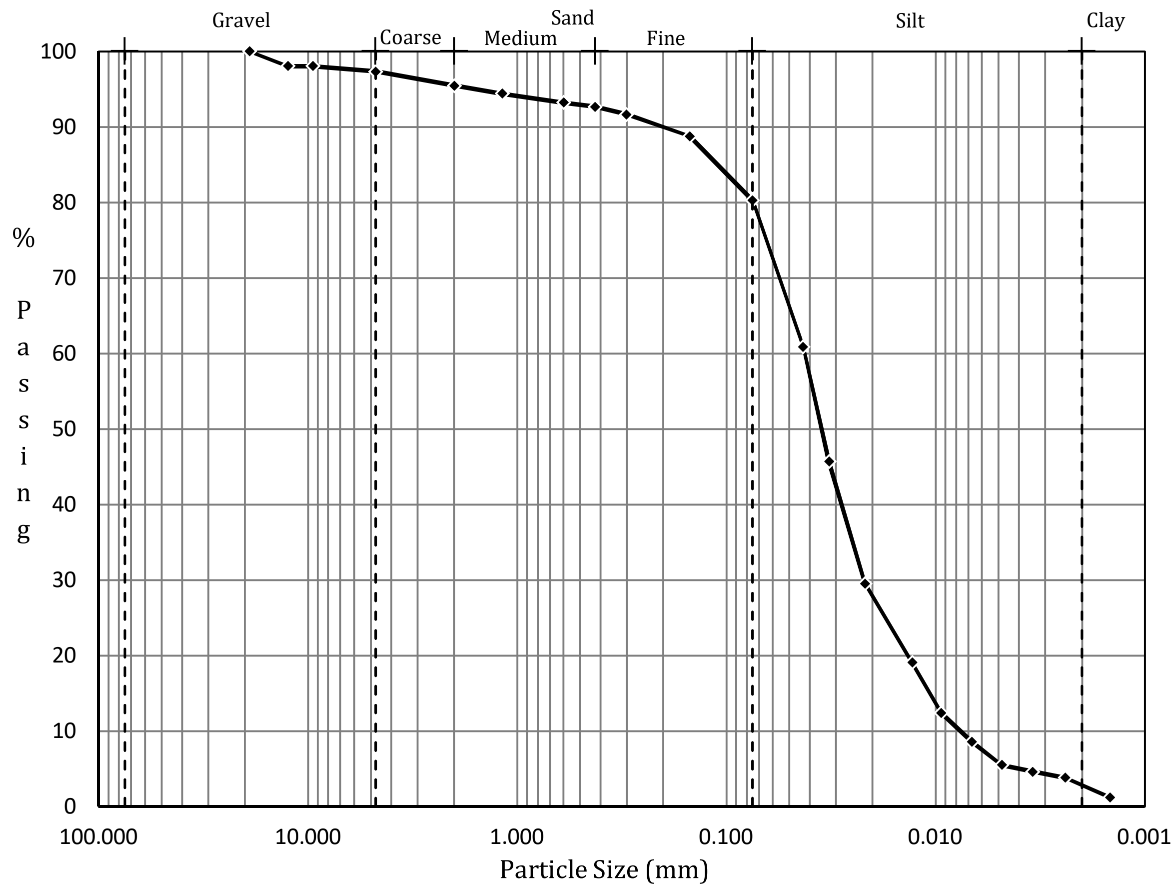
Sieve Analysis

Sieve Size (mm)	% Passing
75	
37.5	
25	
19	100.0
12.5	98.1
9.5	98.1
4.75	97.4
2.00	95.5
1.18	94.4
0.600	93.2
0.425	92.7
0.300	91.7
0.150	88.8
0.075	80.3

Hydrometer Analysis

Diameter of particle (mm)	% of soil in suspension
0.0430	60.9
0.0323	45.7
0.0218	29.5
0.0130	19.1
0.0094	12.4
0.0067	8.5
0.0048	5.5
0.0034	4.6
0.0024	3.8
0.0015	1.2

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	2.6 %
Sand :	< 4.75mm and > 0.075mm	17.1 %
Silt :	< 0.075mm and > 0.002mm	76.5 %
Clay :	< 0.002mm	3.8 %

Moisture Content : 14.3 %

Tested in accordance with AASHTO T88 Particle Size Analysis of Soils (modified)

Report Date: January 15, 2018

Reviewed By:
Bryan Morrison, BSc.

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ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS (HYDROMETER)

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Lab ID: S18016

Client Project: HB Tailings Facility

Attn: Peter Mikes
CC: -

Date Received: January 8, 2018

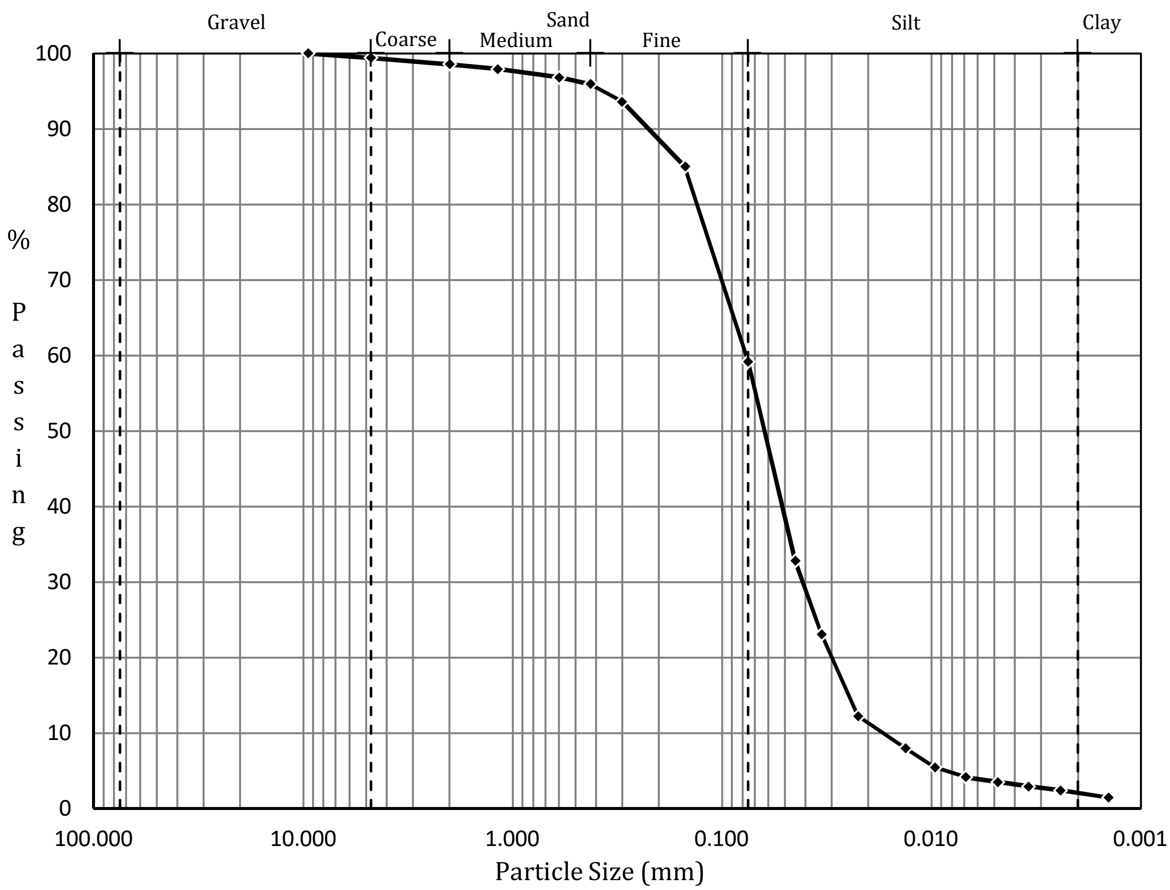
Sample Description: SAND and SILT, trace gravel, trace clay
Sample ID SRK17-TP11-1
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Sieve Analysis	
Sieve Size (mm)	% Passing
100	
75	
37.5	
19	
12.5	
9.5	100.0
4.75	99.4
2.00	98.6
1.18	97.9
0.600	96.8
0.425	95.9
0.300	93.6
0.150	85.0
0.075	59.2

Hydrometer Analysis	
Diameter of particle (mm)	% of soil in suspension
0.0447	32.8
0.0334	23.1
0.0224	12.2
0.0133	8.0
0.0096	5.4
0.0068	4.1
0.0048	3.5
0.0034	2.9
0.0024	2.4
0.0014	1.5

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	0.6 %
Sand :	< 4.75mm and > 0.075mm	40.2 %
Silt :	< 0.075mm and > 0.002mm	56.8 %
Clay :	< 0.002mm	2.4 %

Moisture Content : 16.6 %

Tested in accordance with AASHTO T88 Particle Size Analysis of Soils (modified)

Report Date: January 15, 2018

Reviewed By:
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ARTECH
CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Lab ID: S18017
Client Project: HB Tailings Facility

Attn: Peter Mikes
CC: -

Date Received: January 8, 2018

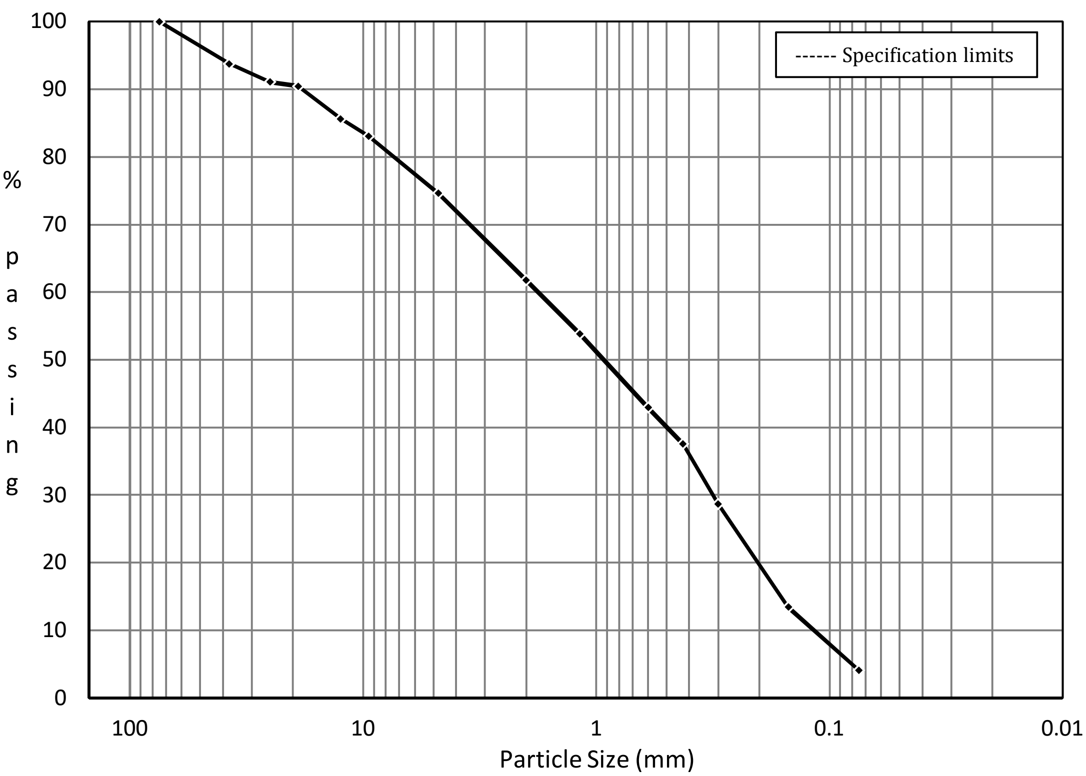
Sample Description: Gravelly SAND, trace silt/clay
Sample ID: SRK17-TP12-1
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0	100.0	
37.5	93.8	
25.0	91.1	
19.0	90.5	
12.5	85.6	
9.5	83.1	
4.75	74.6	
2.00	61.8	
1.18	53.9	
0.600	42.9	
0.425	37.5	
0.300	28.6	
0.150	13.4	
0.075	4.1	

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	25.4 %
Sand :	< 4.75mm and > 0.075mm	70.5 %
Silt/Clay :	< 0.075mm	4.1 %

Moisture Content: 6.9%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:
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ARTECH
CONSULTING LTD.

PARTICLE SIZE ANALYSIS (HYDROMETER)

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Lab ID: S18018

Client Project: HB Tailings Facility

Attn: Peter Mikes
CC: -

Date Received: January 8, 2018

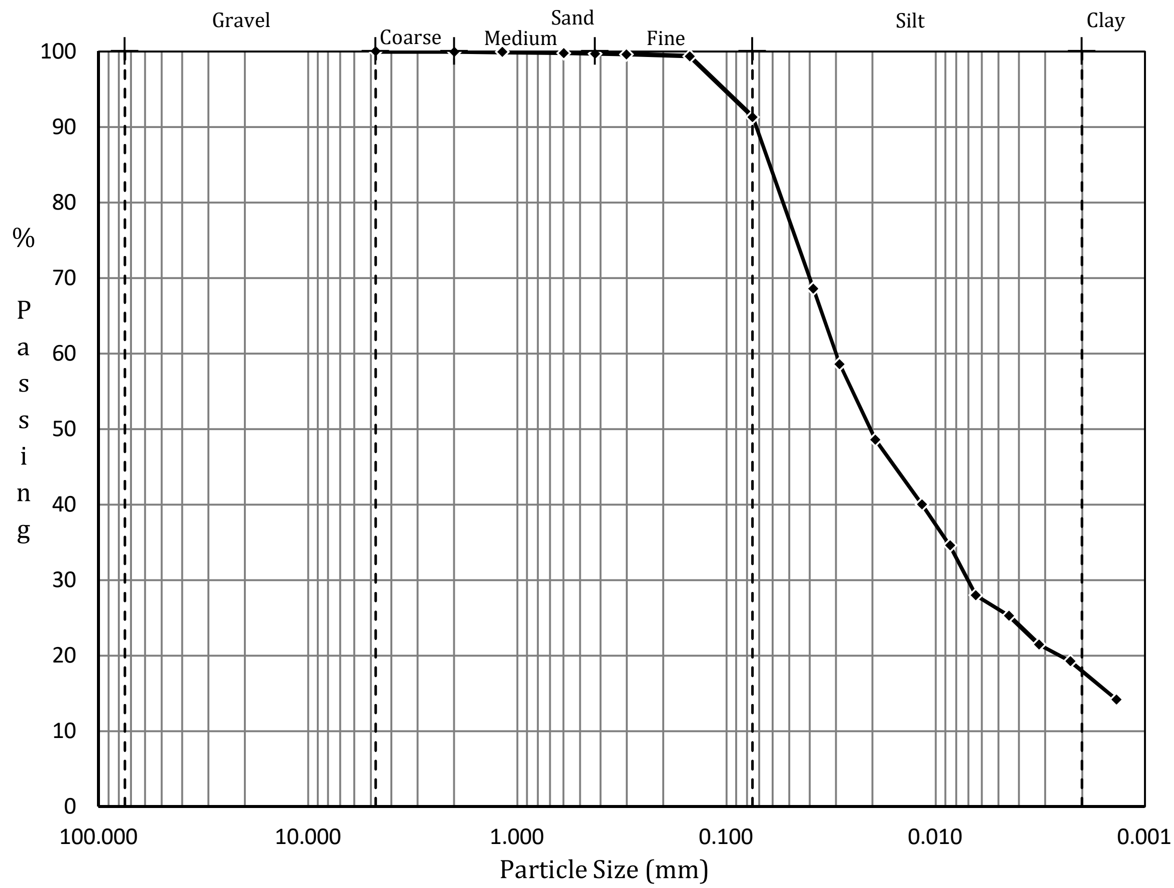
Sample Description: SILT, some clay, trace sand
Sample ID SRK17-TP13-1
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Sieve Analysis	
Sieve Size (mm)	% Passing
75	
37.5	
25	
19	
12.5	
9.5	
4.75	100.0
2.00	100.0
1.18	99.9
0.600	99.8
0.425	99.7
0.300	99.6
0.150	99.4
0.075	91.3

Hydrometer Analysis	
Diameter of particle (mm)	% of soil in suspension
0.0384	68.6
0.0288	58.6
0.0194	48.6
0.0116	40.0
0.0086	34.6
0.0064	27.9
0.0045	25.2
0.0032	21.4
0.0023	19.2
0.0014	14.2

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	0.0 %
Sand :	< 4.75mm and > 0.075mm	8.7 %
Silt :	< 0.075mm and > 0.002mm	72.1 %
Clay :	< 0.002mm	19.2 %

Moisture Content : 23.0 %

Tested in accordance with AASHTO T88 Particle Size Analysis of Soils (modified)

Report Date: January 15, 2018

Reviewed By:
Bryan Morrison, BSc.

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ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18019

Client Project: HB Tailings Facility

Date Received: January 8, 2018

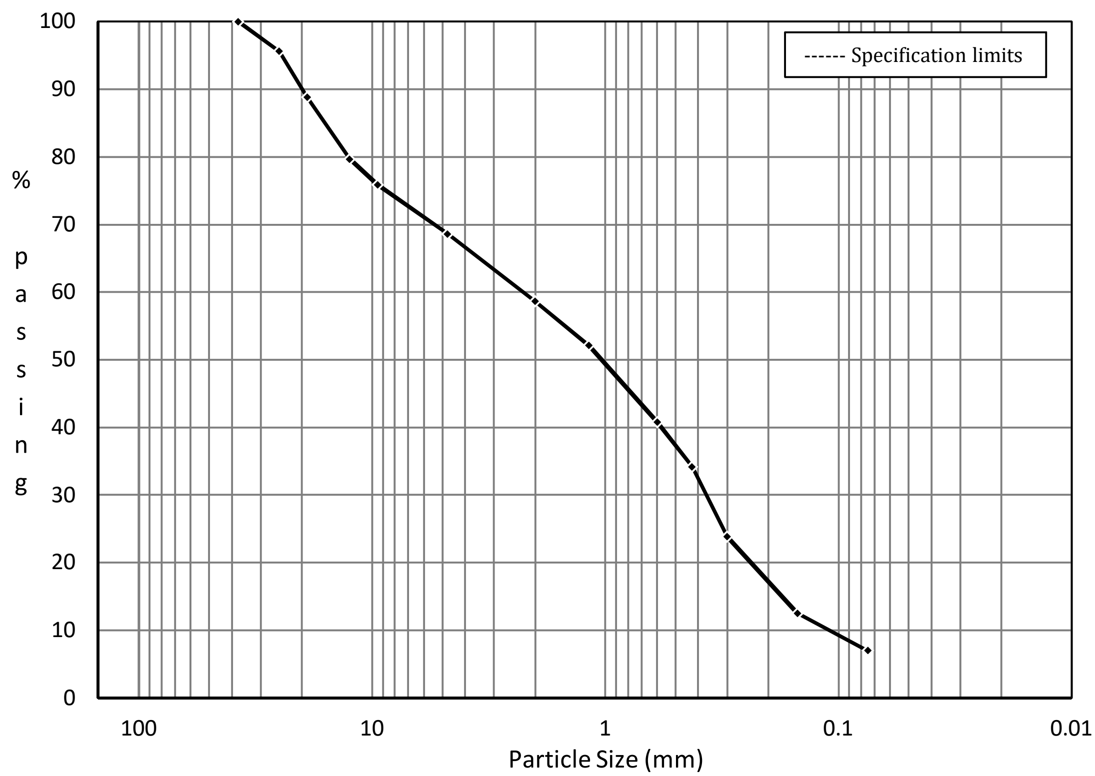
Sample Description: Gravelly SAND, trace silt/clay
Sample ID: SRK17-TP14-1
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0		
37.5	100.0	
25.0	95.6	
19.0	88.9	
12.5	79.7	
9.5	75.9	
4.75	68.6	
2.00	58.6	
1.18	52.1	
0.600	40.8	
0.425	34.2	
0.300	23.8	
0.150	12.5	
0.075	7.0	

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	31.4 %
Sand :	< 4.75mm and > 0.075mm	61.6 %
Silt/Clay :	< 0.075mm	7.0 %

Moisture Content: 5.6%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:

Bryan Morrison, BSc.

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ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS (HYDROMETER)

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18020

Client Project: HB Tailings Facility

Date Received: January 8, 2018

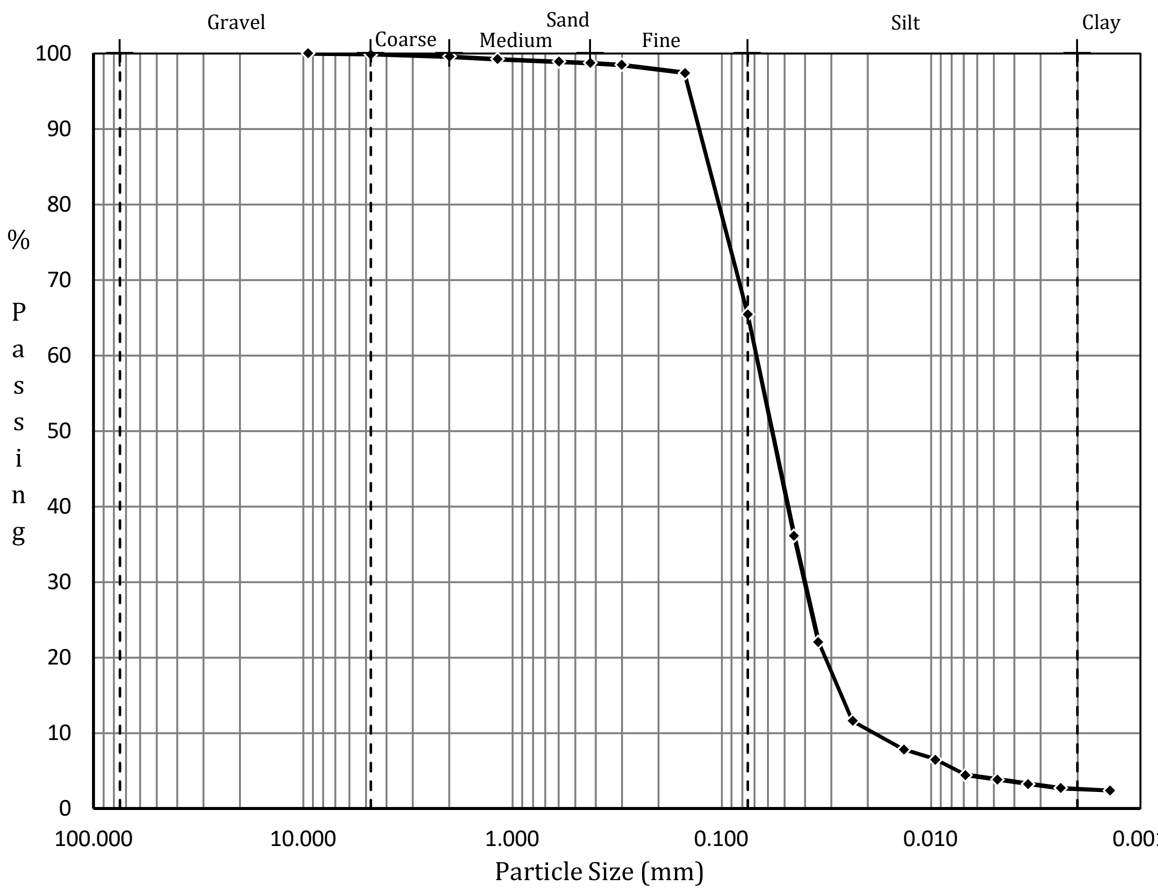
Sample Description: Sandy SILT, trace gravel, trace clay
Sample ID SRK17-TP14-2
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Sieve Analysis	
Sieve Size (mm)	% Passing
100	
75	
37.5	
19	
12.5	
9.5	100.0
4.75	99.9
2.00	99.6
1.18	99.3
0.600	98.9
0.425	98.8
0.300	98.5
0.150	97.4
0.075	65.4

Hydrometer Analysis	
Diameter of particle (mm)	% of soil in suspension
0.0452	36.1
0.0345	22.1
0.0238	11.6
0.0134	7.8
0.0095	6.4
0.0068	4.4
0.0048	3.8
0.0034	3.2
0.0024	2.7
0.0014	2.3

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	0.1 %
Sand :	< 4.75mm and > 0.075mm	34.5 %
Silt :	< 0.075mm and > 0.002mm	62.7 %
Clay :	< 0.002mm	2.7 %

Moisture Content : 27.3 %

Tested in accordance with AASHTO T88 Particle Size Analysis of Soils (modified)

Report Date: January 15, 2018

Reviewed By: Bryan Morrison, BSc.

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ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18021

Client Project: HB Tailings Facility

Date Received: January 8, 2018

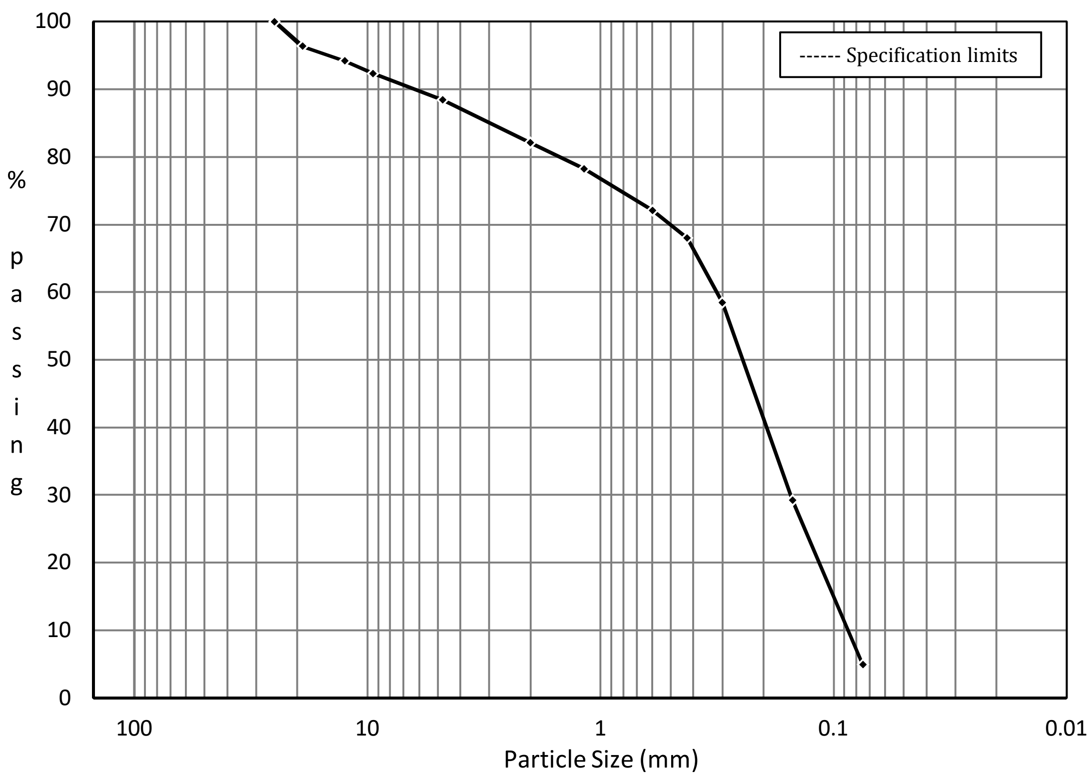
Sample Description: SAND, some gravel, trace silt/clay
Sample ID: SRK17-TP15-1
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Specification: NA

Sieve Analysis		
Sieve Size (mm)	% Passing	Specification limits
75.0		
37.5		
25.0	100.0	
19.0	96.4	
12.5	94.2	
9.5	92.3	
4.75	88.4	
2.00	82.1	
1.18	78.2	
0.600	72.1	
0.425	68.0	
0.300	58.4	
0.150	29.3	
0.075	4.9	

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	11.6 %
Sand :	< 4.75mm and > 0.075mm	83.5 %
Silt/Clay :	< 0.075mm	4.9 %

Moisture Content: 9.4%

Comments:

Tested in accordance with ASTM C136 Sieve Analysis of Fine and Coarse Aggregates /C117 Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

Report Date: January 15, 2018

Reviewed By:

Bryan Morrison, BSc.

Appendix C – East Abutment Area Test Results

PHONE: 250-489-1940 FAX: 250-489-1667 EMAIL: info@artechconsulting.ca
229 Industrial Rd F, Cranbrook, BC V1C 6N4 www.artechconsulting.ca

ARTECH CONSULTING LTD.

PARTICLE SIZE ANALYSIS (HYDROMETER)

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18022

Client Project: HB Tailings Facility

Date Received: January 8, 2018

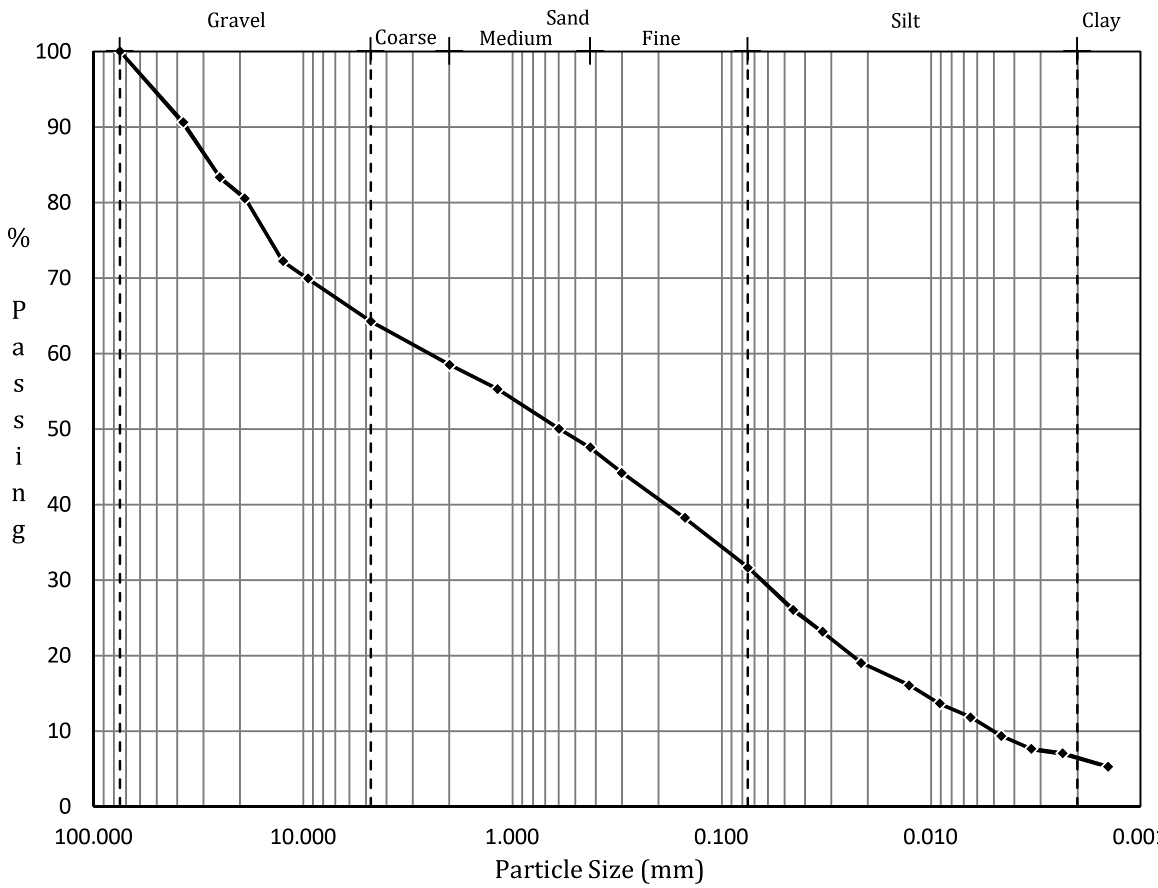
Sample Description: Sandy, silty GRAVEL, trace clay
Sample ID SRK17-TP18-1
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Sieve Analysis	
Sieve Size (mm)	% Passing
75	100.0
37.5	90.6
25	83.3
19	80.6
12.5	72.2
9.5	69.9
4.75	64.2
2.00	58.5
1.18	55.3
0.600	50.1
0.425	47.6
0.300	44.2
0.150	38.2
0.075	31.7

Hydrometer Analysis	
Diameter of particle (mm)	% of soil in suspension
0.0457	26.0
0.0330	23.1
0.0216	19.0
0.0127	16.0
0.0091	13.6
0.0065	11.8
0.0046	9.4
0.0033	7.6
0.0023	7.0
0.0014	5.3

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	35.8 %
Sand :	< 4.75mm and > 0.075mm	32.6 %
Silt :	< 0.075mm and > 0.002mm	24.6 %
Clay :	< 0.002mm	7.0 %

Moisture Content : 7.2 %

Tested in accordance with AASHTO T88 Particle Size Analysis of Soils (modified)

Report Date: January 15, 2018

Reviewed By:
Bryan Morrison, BSc.

PHONE: 250-489-1940 FAX: 250-489-1667 EMAIL: info@artechconsulting.ca
229 Industrial Rd F, Cranbrook, BC V1C 6N4 www.artechconsulting.ca

ARTECH
CONSULTING LTD.

PARTICLE SIZE ANALYSIS (HYDROMETER)

Project No: 18.0002.AR
Project: SRK Consulting Soil Analysis
Client: SRK Consulting

Attn: Peter Mikes
CC: -

Lab ID: S18023

Client Project: HB Tailings Facility

Date Received: January 8, 2018

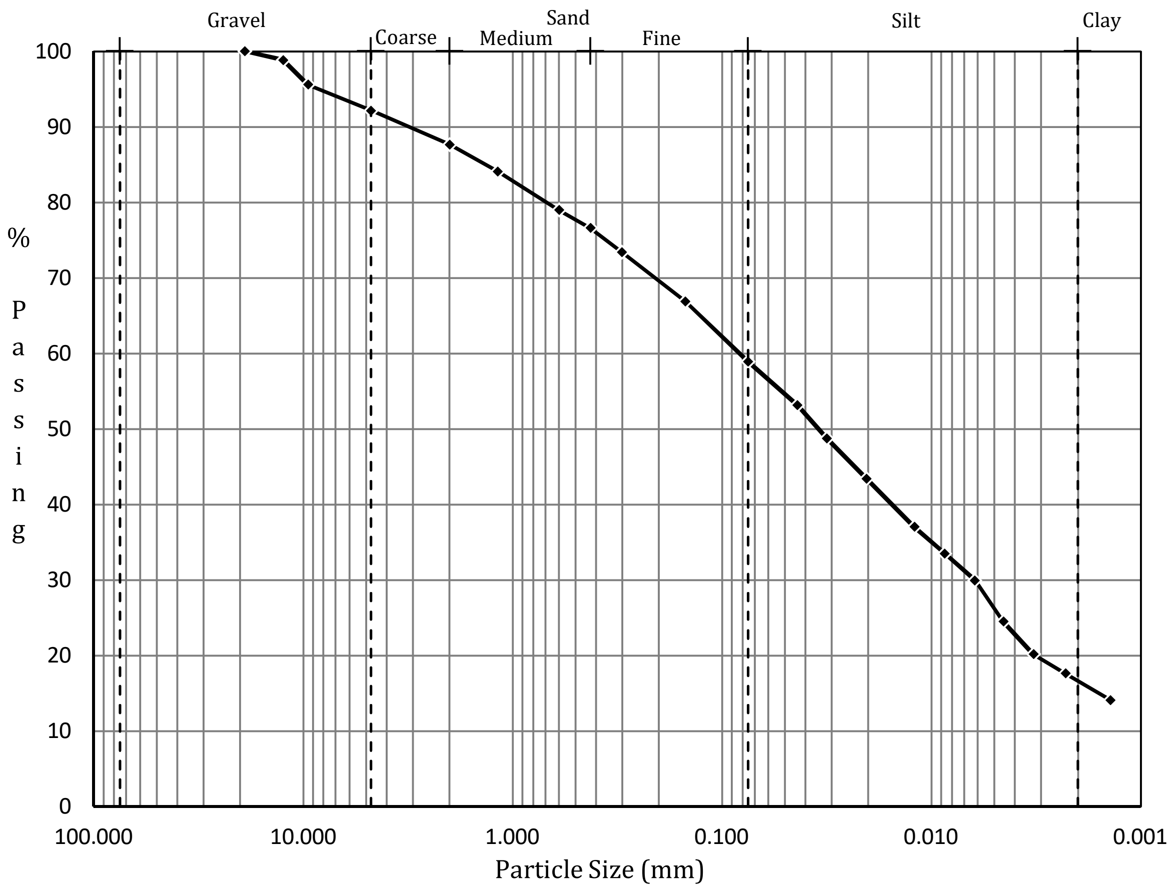
Sample Description: Sandy SILT, some clay, trace gravel
Sample ID SRK17-TP18-2
Sample Source: Geotechnical Investigation

Sample Date: -
Sample Time: -
Sampled By: Client

Sieve Analysis	
Sieve Size (mm)	% Passing
75	
37.5	
25	
19	100.0
12.5	98.9
9.5	95.6
4.75	92.2
2.00	87.7
1.18	84.1
0.600	79.0
0.425	76.6
0.300	73.4
0.150	66.9
0.075	58.9

Hydrometer Analysis	
Diameter of particle (mm)	% of soil in suspension
0.0436	53.1
0.0316	48.7
0.0204	43.4
0.0121	37.0
0.0086	33.5
0.0062	30.0
0.0045	24.5
0.0033	20.2
0.0023	17.6
0.0014	14.1

% PASSING VS PARTICLE SIZE



Summary

Cobble :	>75mm	0.0 %
Gravel :	< 75mm and > 4.75mm	7.8 %
Sand :	< 4.75mm and > 0.075mm	33.3 %
Silt :	< 0.075mm and > 0.002mm	41.3 %
Clay :	< 0.002mm	17.6 %

Moisture Content : 16.2 %

Tested in accordance with AASHTO T88 Particle Size Analysis of Soils (modified)

Report Date: January 15, 2018

Reviewed By:

Bryan Morrison, BSc.

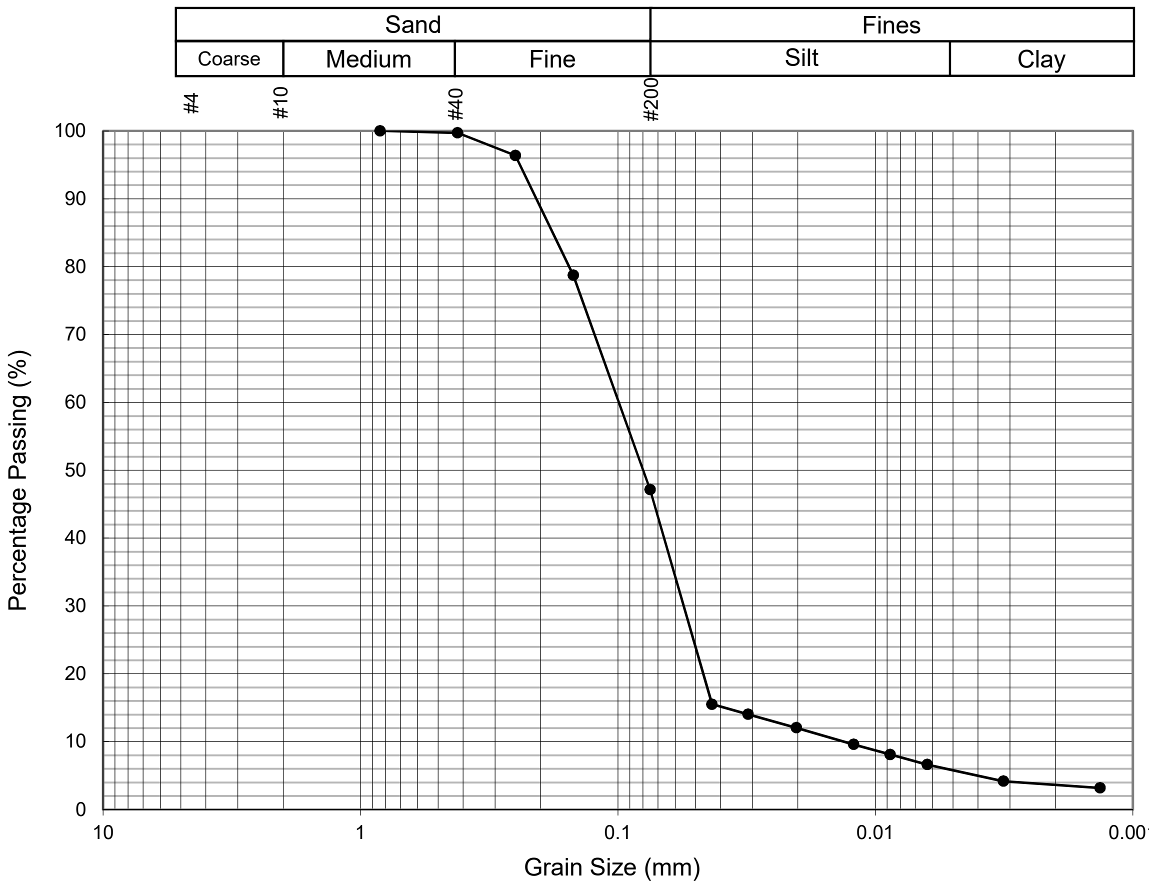
TETRA TECH CANADA INC.

TETRA TECH

Form Nº TT106-107

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 8, 2017
Borehole:	SRK17-TP20-1 Sample No.: Block	Depth (m):	-

Particle Size Distribution (ASTM D422)



Sample No.	Depth (m)	Percentage of Material by Weight (%)					
		Gravel	Sand			Fines	
			Coarse	Medium	Fine	Silt	Clay
Block	-	0	0	0	53	41	6

Comments:

Prepared by:	PC	Checked by:	PS	Approved by:	PS
Date:	December 8, 2017	Date:	December 11, 2017	Date:	December 11, 2017

TETRA TECH CANADA INC.

TETRA TECH

Form Nº TT104

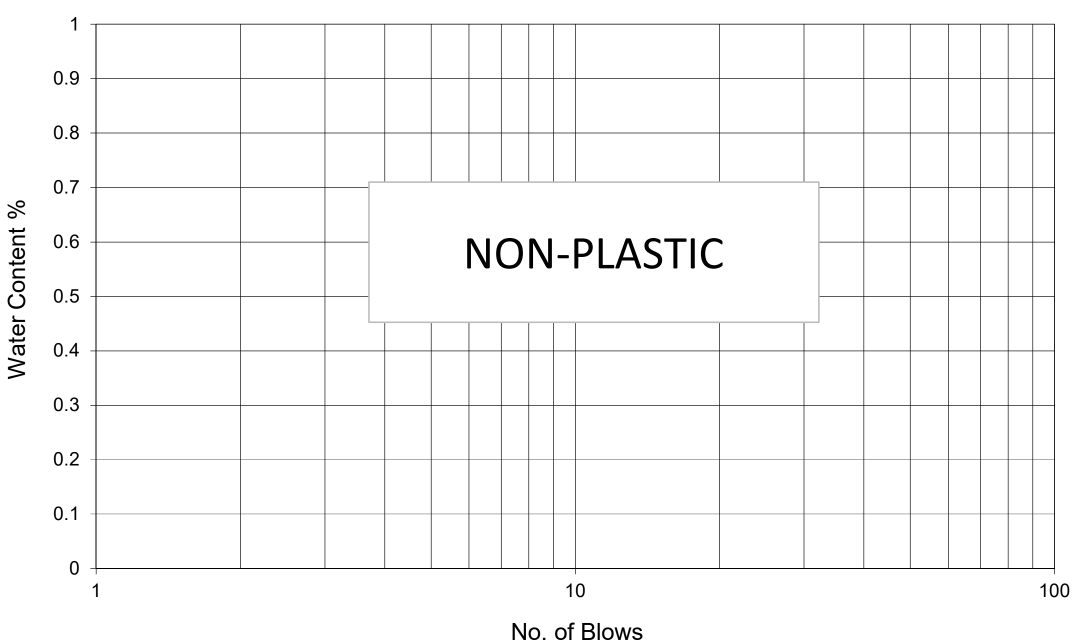
Project:	SRK - HB Tailings			Project No.:	17-MTS-038
Location:	Salmo, BC			Date:	December 11, 2017
Borehole:	SRK17-TP20-1	Sample No.:	Block	Depth (m):	-

Liquid Limit, Plastic Limit and Plasticity Index of Soils (ASTM D4318)

LIQUID LIMIT								PLASTIC LIMIT						
TIN No.	Tare + Weight of Wet Soil (g)	Tare + Weight of Dry Soil (g)	Weight of Tin (g)	Weight of Water (g)	Weight of Dry Soil (g)	Water Content (%)	No. of Blows	TIN No.	Tare + Weight of Wet Soil (g)	Tare + Weight of Dry Soil (g)	Weight of Tin (g)	Weight of Water (g)	Weight of Dry Soil (g)	Water Content (%)

Classification of the material : ____________

______ % with respect to the total of the material smaller than sieve No. 40



Observations: ______________________________

____

Prepared by:	PC	Checked by:	PS	Approved by:	PS
Date:	December 11, 2017	Date:	December 11, 2017	Date:	December 11, 2017

OQM CERTIFIED

TETRA TECH CANADA INC.

TETRA TECH

Form Nº TT109

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 8, 2017
Borehole:	SRK17-TP20-1		

Specific Gravity (ASTM D854)

Sample Number	Depth (m)	Volumetric flask No.	Weight of flask and soil (g)	Weight of flask, water and soil (g)	Weight of dry solid (g)	Temperature (°C)	Specific Gravity Gs
Block	-	16	246.48	714.85	78.42	19	2.72

Comments :

Prepared by:	PC	Checked by:	PS	Approved by:	PS
Date:	December 8, 2017	Date:	December 12, 2017	Date:	December 12, 2017

OQM CERTIFIED

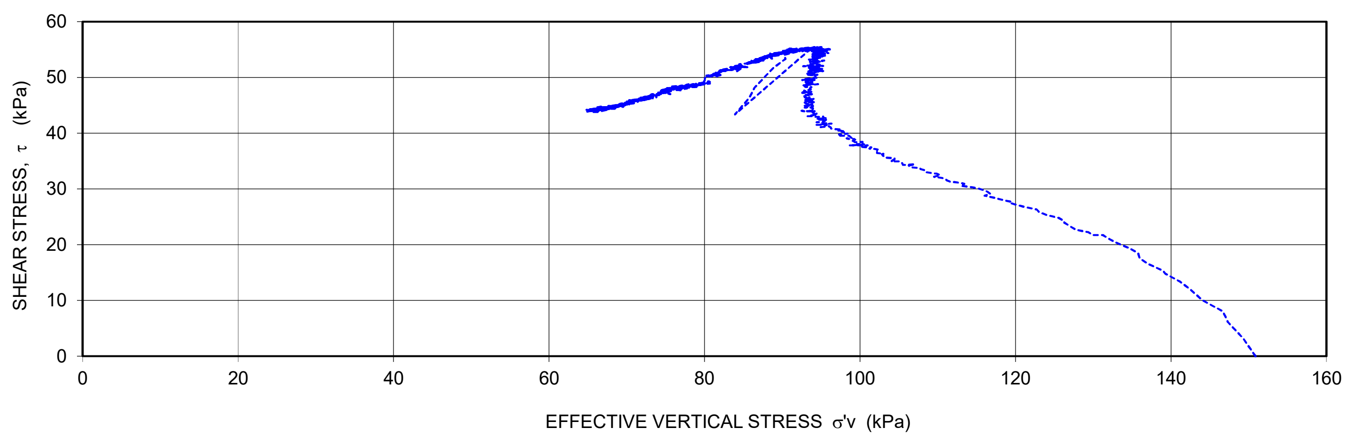
TETRA TECH CANADA INC.

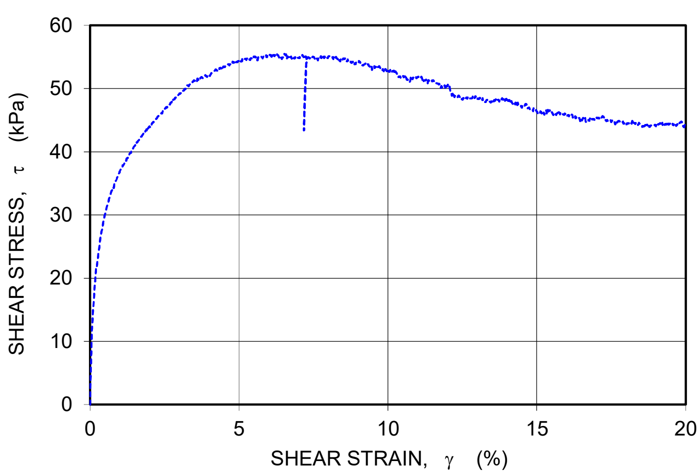
TETRA TECH

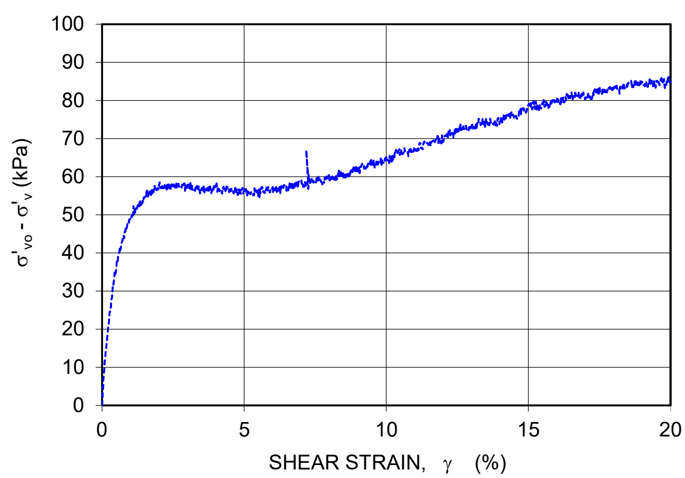
Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 11, 2017
Borehole:	SRK17-TP20-1	Depth (m):	-
Sample No.:	Block - 150kPa		

Direct Simple Shear (ASTM D6528)

Initial Height (mm):	23.6	**Weight of Specimen (g):**	188.19	**Initial Void Ratio, e_o:**	0.80
Diameter of Ring (mm):	73.5	**Total Unit Weight (kN/m^3):**	18.44	**Final Void Ratio, e_f:**	0.76
Specific Gravity, Gs:	2.72	**Dry Unit Weight (kN/m^3):**	14.84	**Natural Water Content (%):**	24.3
Final Water Content (%):	24.0	**Initial Degree of Saturation, Sr (%):**	82.9	**Final Degree of Saturation, Sr (%):**	86.0







Type of Test: Constant Volume					
Sample No.	Depth (m)	Total Unit Weight (kN/m^3)	Effective Vertical Stress, σ'v (kPa)	Strain Rate (%/hour)	Test OCR
Block - 150kPa	-	18.4	150	5	-

Comments: DSS sample trimmed from block sample

Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 11, 2017	Date:	December 11, 2017	Date:	December 13, 2017

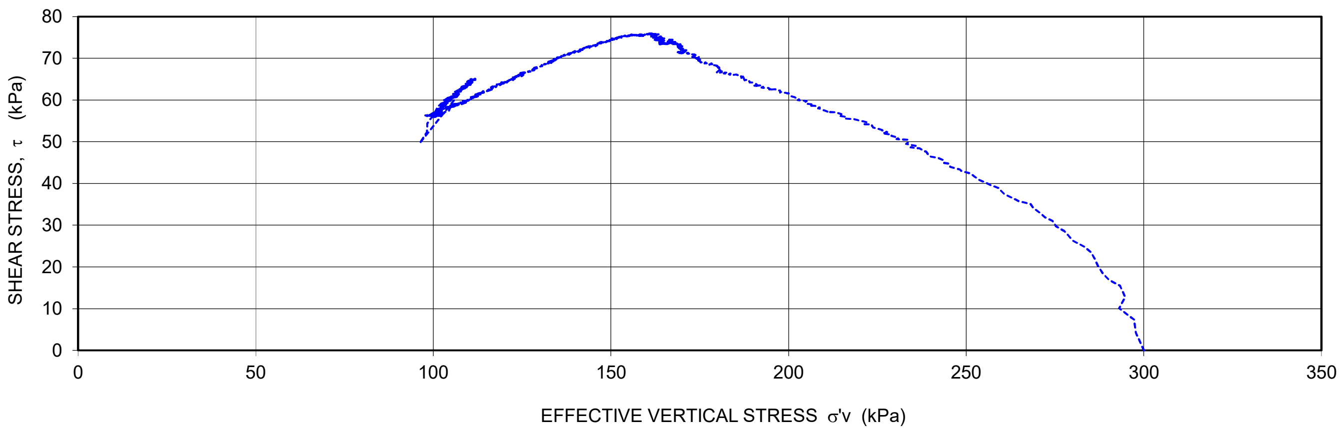
OQM CERTIFIED

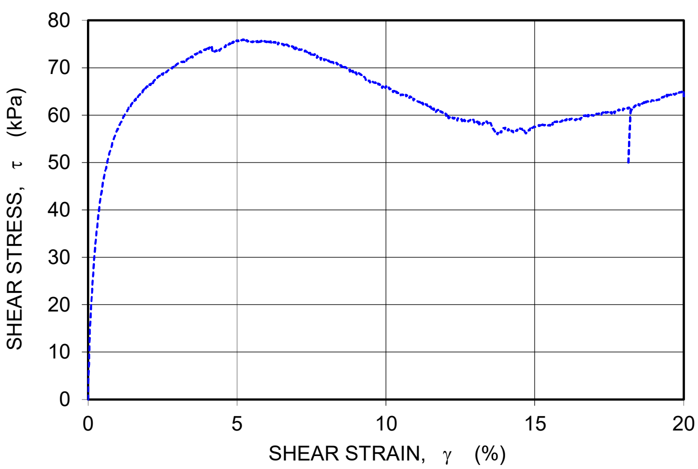
TETRA TECH CANADA INC.

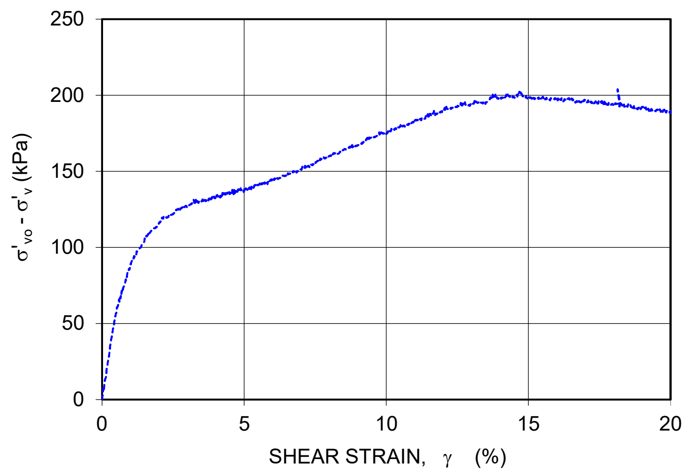
Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 11, 2017
Borehole:	SRK17-TP20-1	Depth (m):	-
Sample No.:	Block - 300kPa		

Direct Simple Shear (ASTM D6528)

Initial Height (mm):	23.6	**Weight of Specimen (g):**	181.46	**Initial Void Ratio, e_o:**	0.86
Diameter of Ring (mm):	73.5	**Total Unit Weight (kN/m^3):**	17.80	**Final Void Ratio, e_f:**	0.78
Specific Gravity, Gs:	2.72	**Dry Unit Weight (kN/m^3):**	14.34	**Natural Water Content (%):**	24.1
Final Water Content (%):	24.2	**Initial Degree of Saturation, Sr (%):**	76.3	**Final Degree of Saturation, Sr (%):**	83.7







Type of Test: Constant Volume					
Sample No.	Depth (m)	Total Unit Weight (kN/m^3)	Effective Vertical Stress, σ'v (kPa)	Strain Rate (%/hour)	Test OCR
Block - 300kPa	-	17.8	300	5	-

Comments: DSS sample trimmed from block sample

Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 11, 2017	Date:	December 11, 2017	Date:	December 13, 2017

TETRA TECH CANADA INC.

TETRA TECH

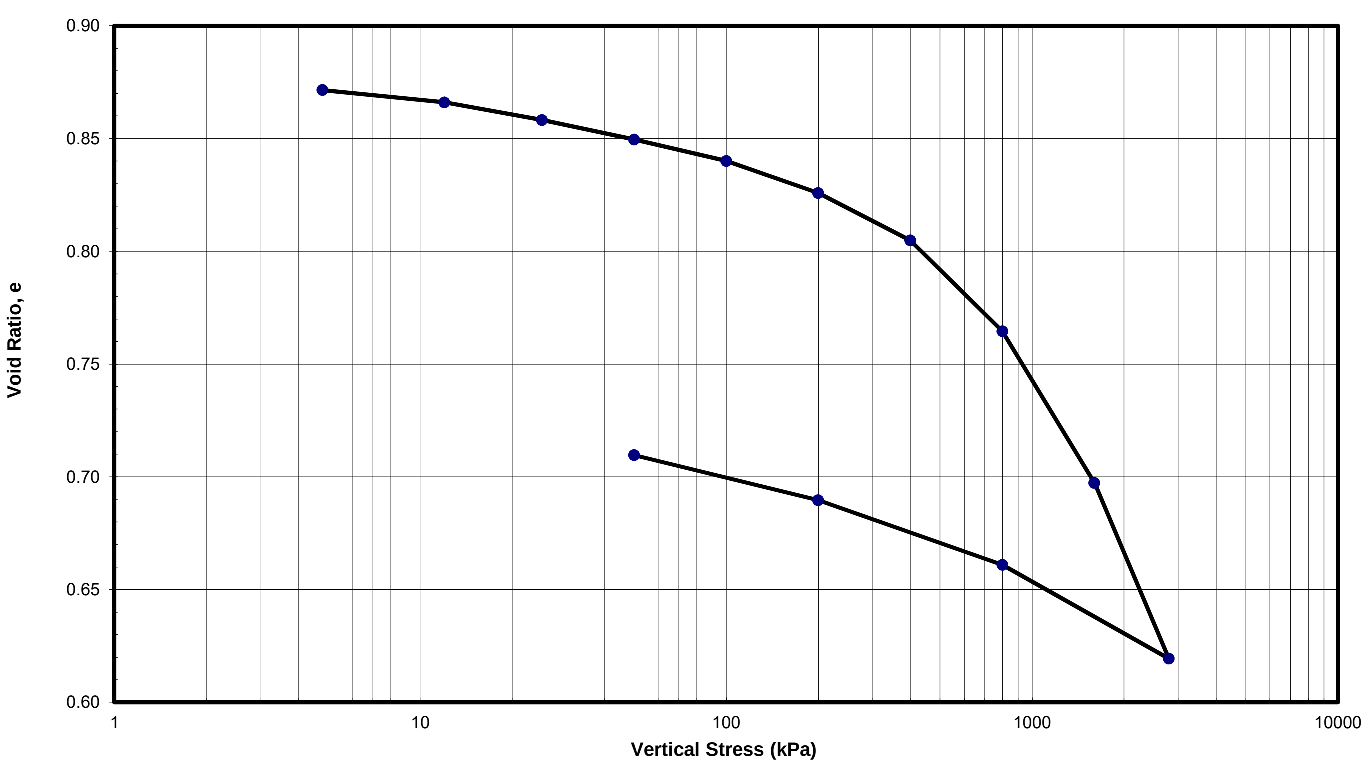
Form Nº TT117a

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 14, 2017
Borehole:	SRK17-TP20-1	Station:	LIR2
Sample No.:	Block	Depth (m):	-

One-Dimensional Consolidation (ASTM D2435)

Weight of Ring (g):	211.90	**Ring + Wet Weight (g):**	356.31	**Initial Void Ratio, e:**	0.87
Initial Height (mm):	25.40	**Ring + Dry Weight (g):**	328.81	**Height of Soil, Hs (mm):**	13.57
Diameter of Ring (mm):	63.50	**Water Content (%):**	23.5	**Height of Void, Hv (mm):**	11.83
Unit Weight (kN/m^3)	17.61	**Specific Gravity, Gs:**	2.72		

Step No.	Vertical Stress (kPa)	Height of Sample (mm)	Vertical Strain (%)	Final Void Ratio e_f	Change in Void Ratio e	Coefficient of Compressibility a_v (m^2/MN)	Coefficient of Volume Compressibility m_v (m^2/MN)
1	5	25.4000	0.0000	0.8715	0.00		
2	12	25.3263	0.2900	0.8660	0.01	0.7525	0.40
3	25	25.2197	0.7100	0.8582	0.01	0.6046	0.32
4	50	25.1028	1.1700	0.8496	0.01	0.3443	0.18
5	100	24.9733	1.6800	0.8400	0.01	0.1909	0.10
6	200	24.7802	2.4400	0.8258	0.01	0.1422	0.08
7	400	24.4958	3.5600	0.8048	0.02	0.1048	0.06
8	800	23.9497	5.7100	0.7646	0.04	0.1006	0.05
9	1600	23.0353	9.3100	0.6972	0.07	0.0842	0.05
10	2800	21.9786	13.4700	0.6194	0.08	0.0649	0.03
11	800	22.5425	11.2500	0.6609	-0.04	0.0208	0.01
12	200	22.9311	9.7200	0.6896	-0.03	0.0477	0.03
13	50	23.2029	8.6500	0.7096	-0.02	0.1335	0.07



Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 14, 2017	Date:	December 15, 2017	Date:	December 18, 2017

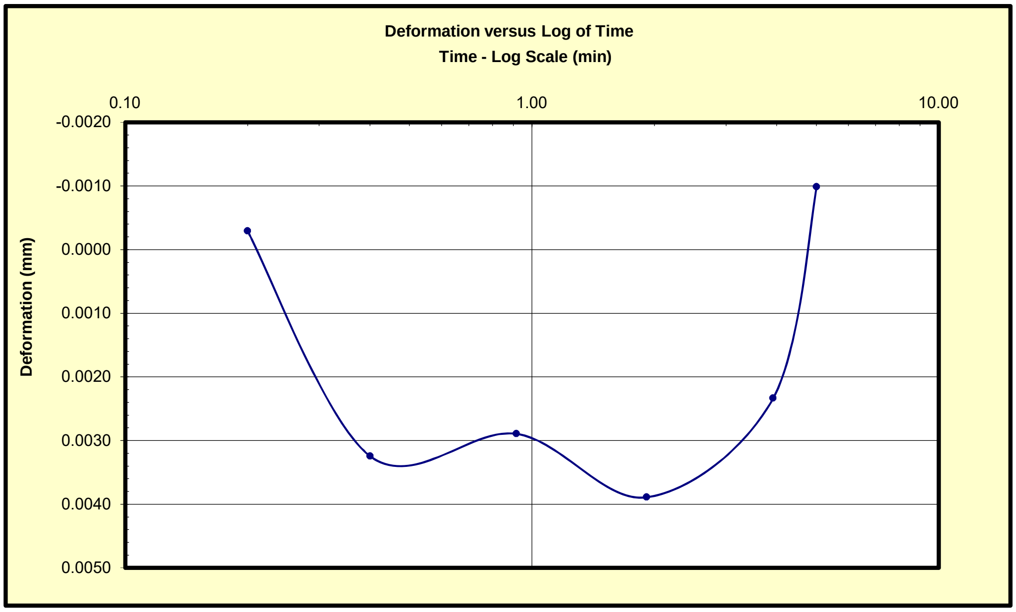
OQM CERTIFIED

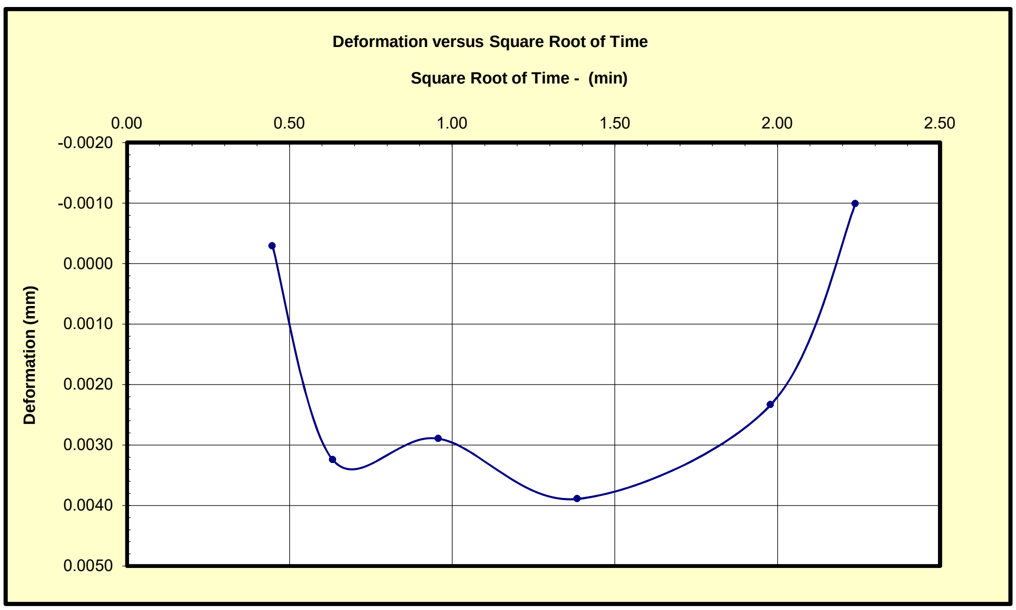
TETRA TECH CANADA INC.

Form Nº TT117a-1

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 14, 2017
Borehole:	SRK17-TP20-1	Station:	LIR2
Sample No.:	Block	Depth (m):	-
Consolidation Step:	1	Vertical Stress (kPa):	4.8

One-Dimensional Consolidation (ASTM D 2435)





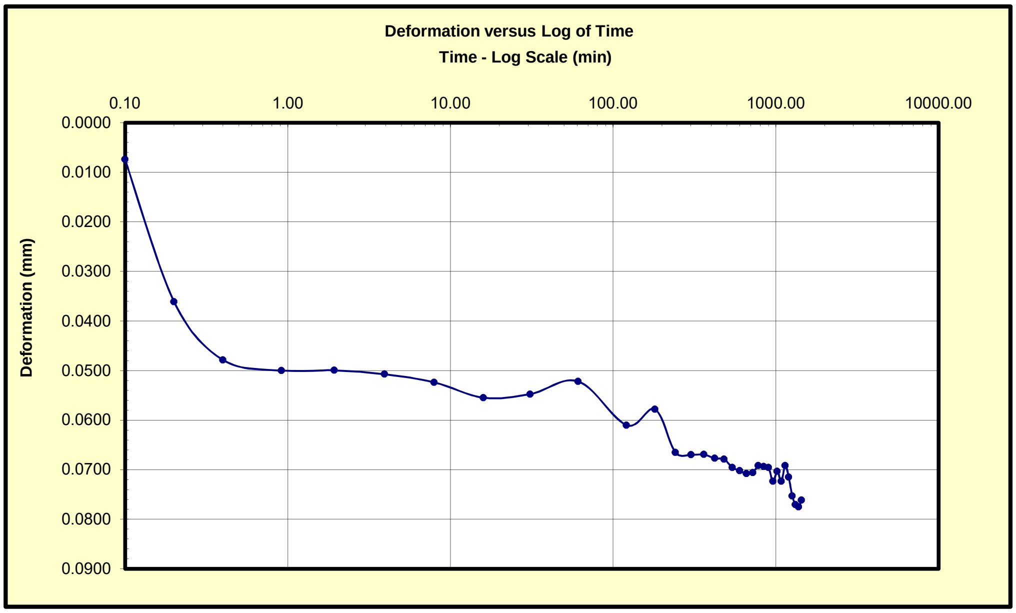
Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 14, 2017	Date:	December 15, 2017	Date:	December 18, 2017

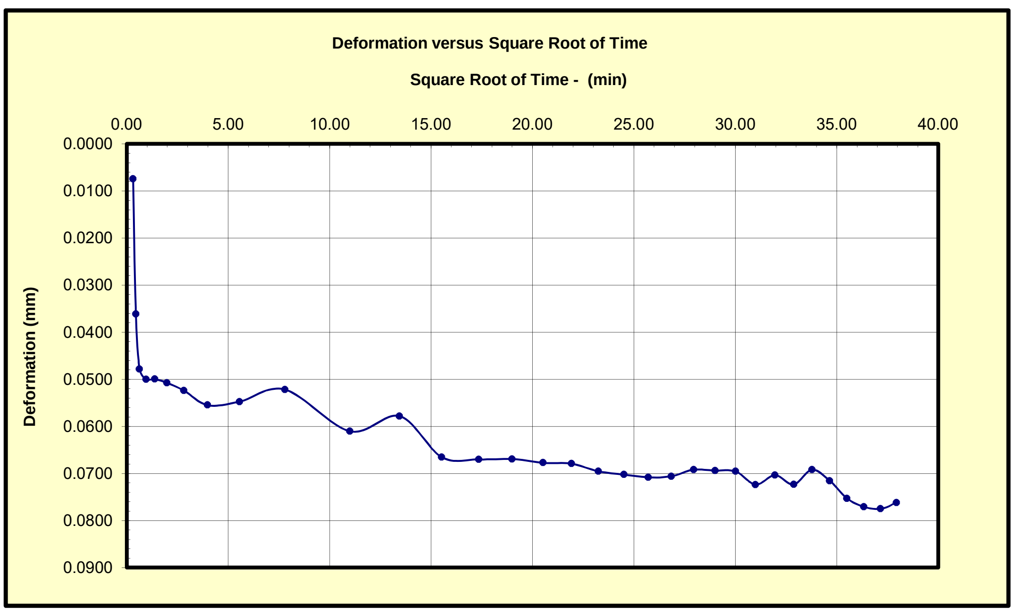
TETRA TECH CANADA INC.

Form Nº TT117a-1

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 14, 2017
Borehole:	SRK17-TP20-1	Station:	LIR2
Sample No.:	Block	Depth (m):	-
Consolidation Step:	2	Vertical Stress (kPa):	12.0

One-Dimensional Consolidation (ASTM D 2435)





Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 14, 2017	Date:	December 15, 2017	Date:	December 18, 2017

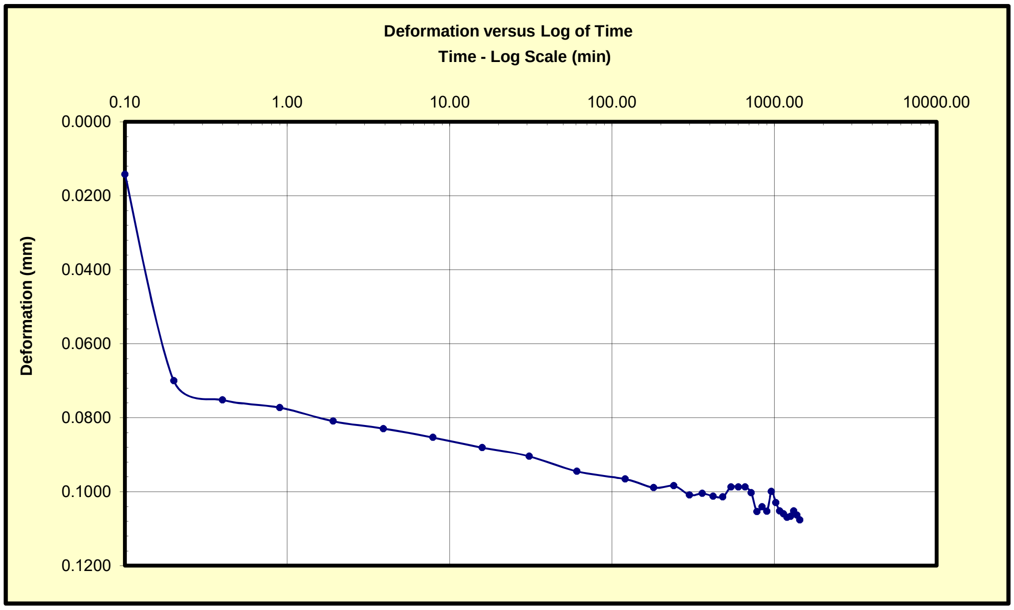
TETRA TECH CANADA INC.

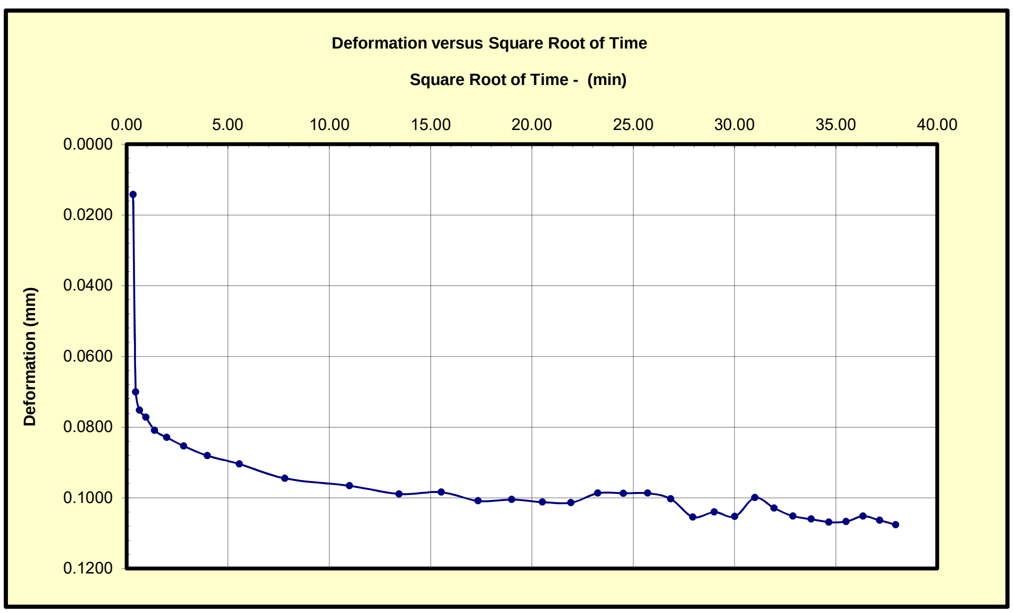
TETRA TECH

Form Nº TT117a-1

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 14, 2017
Borehole:	SRK17-TP20-1	Station:	LIR2
Sample No.:	Block	Depth (m):	-
Consolidation Step:	3	Vertical Stress (kPa):	25.0

One-Dimensional Consolidation (ASTM D2435)





Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 14, 2017	Date:	December 15, 2017	Date:	December 18, 2017

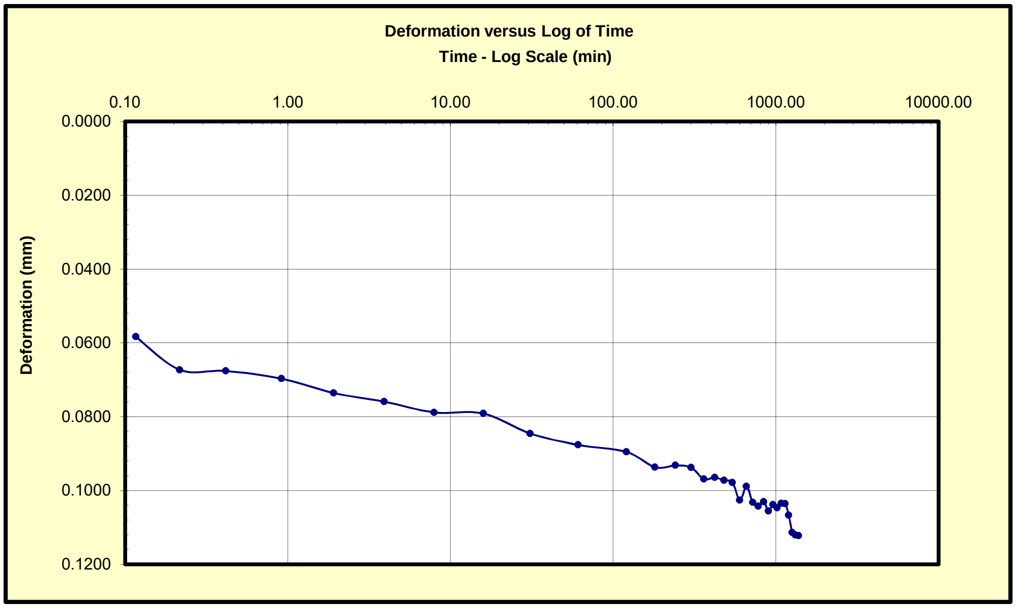
TETRA TECH CANADA INC.

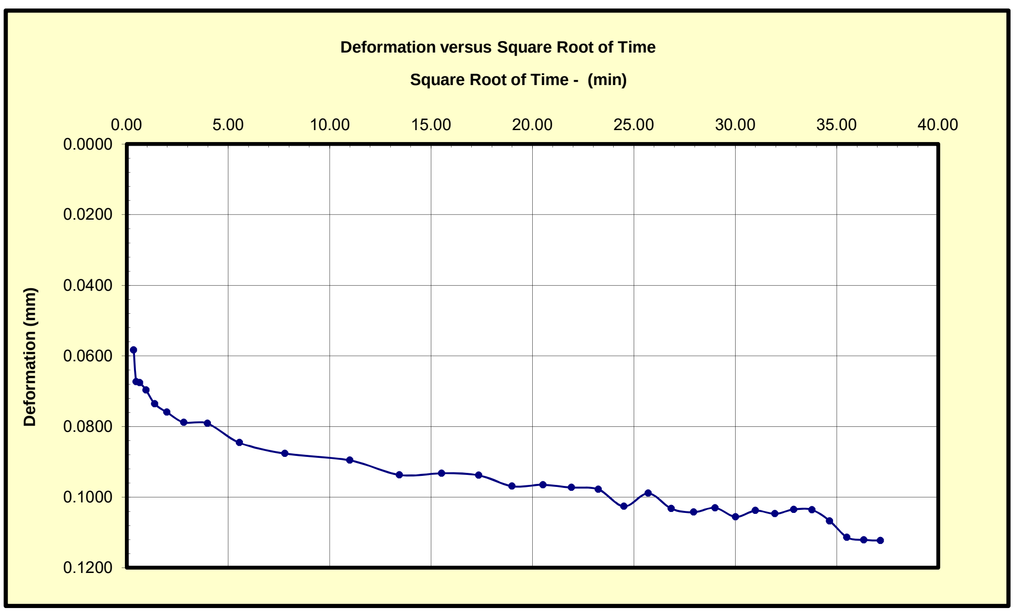
TETRA TECH

Form Nº TT117a-1

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 14, 2017
Borehole:	SRK17-TP20-1	Station:	LIR2
Sample No.:	Block	Depth (m):	-
Consolidation Step:	4	Vertical Stress (kPa):	50.0

One-Dimensional Consolidation (ASTM D2435)





Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 14, 2017	Date:	December 15, 2017	Date:	December 18, 2017

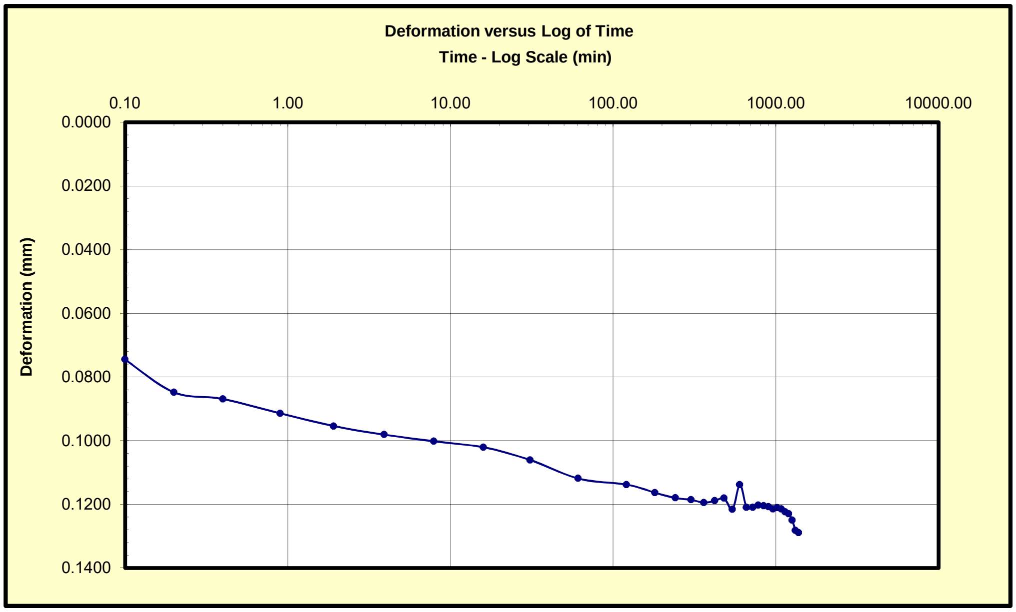
TETRA TECH

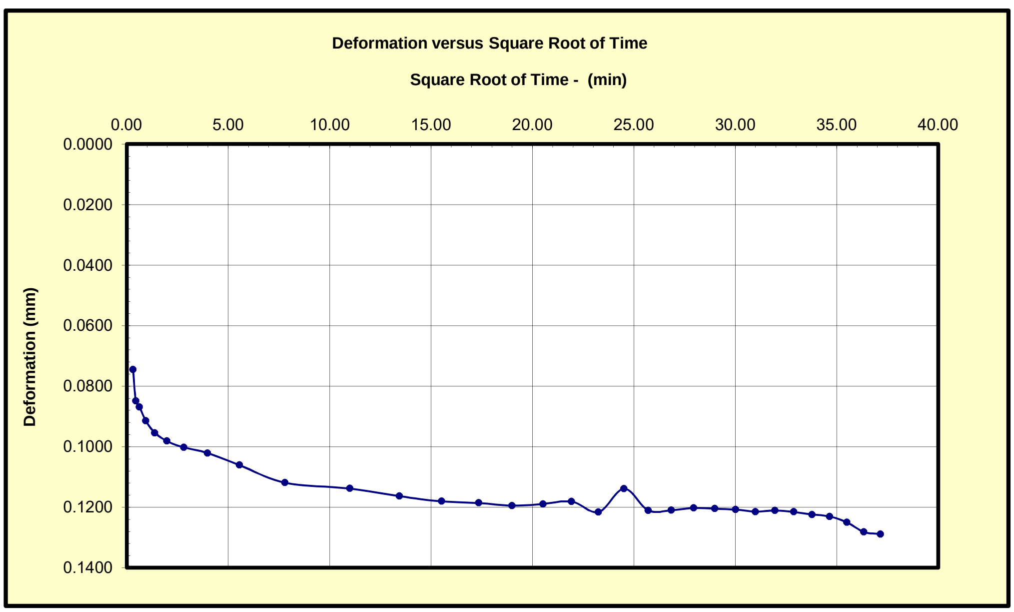
TETRA TECH CANADA INC.

Form Nº TT117a-1

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 14, 2017
Borehole:	SRK17-TP20-1	Station:	LIR2
Sample No.:	Block	Depth (m):	-
Consolidation Step:	5	Vertical Stress (kPa):	100.0

One-Dimensional Consolidation (ASTM D2435)





Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 14, 2017	Date:	December 15, 2017	Date:	December 18, 2017

OQM CERTIFIED

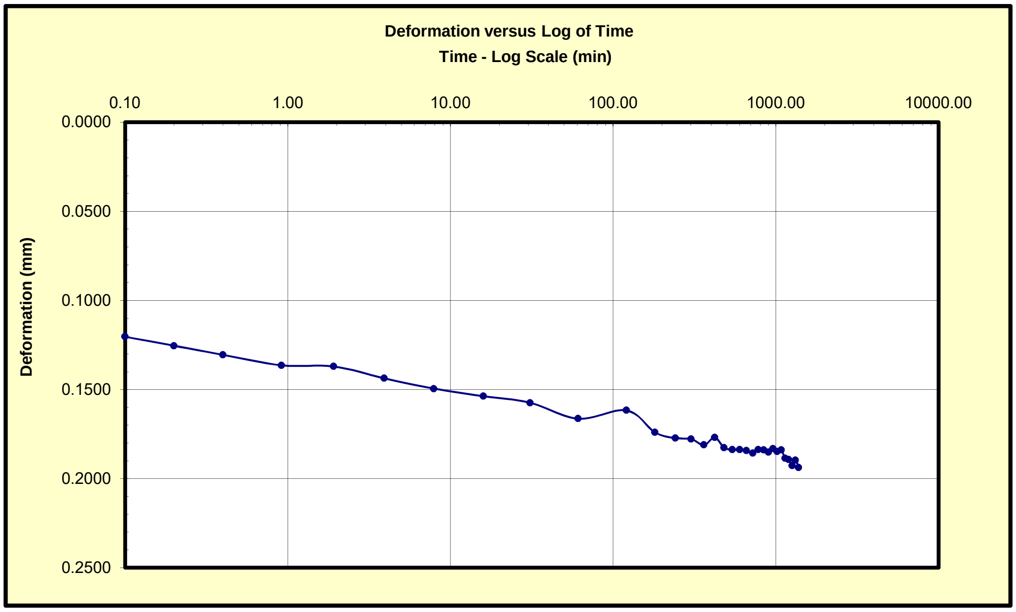
TETRA TECH

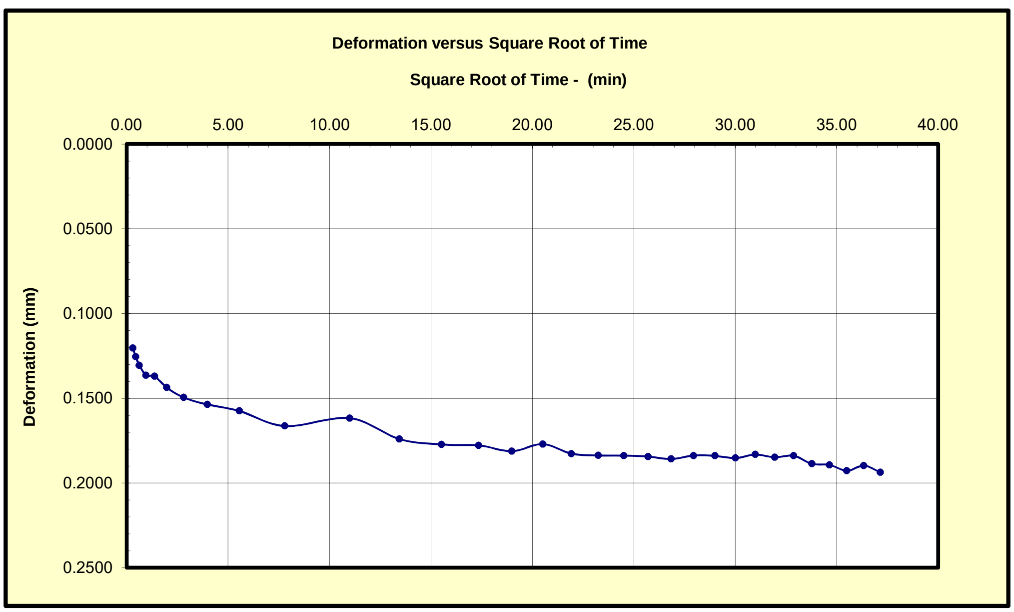
TETRA TECH CANADA INC.

Form Nº TT117a-1

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 14, 2017
Borehole:	SRK17-TP20-1	Station:	LIR2
Sample No.:	Block	Depth (m):	-
Consolidation Step:	6	Vertical Stress (kPa):	200.0

One-Dimensional Consolidation (ASTM D2435)





Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 14, 2017	Date:	December 15, 2017	Date:	December 18, 2017

OQM CERTIFIED

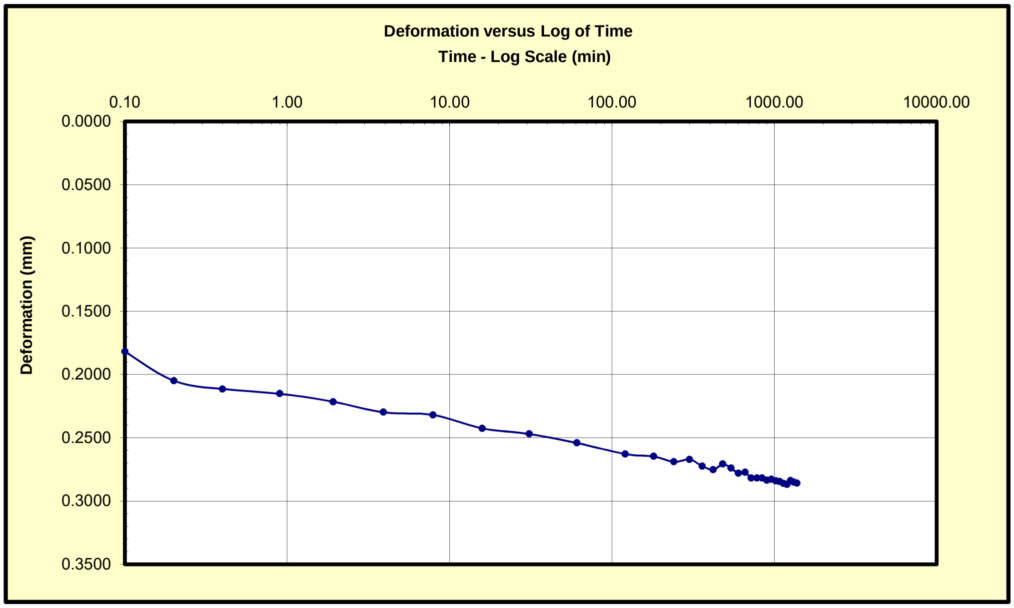
TETRA TECH

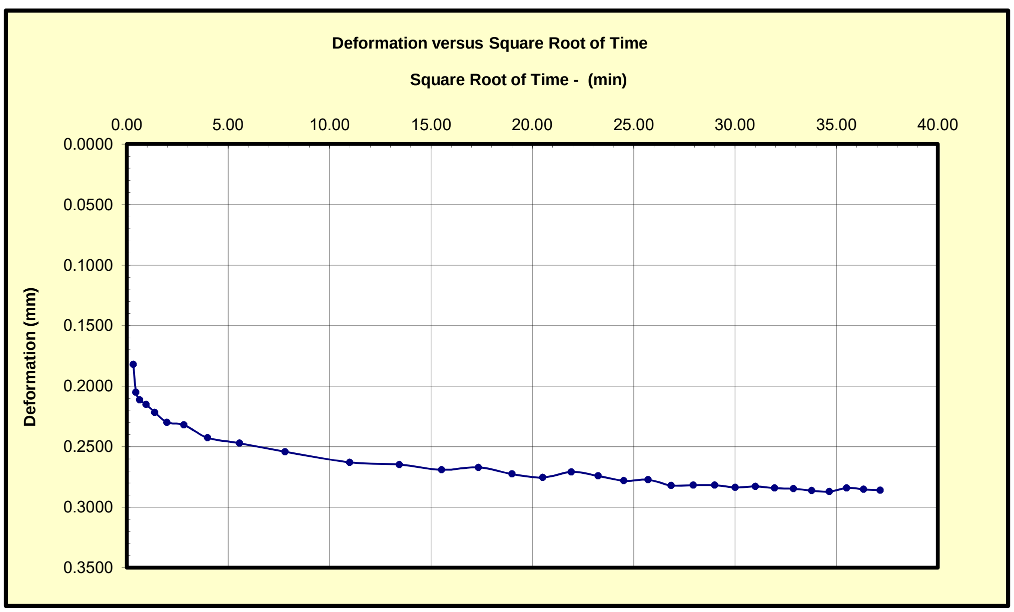
TETRA TECH CANADA INC.

Form Nº TT117a-1

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 14, 2017
Borehole:	SRK17-TP20-1	Station:	LIR2
Sample No.:	Block	Depth (m):	-
Consolidation Step:	7	Vertical Stress (kPa):	400.0

One-Dimensional Consolidation (ASTM D2435)





Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 14, 2017	Date:	December 15, 2017	Date:	December 18, 2017

OQM CERTIFIED

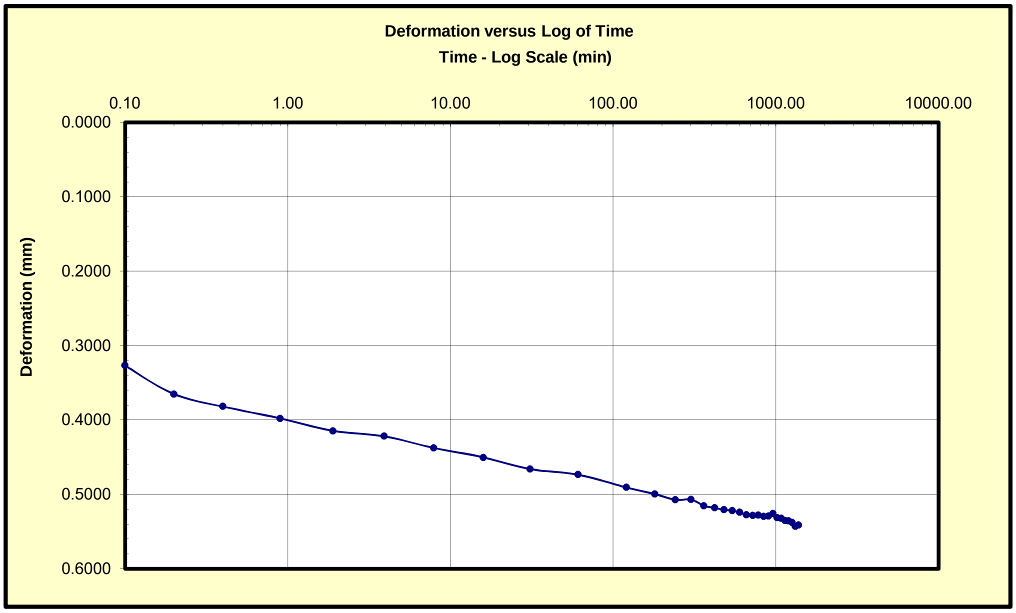
TETRA TECH CANADA INC.

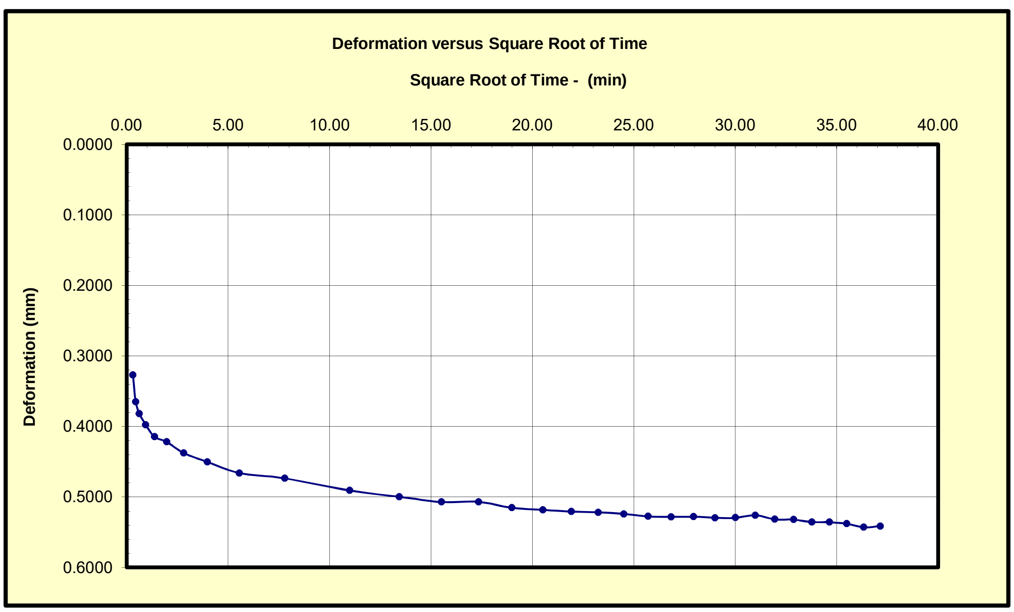
TETRA TECH

Form Nº TT117a-1

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 14, 2017
Borehole:	SRK17-TP20-1	Station:	LIR2
Sample No.:	Block	Depth (m):	-
Consolidation Step:	8	Vertical Stress (kPa):	800.0

One-Dimensional Consolidation (ASTM D2435)





Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 14, 2017	Date:	December 15, 2017	Date:	December 18, 2017

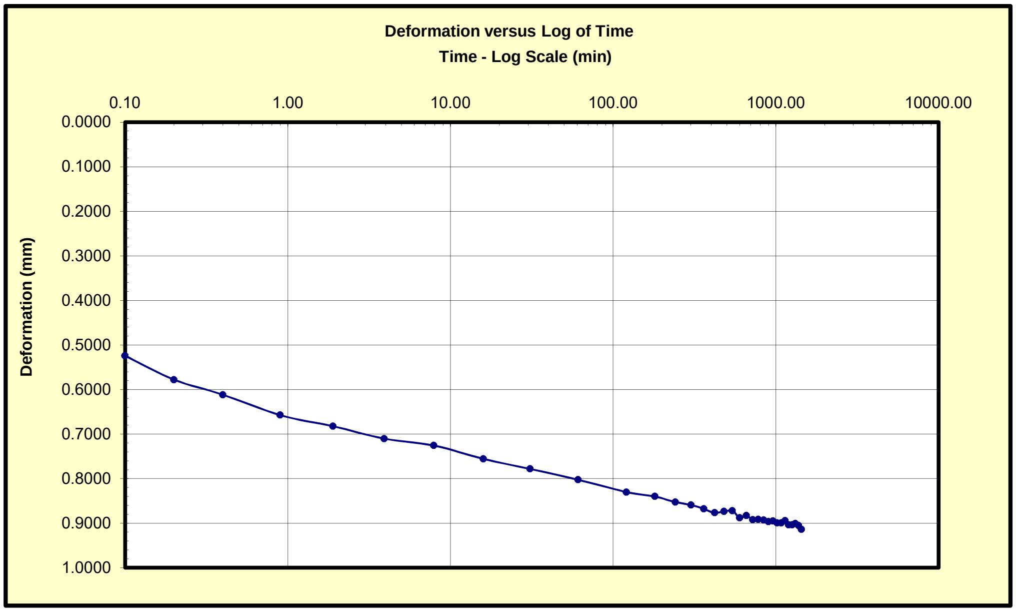
OQM CERTIFIED

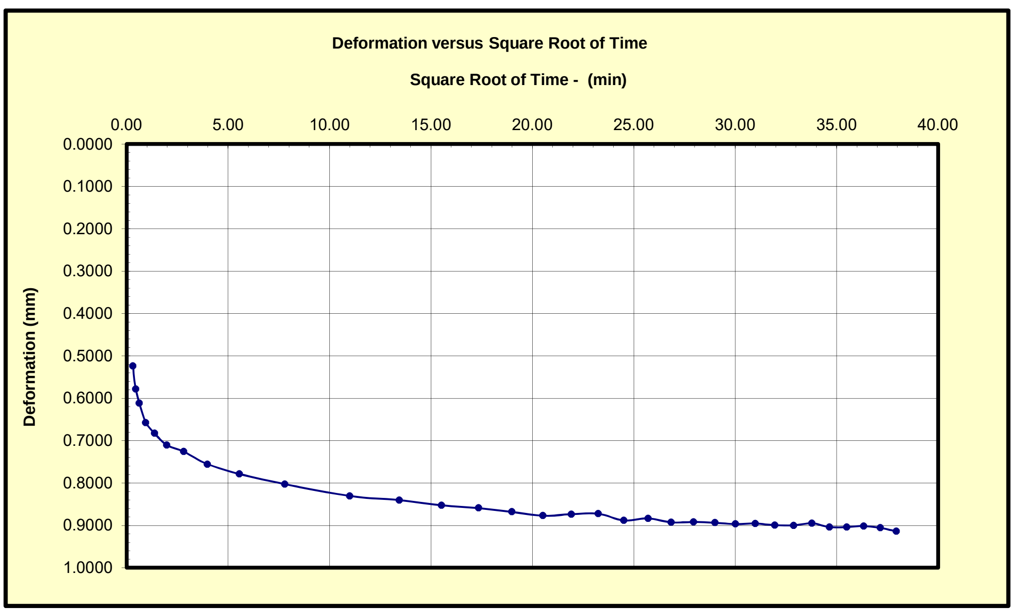
TETRA TECH CANADA INC.

Form Nº TT117a-1

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 14, 2017
Borehole:	SRK17-TP20-1	Station:	LIR2
Sample No.:	Block	Depth (m):	-
Consolidation Step:	9	Vertical Stress (kPa):	1600.0

One-Dimensional Consolidation (ASTM D2435)





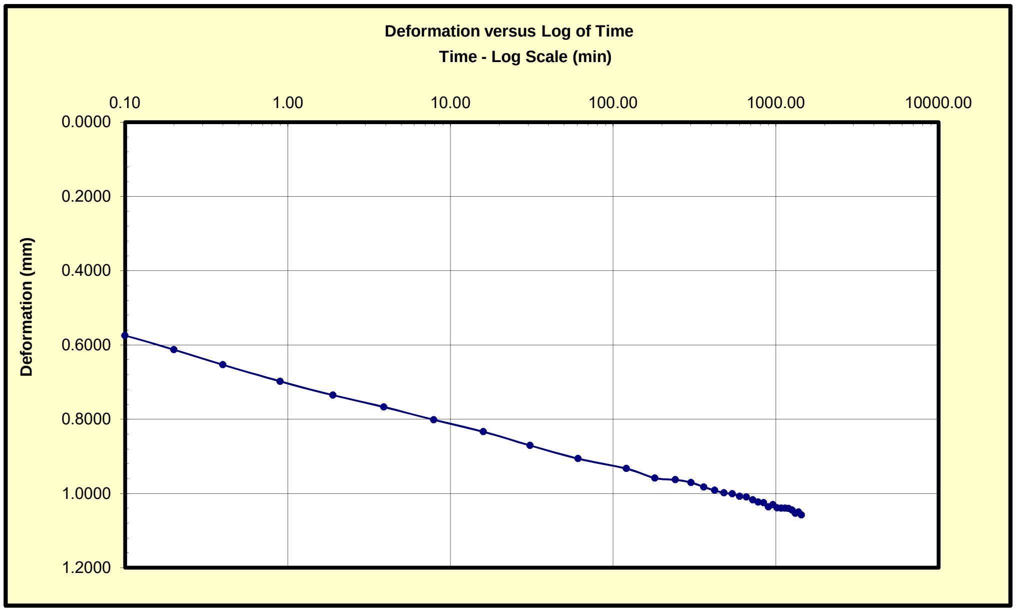
Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 14, 2017	Date:	December 15, 2017	Date:	December 18, 2017

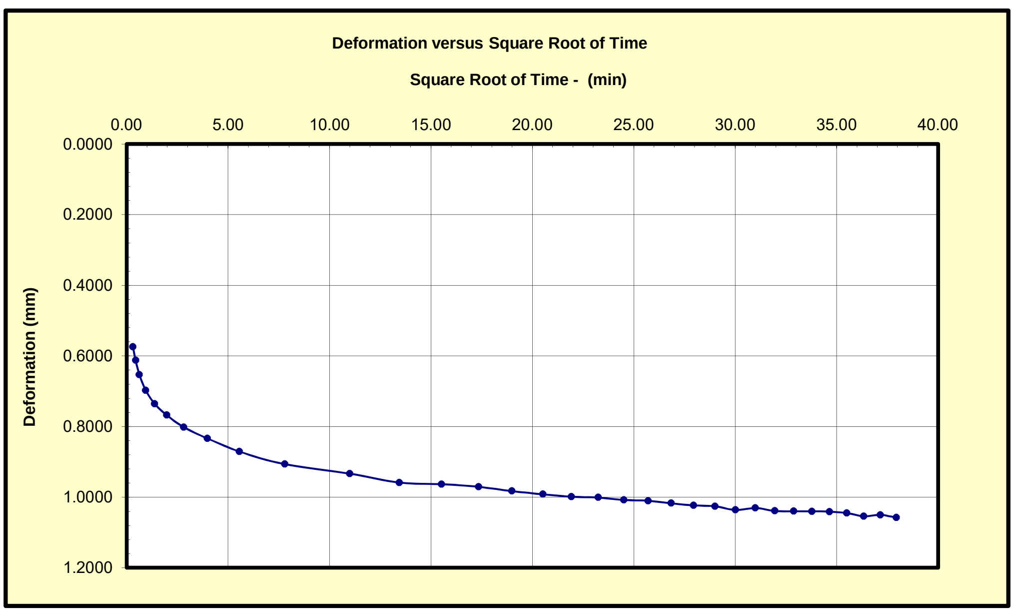
TETRA TECH CANADA INC.

Form Nº TT117a-1

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 14, 2017
Borehole:	SRK17-TP20-1	Station:	LIR2
Sample No.:	Block	Depth (m):	-
Consolidation Step:	10	Vertical Stress (kPa):	2800.0

One-Dimensional Consolidation (ASTM D2435)





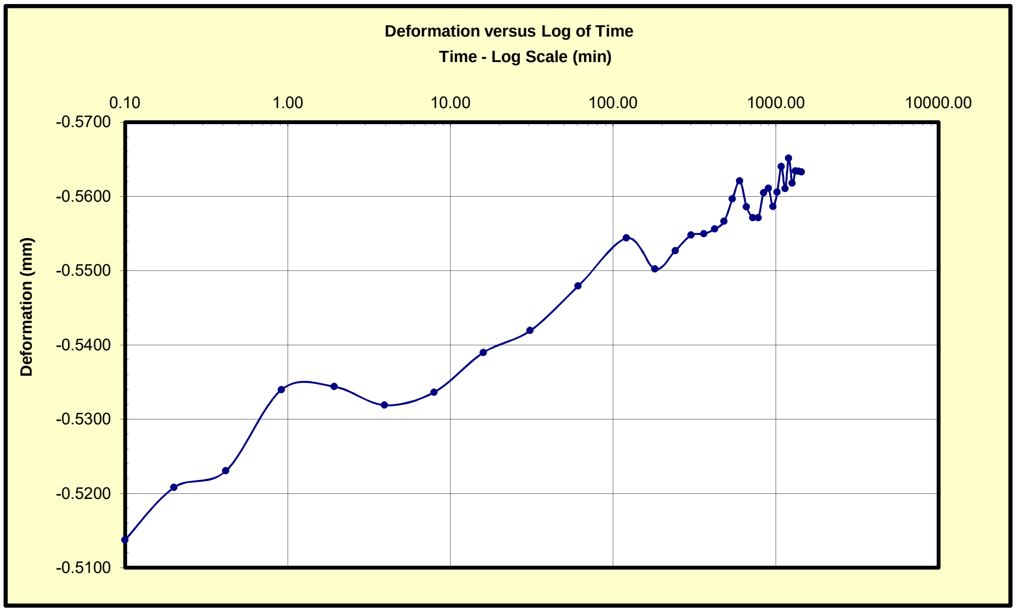
Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 14, 2017	Date:	December 15, 2017	Date:	December 18, 2017

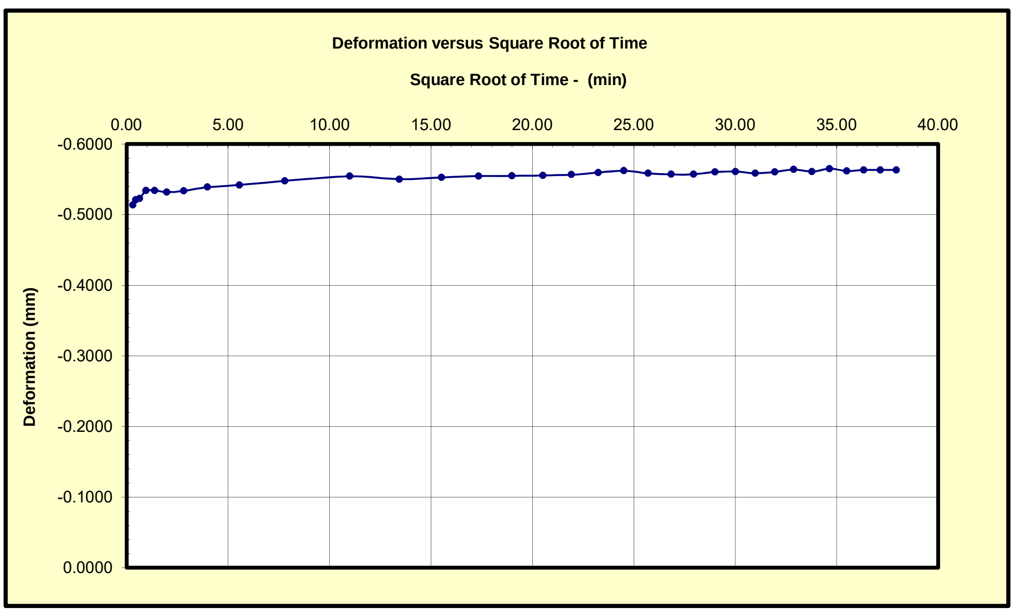
TETRA TECH CANADA INC.

Form Nº TT117a-1

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 14, 2017
Borehole:	SRK17-TP20-1	Station:	LIR2
Sample No.:	Block	Depth (m):	-
Consolidation Step:	11	Vertical Stress (kPa):	800.0

One-Dimensional Consolidation (ASTM D2435)





Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 14, 2017	Date:	December 15, 2017	Date:	December 18, 2017

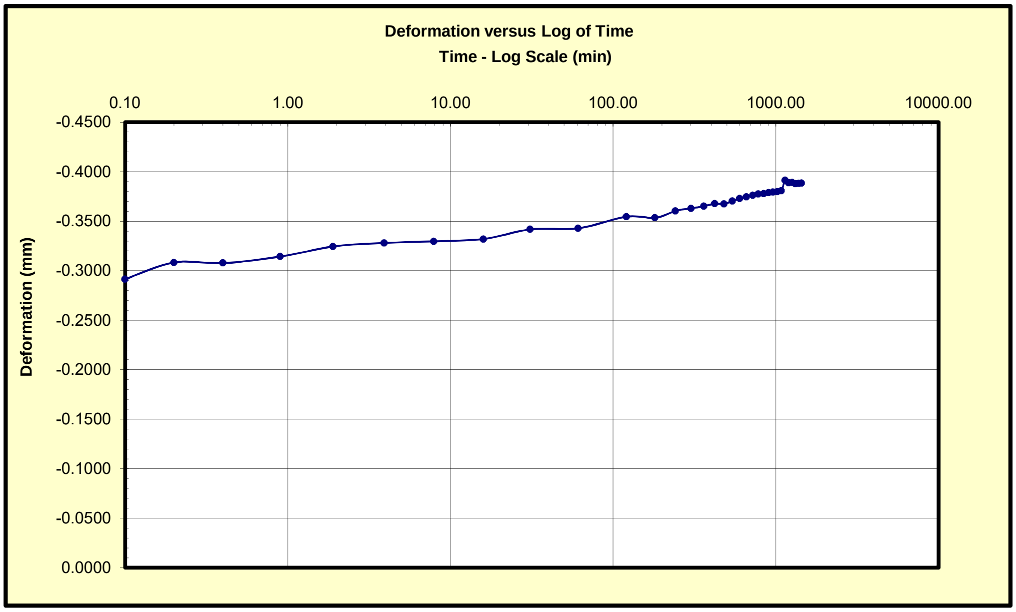
TETRA TECH CANADA INC.

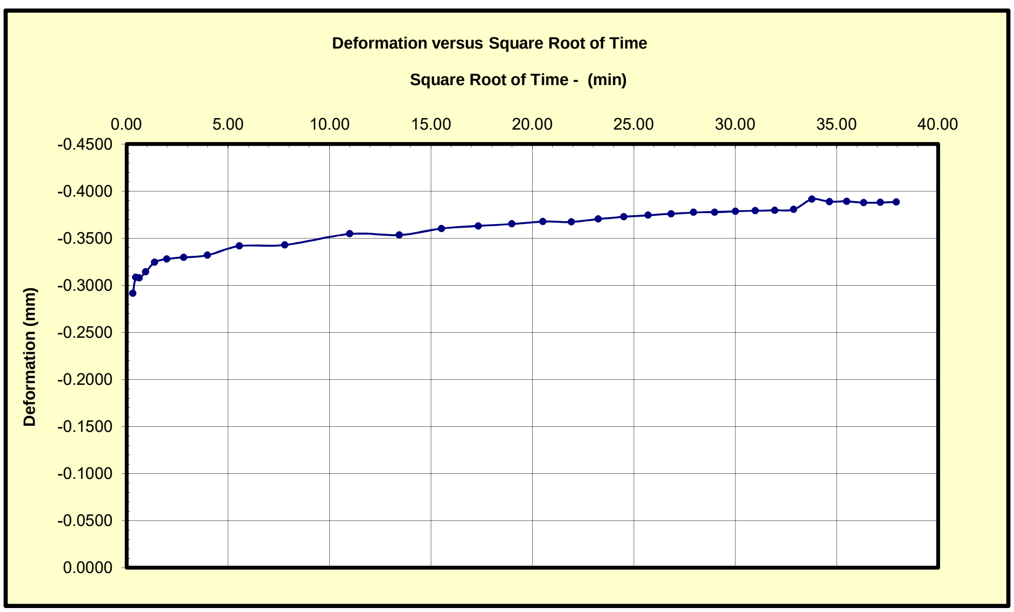
TETRA TECH

Form Nº TT117a-1

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 14, 2017
Borehole:	SRK17-TP20-1	Station:	LIR2
Sample No.:	Block	Depth (m):	-
Consolidation Step:	12	Vertical Stress (kPa):	200.0

One-Dimensional Consolidation (ASTM D2435)





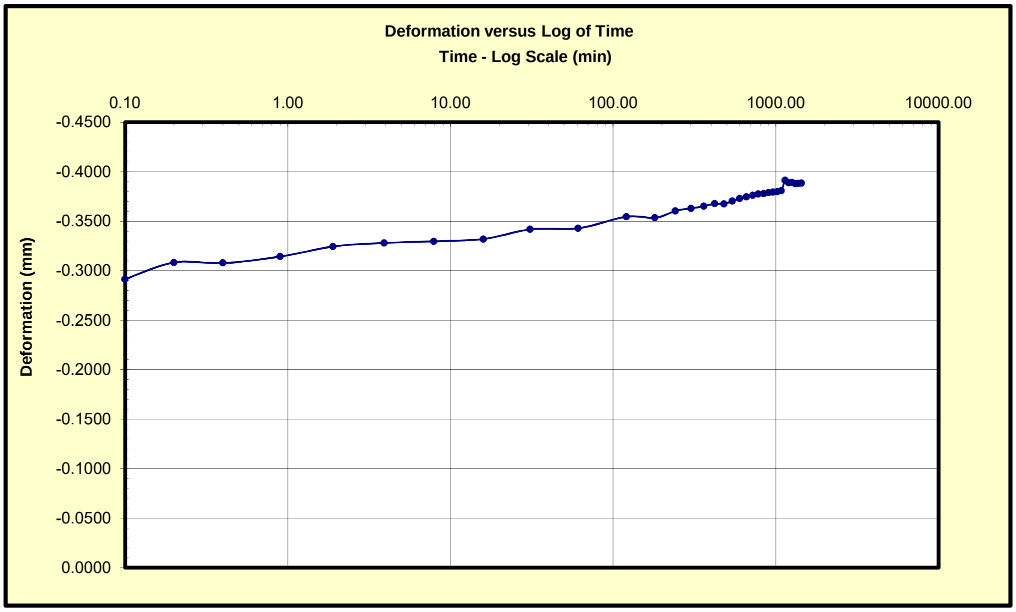
Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 14, 2017	Date:	December 15, 2017	Date:	December 18, 2017

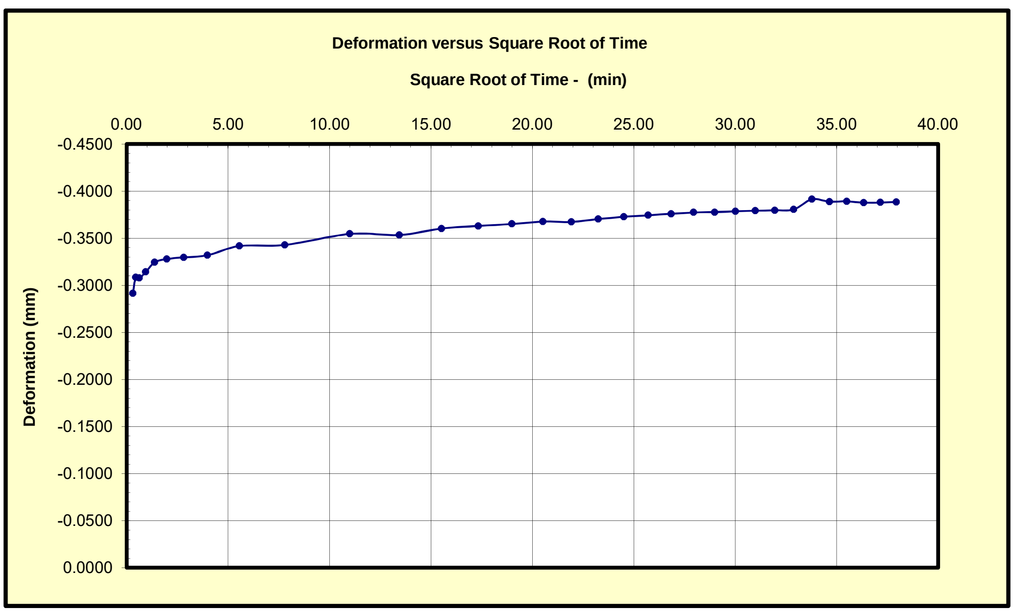
TETRA TECH CANADA INC.

Form Nº TT117a-1

Project:	SRK - HB Tailings	Project No.:	17-MTS-038
Location:	Salmo, BC	Date:	December 14, 2017
Borehole:	SRK17-TP20-1	Station:	LIR2
Sample No.:	Block	Depth (m):	-
Consolidation Step:	13	Vertical Stress (kPa):	50.0

One-Dimensional Consolidation (ASTM D2435)





Prepared By:	PC	Checked By:	PS	Approved By:	JPS
Date:	December 14, 2017	Date:	December 15, 2017	Date:	December 18, 2017

Appendix F-2 – Cover Borrow Investigation

SRK Consulting (Canada) Inc.
2200–1066 West Hastings Street
Vancouver, BC V6E 3X2

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F: +1.604.687.5532
vancouver@srk.com
www.srk.com

Memo

To:	File	**Client:**	Regional District of Central Kootenay
From:	Peter Mikes, PEng.	**Project No:**	1CR012.005.800
Cc:	Daryl Hockley	**Date:**	December 13, 2019
Subject:	HB Mine Tailings Facility - Cover Borrow Investigation		

1 Introduction

The closure and remediation of the HB Mine Tailings Facility is estimated to require between 100,000 and 130,000 m^3 of borrow with approximately 90,000 m^3 of this volume required to cover the tailings.

The objective of the tailings cover is to provide dust and erosion control, prevent direct contact by humans and wildlife, and to provide a growth medium to support sustainable vegetation. Mo specific material specification is required to meet the tailings cover objectives, however a well-graded material with over 10% fines is preferred to reduce infiltration to the practical extent possible and to be able to retain moisture within the cover to aid in revegetation.

A test pit borrow investigation was undertaken on October 10 and 11, 2018 at the "Till Borrow Area" located to the southeast of the Central Landfill. The objective of the investigation was to confirm sufficient borrow volume is available for the project. Additional borrow is also available at the Landfill Sand and Gravel Borrow Area located to the east of the Central Landfill where test pits were excavated in 2017 (SRK 2018). The general location of both borrow areas are provided in Figure 1.

This report provides a summary of the test pit program and an estimate of the available borrow volume.

2 Test Pit Program

2.1 Overview

The test pit investigation occurred on October 10 and 11, 2018. Weather throughout the investigation was partly cloudy to overcast with temperatures ranging between -2 and 13 °C. Twenty test pits were excavated using a CAT 315 excavator with a maximum reach of approximately 5 m. The excavator and operator were provided by Custom Dozing Ltd. under contract to the RDCK. SRK field engineer Peter Mikes was present during the test pit excavations to log and collect samples. In addition, Linden Terry of SNC-Lavalin Environment (representing Teck Resources), was on-site during the test pit program to collect samples to determine its suitability as a backfill material for a separate project.

Logging was completed as per the Unified Soil Classification System (ASTM D-2487). Grab samples were collected from representative soil units and were placed in Zip-Loc bags to aid in preserving moisture contents.

2.2 Test Pit Locations

Table 1 lists the co-ordinates, depths and reason for termination of each test pit, with the locations plotted in Figure 2. In general, the test pits were located along old access roads, or within areas of disturbance. Most test pits were terminated prior to reaching the excavators' maximum depth due to time considerations, with the preference during the investigation to complete more test pits rather than reach the maximum depth.

Table 1: Test Pit Locations

Test Pit ID	Easting (m)	Northing (m)	Total Depth (m)	Reason for Termination
SRK18-TP-01	482,344.4	5,442,648.6	3.0	Hard digging, slow progress
SRK18-TP-02	482,354.8	5,442,530.5	3.5	Hard digging, slow progress
SRK18-TP-03	482,312.5	5,442,466.3	2.7	Hard digging, slow progress
SRK18-TP-04	482,334.4	5,442,404.6	2.7	Hard digging, slow progress
SRK18-TP-05	482,429.0	5,442,493.4	3.0	Hard digging, slow progress
SRK18-TP-06	482,417.8	5,442,541.0	4.8	End of reach
SRK18-TP-07	482,410.8	5,442,571.9	3.3	Hard digging, slow progress
SRK18-TP-08	482,399.8	5,442,623.1	2.8	Suspected bedrock
SRK18-TP-09	482,473.4	5,442,513.1	4.0	End of reach
SRK18-TP-10	482,326.3	5,442,369.4	3.1	Suspected bedrock
SRK18-TP-11	482,343.3	5,442,323.9	3.1	Suspected bedrock
SRK18-TP-12	482,386.8	5,442,317.1	2.4	Hard digging, slow progress
SRK18-TP-13	482,512.4	5,442,546.7	4.0	End of reach
SRK18-TP-14	482,243.7	5,442,429.6	3.7	Hard digging, slow progress
SRK18-TP-15	482,181.4	5,442,424.9	2.7	Hard digging, slow progress
SRK18-TP-16	482,147.9	5,442,399.4	3.5	Hard digging, slow progress
SRK18-TP-17	482,125.0	5,442,387.1	2	Hard digging, slow progress
SRK18-TP-18	482,138.4	5,442,465.6	2.3	Hard digging, slow progress
SRK18-TP-19	482,168.2	5,442,570.7	4.5	Test pit sloughing
SRK18-TP-20	482,093.0	5,442,580.4	2.3	Time restriction

Note: Co-ordinates are UTM NAD83.

2.3 Sample Collection and Testing Program

Representative grab samples were collected from each material type encountered (Table 2). At this time, no testing of the samples is proposed as the materials were found to be similar to those encountered in previous investigations (Table 3).

Table 2: Summary of Grab Samples Collected

Test Pit	Sample ID	Representative Depth (m)
SRK18-TP01	TP1-1	1.0 – 1.5 m
SRK18-TP02	TP2-1	1.0 – 1.5 m
SRK18-TP03	TP3-1	0.5 – 1.0 m
SRK18-TP05	TP5-1	0.5 – 1.0 m
SRK18-TP09	TP9-1	1.0 – 1.5 m
SRK18-TP10	TP10-1	1.0 – 1.5 m
SRK18-TP13	TP13-1	0.5 – 1.0 m
SRK18-TP14	TP14-1	1.0 – 1.5 m
SRK18-TP15	TP15-1	0.5 – 1.0 m
SRK18-TP16	TP16-1	0.5 – 1.0 m
SRK18-TP17	TP17-1	0.5 – 1.0 m
SRK18-TP19	TP19-1	1.0 – 1.5 m
SRK18-TP20	TP30-1	1.0 – 1.5 m

Table 3: Relevant References to Previous Investigations

Report	Description
Central Landfill Closure Plan (AMEC 2014)	• Fifteen test pits were excavated in 2014 within the current footprint of the Till Borrow Area. • Geotechnical testing consisted of five particle size distributions, two compaction tests, and two permeability tests.
HB Mine Tailings Facility 2017 Test Pit Investigation (SRK 2017)	• Eight test pits were excavated at the Landfill Sand and Gravel Borrow Area (Figure 1). • Geotechnical testing included eleven particle size distribution tests.
Review of HB Dam Zones and Material Properties (SRK 2018)	• Provides a review of all geotechnical data that has been tested on the property related to the HB Dam. Includes testing of till, glaciolacustrine, and sand and gravel materials.

3 Summary and Results

3.1 Field Observations

Figure 2 provides a summary of the test pit logs in the Till Borrow Area. All test pits were dry, except for SRK18-TP-05 and -19.

Within the disturbed borrow footprint, the test pits indicate the existing borrow will be able to be deepened, with till observed at all locations (SRK18-TP-01 to -03, and SRK18-TP-14). The material generally consists of silty sand (or sandy silt) with gravel and cobbles, which is consistent with the test pits provided in AMEC (2014). At the north end of the borrow area, the 5 m high cut slopes along the landfill road indicate the till deposit is thicker than the 2.5 to 4.0 m able to be excavated in the test pits.

Seven test pits were excavated to the south and southwest of the Till Borrow Area (SRK18-TP-10 to -12 and SRK18-TP-15 to -18) and was generally coarser than the material within the Till Borrow Area. Difficult digging conditions were encountered at each test pit, and each were terminated prior to reaching maximum excavator depth due to slow excavation progress and the general lack of fines[1]. Two of the test pits (SRK18-TP-10 and SRK18-TP-11) are suspected to have encountered bedrock at an approximate depth of 3 m.

Six test pits were excavated to the east of the Till Borrow Area (SRK18-TP-05 to 09, and SRK18-TP-13). Test pit SRK18-TP-08 was excavated adjacent to a bedrock outcrop located approximately 25 m to the east, and encountered bedrock at a depth of 2.8 m. Further to the south, test pits SRK18-TP-06, -07, -09 and -13 all encountered fine-grained glaciolacustrine material ranging from fine sands to silts and clays. SRK18-TP-05 encountered till at a depth of 2.0 m with the overlying material consisting of a coarser silty sand with gravel and cobbles. Water was observed to be entering the test pit at the top of the till layer.

Two test pits were excavated at the base of the large road cut to the northwest of the Till Borrow Area (SRK18-TP-19 and -20). The exposed cut-slope above the test pits has a height of approximately 6 m and consists of sandy with gravel and cobbles, with variable fines content. Clean sand and gravel material was encountered in SRK18-TP-19 at a depth of 1.5 m, with the material becoming increasingly wet with depth. The test pit was terminated at a depth of approximately 4.5 m due to excessive sloughing.

3.2 Borrow Volume Estimates

Borrow development plans and sections were developed for both the Till Borrow Area and the Landfill Sand and Gravel Borrow Area based on the test pit results. Figure 3 provides a plan of the Till Borrow Area Expansion, while Figure 4 provides a plan of the Landfill Sand and Gravel Borrow Area Expansion based on the 2017 investigation test pits (SRK 2017). Figure 5 provides

[1] Commonly, a fines content greater than 10% is preferred for soil covers to retain moisture to support vegetation.

sections for both borrow areas. Both borrow areas are designed to have a 5% grade on the pit floors, with side-slopes of 2H:1V or flatter.

The Till Borrow Area Expansion (Figure 3) assumes the following:

- The north end of the existing borrow area (Area 1) can be excavated down to the base of the slope along the access road, with the cut slope extended approximately 10 m into the borrow area.
- The south end of the existing borrow area (Area 2) can be deepened by 5 m.
- The Southeast Expansion Area has a typical 3 m excavation depth and is designed to drain towards the ephemeral stream located south of the expansion footprint (near SRK18-TP-04).
- The Southwest Expansion Area can be deepened by 4 m along the base of the existing slope along the access road, and the slope face can be pushed back by approximately 30 m.

The expansion of the Landfill Sand and Gravel Borrow Area assumes the following:

- The existing floor of the borrow area can be deepened by approximately 4 m (Phase 1), and,
- The existing slope of the borrow can be pushed back by approximately 20 m.

Table 4 provides a summary of the estimated volumes of available borrow material for each borrow area. Two volume estimates were prepared: the minimum expected volume based on an average depth of 3.0 m throughout each borrow footprint, and the best estimate volume based on the borrow development designs presented in Figure 3 to 5.

Table 4: Borrow Area Volume Estimate

Zone	Area (m^2)	Minimum Expected Volume (m^3)	Best Estimate Volume (m^3)
Till Borrow Area			
Existing Footprint Area 1	16,000	48,000	61,900
Existing Footprint Area 2	62,350	38,700	62,400
Southeast Expansion Area	16,140	48,400	49,000
Southwest Expansion Area	11,150	33,500	61,90
Subtotal - Till Borrow Area		*168,600*	*235,000*
Landfill Sand and Gravel Borrow Area	12,000	36,000	50,200
Grand Total		**205,000**	**285,200**

Notes:

1. The minimum expected volume estimate assumes an average excavation depth of 3.0 for each area.
2. The best estimate volumes are based on the borrow development designs presented in Figure 3 to 5.

4 Conclusions and Recommendations

The closure and remediation design for the HB Mine Tailings Facility is estimated to require between 100,000 and 130,000 m^3 of borrow material, with 90,000 m^3 required to cover the tailings.

Volume estimates of the Till Borrow Area indicated there is sufficient borrow material for the project, with a minimum estimate of 168,600 m^3 and a best estimate volume of 235,000 m^3. The Landfill Sand and Gravel Borrow Area is estimated to provide an additional 36,000 to 50,000 m^3 of material.

Where till and fine-grained materials are required for the project, they may be sourced from either existing footprint or Southeast Expansion Area of the Till Borrow Area. The tailings cover soils are recommended to be sourced from these areas.

Where coarse-grained materials are required for the project, they may be sourced from either the Southwest Expansion Area of the Till Borrow Area, or the Landfill Sand and Gravel Borrow Area.

We trust this memorandum meets with your project requirements. Please contact the undersigned at (604) 681.4196 if you have any questions or concerns.

Yours truly,

SRK Consulting (Canada) Inc.

PROFESSIONAL
PROVINCE OF
P. H. MIKES
33319
BRITISH COLUMBIA
Dec. 13/2019
ENGINEER

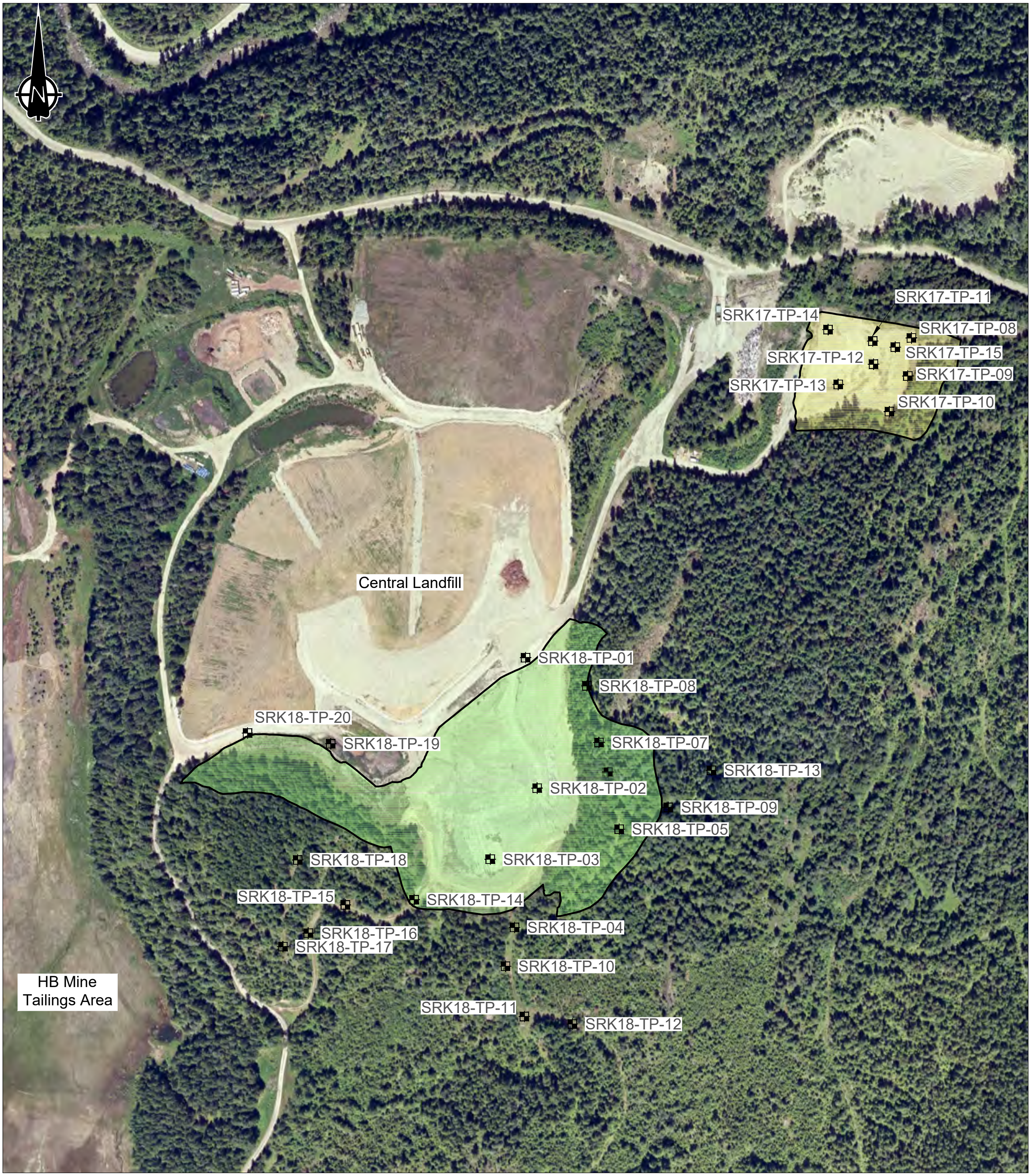
Peter Mikes, P.Eng.
Principal Consultant

5 References

Amec Foster Wheeler Environment & Infrastructure. 2015. Central Landfill Closure Plan. Report prepared for the Regional District of Central Kootenay. May 1.

SRK Consulting (Canada) Inc. 2018. HB Mine Tailings Facility – 2017 Test Pit Investigation. Report prepared for the Regional District of Central Kootenay. SRK Project Number 1CR012.004. March.

Figures



LEGEND

- Test Pit Location
- Sand and Gravel Borrow Area
- Till Borrow Area

0m 50 100 150 200

srk consulting

REGIONAL DISTRICT CENTRAL KOOTENAY

2018 Borrow Investigation

General Arrangement

SRK JOB NO.: 1CR012.005.800

FILE NAME: 1CR012.005 - GA.dwg

HB Mine Tailings Facility

DATE:	APPROVED:	FIGURE:
November 2018	PHM	1

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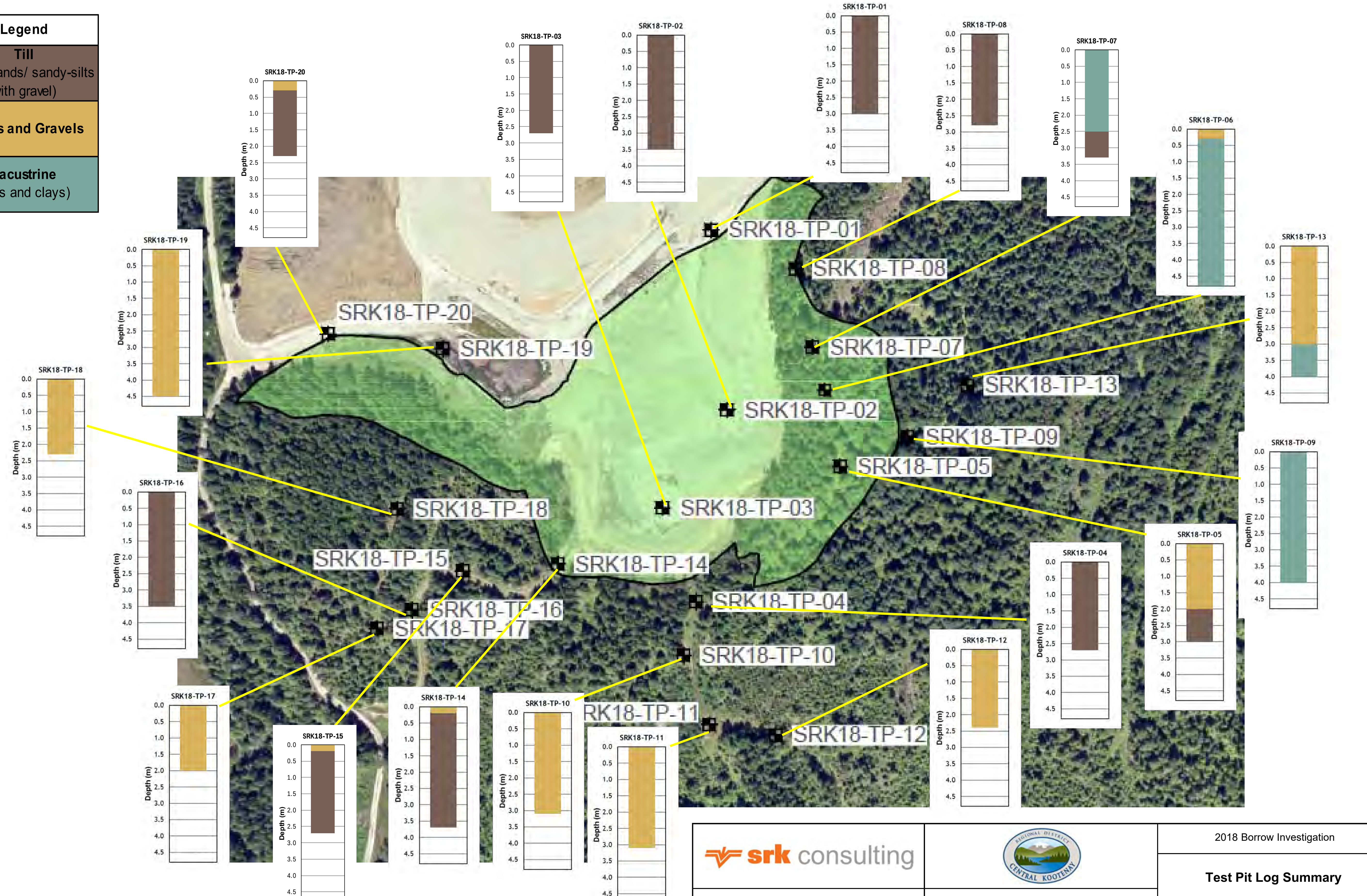
Legend

- **Till** (silty -sands/ sandy-silts with gravel)
- **Sands and Gravels**
- **Lacustrine** (silts and clays)



srk consulting

Job No: 1CR012.005.800

Filename: Stick-Log_Figure_1CR012-005-800.pptx

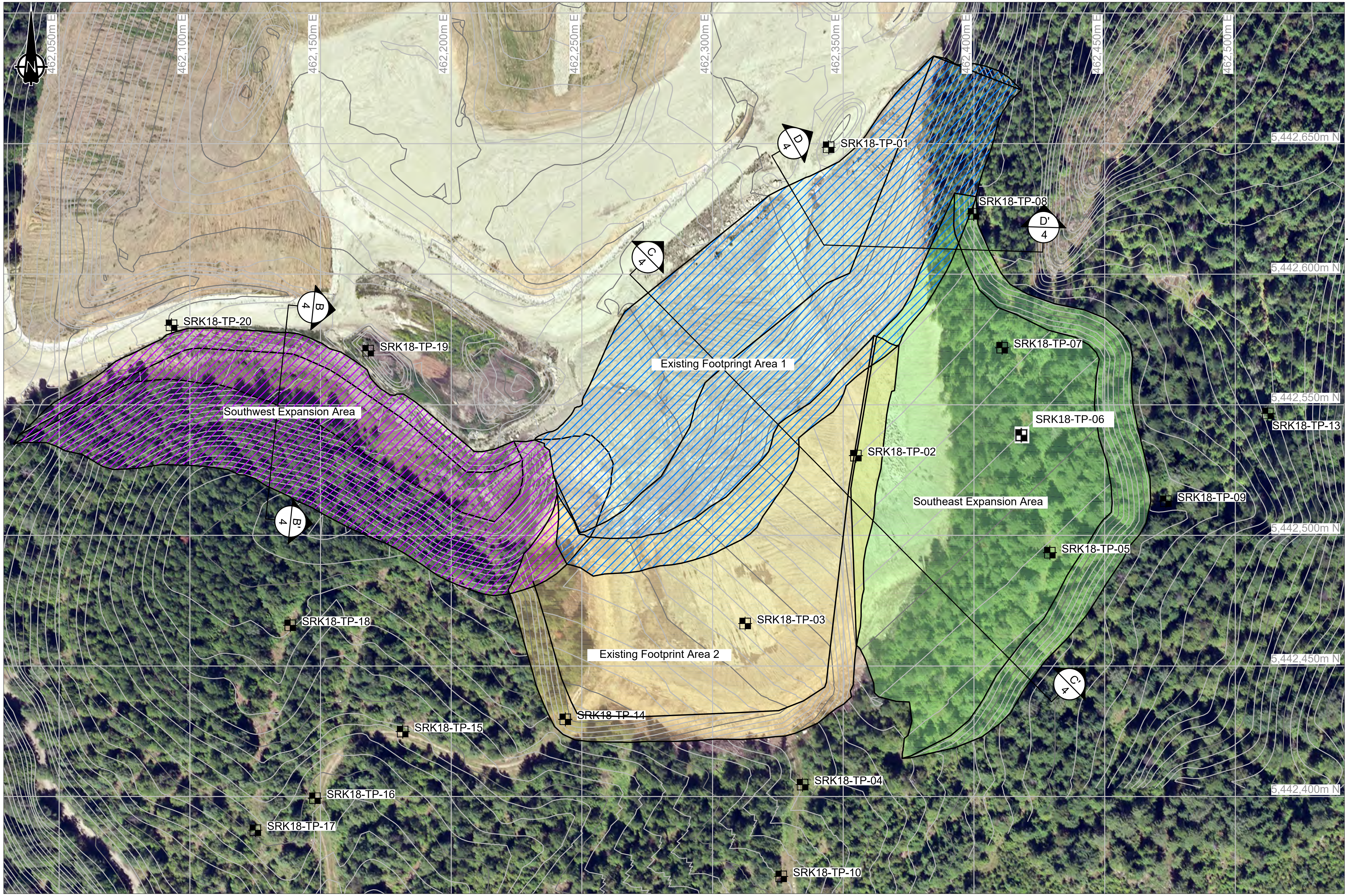
REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

2018 Borrow Investigation

Test Pit Log Summary

Date:	Approved:	Figure:
November 2018	PHM	2



LEGEND

- 2018 Investigation Location
- South West Expansion Area
- Existing Footprint Area 1
- Existing Footprint Area 2
- South East Expansion Area

NOTES

1. Contours shown at 1.0m intervals, and are indicative of proposed excavation final conditions.
2. All dimensions are in meters unless otherwise stated.

MATERIAL QUANTITIES AND AREAS

Southwest Expansion Area
Area: 11,150m²
Volume: 61,860m³

Existing Footprint Area 1
Area: 16,000m²
Volume: 76,700m³

Existing Footprint Area 2
Area: 12,900m²
Volume: 62,350m³

Southeast Expansion Area
Area: 16,140m²
Volume: 48,950m³

0m 10 20 30 40 50 60

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SRK JOB NO.: 1CR012.005
FILE NAME: 1CR012.005 - Borrow.dwg

REGIONAL DISTRICT CENTRAL KOOTENAY

HB Mine Tailings Facility

2018 Borrow Investigation

Proposed Till Borrow Area Expansion

DATE:	APPROVED:	FIGURE:
November 2018	PHM	3

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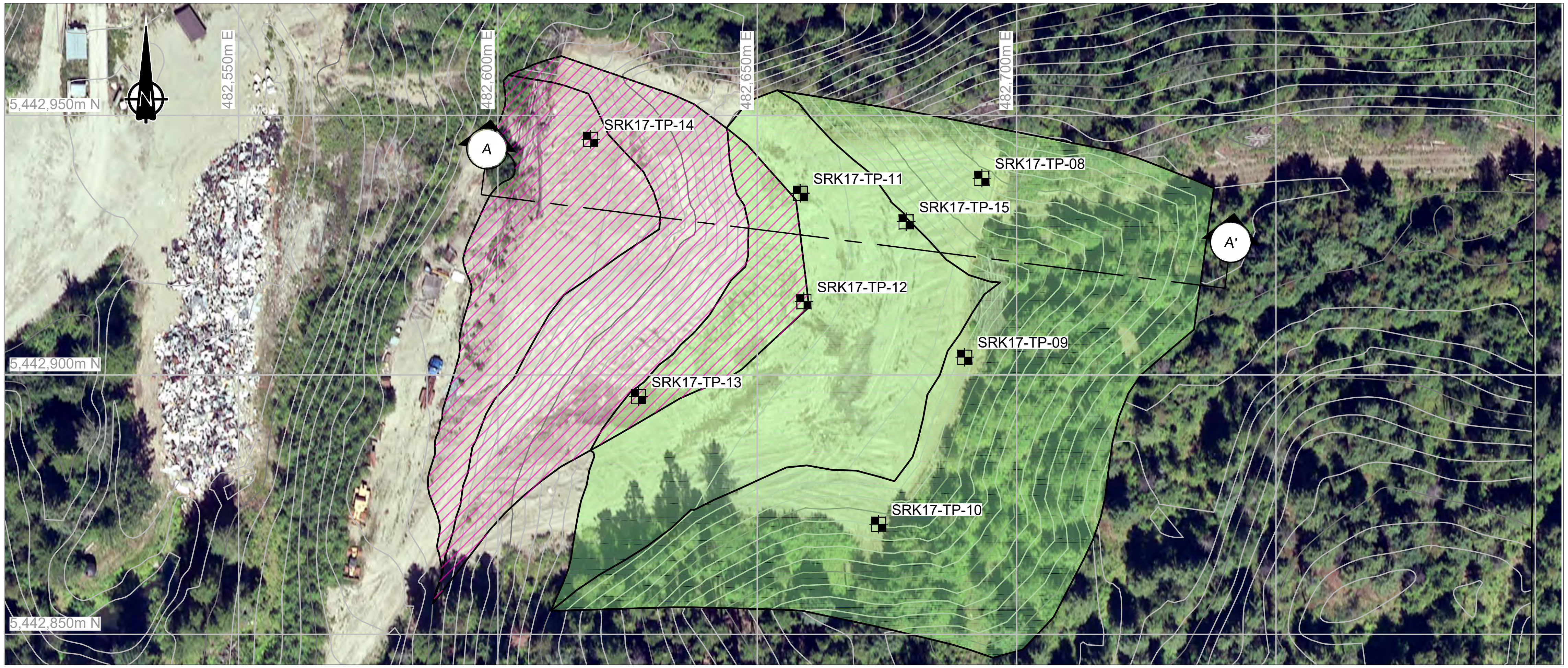


Landfill Sand and Gravel Borrow Area Plan View

0m 5 10 15 20 25 30

LEGEND

- 2017 Investigation Location
- Phase 1 Area
- Phase 2 Area

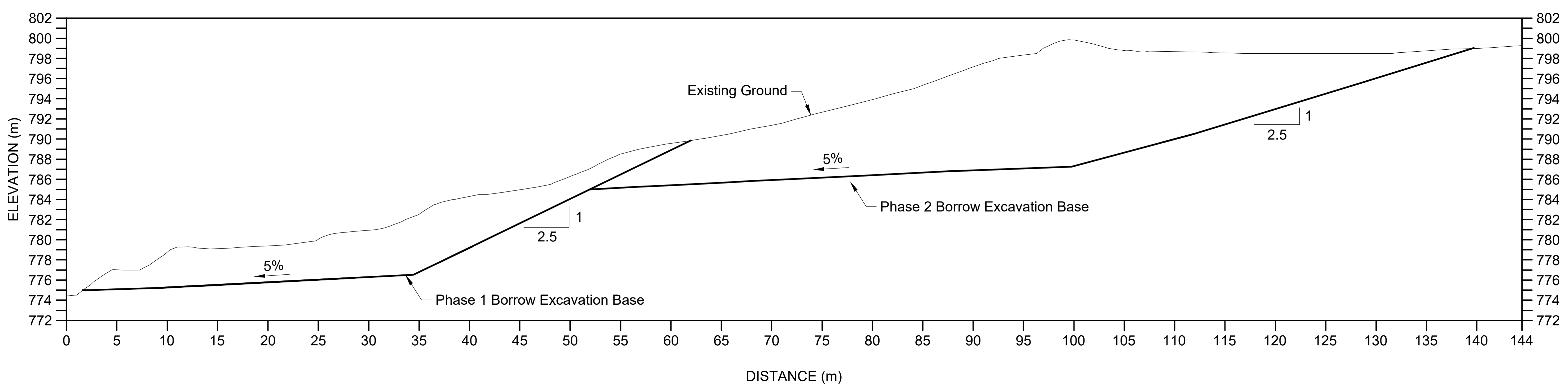
NOTES

1. Contours shown at 1.0m intervals.
2. All dimensions are in meters unless otherwise noted.

MATERIALS AND QUANTITIES

Phase 1 Excavation
Area: 4,160m²
Volume: 8,400m³

Phase 2 Excavation
Area: 9,100m²
Volume: 41,800m³



A
-
Cross Section A-A'

0m 5 10 15 20

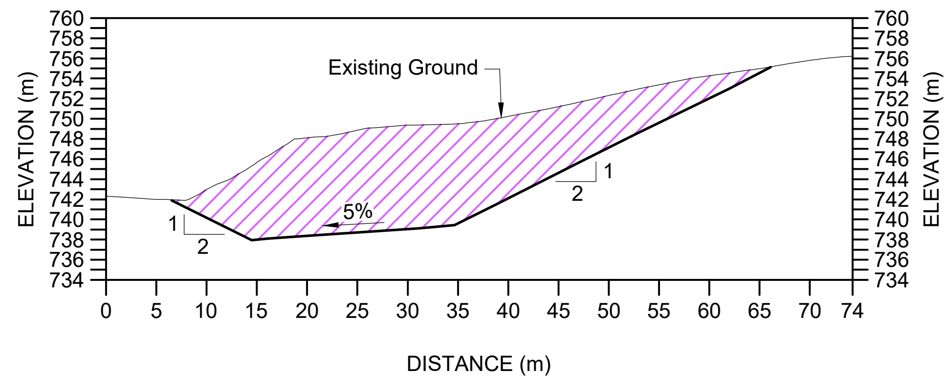
srk consulting	REGIONAL DISTRICT CENTRAL KOOTENAY	2018 Borrow Investigation Proposed Landfill Sand and Gravel Borrow Area Expansion
SRK JOB NO.: 1CR012.005 FILE NAME: 1CR012.005 - S&G.dwg	HB Mine Tailings Facility	DATE: November 2018 · APPROVED: PHM · FIGURE: 4

LEGEND

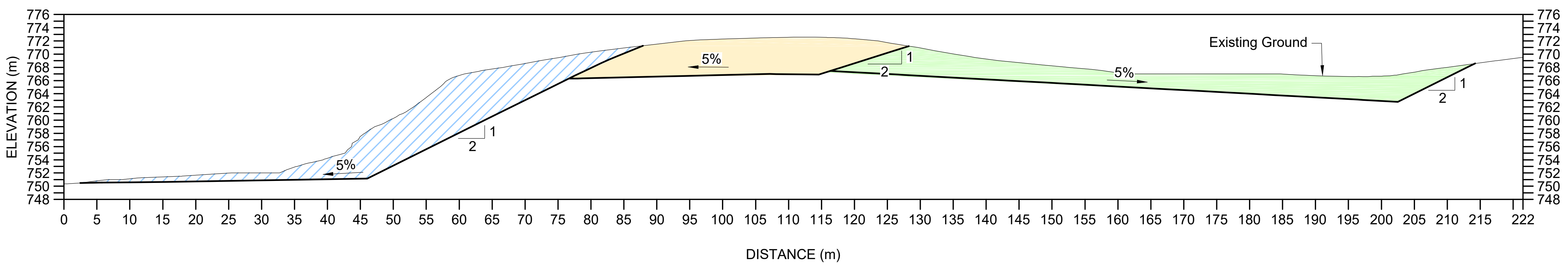
- 2018 Investigation Location
- South West Expansion Area
- Existing Footprint Area 1
- Existing Footprint Area 2
- South East Expansion Area

NOTES

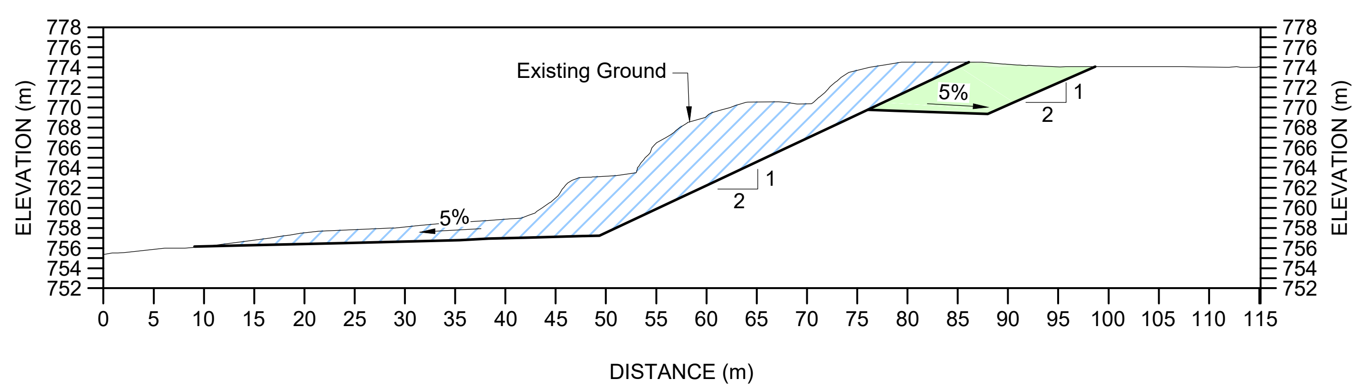
1. All dimensions are in meters unless otherwise stated.



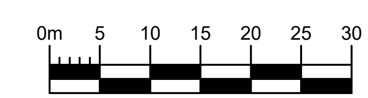
B / 3 **Cross Section B-B'**



C / 3 **Cross Section C-C'**



D / 3 **Cross Section D-D'**



srk consulting

SRK JOB NO.:	1CR012.005
FILE NAME:	1CR012.005 - Borrow.dwg

Regional District Central Kootenay

HB Mine Tailings Facility

2018 Borrow Investigation

Proposed Borrow Area Expansion Cross Sections

DATE:	APPROVED:	FIGURE:
November 2018	PHM	5

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Appendix G – Stakeholder Consultation Record

Proponent: First Nation Engagement Communication Log

FIRST NATION:

PROPONENT NAME:	**Regional District of Central Kootenay**	**PROVINCIAL CONTACT/ CONSULTATION LEAD:**	**Louise Bett, FLNRO**
PROPONENT LEAD:	**Alayne Hamilton, Amy Wilson**	**LOCATION (REGION/ RESOURCE DISTRICT):**	**Southeast Region/Selkirk Natural Resource District**
PROPOSED PROJECT/ ACTIVITY(IES):	**HB Mine Tailings Facility - Final Reclamation and Closure Plan**	**DATE SUBMITTED TO PROVINCE:**	**30-Jun-19**
APPLICATION TYPE(S) AND FILE #'S *(where*	**Mines Act Permit Amendment Application, Permit M-218. Amphibian Salvage and Fish Salvage Permits. Temporary Effluent Discharge Approval under Environmental Management Act.**		

Date	Activity	Proponent Contact	First Nation Contact	Purpose	Notes
23-Oct-18	Email	Alayne Hamilton, Shanna Eckman	Tobacco Plains Indian Band Tania Brewer, Band Administrator	Email provided by province was returned. Called office for appropriate contact. RDCK sending initial project introduction letter, Preliminary Design Report, select design drawings, archaeological overview assessment, KMZ file of project boundary.	No response
23-Oct-18	Email	Alayne Hamilton, Shanna Eckman	St. Mary's Indian Band Andrea Alexander, Reception	Email provided by province was returned. Called office for appropriate contact. RDCK sending initial project introduction letter, Preliminary Design Report, select design drawings, archaeological overview assessment, KMZ file of project boundary. Email was returned.	No response
23-Oct-18	Email	Alayne Hamilton, Shanna Eckman	Lower Kootenay Band info@lowerkootenay.com	RDCK sending initial project introduction letter, Preliminary Design Report, select design drawings, archaeological overview assessment, and KMZ file of project boundary.	No response
23-Oct-18	Email	Alayne Hamilton, Shanna Eckman	Akisqnuk First Nation Adrian Bergles, Lands Manager	RDCK sending initial project introduction letter, Preliminary Design Report, select design drawings, archaeological overview assessment, and KMZ file of project boundary.	No response
23-Oct-18	Email	Alayne Hamilton, Shanna Eckman	Lower Similkameen Indian Band referrals.coordinator@lsib.net	RDCK sending initial project introduction letter, Preliminary Design Report, design drawings, archaeological overview assessment, KMZ file of project boundary	No response
23-Oct-18	Email	Alayne Hamilton, Shanna Eckman	Shuswap Indian Band Diana L. Thomas, Consultation Coordinator	RDCK sending initial project introduction letter, Preliminary Design Report, design drawings, archaeological overview assessment, KMZ file of project boundary	SIB emailed that documentation had been reviewed, and band would like to meet. Meeting was set up for December 10, at SIB office in Invermere.
10-Dec-18	Meeting	Alayne Hamilton, Amy Wilson	Shuswap Indian Band Diana Cote, Diana Thomas, Pauline Eugene	RDCK and SIB meet to discuss project. Discussed limited new disturbance areas, environmental components of the project including draining the tailings pond, possible environmental impacts, current environmental site conditions, surface and groundwater quality, and permits/approvals to be applied for. SIB requested that they have input on the reclamation seedmix, be included in the invitation to tender, and requested an additional archaeological overview assessment, with possible on site archaeological work, and a cultural heritage review. SIB indicated they would email a cost estimate for the proposed work after the meeting, and share the preferred reclamation seedmix.	At the time of the meeting, RDCK was not aware that a Temporary Approval for discharge under the Environmental Management Act would be required, so that application was not discussed; however, draining of the pond including planned methods of draining, pond water quality, and obtaining a WSA Change Approval for the work was discussed in detail.
19-Dec-18	Email	Alayne Hamilton	Shuswap Indian Band Diana Thomas, Pauline Eugene, Lavonne Johnson	Meeting follow up email. Sending RDCKs approved 2011 seedmix for review. Requested SIB contractor contact information to add to RDCK contractor list, and requested a phone call to discuss additional archaeological and culturally significant resources work that SIB recommended in meeting.	No response
5-Feb-19	Email	Alayne Hamilton	Shuswap Indian Band Diana L. Thomas, Consultation Coordinator	Secondary meeting follow up email to request response.	No response
29-Mar-19	Phone Call	Alayne Hamilton	Shuswap Indian Band Diana L. Thomas, Consultation Coordinator	Follow up phone call from above. Left message with reception requesting Diana Thomas, Pauline Eugene or Lavonne Johnson follow up.	No response
8-May-18	Phone Call	Alayne Hamilton	Shuswap Indian Band Pauline Eugene, Cultural Heritage Coordinator	Final follow up phone call. Left voicemail.	No response
23-Oct-18	Email	Alayne Hamilton, Shanna Eckman	Ktunaxa Nation Council referrals@ktunaxa.org	RDCK sending initial project introduction letter, Preliminary Design Report, design drawings, archaeological overview assessment, KMZ file of project boundary	KNC request to meet. Set up meeting for December 19, rescheduled for January 15.
12-Dec-18	Email	Alayne Hamilton	Ktunaxa Nation Council Erin Robertson, Lands Project Officer	RDCK emailing link to full HB Preliminary Design Report and supporting studies.	Received
15-Jan-19	Meeting	Amy Wilson, Alayne Hamilton	Ktunaxa Nation Council Erin Roberston, Kenton Andreashuk, and Alison Burton	RDCK and KNC meet to discuss project. Discussed the limited new disturbance area, environmental components of the project including draining the tailings pond, capping the tailings, and expanding borrow areas, possible environmental impacts, environmental site conditions, surface and groundwater quality, permits to be applied for. KNC requested that they review the proposed reclamation seedmix, and requested water quality data.	At the time of the meeting, RDCK was not aware that a Temporary Approval for discharge under the Environmental Management Act would be required, so that application was not discussed; however, draining of the pond including planned methods of draining, pond water quality, and obtaining a WSA Change Approval

Proponent: First Nation Engagement Communication Log			
FIRST NATION:			
PROPONENT NAME:	**Regional District of Central Kootenay**	**PROVINCIAL CONTACT/ CONSULTATION LEAD:**	**Louise Bett, FLNRO**
PROPONENT LEAD:	**Alayne Hamilton, Amy Wilson**	**LOCATION (REGION/ RESOURCE DISTRICT):**	**Southeast Region/Selkirk Natural Resource District**
PROPOSED PROJECT/ ACTIVITY(IES):	**HB Mine Tailings Facility - Final Reclamation and Closure Plan**	**DATE SUBMITTED TO PROVINCE:**	**30-Jun-19**
APPLICATION TYPE(S) AND FILE #'S *(where*	**Mines Act Permit Amendment Application, Permit M-218. Amphibian Salvage and Fish Salvage Permits. Temporary Effluent Discharge Approval under Environmental Management Act.**		

Date	Activity	Proponent Contact	First Nation Contact	Purpose	Notes
1-Feb-19	Email	Alayne Hamilton	Ktunaxa Nation Council Erin Roberston, Kenton Andreashuk, and Alison Burton	Meeting follow up. RDCK sending 2011 Reclamation seed mix, Teck remediation plan of downstream properties, and 2017 Reclamation Report with historical water quality data.	Documents were received, KNC provided no comments.
23-Mar-19	Email	Alayne Hamilton	Ktunaxa Nation Council Erin Robertson, Lands Project Officer	RDCK sending proposed reclamation seed mix for review, as requested by KNC.	
22-Apr-19	Email	Alayne Hamilton	Ktunaxa Nation Council Erin Robertson, Lands Project Officer	Response from KNC on seedmix - no time to review, but would recommend a native blend.	RDCK will proceed with plan utilizing native seed blend
23-Oct-18	Email	Alayne Hamilton, Shanna Eckman	Okanagan Indian Band Chief and Council okibreferrals@okanagan.org	RDCK sending initial project introduction letter, Preliminary Design Report, design drawings, archaeological overview assessment, KMZ file of project boundary	No response
23-Oct-18	Email	Alayne Hamilton, Shanna Eckman	Penticton Indian Band Chief and Council, referrals@pib.ca	RDCK sending initial project introduction letter, Preliminary Design Report, design drawings, archaeological overview assessment, KMZ file of project boundary	
18-Dec-18	Email	Alayne Hamilton	Penticton Indian Band Natasha Slack, Referrals Clerk	PIB response to Letter, including invoice for referral review and request for 60 day extension.	
18-Dec-18	Phone Call	Alayne Hamilton	Penticton Indian Band Natasha Slack, Referrals Clerk	PIB called to request extension to comment period. RDCK not able to extend the deadline as design was very near completion, but RDCK is able to answer project questions and share all related project information.	
18-Dec-18	Email	Alayne Hamilton	Penticton Indian Band Natasha Slack, Referrals Clerk	RDCK sending email summarizing phone discussion, with offer to share full Preliminary Design Report and supporting studies for review.	No response
17-Jan-19	Email	Alayne Hamilton	Penticton Indian Band Natasha Slack, Referrals Clerk	RDCK notifying PIB that HB Closure Plan was delayed and that a comment period extension and meeting could still be accomodated.	No response
29-Mar-19	Phone Call	Alayne Hamilton	Penticton Indian Band Natasha Slack, Referrals Clerk	RDCK called PIB office to inquire about comment period extension or a meeting. Spoke with another referrals clerk about the project and the delay. Asked for PIB to provide an email or verbal response.	No response
8-May-19	Phone Call	Alayne Hamilton	Penticton Indian Band Natasha Slack, Referrals Clerk	Called PIB office to follow up on emails and phone call. Left voicemail message on general refferals phone number.	No response
23-Oct-18	Email	Alayne Hamilton, Shanna Eckman	Okanagan Nation Alliance Chief and Council director@syilx.org	RDCK sending initial project introduction letter, Preliminary Design Report, design drawings, archaeological overview assessment, KMZ file of project boundary	No response
11-Dec-18	Phone Call	Rachel George	Okanagan Nation Alliance Pauline Terbasket, Executive Director.	Spoke with Administrator about receipt of information package. Left message for Pauline Terbasket asking if ONA has any comments to please respond.	No Response
23-Oct-18	Email	Alayne Hamilton, Shanna Eckman	Upper Nicola Band Brian Holmes, Councillor	Email provided by province was returned. Called office for appropriate contact. RDCK sending initial project introduction letter, Preliminary Design Report, design drawings, archaeological overview assessment, KMZ file of project boundary	No response

Appendix H – Prediction of Geochemical Performance Under Proposed Remediation Conditions

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Memo

To:	Amy Wilson	**Client:**	Regional District of Central Kootenay
From:	Stephen Day, PGeo	**Project No:**	1CR012.003
Cc:	Peter Mikes, Kaitlyn Kooy (SRK)	**Date:**	December 13, 2019
Subject:	Prediction of Geochemical Performance of HB Tailings Under Proposed Remediation Conditions		

1 Introduction

A geochemical assessment of the HB Mine Tailings Facility was recommended in the 2016 preliminary remediation and closure assessment (SRK 2016) for passive closure of the facility to determine the effects of lowering the water level within the facility on water quality. The passive closure would involve drawdown of the water table to prevent ponding of water against the tailings dam. Since the tailings were generated by processing of lead-zinc sulphide ore, the tailings contain sulphide minerals, and the proposed measure will result in exposure of a greater thickness of tailings to oxidation.

A field investigation was completed in December 2016 that consisted of auger drilling at six locations throughout the tailings facility to collect samples for geochemical, geotechnical laboratory testing, as well as polarized light microscopy for asbestos characterization. Details of the drilling program, including borehole logs and laboratory testing results are provided in field investigation report (SRK 2017). This memorandum provides an assessment of the potential for changes to water quality that may be caused by lowering the water table.

2 Conceptual Geochemical Model

A conceptual geochemical model (CGM) was developed to describe the expected performance of the tailings as the water table is drawn down. The CGM provides the basis for interpretation of the results of testwork completed as part of the current program and prediction of pore water chemistry resulting from implementation of the remediation and closure measures.

It is currently understood from previous testwork (Cominco 1999) and the ore type that the HB tailings contain iron, lead and zinc sulphide minerals (pyrite, galena and sphalerite, respectively). Cadmium does not occur as a discrete sulphide mineral but is a trace component of sphalerite. Abundant calcium and magnesium carbonate minerals (calcite and dolomite, respectively) are also present. The tailings are thought to be non-acid generating in perpetuity because carbonate content far exceeds sulphide content. Pore water chemistry, including the concentrations of heavy metals contained in the sulphides will be controlled at relatively low levels by the non-acidic carbonate weathering environment. For example, the solubility of zinc is controlled by the mineral smithsonite ($ZnCO_3$) according to the following reaction:

$Zn^{2+} + HCO_3^- \rightarrow ZnCO_3 + H^+$

Under less acidic conditions (lower H^+), the reaction moves to the right removing dissolved zinc (Zn^{2+}) from solution and forming smithsonite.

Under weathering conditions resulting from oxygen diffusion into the tailings, sulphide minerals will oxidize to sulphates, the acid generated will be neutralized by reaction with carbonate minerals and the main metals of concern (cadmium, lead and zinc) will be precipitated as their carbonates (Day and Bowell 2005). Sulphate will likely be precipitated as calcium sulphate.

Conceptually, these secondary minerals (such as smithsonite) are expected to be forming readily and controlling the concentrations of metals in the current tailings pore water. Day and Bowell (2005) documented the presence of cadmium and zinc carbonate in oxidizing carbonate-rich tailings at the Sä Dena Hes Mine where the weathering environment is probably similar to the HB Mine tailings. While lowering of the water table will potentially result in a greater mass of tailings being exposed to oxidation, the secondary minerals will continue to form and prevent pore water tailings concentrations from increasing above current levels.

A test program was designed to evaluate this conceptual model.

3 Sampling and Analysis Program

SRK collected eight samples from the unsaturated zone of the tailings where weathering is assumed to be occurring (SRK 2017). Tailings below the water table are expected to be protected from oxidation by the low concentration of oxygen dissolved in the water.

The samples were analysed for acid-base account to evaluate the potential for acid generation, metal concentrations, and water leachable chemistry. To assist with interpretation of the chemistry, moisture content of the tailings was determined.

Selected results are provided in Table 1 and Table 2. Full results are provided in Appendix C of SRK (2017).

Table 1. Selected Characteristics of Solids

Sample ID	Total S %	Carbonate kg $CaCO_3$/t	AP kg$CaCO_3$/t	NP/AP	Cd mg/kg	Pb mg/kg	Zn mg/kg
SRK-1 COMP.	5.9	800	170	4.4	38	1400	3700
SRK-2 COMP.	3.6	850	92	9	34	1800	3000
SRK-3 COMP.	2.9	880	83	8.7	34	1600	3200
SRK-4 COMP.	3.7	920	94	9.3	26	1200	2400
SRK-5 COMP.	3.5	920	100	8.5	26	1300	2500
SRK-6 COMP.	6.4	820	180	4.3	41	2000	4000
SRK-6 COMP. DUP	6.4	820	180	4.3	44	2000	4000
SRK-1-G07	6.4	800	190	4.1	50	2400	4600
SRK-5-G07	4.2	880	130	6.7	33	1400	3000

Source: P:\01_SITES\HB_Mine\1CR012.003_Tailings Characterization\!080_Deliverables\02_GeochemAssessment\tables\[HB_Tailings_Geochem_1CR012003_SJD_REV00.xlsx]

Notes:

1. Acid potential (AP) was calculated from total sulphur less the sulphur calculated to be associated with lead and zinc.
2. NP/AP uses Carbonate to calculate NP.

Table 2. Moisture Content and Selected Leach Results

Sample ID	Moisture %	pH	SO_4 mg/L	Cd mg/L	Pb mg/L	Zn mg/L
SRK-1-G03 (2.13-2.44M)	18%	7.3	1700	0.0051	0.091	8.4
SRK-1-G04 (3.05-3.66M)	17%	7.5	1100	0.0021	0.035	1.8
SRK-2-G01 (0.61-0.76M)	23%	7.4	1800	0.0046	0.023	1.8
SRK-2-G02 (1.22-1.83M)	22%	7.5	1500	0.0031	0.064	3.5
SRK-3-G01 (0.61-0.91M)	19%	7.4	1500	0.0065	0.1	5.3
SRK-4-G01 (0.46-0.61M)	22%	7.5	1300	0.00034	0.0048	0.18
SRK-4-G03 (1.22-1.83M)	18%	7.5	1300	0.0025	0.043	2.2
SRK-4-G05 (2.74-3.35M)	15%	7.7	1000	0.0033	0.079	2.5
SRK-5-G01 (0.61-0.76M)	18%	7.5	1200	0.00048	0.014	0.32
SRK-5-G02 (1.47-1.83M)	17%	7.7	1100	0.0015	0.013	2.5
SRK-6-G01 (0.61-0.76M)	14%	7.8	1600	0.0053	0.03	2.5
SRK-6-G02 (1.22-1.83M)	18%	7.3	1400	0.0034	0.11	8.2
SRK-6-G03 (2.74-3.35M)	16%	7.6	890	0.0015	0.079	0.87
SRK-1-G07 (8.84-9.45M)	19%	7.5	1300	0.019	0.12	5.1
SRK-5-G07 (11.89-12.50 M)	18%	7.6	880	0.0061	0.096	2.1

Source: P:\01_SITES\HB_Mine\1CR012.003_Tailings Characterization\!080_Deliverables\02_GeochemAssessment\tables\[HB_Tailings_Geochem_1CR012003_SJD_REV00.xlsx]

4 Interpretation

4.1 Acid Generation Potential

The tailings had the expected characteristics. Average acid potential (AP) was 136±45[1] kg$CaCO_3$/t with sulphide mineralogy dominated by iron sulphide, followed by zinc and lead. The carbonate content indicated average neutralization potential (NP) of 805±53 kg $CaCO_3$/t. These results indicated that the tailings contain roughly 80% equivalent calcium carbonate. The average NP/AP was 5.9 with a range of 4.1 to 9.3 indicated by the individual samples. The appropriate NP/AP threshold for defining potentially acid generating for these tailings is 2. The tailings are therefore conclusively classified as non-acid generating in perpetuity.

[1] In this report, uncertainty of average is indicated by the standard deviation.

4.2 Pore Water Chemistry

The chemistry of water chemistry extracts performed at a leach ratio of 0.5 L/kg and the moisture contents were used to estimate pore water chemistry. That is, the tailings samples contain water in contact with the oxidizing tailings, and the water leach test dilutes the pore water. The moisture content determinations allow the leach chemistry to be expressed approximately as pore water chemistry. The method yielded average sulphate concentration so 3600±800 mg/L, lead of 0.17±0.11 mg/L and zinc of 8.8±7.0 mg/L.

The resulting pore water chemistry estimates were then evaluated using the geochemical model PHREEQC (Parkhurst and Appelo 1995) to determine if secondary minerals were controlling water chemistry. This numerical code uses thermodynamic data to assess whether metal concentrations are consistent with the presence of secondary minerals like smithsonite. The assessment is based on calculation of saturation indices for the solution chemistry. For a given solution, a saturation index can be calculated for any mineral. Saturation indices well below zero indicate theoretically that the mineral could not form from the solution, whereas saturation indices above zero indicate that the mineral could form from the solution, or that the solution was formed by dissolved the mineral.

Based on average saturation indices of gypsum, calcite, smithsonite (zinc carbonate) and rhodochrosite (manganese carbonate) of 0.3±0.1, 1.0±0.2, -0.2±0.4 and -0.2±0.4 (respectively), it was concluded that these secondary minerals are probably already present or forming in the weathering profile of the tailings, and are therefore expected to control pore water chemistry as the water table is lowered.

PHREEQC can also be used to estimate pore water for the tailings by setting saturation indices to 0 and equilibrating the solution with atmospheric CO_2 (partial pressure of $10^{-3.4}$). Table 3 shows an example of pore water chemistry calculated for two tailings sample assuming that gypsum, calcite, rhodochrosite and smithsonite are controlling water chemistry. Due to the methodology and uniformity of the leach extraction results, the estimated pore water chemistry is not markedly different for the two samples.

Table 3. Equilibrated Pore Water in the HB Mine Tailings Calculated for Two Typical Samples

Sample	pH	SO_4 mg/L	Alkalinity mg$CaCO_3$/L	Ca mg/L	Mg mg/L	Mn mg/L	Pb mg/L	Cd mg/L	Zn mg/L
SRK-3-G01 (0.61-0.91 m)	7.8	2400	50	570	230	0.75	0.27	0.017	31
SRK-6-G01 (0.61-0.76 m)	7.7	2500	50	590	310	0.48	0.10	0.020	32

Source: P:\01_SITES\HB_Mine\1CR012.003_Tailings Characterization\!080_Deliverables\02_GeochemAssessment\tables\[HB_Tailings_Geochem_1CR012003_SJD_REV00.xlsx]

5 Conclusion

It is concluded that lowering the water table for remediation will not substantially alter pore water chemistry.

SRK Consulting (Canada) Inc.

Stephen Day, PGeo
Corporate Consultant (Geochemistry)

Disclaimer—SRK Consulting (Canada) Inc. has prepared this document for Regional District of Central Kootenay. Any use or decisions by which a third party makes of this document are the responsibility of such third parties. In no circumstance does SRK accept any consequential liability arising from commercial decisions or actions resulting from the use of this report by a third party.

The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

6 References

Cominco Ltd., 1999. Re: ABA Tailings of H.B. Mine Tailings. Letter from Bruce Donald to R. Rosentreter of BC Ministry of Energy and Mines dated July 28.

Day, S.J. and Bowell, R. J. 2005. Atypical and typical zinc geochemistry in a carbonate setting, Sä Dena Hes Mine, Yukon Territory, Canada. Geochemistry: Exploration, Environment, Analysis, August 2005, v. 5, p. 255-266,

Parkhurst, D.L. and Appelo, C.A.J., 1999, User's guide to PHREEQC (Version 2)—A computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations: U.S. Geological Survey Water-Resources Investigations Report 99-4259, 310 p

SRK Consulting (Canada) Ltd., 2016. HB Mine Tailings Facility Remediation and Closure Preliminary Assessment. Prepared for Regional District of Central Kootenay. SRK Project Number 1CR012.001. August.

SRK Consulting (Canada) Ltd., 2017. HB Mine Tailings Facility – 2016 Tailings Characterization Factual Report. Prepared for Regional District of Central Kootenay. SRK Project Number 1CR012.001. May.

Appendix I – Water and Load Balance

HB Mine Tailings Facility - Water Quality Prediction Model

Prepared for

Regional District of Central Kootenay

Prepared by

srk consulting

SRK Consulting (Canada) Inc.
1CR012.006
July 2019

HB Mine Tailings Facility - Water Quality Prediction Model

July 2019

Prepared for

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Web: www.srk.com

Project No: 1CR012.006

File Name: HBMine_WaterQualityPredictions_1CR012.005_FINAL_20190715.docx

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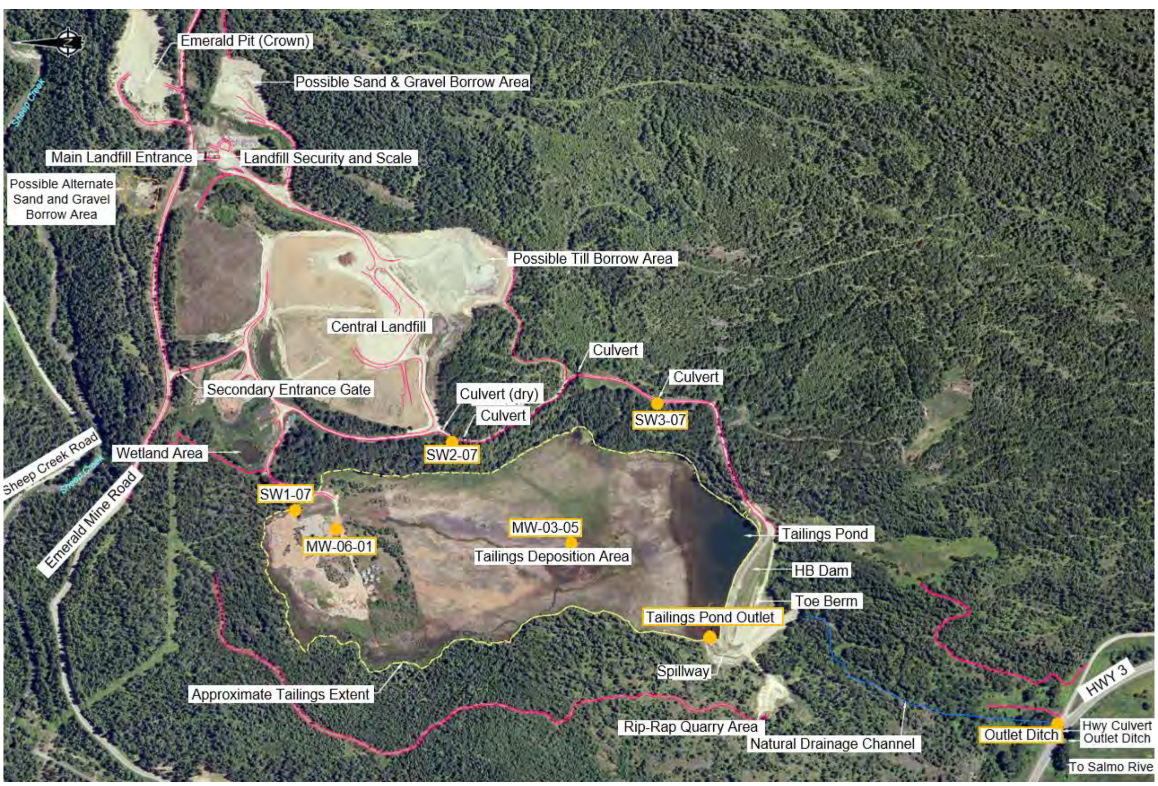
1 Introduction

The HB Mine Tailings Facility (TSF) near Salmo, BC contains tailings from the HB Mine, a lead-zinc mine that operated from 1955 to 1966 and from 1974 to 1978. The tailings facility has been under the care of the Regional District of Central Kootenay (RDCK) since 1998.

The RDCK has elected to remediate the site to "passive closure" with the intent to reduce liability and the resources required to maintain the facility in its current form. SRK Consulting (Canada) Inc. was contracted to carry out the design for closure and reclamation of the facility.

The major drainage in the area is the Salmo River located in a floodplain area west of the tailings facility. The tailings deposition area is approximately 26 ha and situated in a hanging valley (Figure 1). The tailings facility receives runoff originating from the Central Landfill, to the East of the site. Water from the tailings facility discharges towards the south in an ephemeral stream that flows through a man-made ditch system to the Salmo River.

A simple water and load balance model was prepared for supporting the closure design presented in the 2019 Mines Act Permit Amendment application. Predicted water quality was evaluated to assist in determining if the tailings cover will sufficiently improve water quality at the downstream property line adjacent to Highway 3.



Source: \\van-svr0\Projects\01_SITES\HB_Mine\!020_Site_Wide_Data\Global Mapper\HBDam_SiteMap_mcc.dwg

Figure 1: HB Mine Tailings Facility Site Map

2 Model Framework

2.1 Conceptual Model

The model considers inputs from the upland landfill, runoff from upstream catchments, direct precipitation onto the facility, and outflows through the spillway, downstream seepage and additional runoff from the catchment between the dam and the Outlet Ditch. A block flow diagram illustrates the flow paths represented in the model for both the pre-closure TSF configuration (Figure 2 (a)), and the post-closure configuration (Figure 2 (b)). In post closure, the tailings are covered and the inlet to the spillway is lowered such that it drains the pond.

The water balance makes use of annual precipitation inputs and the average monthly discharge distributions from the Salmo River to model volumetric flow rates from upstream catchment areas to the TSF. The model was calibrated by comparing the calculated flows with observed flows from select monitoring stations. The water quality parameters that are monitored seasonally (spring and fall) are further applied in the mass balance loadings calculations.

The mass balance accounts for loading sources within the model domain, as well as fluxes in and out of the model domain. Loading rates are estimated by assigning source water quality concentrations to the inflows for the corresponding sub-catchments estimated in the water balance. Parameter concentrations at each model node is determined by summing the parameter load reporting to that node and dividing by the total volume at that node. For most parameters, loadings are assumed to be conservative (i.e., not attenuated). Aluminum, Iron, manganese and zinc were over-estimated using this approach, and estimates of attenuation, developed based on calibration with monitoring data, were applied for these parameters.

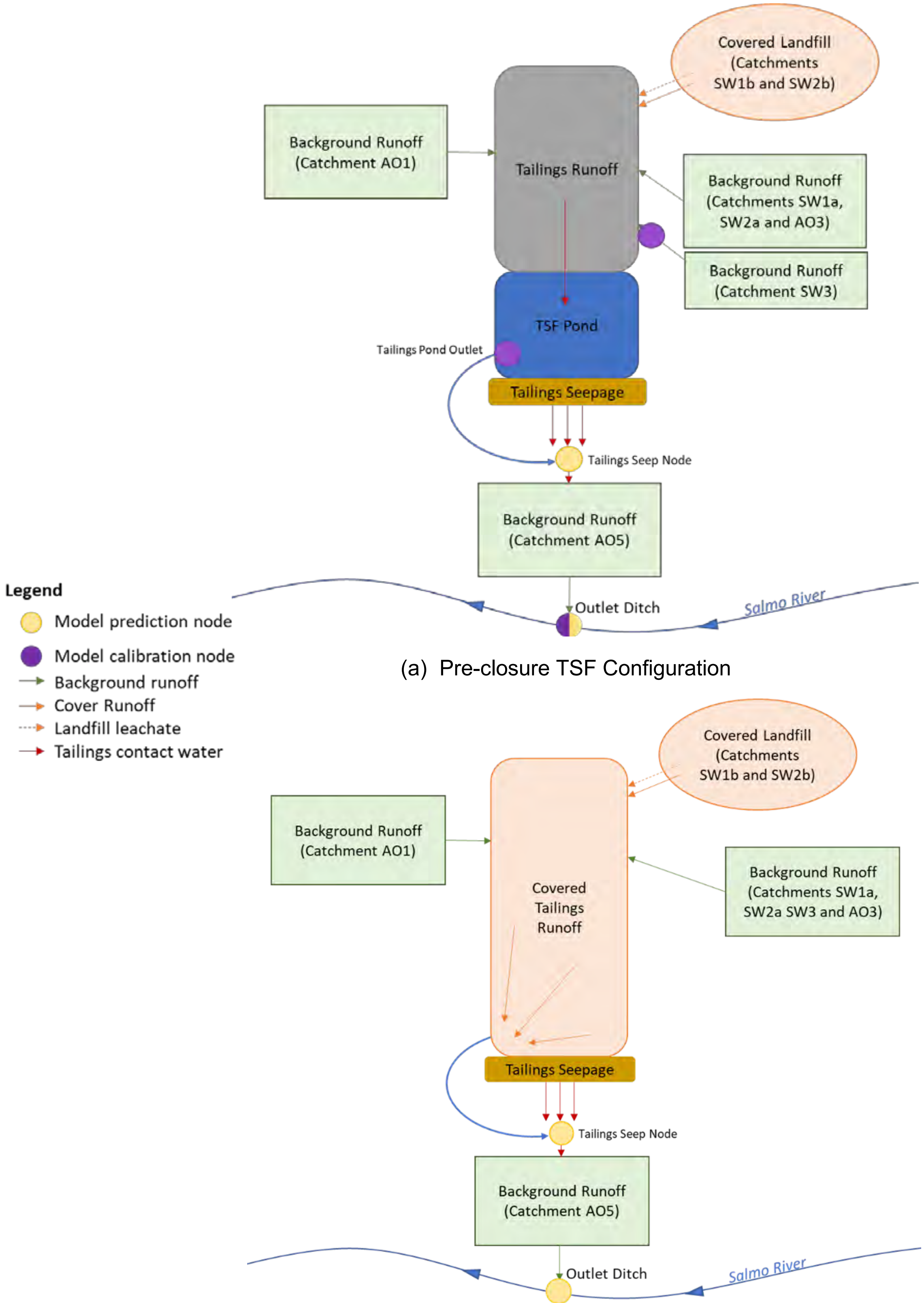
The model was set up and calibrated for existing conditions. The calibrated inputs were then applied to the current TSF configuration using average hydrological conditions and average source terms including attenuation estimates for some parameters (Current Condition), and to the post-closure TSF configuration including covered tailings with an assumed 20% infiltration rate (Base Case). The model's assumptions were evaluated with sensitivity analyses for infiltration rates, source terms, attenuation factors and hydrological conditions.

2.2 Model Platform and Timescale

The water and load balance model was developed using Excel.

The model was calibrated using data collected between 2011 and 2018.

Results are provided as monthly averages. BC Water Quality Guidelines for Protection of Aquatic Life (BC WQG) are applied at the Outlet Ditch to the average of all samples collected in a calendar month. Therefore, the selection of model output as monthly average projections is considered adequate to inform water management for closure.



(a) Pre-closure TSF Configuration

(b) Post-closure TSF Configuration

Figure 2: Block Flow Diagram of Flow Paths in the Water and Load Balance Model

2.3 Prediction Nodes and Parameters

Water and load balance predictions were developed for three nodes:

1. Tailings Pond Outlet, used for calibration,
2. Tailings Seepage, used to assess water quality immediately downstream of the confluence of the spillway and seepage through the tailings dam, and,
3. The Outlet Ditch, used to assess water quality at the HB Dam property line.

Water quality predictions were developed for identified contaminants of potential concern (COPCs), described in Section 3.2.1. The COPC's identified were aluminum, cadmium, chromium, copper, iron, lead, manganese, sulphate, sulphide, and zinc.

3 Inputs

3.1 Flow

Surface water flows were calculated by multiplying the annual precipitation to site catchment areas and applying a runoff coefficient and monthly runoff distribution. Each of these inputs is discussed in the following sub-sections.

3.1.1 Catchment Areas

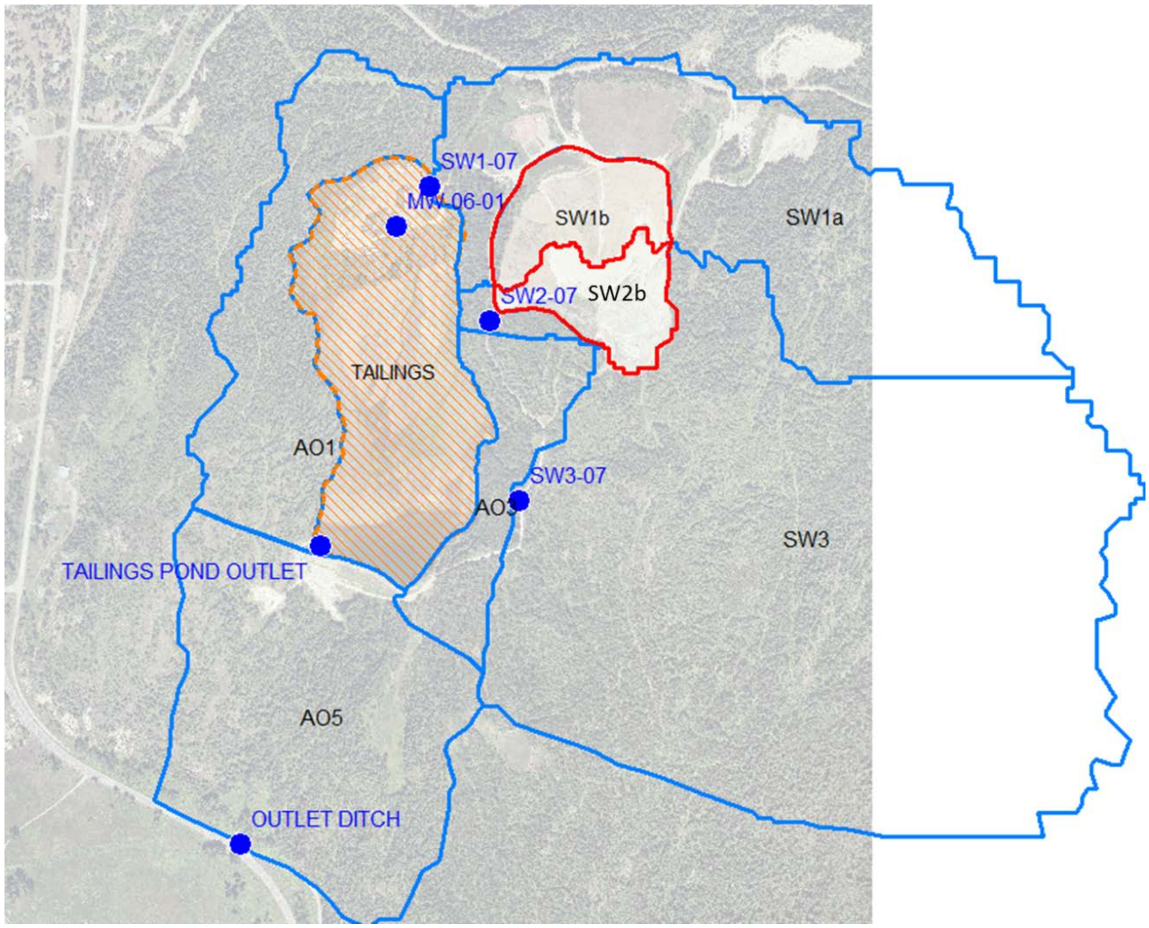
For modelling purposes, the project area and its surroundings were divided into catchments. The site catchment areas were determined with topographic data from site using Global Mapper (Table 1, Figure 3). The project area was divided such that each catchment had a unique combination of flow path and source term.

Table 1: Catchment Areas for RDCK Central Landfill and HB Mine Tailings Facility

Catchment	Monitoring Station	Area (Km^2)
SW1a	SW1-07	0.415
SW1b	SW1-07	0.071
SW2a	SW2-07	0.015
SW2b	SW2-07	0.059
SW3	SW3-07	1.141
AO1	-	0.210
AO3	Tailings Pond Outlet	0.103
AO5	Outlet Ditch	0.378
Tailings Area	MW-06-01	0.250

"-" indicates that no station is monitored on this catchment.

Source:"\\srk.ad\dfs\na\van\Projects\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\WaterQualityPredictions\Model\BMine_WaterQualityPredictionModel_1CR012.005_CAJ_MC_v12.xlsx"



Source: \\van-svr0\Projects\01_SITES\HB_Mine\!020_Site_Wide_Data\Global Mapper\HBTailings_CatchmentDelineations.gmw

Figure 3: Catchment Area Delineation for RDCK Central Landfill and HB Mine Tailings Facility

3.1.2 Annual Precipitation

The annual precipitation data for the site was determined by using the nearest climate station and adjusting the records to site. The Castlegar Station was selected based on a search of Environmental Canada Database. To adjust the Castlegar record to site, Castlegar's Mean Annual Precipitation (MAP) of 738 mm was compared to the site's MAP of 808 mm, which was calculated from a regional regression analysis (SRK, 2017a). This 9% increase from Castlegar to site was used to adjust the annual Castlegar record. Table 2 shows the annual precipitation for the water balance calibration period beginning in 2009.

Table 2: Annual Precipitation at HB Mine Tailings Facility 2009-2018

Year	Mean Annual Precipitation [mm]
2009	649
2010	733
2011	698
2012	1163
2013	707
2014	836
2015	758
2016	1024
2017	829
2018	817

Source:"\\srk.ad\dfs\na\van\Projects\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\WaterQualityPredictions\Model\BMine_WaterQualityPrediction Model_1CR012.005_CAJ_MC_v12.xlsx"

A frequency analysis was completed on the adjusted record to determine extreme event conditions. The Castlegar record begins in 1965 and has 52 complete years of records. This record was adjusted to site and was fitted to a Gumbel distribution to calculate the 10-year wet and 10-year dry annual precipitation events (Table 3)

Table 3: Frequency Analysis Results

Event	Annual Precipitation [mm]
Wet 10 Year	989
Mean	738
Dry 10 Year	665

Source:"\\srk.ad\dfs\na\van\Projects\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\WaterQualityPredictions\Model\BMine_WaterQualityPrediction Model_1CR012.005_CAJ_MC_v12.xlsx"

3.1.3 Monthly Distribution of Flow

A search of Environmental Canada Database found the nearby hydrometric station of Salmo River Near Salmo (08NE074). The Salmo record provides daily flow since 1949. This record was used to calculate the average monthly unit discharge for the watercourse and the average monthly flow distribution as a percentage of total flow (Table 4).

Table 4: Unit Discharge and Monthly Flow Distribution for Salmo Hydrometric Station

Month	Unit Discharge ($m^3/s/km^2$)	Monthly Distribution
Jan	0.0059	2%
Feb	0.0049	2%
Mar	0.0095	4%
Apr	0.0461	18%
May	0.0870	33%
Jun	0.0545	21%
Jul	0.0167	6%
Aug	0.0054	2%
Sep	0.0059	2%
Oct	0.0070	3%
Nov	0.0081	3%
Dec	0.0091	3%

Source:"\\srk.ad\dfs\na\van\Projects\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\WaterQualityPredictions\Model\BMine_WaterQualityPredictionModel_1CR012.005_CAJ_MC_v12.xlsx"

3.1.4 Runoff Coefficients

The runoff coefficient for natural, unimpacted catchments was obtained by applying the Nash-Sutcliffe Efficiency (NSE) statistic to modelled and observed flows for station SW3-07. The runoff coefficient was adjusted to optimize the NSE statistic to determine the best possible fit between calculated and empirical data. This resulted in a runoff coefficient of 0.72 for natural catchments.

A similar exercise was performed for the Tailings Pond Outlet station to obtain the optimized tailings runoff coefficient. Again, the runoff coefficient for tailings was adjusted to optimize the NSE statistic to determine the best possible fit between calculated and empirical data at the Tailings Pond Outlet. The runoff coefficient was determined to be 0.80.

The cover material runoff coefficient was assumed to be equal to the natural catchment runoff coefficient (i.e., the same as adjacent land use).

3.1.5 Seepage

Estimates of seepage rates through the dam were made based on monitored flows through a weir located downstream of the dam and upstream of the spillway. For the calibration period, measured weir flows were used as seepage rates. For the predictive period, average weir flow data was applied as seepage rates throughout the year for all prediction scenarios. Seepage rates are assumed to be steady state, with seasonal changes in tailings saturation and pressure gradients having a negligible impact on seepage rate.

3.2 Water Quality

3.2.1 Screening for COPCs

Water quality data at the Outlet Ditch was screened for contaminants of potential concern (COPCs). COPCs were identified by comparing site water quality results with the BC WQG and the lowest relevant BC Contaminated Site Regulations Water Standard (CSR). If a parameter exceeded the water quality thresholds, it was identified as COPCs, and was included as a model parameter.

The COPC's determined were the following: aluminum, cadmium, chromium, copper, iron, lead, manganese, sulphate, sulphide and zinc. Sulphate, sulphide and all metals displayed multiple exceedances at the Outlet Ditch throughout the eight-year sampling period. Additional details are provided for each parameter in the context of predictions results presented in Section 5.1.

3.2.2 Source Terms

The model source terms were based on the sites' historic water quality monitoring data collected between 2011 and 2018. Bi-annual monitoring surveys included stations SW1-07, SW2-07, SW3-07, SW4-07, Outlet Ditch, and Tailings Pond Outlet for surface water quality trends. The compiled dataset includes results for field parameters (pH, temperature, ORP), general chemistry (pH, alkalinity, hardness, total dissolved solids, total suspended solids), nutrients (nitrate, nitrite, ammonia, phosphorus), ions (sulphate, chloride, fluoride) and total metals (Al, Ag, As, Ba, Be, Bi B, Cd, Cr, Co, Cu, Fe, Pb, Hg, Li, Mg, Mn, Mo, Na, Ni, Sb, Se, Sn, Sr, Te, Tl, Ti, U, V, Zn, Zr).

Average source terms, based on the median of historical measured concentrations, and upper case source terms, based on the 95th percentile of historical measured concentrations, were developed for each water type at the site, including natural runoff, cover runoff, landfill leachate runoff and tailings contact water.

Natural Runoff

The natural runoff source term is based on monitoring data collected at SW3-07. Station SW3-07 is located on the east side of the tailings facility, at the SW3 culvert. This station is the only monitoring location collecting solely background water. Other monitoring stations such as SW1-07 and SW2-07 receive landfill impacted water. For this reason, station SW3-07 was chosen to represent natural background water quality. The natural runoff source term reported high background concentrations of aluminum, iron and sulphide concentrations, likely in part due to the measurements being reported as totals.

The natural runoff source term is applied to runoff from the following catchments: AO1, AO3, AO5, SW1a, SW2a and SW3 (Figure 4).

Cover Runoff

The tailings facility will be capped with the same cover material used to cap the landfill. Runoff from the landfill area, that is not also mixed with landfill leachate, is represented by monitoring data collected at SW2-07. The SW2 culvert is located Northeast of the tailings facility and collects surface flows from the southern part of the landfill (Figure 1). This area includes a metal storage facility, leading to conservatively high concentrations of some metals. In addition, metals samples collected at SW2-07 were unfiltered, and represent both the dissolved and suspended fractions of metals. High concentrations of Total Suspended Solids (TSS) are correlated to high concentrations of iron (Figure 4), a pattern which is reflected in concentrations of other metals. Suspended sediments are not expected to behave conservatively as water high in TSS flows through the facility. The accuracy of predictions of iron concentrations, and concentrations of other metals, at downstream locations using a mass balance approach are negatively impacted by the use total metals concentrations for upstream water quality inputs.

The cover runoff source term is applied to the landfill runoff in catchment SW2b, and the tailings cover runoff in the post-closure scenarios.

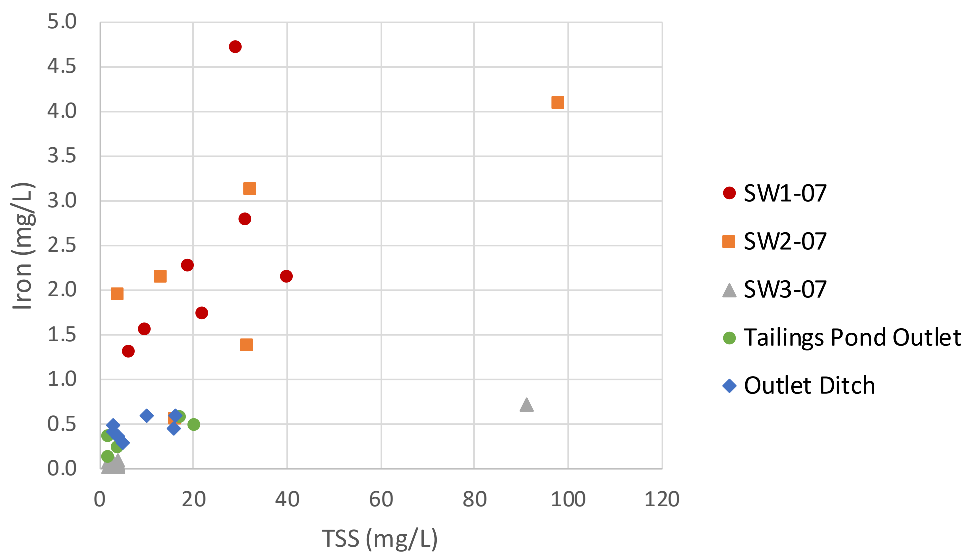


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Figure 4: Total Iron Concentrations as a Function of Suspended Solids

Landfill Area

The landfill impacted surface water source term was determined from station SW1-07. The station is also located to the Northeast of the tailing facility, west of the landfill, and collects water flows from background and landfill impacted sources (Figure 1). This monitoring station was selected to represent the mix of runoff from the catchment area upstream of SW1-07, including background runoff from catchment SW1a, and landfill surface runoff and leachate from catchment SW1b.

Tailings Contact Water

SRK (2017b) concluded that lowering the water table for remediation will not substantially alter pore water chemistry. Therefore, the tailings contact water source term was based on monitoring data from groundwater well MW-06-01, located at the northern end of the tailings facility. This location was selected to represent tailings contact water because it is documented to be screened within tailings material. It is also found to have analogous sulphate concentrations to that described by SRK (2017b).

The tailings contact water source term is applied to:

- meteoric water falling directly on the facility during the calibration period and Current Conditions scenario,
- infiltration water in the Base Case scenario, and,
- seepage from the dam.

3.3 Assumptions

The following assumptions were applied in the water quality prediction model:

- Channels on the tailings surface were assumed to convey water from upstream catchments, and not sufficiently contact tailings to acquire tailings contact water chemistry. This assumption was applied both for the pre-closure and post-closure scenarios.
- A 20% infiltration rate was assumed for meteoric water that falls directly on the tailings cover in the post-closure scenario. The rate was selected considering the Hydrologic Evaluation of Landfill Performance (HELP) infiltration modelling of the cover material completed in support of the Central Landfill closure (AMEC 2015) and considering the low permeability tailings beneath the cover. This base case assumption is evaluated through sensitivity analyses (Section 5.2).
- Attenuation factors were applied at the modelling nodes to address the over-prediction of aluminum, iron, manganese and zinc. Attenuation factors were determined empirically by determining the fraction of the load determined using the mass balance approach that accounts for the measured concentration at the Tailings Outlet and Outlet Ditch during the calibration period, weighting more heavily monitoring data collected post-2015 landfill remediation work (Table 5). Attenuation factors were then applied at these locations in the predictive period. Attenuation mechanism that could account for the reduction in concentrations estimated for these parameters include sedimentation, precipitation as secondary minerals including smithsonite (zinc carbonate) and rhodochrosite (manganese carbonate) (SRK 2017b), and co-precipitation with iron at near-neutral pH.

Table 5: Empirically Derived Attenuation Factors

Parameter	Attenuation Factor
Aluminum	0.2
Iron	0.1
Manganese	0.2
Zinc	0.3

Source:"\\srk.ad\dfs\na\van\Projects\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\WaterQualityPredictions\Model\BMine_WaterQualityPrediction Model_1CR012.005_CAJ_MC_v12.xlsx"

4 Model Evaluation

4.1 QA/QC

4.1.1 Model Review

The water quality prediction model was reviewed. The review process included the following steps:

- Checking that data sources are representative and are documented.
- Verifying loadings flow rates are correctly calculated, including unit conversations.
- Verifying loadings rates are correctly calculated and based on the appropriate source terms.
- Verifying model functions and expressions to ensure they are working as intended.
- Thorough calibration at prediction nodes.
- Using professional judgement and experience to evaluate if results reflect the understanding of the project and model inputs.
- Documenting quality control procedures and results.

4.1.2 Recommendations for further refinement

The northern area of the tailings has undergone preliminary covering procedures as part of the closure. For future iterations, it's suggested to account for the covered area north of the tailings facility (currently encompassed within catchment AO1) and assign corresponding cover material source terms to best represent parameter concentrations.

The catchment areas were based on detailed site aerial photographs and topographic contours. The catchment accuracy is limited by the extent of the files. The maps provided partial information to delineate catchments SW1a and SW3, which required overlaying with the SRTM Worldwide Elevation Dataset to account for missing sections. This measure increased error margins for catchment delineations, given the significant transition of data resolution. For future iterations, its suggested to consider a greater area extent when updating data and conducting aerial monitoring.

4.2 Calibration

A combination of quantitative and qualitative evaluations was completed to assess the model validation and recalibration.

The accuracy of modelled flows was evaluated using the Nash-Sutcliffe Efficiency (NSE) statistic. The quality of input data did not allow for a 'good' fit (i.e., NSE>0.65) between observed and modelled flows, however the NSE was used to optimize the fit. This approach was also applied at the Outlet Ditch and the Tailings Outlet, for a total of 3 flow calibration points. Runoff coefficients for natural catchments and the tailings runoff were adjusted to optimize flow calibration.

Water quality predictions were evaluated based on the degree of agreement between observed and modelled concentrations of sulphate and calcium. The calibration focused on sulphate and calcium because they are expected to be mobile and act geochemically conservatively at the concentrations present at HB Dam. These parameters were also used to test the validity of source assumptions; specifically, to assess the feasibility of using monitoring data from station MW-06-01 as the basis for the tailings contact water source term. Sulphate and calcium predictions were evaluated with respect to range of measured concentrations, timing and magnitude of seasonal concentration fluctuations.

Aluminum, iron, manganese and zinc were calibrated using empirically determined attenuation factors. Loading were multiplied by an attenuation factor that best matched calculated to observed concentrations for these parameters.

5 Results

5.1 Results for Covered Tailings

Predictions for current conditions were compared with the post-closure configuration (Table 6). The adequacy of the cover design was evaluated immediately after the flows exit the TSF (Tailings Seepage node) and at the property line (Outlet Ditch node). Water quality results are discussed for all COPCs. Results were compared to BCWQG and the BC Contaminated Site Regulations Water Standards for Aquatic Life (CSR). Where guidelines were hardness dependent, the predicted hardness for each node was used to calculate guideline values.

Table 6: Summary of Current Conditions and Post-Closure Configuration Scenarios

Parameter	Current Condition	Post-Closure Configuration (Base Case)
Hydrological Condition	Average	Average
Source Terms	Average	Average
Cover Infiltration Rate	n/a	20%
Attenuation Factor	Various (see Table 5)	Various (see Table 5)

Source: Compiled in text.

5.1.1 Sulphate

Sulphate was screened as a COPC because it exceeded BC WQG at the Outlet Ditch one time in November 2012.

The range of predicted copper concentrations are presented in Table 7. Sulphate originates almost entirely from the tailings contact water, which is reduced by 80% in the base case. Predicted sulphate concentrations at the Outlet Ditch node for the current condition are within the range of historical measurements and below the BC WQG. Concentrations at the Outlet Ditch are lower than the Tailings Seepage node because of dilution from background runoff from catchment AO5. Sulphate concentrations are predicted to improve in post-closure, and remain well below the BC WQG of approximately 309 mg/L.

Table 7: Predicted Sulphate Concentrations

Node	Uncovered Tailings (Current Conditions)	Covered Tailings (Base Case)
Tailings Seepage	178 to 300 mg/L	54 to 154 mg/L
Outlet Ditch	154 to 261 mg/L	47 to 134 mg/L

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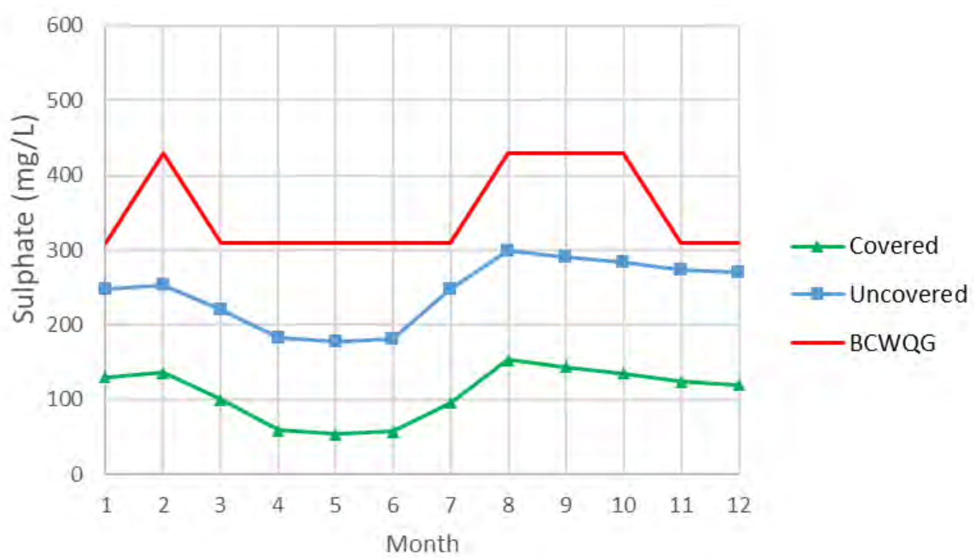

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Figure 5: Predicted Sulphate Concentrations for Pre and Post Closure at Tailings Seep

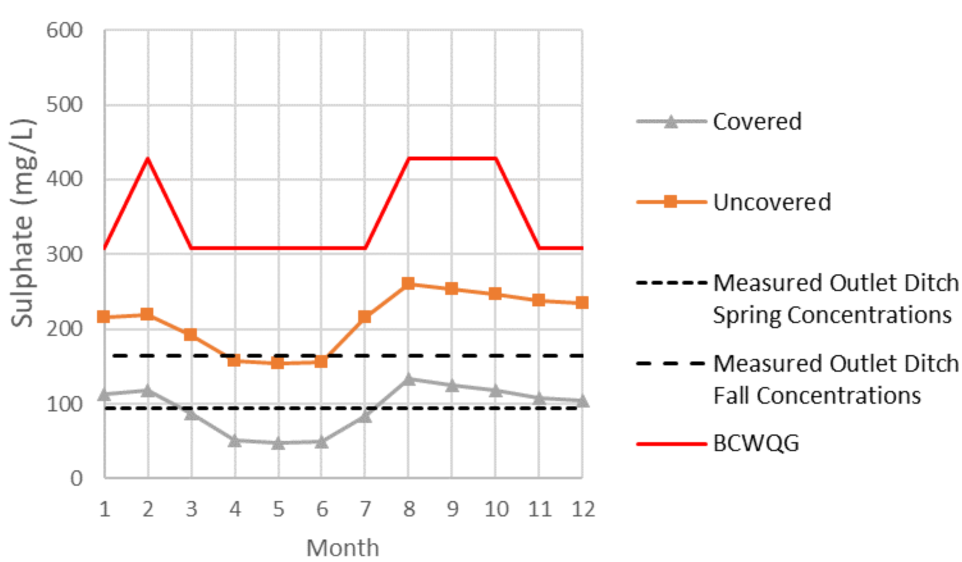

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Figure 6: Predicted Sulphate Concentrations for Pre and Post Closure at Outlet Ditch

5.1.2 Sulphide

Sulphide was screened as a COPC because its' concentration consistently exceeded BC working WQG working guideline prior to 2013, and the CSR twice in 2011. In recent years, the analytical detection limit has been higher than the water quality thresholds, and so has been insufficient to resolved exceedances. In addition, no sulphide data is available from monitoring data from groundwater well MW-06-01 on which to base a sulphide source term for tailings contact water. Source terms for other sources were developed using non-detected results.

The range of predicted sulphide concentrations are presented in Table 8. Predicted sulphide concentrations do not differ between the uncovered and covered scenarios. The primary source of sulphide is background runoff, followed by the upstream landfill area. Loadings from both sources are not expected to change based on proposed remedial efforts. The data available limits the ability of water quality modelling to resolve potential sulphide concentrations below the water quality threshold being applied.

Table 8: Predicted Sulphide Concentrations

Node	Uncovered Tailings (Current Conditions)	Covered Tailings (Base Case)
Tailings Seepage	0.0074 to 0.0094 mg/L	0.0074 to 0.0094 mg/L
Outlet Ditch	0.0071 to 0.0093 mg/L	0.0071 to 0.0093 mg/L

Note: Predicted sulphide concentrations are less than analytical detection limits applied in routine water quality monitoring.

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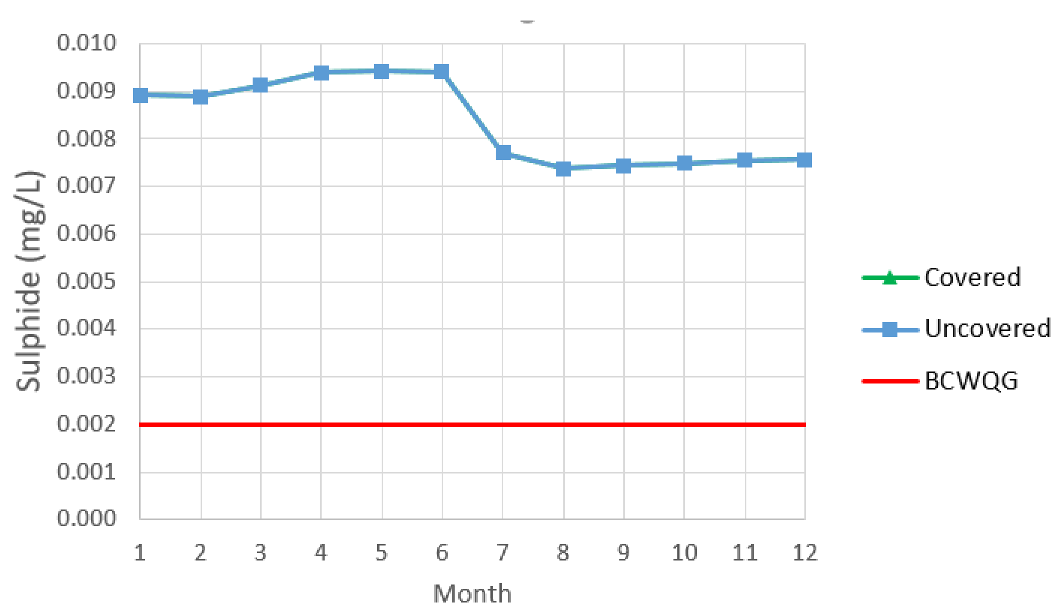

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Figure 7: Predicted Sulphide Concentrations for Uncovered and Covered Tailings at Tailings Seep

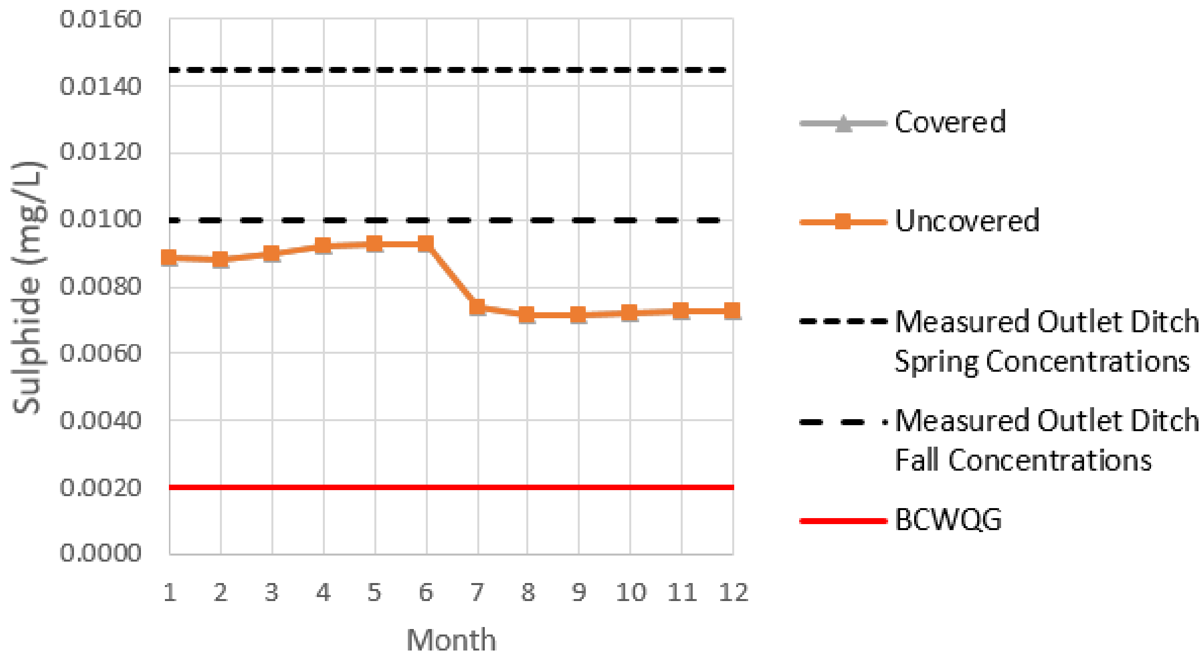

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Figure 8: Predicted Sulphide Concentrations for Uncovered and Covered Tailings at Outlet Ditch

5.1.3 Aluminum

Monitoring data for all parameters are provided for the total fraction of metals, including both dissolved and suspended fractions. The BC WQG for aluminum is for the dissolved fraction and was conservatively applied to screen the data available for total aluminum. Aluminum was screened as a COPC because it has regularly exceeded BC WQG for the dissolved fraction, most recently in 2016.

The range of predicted aluminum concentrations are presented in Table 9. Aluminum concentrations are predicted to exceed the BC WQG when fall, or low flow, source terms are applied for both the uncovered and covered scenarios. The cover material is the primary source of aluminum, followed by background runoff. Aluminum concentrations are predicted to increase after the tailings are covered.

Source terms were developed with total metals concentrations. A relationship between elevated TSS and elevated concentrations of several total metals including aluminum is discussed in Section 3.2.2. A predicted increase in aluminum concentration with a cover in place may be an artifact of using total metals concentrations to develop the source terms.

Table 9: Predicted Aluminum Concentrations

Node	Uncovered Tailings (Current Conditions)	Covered Tailings (Base Case)
Tailings Seepage	0.021 to 0.071 mg/L	0.053 to 0.134 mg/L
Outlet Ditch	0.029 to 0.079 mg/L	0.057 to 0.133 mg/L

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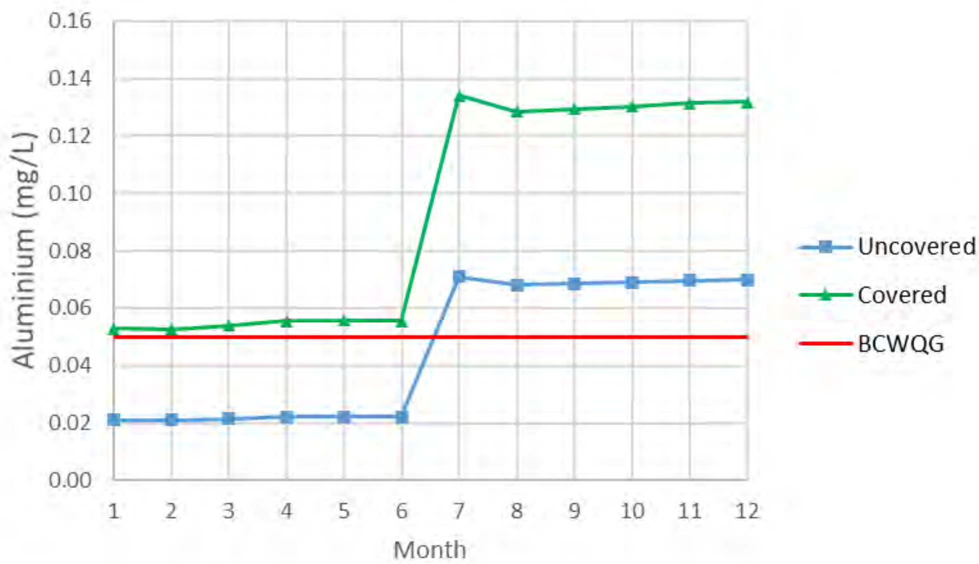

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Figure 9: Predicted Aluminum Concentrations for Uncovered and Covered Tailings at Tailings Seepage

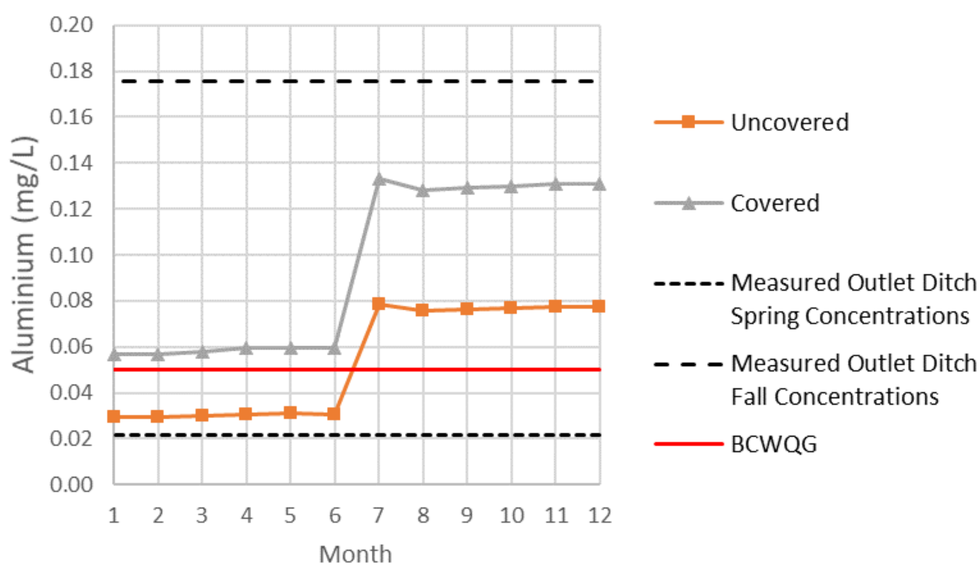

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Figure 10: Predicted Aluminum Concentrations for Uncovered and Covered Tailings at Outlet Ditch

5.1.4 Cadmium

Monitoring data for all parameters are provided for the total fraction of metals, including both dissolved and suspended fractions. The BC WQG for cadmium is for the dissolved fraction and was conservatively applied to screen the data available for total cadmium. Cadmium was screened as a COPC because it has exceeded BC WQG and CSR for aquatic life on a regular basis throughout the monitoring record (2011 to 2018).

The range of predicted cadmium concentrations are presented in Table 10. Cadmium originates almost entirely from the tailings contact water, which is reduced by an assumed 80% with the placement of a cover. Although cadmium levels are predicted to improve with the cover, they are still predicted to exceed the hardness dependent BC WQG which ranged from 0.0036 to 0.00019 mg/L based on predicted hardness.

Table 10: Predicted Cadmium Concentrations

Node	Uncovered Tailings (Current Conditions)	Covered Tailings (Base Case)
Tailings Seepage	0.00065 to 0.00143 mg/L	0.00019 to 0.00069 mg/L
Outlet Ditch	0.00056 to 0.00124 mg/L	0.00016 to 0.00060 mg/L

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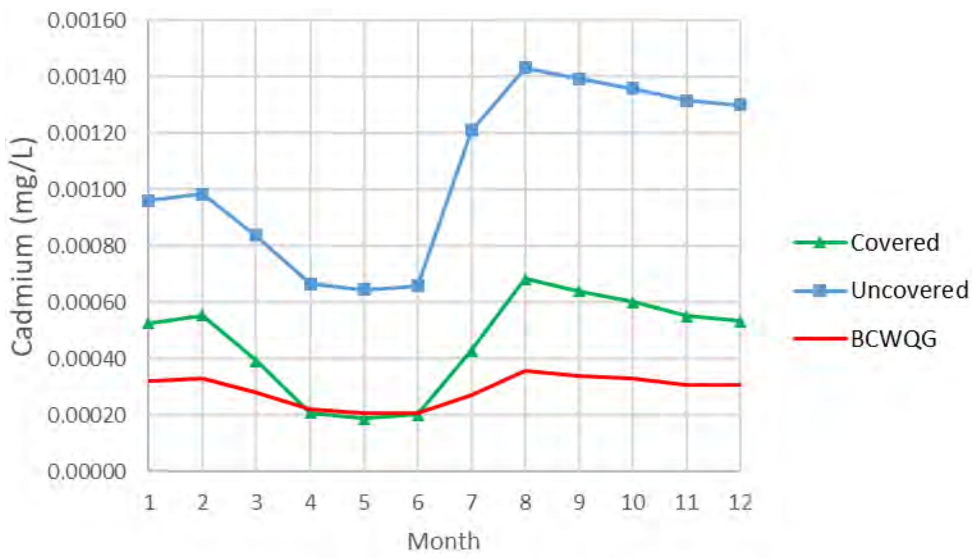

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Figure 11: Predicted Cadmium Concentrations for Uncovered and Covered Tailings at Tailings Seep

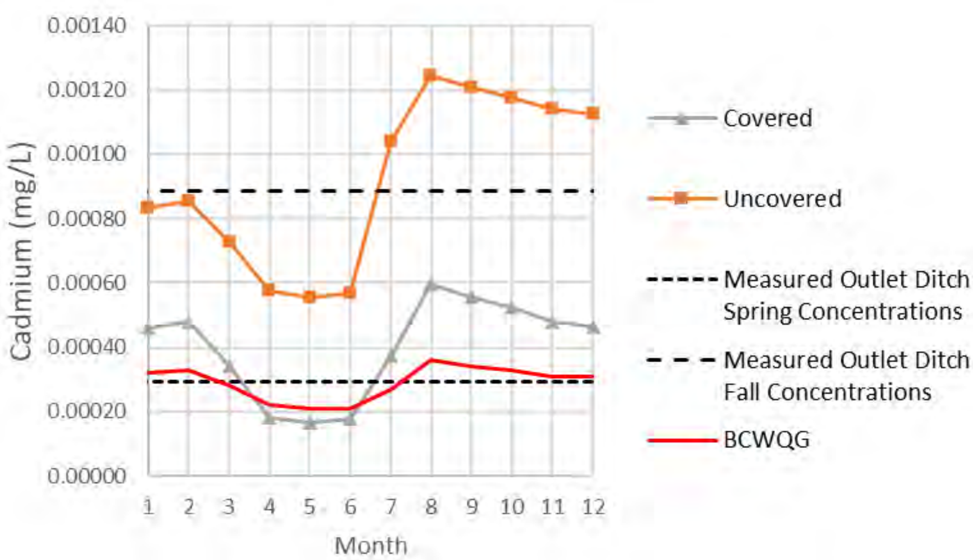

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Figure 12: Predicted Cadmium Concentrations for Uncovered and Covered Tailings at Outlet Ditch

5.1.5 Chromium

The BC working WQG for chromium are particular to two chromium species, specifically Cr(III) with a BC WQG of 0.0089 mg/L and Cr(V) with a BC WQG of 0.001 mg/L. Similarly, the CSR water standards are also for Cr(III) at 0.005 mg/L and Cr(V) at 0.008 mg/L. The water quality thresholds for Cr(V) were conservatively applied to screen the available data which is for total chromium (all chromium species in both total and dissolve fractions). Chromium was identified as a COPC because it exceeded the BC WQG for Cr(V) once in April 2012 and once in May 2018.

The range of predicted chromium concentrations are presented in Table 11. Chromium concentrations are predicted to exceed the BC WQG when fall, or low flow, source terms are applied for both the uncovered and covered scenarios. Runoff from background catchments is the primary source of chromium, however the cover material has the highest source term for this parameter. Because of this, chromium concentrations are predicted to increase after the tailings are covered.

The relevance of these results is uncertain given that no BC WQG exists comparable to the monitoring data that was used to develop model inputs.

Table 11: Predicted Chromium Concentrations

Node	Uncovered Tailings (Current Conditions)	Covered Tailings (Base Case)
Tailings Seepage	0.00081 to 0.00130 mg/L	0.00096 to 0.00160 mg/L
Outlet Ditch	0.00081 to 0.00126 mg/L	0.00094 to 0.00152 mg/L

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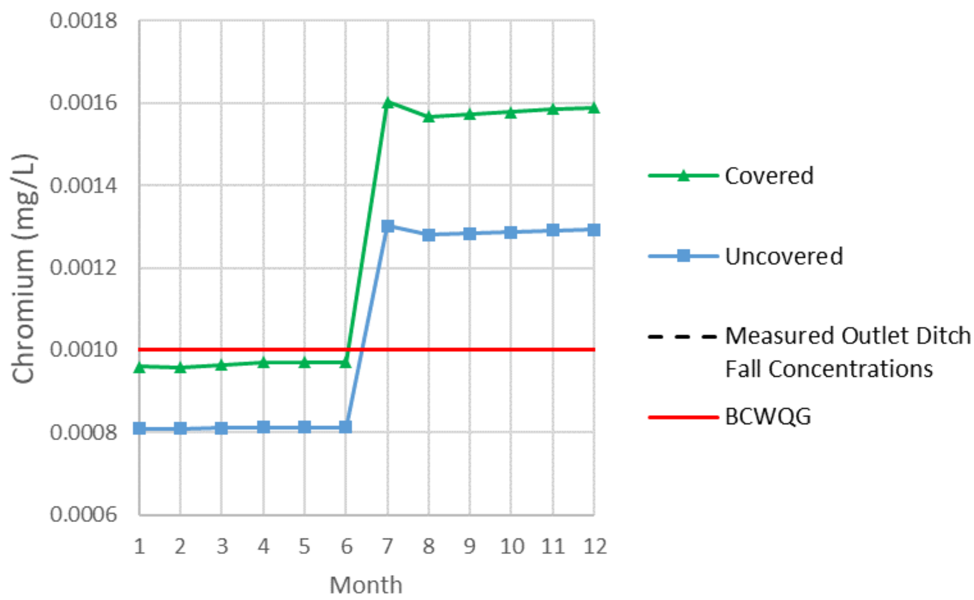

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Figure 13: Predicted Chromium Concentrations for Uncovered and Covered Tailings at Tailings Seep

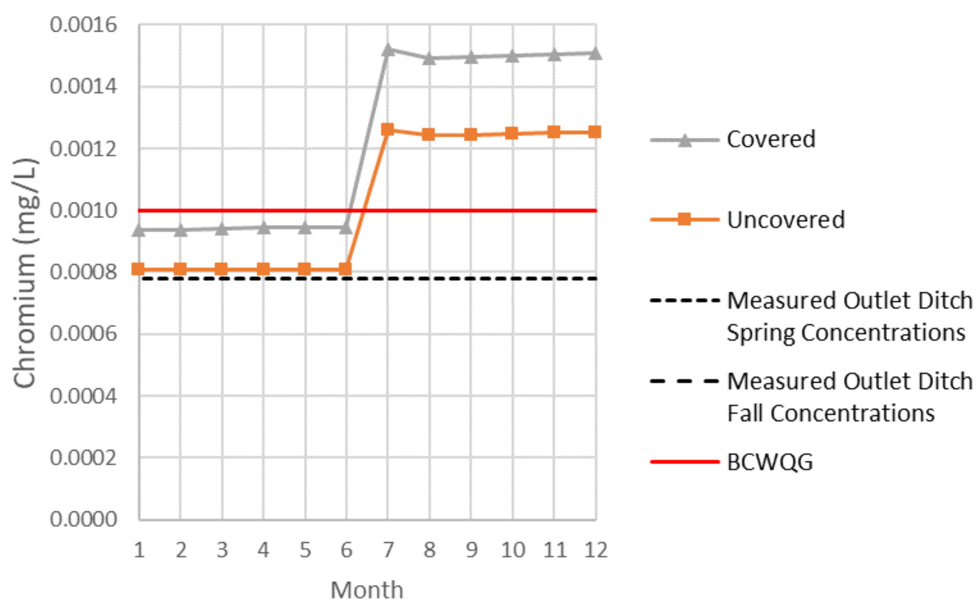

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Figure 14: Predicted Chromium Concentrations for Uncovered and Covered Tailings at Outlet Ditch

5.1.6 Copper

Copper was screened as a COPC because it exceeded BC WQG in two samples collected in April 2013.

The range of predicted copper concentrations are presented in Table 12. The predicted concentrations for the uncovered and covered scenarios are the same within the uncertainty of the model. For both scenarios, the range of copper concentrations are predicted to remain below the hardness depend BC WQG and the lowest CSR of 0.2 mg/L.

Table 12: Predicted Copper Concentrations

Node	Uncovered Tailings (Current Conditions)	Covered Tailings (Base Case)
Tailings Seepage	0.0018 to 0.0042 mg/L	0.0017 to 0.0044 mg/L
Outlet Ditch	0.0017 to 0.0038 mg/L	0.0015 to 0.0040 mg/L

Source:"\\srk.ad\dfs\na\van\Projects\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\WaterQualityPredictions\Model\BMine_WaterQualityPrediction Model_1CR012.005_CAJ_MC_v12.xlsx"

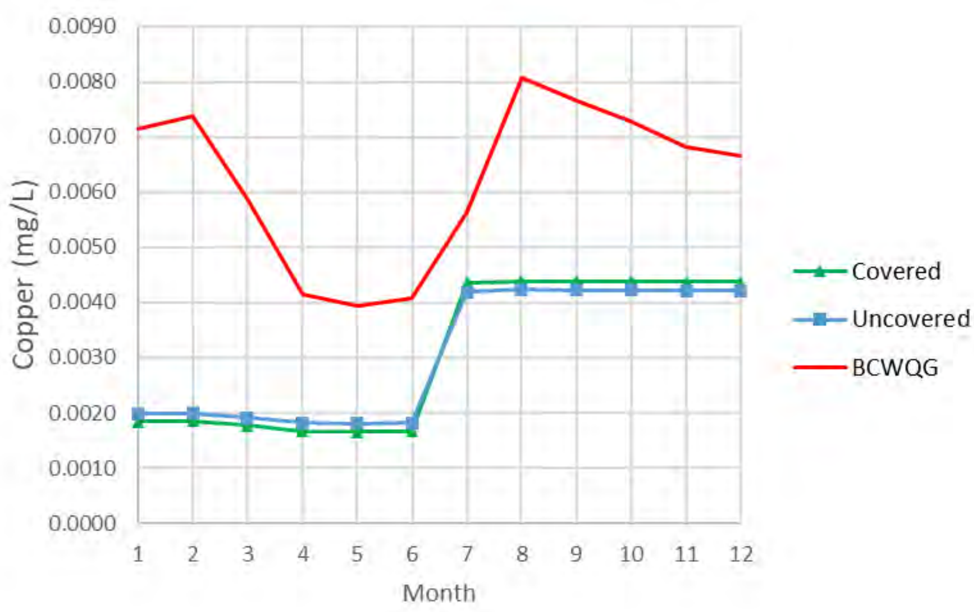

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Figure 15: Predicted Copper Concentrations for Uncovered and Covered Tailings at Tailings Seep

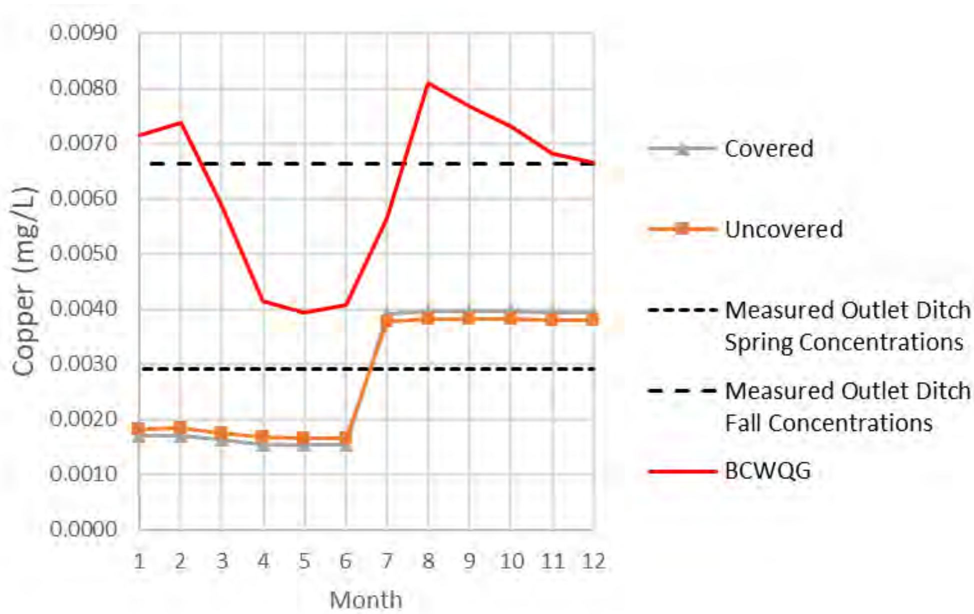

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Figure 16: Predicted Copper Concentrations for Uncovered and Covered Tailings at Outlet Ditch

5.1.7 Iron

Monitoring data for all parameters are provided for the total fraction of metals, including both dissolved and suspended fractions. For the purposes of this work, iron was conservatively screened against BC WQG for dissolved iron which are lower than those for total iron. Iron was included as a COPC because its concentration has exceeded both BC WQG and CSR guidelines, most recently in 2015.

The range of predicted iron concentrations are presented in Table 13. Predicted iron concentrations at the both nodes, and for both scenarios (covered and uncovered) are below BC WQG and CSR thresholds for dissolved iron of 0.35 and 0.3 mg/L, respectively. The primary iron source on site is the tailings contact water. The model predicts iron levels to decrease with a tailings cover. Iron is predicted to be slightly lower at the Outlet Ditch than at the Tailings Seepage node resulting from modest dilution from the AO5 catchment runoff.

Table 13: Predicted Iron Concentrations

Node	Uncovered Tailings (Current Conditions)	Covered Tailings (Base Case)
Tailings Seepage	0.17 and 0.31 mg/L	0.08 and 0.20 mg/L
Outlet Ditch	0.16 and 0.29 mg/L.	0.08 and 0.19 mg/L

Source:"\\srk.ad\dfs\na\van\Projects\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\WaterQualityPredictions\Model\BMine_WaterQualityPredictionModel_1CR012.005_CAJ_MC_v12.xlsx"

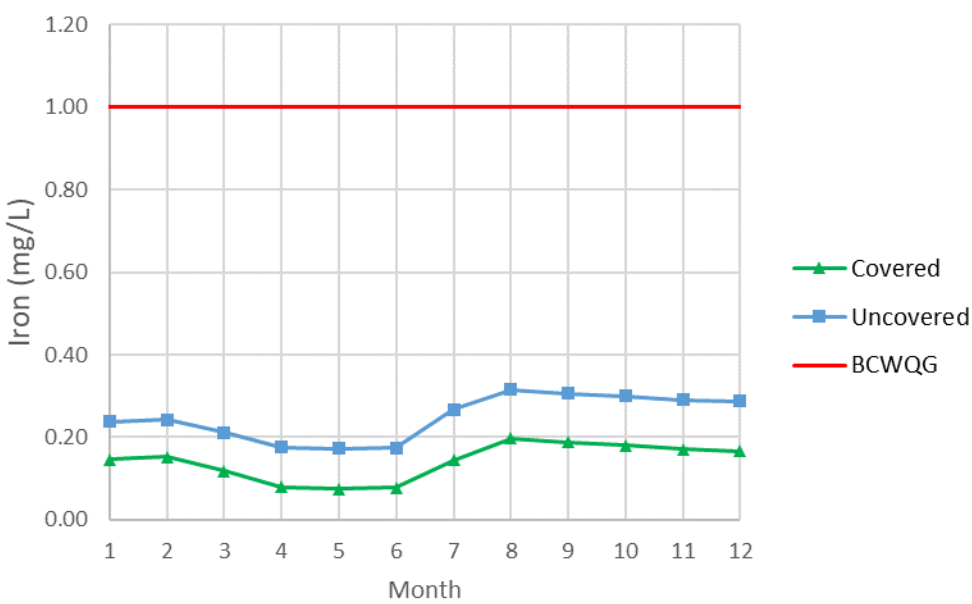

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Figure 17 Predicted Iron Concentrations for Uncovered and Covered Tailings at Tailings Seep

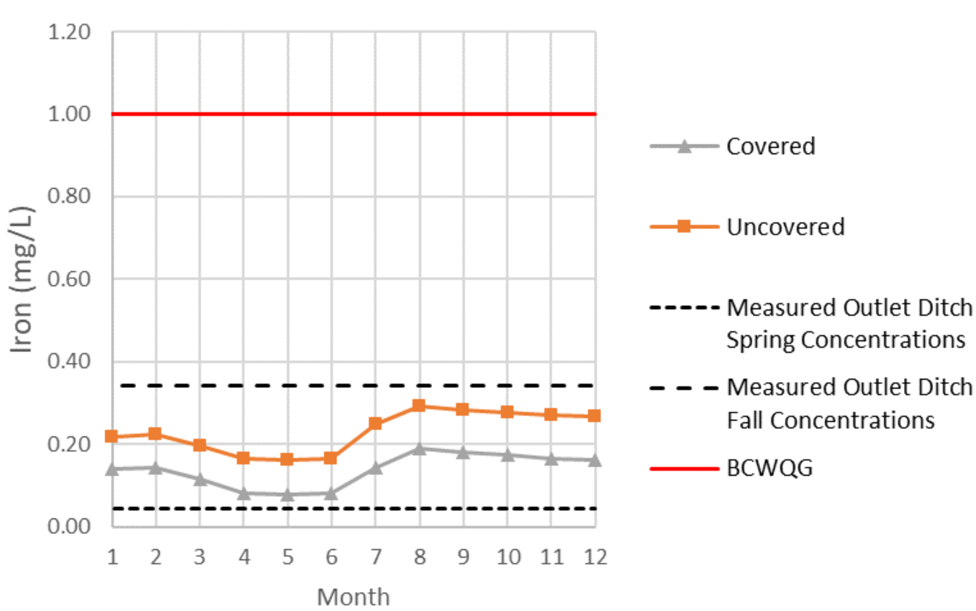

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Figure 18 Predicted Iron Concentrations for Uncovered and Covered Tailings at Outlet Ditch

5.1.8 Lead

Lead was screened as a COPCs because its concentrations exceeded CSR for drinking water several times in 2013 and 2014. Lead has also exceeded the BC WQG one time in April 2013.

The range of predicted lead concentrations are presented in Table 14. Lead originates in almost equal parts from background runoff and tailings contact water. With a cover, lead concentrations are expected to decrease. Concentrations at the Outlet Ditch are lower than the Tailings Seepage node because of dilution from background runoff from catchment AO5. Both current conditions and the base case predict concentrations to remain below the hardness dependent BC WQG and CSR of 0.01 mg/L.

Table 14: Predicted Lead Concentrations

Node	Uncovered Tailings (Current Conditions)	Covered Tailings (Base Case)
Tailings Seepage	0.0056 to 0.0072 mg/L	0.0025 to 0.0043 mg/L
Outlet Ditch	0.0021 to 0.0063 mg/L	0.0012 to 0.0038 mg/L

Source:"\\srk.ad\dfs\na\van\Projects\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\WaterQualityPredictions\Model\BMine_WaterQualityPredictionModel_1CR012.005_CAJ_MC_v12.xlsx"

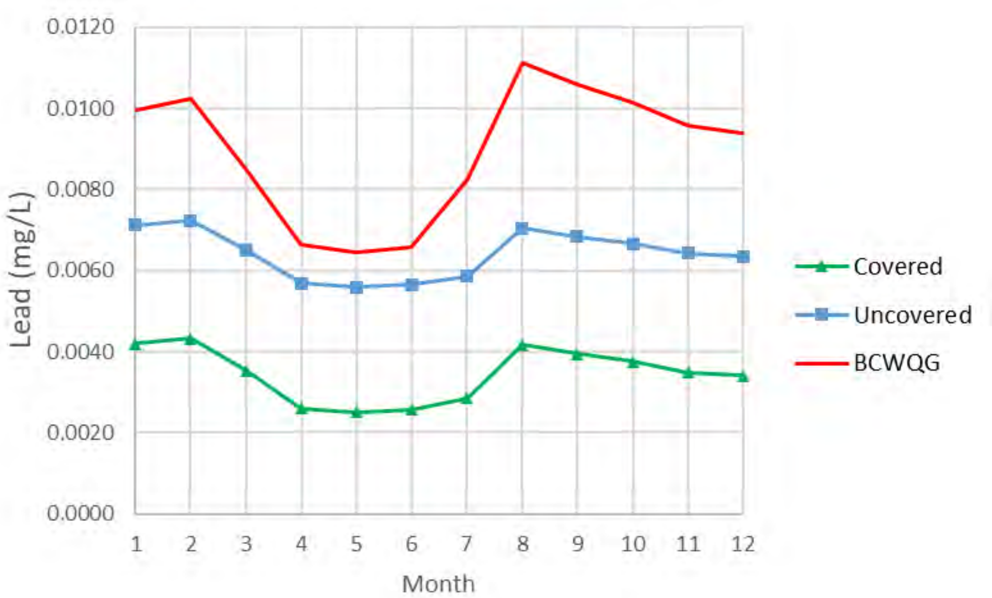

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Figure 19: Predicted Lead Concentrations for Uncovered and Covered Tailings at Tailings Seep

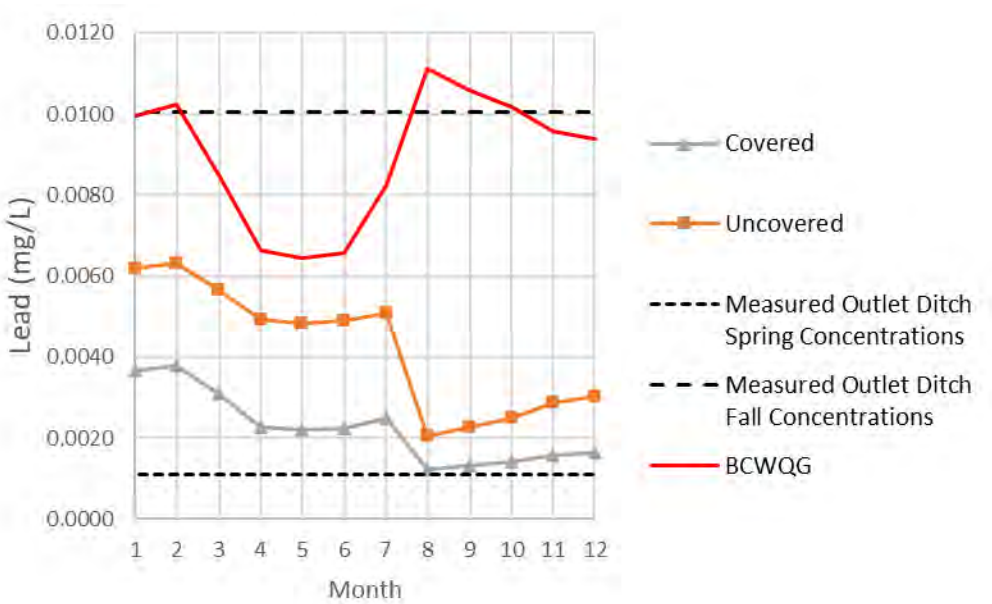

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Figure 20: Predicted Lead Concentrations for Uncovered and Covered Tailings at Outlet Ditch

5.1.9 Manganese

Manganese was screened as a COPC because its concentration exceeded the CSR for irrigation several times, most recently in May 2018.

The range of predicted manganese concentrations are presented in Table 15. Predicted concentrations for both nodes, and for both scenarios (covered and uncovered) are below BC WQG, which ranges from 0.99 to 1.4 mg/L, and the lowest CSR guideline, 0.2 mg/L. Predicted manganese concentrations at the Outlet Ditch for the current condition are within the range of historical measurements. Manganese originates in all sources on site, primarily from background runoff with tailings contact water is a secondary contributor to lead loadings. With a cover, manganese concentrations are predicted to further decrease below water quality thresholds.

Table 15: Predicted Manganese Concentrations

Node	Uncovered Tailings (Current Conditions)	Covered Tailings (Base Case)
Tailings Seepage	0.033 and 0.062 mg/L	0.017 to 0.046 mg/L
Outlet Ditch	0.029 and 0.054 mg/L	0.015 to 0.040 mg/L

Source:"\\srk.ad\dfs\na\van\Projects\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\WaterQualityPredictions\Model\BMine_WaterQualityPredictionModel_1CR012.005_CAJ_MC_v12.xlsx"

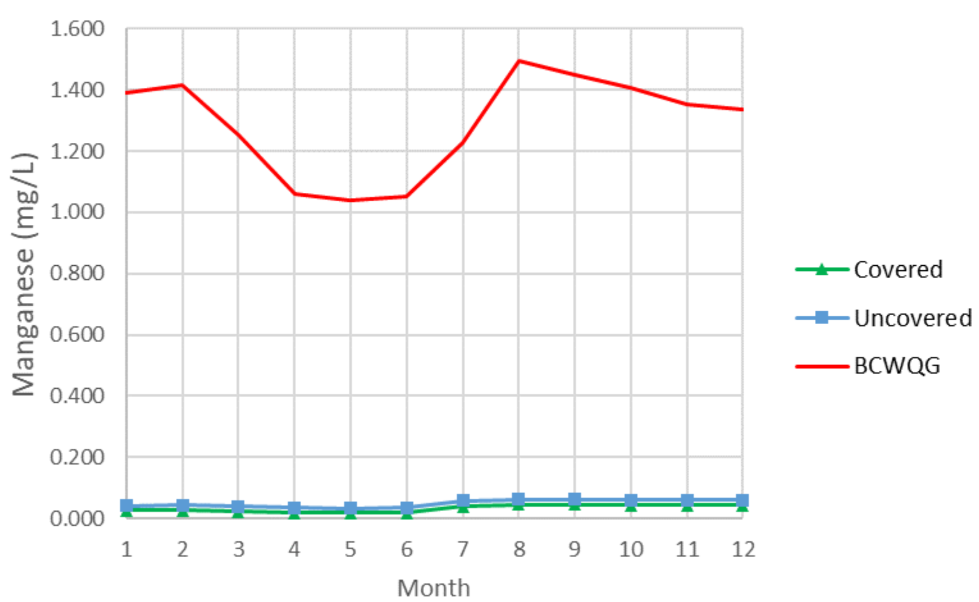

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Figure 21: Predicted Manganese Concentrations for Uncovered and Covered Tailings at Tailings Seep

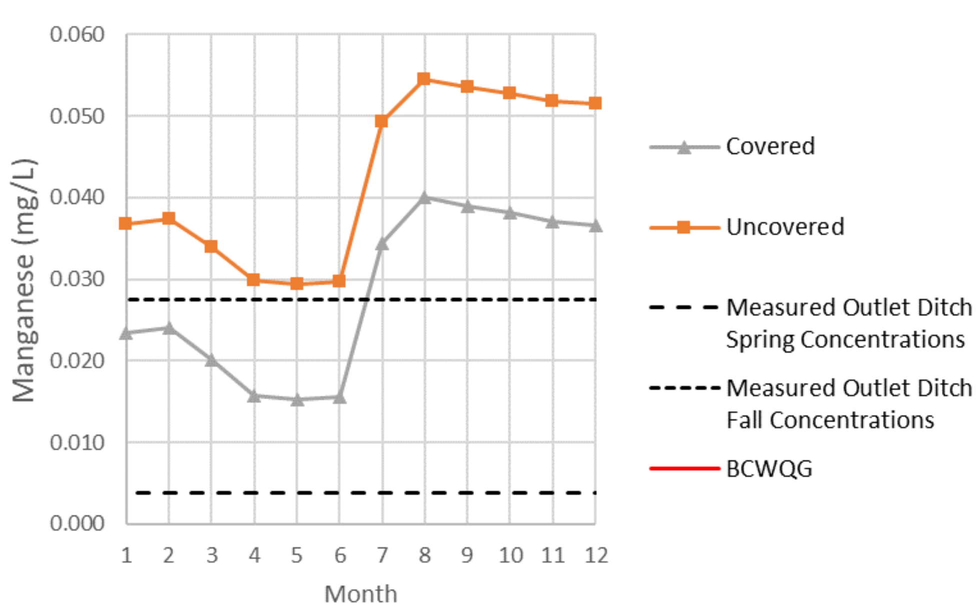

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Figure 22: Predicted Manganese Concentrations for Uncovered and Covered Tailings at Outlet Ditch

5.1.10 Zinc

Zinc has exceeded BC WQG and CSR for aquatic life on a regular basis throughout the monitoring record (2011 to 2018).

The range of predicted zinc concentrations are presented in Table 16. Zinc originates almost entirely from loadings from tailings contact water. Tailings contact water loadings are reduced by an assumed 80% with a cover in place, resulting in an improvement of zinc concentrations downstream of the TSF. Although zinc levels are predicted to improve with the cover, they are still predicted to exceed the hardness dependent BC WQG which ranged from 0.0075 to 0.0082 mg/L based on predicted hardness.

Table 16: Predicted Zinc Concentrations

Node	Uncovered Tailings (Current Conditions)	Covered Tailings (Base Case)
Tailings Seepage	0.21 to 0.39 mg/L	0.05 to 0.18 mg/L
Outlet Ditch	0.18 to 0.34 mg/L	0.05 to 0.16 mg/L

Source:"\\srk.ad\dfs\na\van\Projects\01_SITES\HB_Mine\1CR012.005_2018_TSF_Closure_Design\WaterQualityPredictions\Model\BMine_WaterQualityPrediction Model_1CR012.005_CAJ_MC_v12.xlsx"

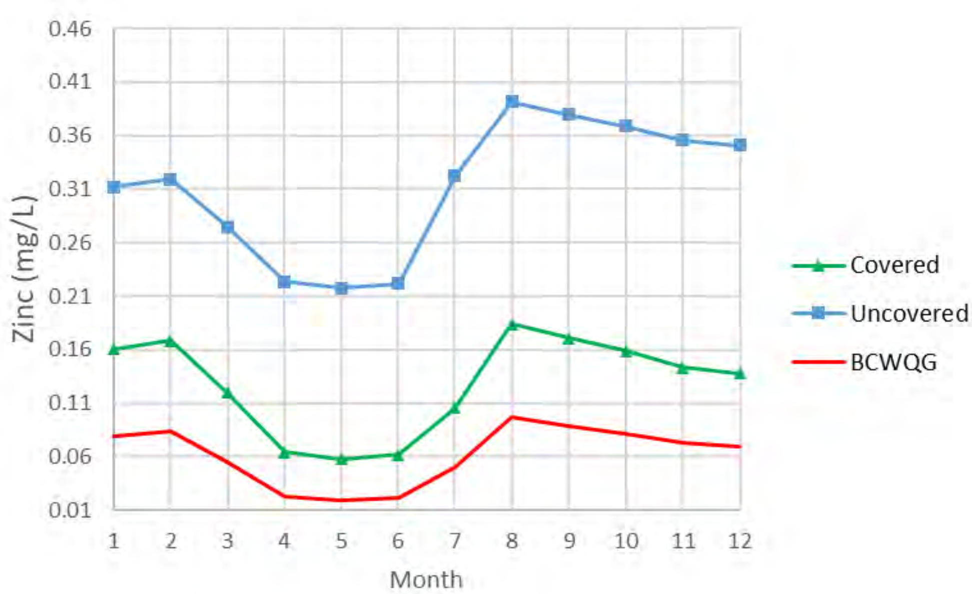

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Figure 23: Predicted Zinc Concentrations for Uncovered and Covered Tailings at Tailings Seep

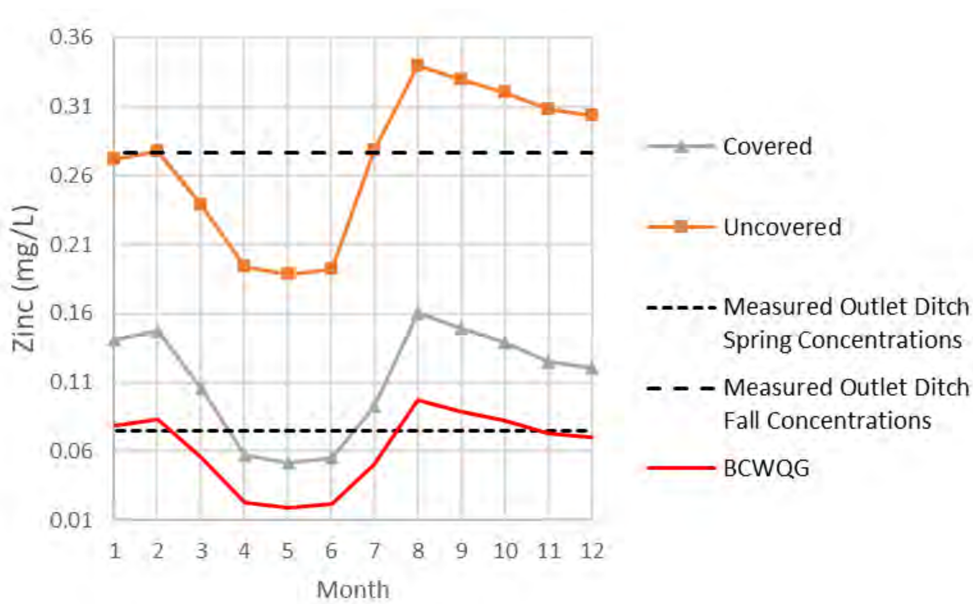

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Figure 24: Predicted Zinc Concentrations for Uncovered and Covered Tailings at Outlet Ditch

5.2 Sensitivity Analysis

The purpose of the sensitivity analysis is to account for uncertainty in the water quality model inputs, as well as to understand how model inputs affect the results. The sensitivity analysis includes an assessment of the following input parameters:

- A range of hydrological conditions including average hydrological conditions, a 1 in 10 dry year and a 1 in 10 wet year.
- A range of source terms including average source terms, and an upper-case source.
- A range of cover infiltration rates.

Table 17 outlines the cases assessed in the sensitivity analysis. The range of predictions from using different input variables are compared against the results generated from the base case model predictions.

Table 17: Sensitivity Cases Modelled

Variable	Case	Covered Tailings	Hydrologic Conditions	Source Terms	Cover Infiltration Rates	Attenuation Factors
Current Conditions	1	No	Average	Average	n/a	n/a
Base Case	2	Yes	Average	Average	20%	n/a
Hydrological Conditions	3a	Yes	1 in 10 Dry	Average	20%	n/a
	3b	Yes	1 in 10 Wet	Average	20%	n/a
Source Terms	4	Yes	Average	Upper Case	20%	n/a
Cover Infiltration Rates	5a	Yes	Average	Average	10%	n/a
	5b	Yes	Average	Average	30%	n/a

Source: Compiled in text.

5.2.1 Range of Hydrological Conditions

To evaluate the impact of hydrological conditions on model results, the sensitivity of sulphate concentrations at the Outlet Ditch was assessed. 1 in 10 dry year (Scenario 3a) and 1 in 10 wet year (Scenario 3b) hydrological conditions were compared to the covered tailings case using average hydrological conditions (Scenario 2)

The predicted concentration of sulphate ranged up to 7% higher during the dry year, and up to 17% lower during a wet year. Similar ranges in parameter concentrations were found for other parameters for this sensitivity. Predictions are moderately sensitive to hydrological conditions that are applied in the model, and that are realized in the field.

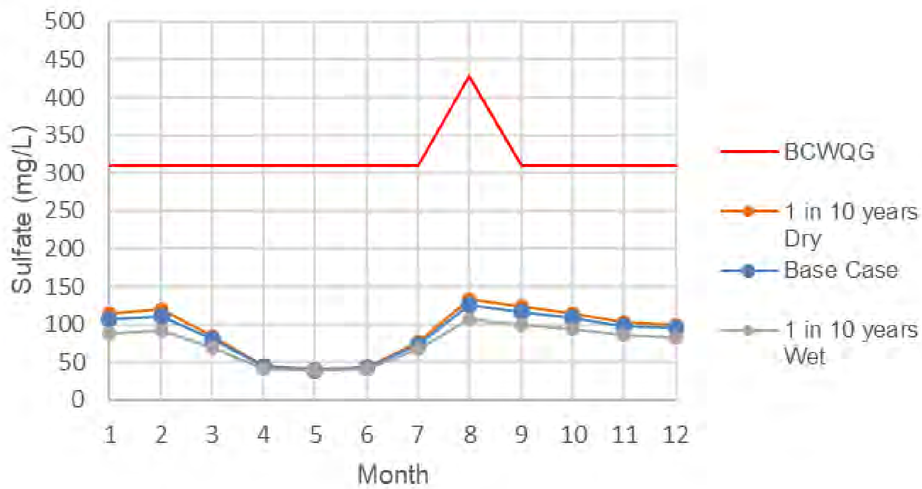

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Figure 25: Sulphate Sensitivity to Hydrological Conditions

5.2.2 Range of Source Terms

To evaluate the impact of source terms on model results, the sensitivity of Outlet Ditch sulphate and iron concentrations to source terms was assessed. Upper case source terms (Scenario 4) were compared to the covered tailings case using average source terms (Scenario 2).

The sensitivity analysis results varied by parameter depending on the natural variability in the monitoring data. The predicted concentration of sulphate ranged up to 18% higher with upper case source terms applied (Figure 26). For cadmium, the predicted concentrations ranged up to 133% higher with the upper case source terms (Figure 27). Predictions are highly sensitive to the source terms that are applied in the model.

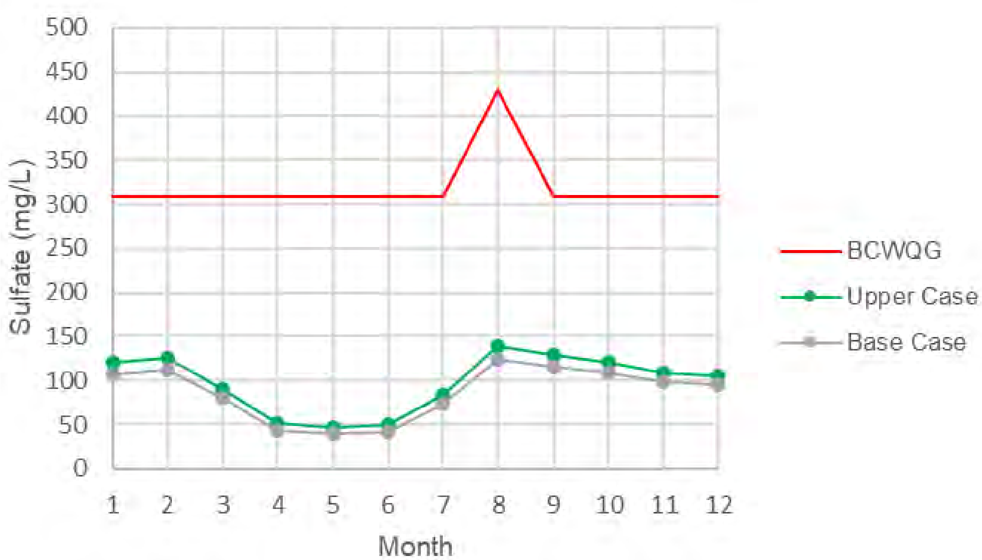

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Figure 26: Sulphate Sensitivity to Source Terms

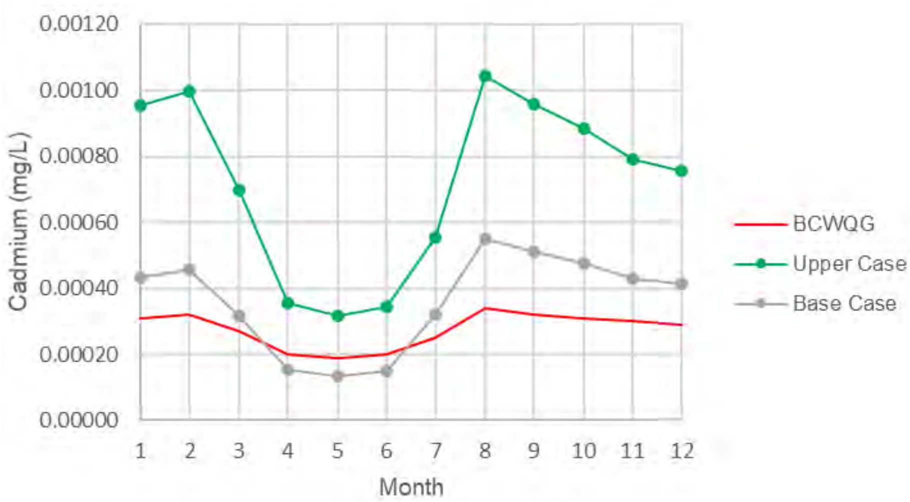

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Figure 27: Cadmium Sensitivity to Source Terms

5.2.3 Range of Cover Infiltration Rates

To evaluate the impact of infiltration rates on model results, the sensitivity of Outlet Ditch sulphate, d cadmium concentrations was assessed. Infiltration rates of 10% (Scenario 5a) and 30% (Scenario 5b) were compared to the covered tailings case using average infiltration conditions (Scenario 2).

A change in infiltration rate results in offsetting the predicted concentrations for parameters that are primarily sourced from tailings contact water. An increase in infiltration rate results in an increased in concentrations. By increasing the infiltration rate from 20% to 30%, sulphate concentrations increased by up to 24% and cadmium increased by up to 26% during low flow months when concentrations are lowest. In both cases, the range of infiltration rates considered did not significantly change predicted concentrations such that there was a difference in whether or not the respective BC WQG was exceeded. Sensitivity of predictions to the cover infiltration rate applied in the model was considered low.

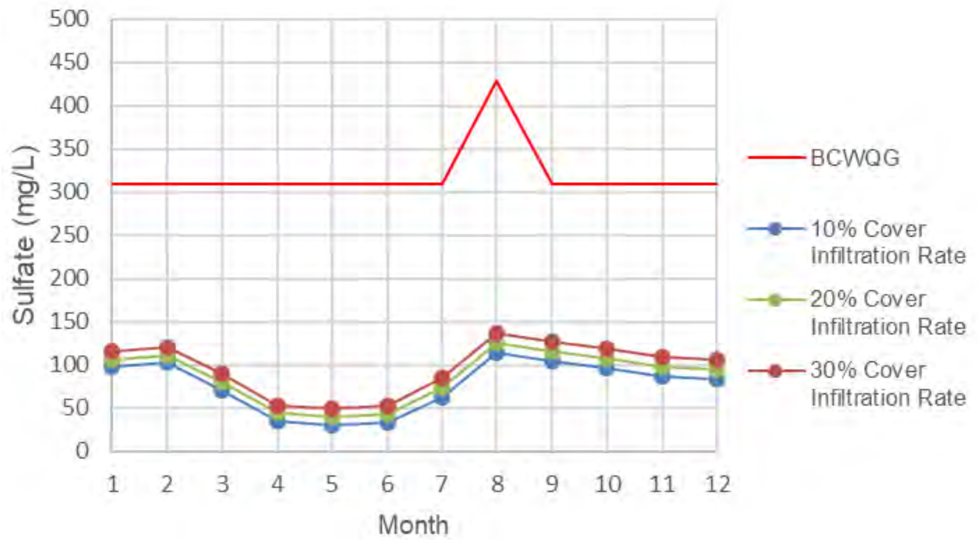

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Figure 28: Sulphate Sensitivity to Infiltration Rates

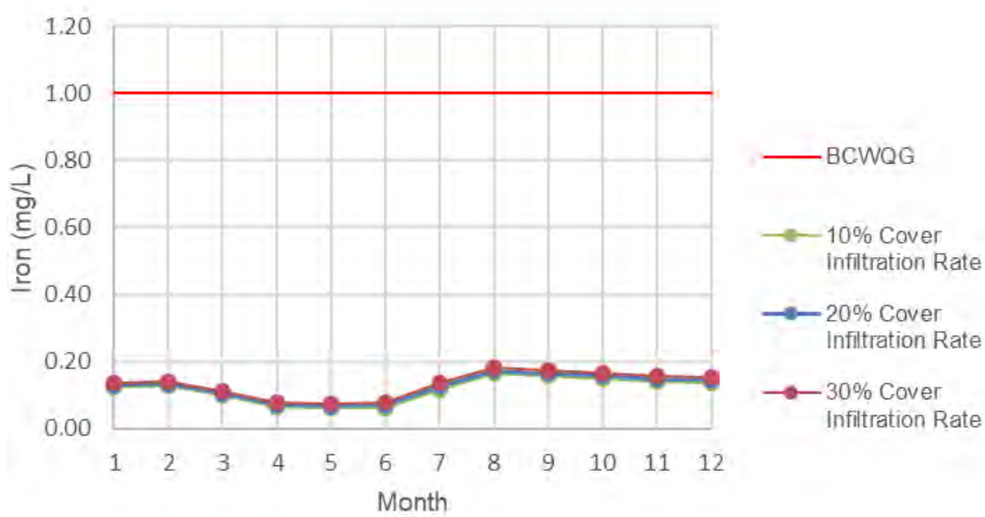

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Figure 29: Cadmium Sensitivity to Infiltration Rates

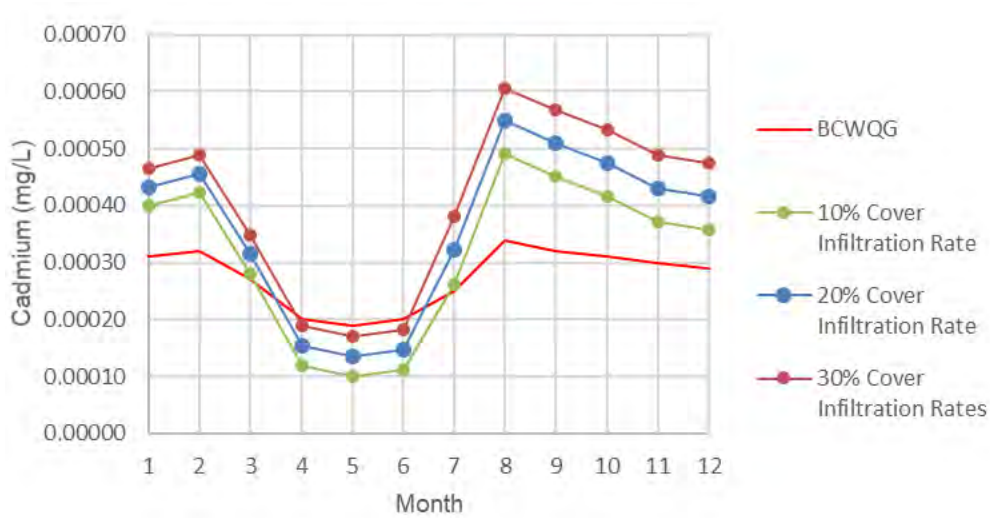

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Figure 30: Iron Sensitivity to Infiltration Rates

6 Conclusion

A simple water and load balance model was prepared for supporting the closure design presented in the 2019 Mines Act Permit Amendment application. A simple Excel based water and load balance was used to evaluate the effectiveness of a tailings cover for compliance with BC Water Quality Guidelines and Contaminated Sites Regulations.

Screening of monitoring data at the Outlet Ditch, downstream of the TSF, was competed to identify Contaminant of Potential Concern. Water quality predictions were developed for these parameters. Based on the water quality modelling exercise, the following conclusions can be made:

Sources:

- The primary source of sulphate, cadmium, iron, lead and zinc is the tailings material and the cover is predicted to reduce concentrations of these parameters at the Outlet Ditch.
- The primary source of chromium, copper, manganese and sulphide is background catchment runoff.
- The primary source of aluminum is the cover material; however, this could be an artifact of source term development based on total metals, which includes both the dissolved and suspended fractions. The suspended fraction will not act conservatively as water flows through the facility.

Water Quality Trends:

- For sulphate, iron, lead and manganese, the cover is predicted to improve water quality. The estimate of current conditions used to compare predicting are below the BC WQG and the cover aids in further reducing concentrations of this parameter.
- For cadmium and zinc, the cover is predicted to improve water quality. However, the reduction in load from covering the tailings is insufficient to reduce the amount of cadmium and zinc loadings to the Outlet Ditch, and these parameters are predicted to exceed BC WQG after the cover is in place. However, conclusions from the Human Health and Ecological Risk Assessment (SLR, 2019) rank these risks as low.
- For chromium, the tailings are not a significant source, and the addition of cover material will increase concentrations to the Outlet Ditch.
- For aluminum, the cover material is a significant source and applying the cover to the TSF will increase concentrations at the Outlet Ditch.
- For copper and sulphide, the presence of a cover makes no difference in the water quality predictions at the Outlet Ditch.

The following parameters are predicted to exceed either the BC WQG (approved or working) or the lowest CSR: aluminum, cadmium, chromium, sulphide and zinc.

Model results were most sensitive to source terms developed for application in the model based on routing monitoring data.

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Christina James, MASc.
Principal Consultant

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

7 References

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SLR Consulting (Canada) Ltd., 2019. HB Mine Tailings Management Facility, Prospective Human Health and Ecological Risk Assessment Salmo, BC. Prepared for the Regional District of Central Kootenay. SLR Project Number: 204.03242.00000. May 2019.

SRK Consulting (Canada) Inc., 2017a. *HB Mine Tailings Facility Closure Design – Hydrological Analysis*. Prepared for the Regional District of Central Kootenay. SRK Project Number 1CR012.004. June 2017.

SRK Consulting (Canada) Inc., 2017b. *Prediction of Geochemical Performance of HB Tailings Under Proposed Remediation Conditions*. Prepared for the Regional District of Central Kootenay. SRK Project Number 1CR012.003. May 2017.

Appendix J – Detailed Design FMEA

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Memo

To:	Alayne Hamilton, RDCK	**Client:**	Regional District of Central Kootenay
From:	Peter Mikes	**Project No:**	1CR012.005
Reviewed by:	Daryl Hockley	**Date:**	May 15, 2019
Subject:	HB Mine Tailings Facility – Detailed Design Risk Assessment		

1 Introduction

As part of the detailed design for the closure and remediation of the HB Mine Tailings Facility, a qualitative risk assessment was performed. This memo provides the results of the risk assessment. It should be read in conjunction with the risk register spreadsheet "**HB_DetailedDesignRisk_Register_20190515.xlsx**".

An initial failure modes and effects analysis (FMEA) was completed on the preliminary design and documented in SRK (2018). The FMEA was conducted as an one-day workshop held in December 2017 that evaluated the risks of the preliminary design as defined in the October 2017 draft report (SRK 2017). The FMEA resulted in no risks rated as high or very high that would generally require design changes or mitigations but did result in several moderately high or moderate risks that required consideration in the detail design.

For the detailed design, it was determined that a formal risk assessment workshop was not necessary to complete this project. The results of the initial FMEA were used as a basis to update the risks evaluated against the detailed design provided in the Remediation and Closure Plan (2019). The results of the updated risk assessment are provided in this memorandum.

The objectives of the risk assessment were to review the risk ratings and ensure that all risks rated moderately or higher were considered or addressed in the detailed design, to update the risk profile for the facility, and to determine if adequate controls are in place for risks that are not able to be practically reduced through further changes to the design.

2 Methodology

The risk register from the FMEA Workshop (Worksheets: "Dam (D)", "Water Con (W)", "Cover (C)", "Implementation (I)", and "Admin (A)") were updated with additional columns that describe:

1. The changes made during the detail design that would affect the risk rating.
2. Design controls that in place to mitigate the risk.

3. Operational controls that are in place to mitigate the risk.

The risk ratings were then evaluated using the same criteria that was used in the initial FMEA Workshop which are provided in Attachment 1 of SRK (2018).

Consideration was given for the addition of new risks to the risk register, however no new risks were identified as the design components in the detailed design are fundamentally the same as the preliminary design.

3 Results

Figures 1 and 2 present the risk rating matrices from the preliminary design FMEA Workshop (Figure 1), and for the detailed design (Figure 2) that show where each risk scenario plotted based on its ratings of likelihood and consequence severity. The complete details of each risk scenario and rating is provided in the risk register spreadsheet.

Typically, risks that are rated as high or very high should be addressed by mitigation measures or changes to the design. Risks that are rated as moderately high or moderate should be monitored, but changes to the design are often not required. Risks that are rated low typically do not usually require specific monitoring or changes to the design.

The figures show that the detailed design has a lower risk profile compared to the preliminary design. No risks were rated as high or very high. The number of moderately high risks was reduced from twenty-five to sixteen. Fourteen of these risks in the extreme consequence and very unlikely category, where the consequence is extreme by definition of the scenario and the likelihood is unable to be lowered any further. The two-remaining moderately high risks are the following:

1. W5: Degradation of the geosynthetic liners in the tailings surface conveyance channel liners resulting in a need for repair; and,
2. I03: During construction, equipment working on soft tailings sink resulting in a risk to worker’s safety.

In both cases, the risks are not practically able to be reduced further through changes to the design. Current estimates of the lifespan of covered liners are typically in the hundreds of years and degradation is expected to be slow, allowing ample time for detection and mitigation. The construction risk of equipment sinking into the tailings can be managed by the contractor through common tailings cover construction practices such as: trafficability trials, use of spotters, avoidance of repeated trafficking over the same area to allow pore pressures to dissipate, and construction of temporary access roads using geosynthetics and increased fill thicknesses.

Likelihood			Risk Classification				
Likelihood	Almost Certain	5	C11	I07, W5			
Likelihood	Likely	4	D14, C2, C8, C10, W9				
Likelihood	Possible	3		I02, I05, C4, C6, W4, W6	I06, W8, A05, A07, A08		
Likelihood	Unlikely	2	C7	D9, D12, C1, A09, A11	D8, D25, C5	I03, D10	D24, W10
Likelihood	Very Unlikely	1	I01, C9	D18, C3, W2, W3, A10	D2, D6, D7, D11, D13, D17, D23, A02, A04	D3, D4, D15	I04, D1, D5, D16, D19, D20, D21, D22, W1, W7, A03, A06, A12, A13
			1	2	3	4	5
			Negligible	Low	Moderate	High	Extreme
			Consequence				

Figure 1: Preliminary Design Risk Rating Matrix

Likelihood	Almost Certain	5	C11	W5			
Likelihood	Likely	4	D14, C2	I07			
Likelihood	Possible	3	C8, C10, W6, W9	I02, I05, C4, C6, W4			
Likelihood	Unlikely	2		I06, D9, D12, C1, A09	C5, A07, A08	I03	
Likelihood	Very Unlikely	1	I01, C9	C3, W2, W3, A10, A11	D2, D7, D8, D11, D13, D17, D18, D23, D25, W8, A02, A04	D3, D4, D10, D15	I04, D1, D5, D16, D19, D20, D21, D22, D24, W1, W10, A03, A12, A13
			1	2	3	4	5
			Negligible	Low	Moderate	High	Extreme
			Consequence				

Figure 2: Detailed Design Risk Rating Matrix

The controls identified to mitigate the risks can be classified into three groups: engineering, construction, and operational (post-closure). The engineering design and controls are described in the design report. A following bullets provide a summary of the construction and operational controls:

Construction Controls

- A Construction and Environmental Management Plan required to be prepared by the contractor that describes the work plan and construction sequencing, erosion control and water management measure requirements, and site-specific heath and safety requirements.

- Trafficability trials are required to determine the areas where equipment is able to traffic over the tailings and where other soft ground construction techniques will be required for cover placement.

- Blast monitoring required during the spillway excavation to ensure blasting does not compromise dam stability.

- QA field inspection services will be required to ensure that tailings boils are repaired and minimized. Geotextile filter layers may be required to be placed over the tailings as a contingency to prevent boils and improve trafficability.

Operational (Post-closure) Controls

- Continued implementation of the surveillance, inspection, monitoring and maintenance plan outlined in the Operations, Monitoring and Surveillance (OMS) Manual, including periodic review and updates to the OMS Manual.

- Continued updates and testing of the Emergency Preparedness and Response Plan (EPRP) for the facility.

4 Closure

The designed design for the closure and remediation of the HB Mine Tailings Facility has reduced the risk profile compared to the preliminary design evaluated in the December 2017 FMEA workshop. The remaining risks are considered to be acceptable and are able to be mitigated with the controls detailed in the design report and outlined in Section 3.

We trust this memorandum meets your present requirements. Should you have any questions or comments, please contact the undersigned at 604-681-4196.

SRK Consulting (Canada) Inc.

Prepared by:

Peter Mikes, PEng
Principal Consultant

5 References

SRK Consulting (Canada) Inc., 2017. HB Mine Tailings Facility Closure and Remediation – Preliminary Design Report - DRAFT. Prepared for Regional District of Central Kootenay. SRK Project Number 1CR012.004. October.

SRK Consulting (Canada) Inc., 2018. HB Mine Tailings Facility Preliminary Design Failure Modes and Effects Analysis Workshop Report. Prepared for Regional District of Central Kootenay. SRK Project Number 1CR012.005. September.

Appendix K – Cost Estimate Basis

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January 30, 2020
Project No: 1CR012.006

HB Mine Tailings Facility Technologist
Regional District of Central Kootenay
Box 590, 202 Lakeside Drive
Nelson, BC V1L 5R4

Attention: Alayne Hamilton

Dear Ms. Hamilton:

HB Mine Tailings Facility – Remediation and Closure Cost Estimate – REV01

This document presents the basis of the reclamation and closure detailed cost estimate for the HB Mine Tailings Facility based on the drawings prepared as part of the 2019 Remediation and Closure Plan.

The following section describe the basis of the estimate and the major cost assumptions. A cost summary is provided in Section 7 with the cost details provided in Attachment 1.

1 Scope of Estimate

The closure activities are detailed within the Remediation and Closure Plan and consist of the major tasks summarized in Table 1.

Table 1: Scope of Estimate

Area	Major Activities
Site Preparation	• Tree clearing and removal • Borrow development and decommissioning • Construction of temporary access roads • Water management including dewatering of the tailings pond (incl. amphibian salvage), and set-up and operation of by-pass pumping systems

U.S. Offices:
Anchorage 907.677.3520
Denver 303.985.1333
Elko 775.753.4151
Fort Collins 970.407.8302
Reno 775.828.6800
Tucson 520.544.3688

Canadian Offices:
Saskatoon 306.955.4778
Sudbury 705.682.3270
Toronto 416.601.1445
Vancouver 604.681.4196
Yellowknife 867.873.8670

Group Offices:
Africa
Asia
Australia
Europe
North America
South America

Area	Major Activities
Spillway	• Bedrock and soil excavation • Geotextile placement • Riprap production and placement • Backfilling of the tailings pond to provide positive drainage to the lowered spillway
Dam Upgrades	• Clearing and grubbing of the expanded toe berm footprint • Construction of the expanded toe berm including drain rock, geotextile, and general fill placement • Removal of the riprap on the upstream face of the dam and construction of the upstream beach
Tailings Surface Drainage Channels	• Channel excavation and placement of a LLDPE geosynthetic liner, protection layer, and turf reinforcement mat • Construction of energy dissipation structures at the upstream ends of the North and South Spur Channels including placement of geotextile and riprap layers • An allowance for road construction over soft ground was included that assumed a 1.5 m fill height over a ten-meter width
Tailings Cover	• Tree removal and clearing of vegetation • Trimming of the tailings surface to fill erosion gullies • Construction of a 0.3 m thick tailings cover • Geotextile placement over areas of soft ground
Revegetation	• Hydroseeding of the tailings cover and disturbed dam footprints • Broadcast seeding of the decommissioned borrow areas
Instrumentation	• Installation of 12 survey monuments • Allowance for replacement of 6 of the dam piezometers (3 wells)
Indirects	• Mobilization and Demobilization • Balance of contractor project costs (quality control including surveying, material technician and testing, overhead, contract administration, etc.) • Owner field costs including as-built reporting, Field Engineer supervision and Engineer-of-Record field visits, environmental monitoring. • Contingency

Area	Major Activities
Post-Closure Monitoring and Maintenance	• Water quality sampling • Annual dam safety inspections • Dam safety reviews (5-year frequency) • Vegetation monitoring • Periodic maintenance (vegetation removal every 10 years) • RDCK staffing and reporting • Closure Management Manual Updates (every 10 years)

2 Basis of Quantities

Earthwork quantities were derived from the engineering drawings presented in the Remediation Plan, with the volume estimates obtained from the 3D design surfaces in AutoCAD Civil 3D. Table 2 provides a summary of basis of the other quantities not obtained from the drawings.

Table 2: Basis of Quantities and Major Assumptions

Site Preparation	• Borrow development stripping costs assume an average thickness of 0.2 m over the borrow area footprint. • Borrow area decommissioning regrading costs assume 31 hrs of a D8 Dozer are required. The dozer productivity calculations were based on Caterpillar handbook productivities and assume an average slope height of 10 m along the borrow area highwall. • 100 m of additional access road was assumed to be required to access the base of the spillway and toe berm. • Initial pond dewatering costs assume a 31 day dewatering period, with a $30,000 allowance for a in-line water filtrations system to address TSS. • Ongoing water management costs assume the construction of 3 water collection sumps are constructed upstream of the tailing impoundment, with the water pumped to the spillway. A $30,000 allowance was included for operation of the pumping systems.
Spillway	• All quantities obtained from engineering drawings.
Dam Upgrades	• All quantities obtained from engineering drawings.
Tailings Surface Drainage Channels	• An allowance 480 m long for road construction consisting of a 10 m wide, and 1.5 m thick layer of fill placed over a layer of geotextile was included. The road length is based on the assumed areas identified as marginal or poor trafficability on the drawings.

Tailings Cover	• The allowance for geotextile placement over areas of soft ground assumes placement is required over 25% of the area identified as having a potential for poor trafficability.
Revegetation	• All quantities obtained from engineering drawings
Instrumentation	• All quantities obtained from engineering drawings
Indirects	• A twelve week construction duration was estimated based on the calculated task productivities and in consideration of a review of the project by a local earthworks contractor. • A contingency of 12.5% was included and applied to all costs. The level of contingency was chosen to be compatible with the level of detail in the engineering drawings and given the potential uncertainty in environmental remediation construction.
Post-Closure Monitoring and Maintenance Costs	• Water Quality monitoring costs assume 17 samples are collected during each sampling event. • During construction, samplings is conducted monthly. • Post closure, sampling is conducted quarterly for the first five years, then semi-annually thereafter (same as the current frequency). • Dam Safety Inspections are to be conducted annually, and Dam Safety Reviews completed every five years. • Vegetation monitoring is assumed to be for the first three years post-closure. • RDCK management costs were provided by the RDCK. • Site maintenance consisting of vegetation removal along the spillway and tailings surface conveyance channels is assumed to be required every 10 years.

3 Basis of Unit Rates

Unit rates were developed based on SRK's experience on other sites of similar size and complexity. Material relocation costs were also evaluated using built up unit rates using productivity calculations that follow common estimation procedures that are routinely used by earthwork calculators. Equipment rates for these calculations were obtained from the BC Blue Book 2018-19.

The unit rates derived by SRK were reviewed by a local earthworks contractor familiar with the site. The unit rates were when updated based on rates provided by the contractor.

4 Net Present Cost Calculations

Net Present Cost (NPC) calculations were applied to the first 100 years of post-closure costs. The calculations applied discount rates of 1.5% for the first two years, 2% for the next three years, and 3%

thereafter. These discount rates are typically used by the BC Ministry of Energy, Mines and Petroleum Resources for reclamation liability estimates.

5 Results

Table 3 summarizes HB Mine Tailings Facility remediation and closure cost estimate.

Table 3: Basis of Quantities and Major Assumptions

Category	Cost
Site Preparation	$212,000
Spillway	$901,000
Dam Upgrades	$148,000
Tailings Surface Conveyance Channels	$485,000
Tailings Cover	$689,000
Revegetation	$340,000
Instrumentation	$85,000
Indirect Costs	$555,000
Contingency	$427,000
Subtotal - Closure Implementation	**$3,841,000**
Post-Closure Monitoring and Maintenance (NPC)	$2,769,000
TOTAL NET PRESENT COST	**$6,611,000**

Source: HB_RemediationPlanCostEstimate_rev13.xlsx

6 Closure

We trust that this report meets with your project requirements. If you have any questions or concerns, please contact Peter Mikes at (604) 681-4196 at your convenience.

Sincerely,
SRK Consulting (Canada) Inc.

PROFESSIONAL
PROVINCE OF
P. H. MIKES
33319
BRITISH COLUMBIA
ENGINEER
Jan 30/20

Peter Mikes, P.Eng.
Principal Constant

Disclaimer—SRK Consulting (Canada) Inc. has prepared this document for Regional District of Central Kootenay. Any use or decisions by which a third party makes of this document are the responsibility of such third parties. In no circumstance does SRK accept any consequential liability arising from commercial decisions or actions resulting from the use of this report by a third party.

The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

Attachment 1 – Cost Estimate Details

Cost Estimate Summary

Project: HB Mine Tailings Facility - Remediation Plan Cost Estimate - Jan 2020
Project No.: 1CM012.006
Client: RDCK
Date of Submission: January 2020
File Location: J:\01_SITES\HB_Mine\1CR012.006_TSF 2019 Design Support\999_CostEstimate

Item	Description	Costs
DIRECT COSTS		
1.1	Site Preparation	$212,409
1.2	Spillway	$900,234
1.3	Dam Upgrades (Toe berm & Upstrem Beach)	$147,932
1.4	Tailings Cover Conveyance Channels	$484,744
1.5	Tailings Cover	$689,219
1.6	Revegetation	$340,318
1.7	Instrumentation	$84,829
SUBTOTAL – DIRECT COSTS		**$2,859,685**
INDIRECT COSTS AND CONTINGENCY		
2.1	Indirect Costs	$554,647
2.2	Contingency	$426,792
SUBTOTAL – INDIRECT COSTS AND CONTINGENCY		**$981,439**
TOTAL CLOSURE COST (Undiscounted)		**$3,841,124**
Monitoring and Maintenance (NPC)		$2,769,479
TOTAL NPC (Closure + Post Closure)		**$6,610,603**

Cost Estimate - HB Mine Tailings Facility

Project: HB Mine Tailings Facility - Remediation Plan Cost Estimate - Jan 2020
Project No.: 1CM012.006
Client: RDCK
Date of Submission: January 2020
File Location: J:\01_SITES\HB_Mine\1CR012.006_TSF 2019 Design Support\999_CostEstimate

Area	Task	Description	Source or Destination	Quantity	Unit	Unit Rate	Cost	Subtotal	Task Cost	Comments/Source
Direct Costs										
1	Site Preparation Activities								$ 212,409	
	Tree Falling and Removal							$ 33,723		
		Till Borrow Area		27,500	m2	$0.70	$19,250			
		S&G Borrow Area		6,320	m2	$0.70	$4,424			
		Quarry		1,400	m2	$0.70	$980			
		Spillway, Toe Berm, and access roads in-between		2,955	m2	$0.70	$2,069			
		Tailings area		20,000	m2	$0.35	$7,000			
	Borrow Development							$ 41,797		
		Strip and stockpile top soil		7,044	m3	$5.00	$35,220			
		Regrade borrows at closure to be 2H:1V or flatter		31	hrs	$215	$6,577			
	Access Roads							$ 6,300		
		Spillway and Toe Berm Access Roads: Road fill		350	m3	$9.00	$3,150			Unit rate: contractor budgetary quote (2018)
		Road Decommissioning		350	m3	$9.00	$3,150			
	Water Management							$ 130,590		
		Amphibian Salvage		1	ls	$17,500	$17,500			Budgetary quote provided by consultant ($14k) with additional 25% contingency.
		Upstream Capture: Construct sumps/berms to capture water entering impoundment (3)		96	m3	$30.00	$2,880			
		Upstream Capture: Operate Pumps to dissipate water		1	ls	$15,000	$15,000			
		Spillway Capture Sump: construct sump at spillway inlet		75	m3	$30.00	$2,250			Unit rate: contractor budgetary quote (2018)
		Spillway Capture Sump: Dewater tailings pond		31	days	$1,000	$31,000			Operating cost from RSMEans, assumes 75 mm centrifugal pump, includes pu
		Spillway Capture Sump: Continued dewatering throughout construction		1	ls	$30,000	$30,000			Allowance costed to be similar to initial dewatering estimate.
		In-line Filtration Treatment system Allowance		1	ls	$30,000	$30,000			Allowance
		Downstream sediment control: Construct sediment trap downstream of spillway		32	m3	$30.00	$960			Unit rate: contractor budgetary quote (2018)
		Downstream sediment control: Allowance for periodic cleaning		1	ls	$1,000	$1,000			
2	Spillway								$ 900,234	
	Spillway Apron							$ 2,160		
		Concrete: tie in for geosynthetics	Spillway	2	m3	$1,000	$2,160			Allowance
	Spillway & Stilling Basin Construction							$ 506,509		
		Strip and stockpile top soil		500	m3	$20	$10,000			
		Rock Excavation: Drill, blast		4,350	m3	$31	$134,850			Unit rate: contractor budgetary quote (2018)
		Rock Excavation: Load haul, dump	Spillway	1,775	m3	$31	$55,025			Unit rate: contractor budgetary quote (2018)
		Rock Excavation: Load haul, dump	Toe berm	2,575	m3	$31	$79,825			Unit rate: contractor budgetary quote (2018)
		Soil excavation: Backfill existing spillway	spillway	4,900	m3	$11	$53,900			Unit rate: contractor budgetary quote (2018)
		Geotextile: Supply and install		3,100	m2	$5.82	$18,034			
		Riprap: Sort and stockpile existing sources		2,175	m3	$20.00	$43,500			
		Riprap: Load, haul, dump, place in spillway		2,175	m3	$40.00	$87,000			
		Riprap: Drill, blast at quarry		325	m3	$15	$4,875			
		Riprap: Sort and stockpile at quarry		325	m3	$20	$6,500			
		Riprap: Load, haul, dump, place in spillway		325	m3	$40	$13,000			
	Tailings Pond Backfill							$391,564		
		Load, haul, dump, place fill	Spillway	828	m3	$5.00	$4,140			Costed as part of spillway excavation
		Load, haul, dump, place fill	Till Borrow	32,972	m3	$11.75	$387,424			
3	Dam Upgrades								$ 147,932	
	Toe Berm Expansion							$ 69,812		
		Remove grass vegetation from dam surface		2,750	m2	$3.00	$8,250			Unit rate: contractor budgetary quote (2018)
		Topsoil stripping: Load, haul, dump	Tailings Area	250	m3	$9.77	$2,443			
		Rock drains: Place and spread	Spillway Rock	900	m3	$5.00	$4,500			Excavation/hauling costed as part of spillway excavation
		Geotextile: Supply and install		600	m2	$3.53	$2,119			
		General Fill: Place and spread	Spillway	10,500	m3	$5.00	$52,500			Excavation/hauling costed as part of spillway excavation
	Upstream Beach							$ 78,120		
		Riprap: Place at other areas	Spillway/Eng.Disp.	1,128	m3	$5.00	$5,640			Past Experience unit rate: Costs to sort and haul included in spillway and eng. Dissipation str. Tasks.
		Fine-grained Fill: Place and Spread	Till Borrow	6,040	m3	$12.00	$72,480			

4	**Tailings Cover Conveyance Channels**								$ 484,744	
	Channel construction							$ 431,464		
		Excavate channels		7,100 m3	$9.72	$69,018				
		Geotextile: Supply and install		650 m2	$5.82	$3,781				
		Riprap (D50= 400mm): Sort, Load, haul, dump, place	Up. Slope Dam	550 m3	$8.82	$4,849				
		Geosynthetic liner: Supply and install		11,450 m2	$17.68	$202,422				
		Protection Layer: Backfill erosion protection material		2,400 m3	$11.75	$28,200				
		TRM: Supply and install		10,800 m2	$11.41	$123,194				
	Allowance for road access construction							$ 53,280		
		Geotextile: Supply and install		4,830 m2	$3.53	$17,055				
		Road fill: Load, haul, dump, spread		7,245 m3	$5.00	$36,225				
		Remove roads following channel construction		7,245 m3	$0.00	$0				
5	**Tailings Cover**								$ 689,219	
	Cover construction							$ 655,178		**$ 1,046,743**
		Cut smaller vegetation to surface		31,300 m2	$0.25	$7,825				Unit rate: contractor budgetary quote (2018)
		Ross-Lands Soils: Import and spread to fill depressions		15,000 m3	$0.00	$0				Cost assumed to be paid by Teck
		Grade tailings area to fill in depressions		140,287 m2	$0.47	$65,233				
		Soil Cover: Place cover	Till Borrow	64,680 m3	$9.00	$582,120				Quantity: 10% wasteage allowance added from AutoCAD neat quantity to allow for settlement and placement thickness tolerance bias. Unit rate: contractor budgetary quote (2018) plus a 50% contingency to account for soft areas/delays.
	Allowance for soft tailings							$ 34,041		
		Geotextile: Supply and install		9,641 m2	$3.53	$34,041				
6	**Revegetation**								$ 340,318	
	Hydroseeding							$ 213,718		
		Hydroseed tailings cover area		252,048 m2	$0.80	$201,638				Unit rate: contractor budgetary quote (2018)
		Hydroseed Toe Berm Expansion		15,100 m2	$0.80	$12,080				Quantity: Includes all disturbed areas near the dam Unit rate: contractor budgetary quote (2018)
	Broadcast Seeding							$ 41,600		
		Borrow Areas		52,000 m2	$0.80	$41,600				
	Allowance for Erosion Control							$85,000		
		Erosion Control Measures		1 ls	$85,000	$85,000				Unit rate: contractor budgetary quote (2018)
7	**Instrumentation**								$ 84,829	
	Survey Monuments							$ 6,000		
		Steel pin encased in concrete - Auger holes 1m deep		12 ea	$500	$6,000				Unit rate: contractor budgetary quote (2018)
	Piezometers (assume existing pipes decommissioned and new ones installed)							$ 78,829		
		Decommission existing pipes		6 ea	$71.85	$431				
		Mobilize Drill rig to site		1 ls	$5,000	$5,000				
		Drill and install PVC		90 m	$229.43	$20,648				
		Engineering oversight (geotech logging)		5 days	$2,400	$12,000				
		Laboratory testing allowance		1 ls	$40,000	$40,000				
		Install steel casing		5 ea	$150.00	$750				
DIRECT COST TOTAL									$ 2,859,685	
Indirect Costs										
	Indirects costs are based on the following weeks on-site for construction			**12 weeks**						
1	**Mobilization and Demobilization**							**$100,000**		
		Mob/Demobilization		1 ls	$100,000	$100,000				Unit rate: contractor budgetary quote (2018)
2	**Contractor Field Costs**							**$114,387**		
		Balance of contractor project costs		4%	$2,859,685	$114,387				Unit rate: contractor budgetary quote (2018) + 1%
3	**Owner Field Costs**							**$340,260**		
		Asbuilt Reporting		1 ls	$50,000	$50,000				
		Site Engineer		12 week	$11,340	$136,080				
		Site Engineer Living Out Allowance/Accommodations		12 week	$1,715	$20,580				Assumes 1 rooms needed per night (including Site Engineer) and $50/person/day for meals, vehicle at $75/day)
		Engineer of Record Site visits		4 ea	$4,000	$16,000				
		Engineer turnaround (1 staff every 2 weeks)		7 ea.	$1,500	$10,500				
		Environmental Monitoring		12 week	$8,925	$107,100				Assumes $100/hr plus $75/day for vehicle
INDIRECT COST TOTAL									$ 554,647	
Contingency									$ 426,792	
	Contingency			12.5%	$ 3,414,332	$ 426,792				
CLOSURE COSTS - TOTAL									**$ 3,841,124**	

Post Closure Cost Details

Project: HB Mine Tailings Facility - Remediation Plan Cost Estimate - Jan 2020
Project No.: 1CM012.006
Client: RDCK
Date of Submission: January 2020
File Location: J:\01_SITES\HB_Mine\1CR012.006_TSF 2019 Design Support\999_CostEstimate

Post Closure Water Sampling/Instrumentation Reading - Cost per Event

Distance from source: (km):	50	Nelson
Average Speed (km/hr):	75	
Transit Time (hrs):	1.3	Two Way

Task	Crew/Unit	Hours	Materials ($)	Labor Cost ($/hr)	Equipment cost ($/hr)	Total Materials ($)	Total Labor ($/hr)	Total Equip ($/hr)	Total Cost ($)
Technical Staff Travel (two way)	2	1.3		$135.00	$15.00	$0.00	$360.00	$20.00	$380.00
Collect data, samples (1 day)	2	5		$135.00	$15.00	$0.00	$1,350.00	$75.00	$1,425.00
Per Diem (Food)	0		$0.00			$0.00	$0.00	$0.00	$0.00
Supplies	1		$50.00			$50.00	$0.00	$0.00	$50.00
Laboratory Analysis	17		$150.00			$2,550.00	$0.00	$0.00	$2,550.00
Reporting	1	20		$135.00		$0.00	$2,700.00	$0.00	$2,700.00
						$0.00	$0.00	$0.00	$0.00
Totals						$2,600	$4,410	$95	$7,105

NOTES:
Assumes consultant from Nelson provides 2 persons with one small truck ($15/hr incl. fuel).
Assumes 6 surface water and 9 GW sampling locations (2015 annual reclamation report), 1 duplicate
Laboratory unit rate from 2018 ALS quote
Piezometer readings also collected.

Post Closure Dam/Geotechnical Inspections - Cost per Year

Distance from source: (km):	n/a	Vancouver
Average Speed (km/hr):		
Transit Time (hrs):	8.0	Two Way

Task	Crew/Unit	Hours	Materials ($)	Labor Cost ($/hr)	Equipment cost ($/hr)	Total Materials ($)	Total Labor ($/hr)	Total Equip ($/hr)	Total Cost ($)
Technical Staff Travel (two way)	1	8.0	$600.00	$180.00		$600.00	$1,440.00	$0.00	$2,040.00
Inspect Site - Engineer	1	3		$200.00		$0.00	$600.00	$0.00	$600.00
Per Diem (Food)	1		$50.00			$50.00	$0.00	$0.00	$50.00
Reporting	1	40		$200.00		$0.00	$8,000.00	$0.00	$8,000.00
						$0.00	$0.00	$0.00	$0.00
Totals						$650	$10,040	$0	$10,690

NOTES:
Travel assumes $600 for flight and car rental.

DAM SAFETY REVIEW

Distance from source: (km):	n/a	Vancouver
Average Speed (km/hr):		
Transit Time (hrs):	8.0	Two Way

Task	Crew/Unit	Hours	Materials ($)	Labor Cost ($/hr)	Equipment cost ($/hr)	Total Materials ($)	Total Labor ($/hr)	Total Equip ($/hr)	Total Cost ($)
Technical Staff Travel (two way)	2	8.0	$600.00	$200.00		$1,200.00	$3,200.00	$0.00	$4,400.00
Inspect Site - Engineer	2	12		$200.00		$0.00	$4,800.00	$0.00	$4,800.00
Per Diem (Food)	4		$50.00			$200.00	$0.00	$0.00	$200.00
Reporting/Review of Data	1	320		$200.00		$0.00	$64,000.00	$0.00	$64,000.00
						$0.00	$0.00	$0.00	$0.00
Totals						$1,400	$72,000	$0	$73,400

NOTES:
Travel assumes $600 for flight and car rental.

Post Closure - Vegetation Monitoring

Distance from source: (km):	50	Nelson
Average Speed (km/hr):	75	
Transit Time (hrs):	1.3	Two Way

Task	Crew/Unit	Hours	Materials ($)	Labor Cost ($/hr)	Equipment cost ($/hr)	Total Materials ($)	Total Labor ($/hr)	Total Equip ($/hr)	Total Cost ($)
Technical Staff Travel (two way)	2	1.3		**$150.00**	**$15.00**	$0.00	$400.00	$20.00	$420.00
Reclamation surveys (1 days on site)	2	10		**$150.00**	**$15.00**	$0.00	$3,000.00	$150.00	$3,150.00
Supplies	1		**$100.00**			$100.00	$0.00	$0.00	$100.00
Laboratory Analysis	15		**$100.00**			$1,500.00	$0.00		
Reporting	1	160		**$150.00**		$0.00	$24,000.00	$0.00	$24,000.00
						$0.00	$0.00	$0.00	$0.00
Totals						**$1,600**	**$27,400**	**$170**	**$27,670**

$150.00

NOTES:
Assumes consultant from Nelson provides 2 persons with one small truck.

Routine Maintenance Event

Distance from source: (km):	50	Nelson
Average Speed (km/hr):	60	
Transit Time (hrs):	1.7	Two Way

Task	Crew/Unit	Hours	Materials ($)	Labor Cost ($/hr)	Equipment cost ($/hr)	Total Materials ($)	Total Labor ($/hr)	Total Equip ($/hr)	Total Cost ($)
Mobilization	6	1.7		**$50.00**	**$300.00**	$0.00	$500.00	$500.00	$1,000.00
Brush crew to clear vegetation (2 days)	5	20		**$50.00**	**$20.00**	$0.00	$5,000.00	$400.00	$5,400.00
Excavator time to clean spillway/debris/c	1	10		**$0.00**	**$200.00**	$0.00	$0.00	$2,000.00	$2,000.00
Debris removal to landfill	1	2		**$0.00**	**$100.00**	$0.00	$0.00	$200.00	$200.00
						$0.00	$0.00	$0.00	$0.00
Totals						**$0**	**$5,500**	**$3,100**	**$8,600**

NOTES:
Brush crew assumes 4 labourers and a foreman, equipment rate assumed.

RDCK Staffing/Reporting - Prior to Remediation

Task	Crew/Unit	Hours	Materials ($)	Labor Cost ($/hr)	Equipment cost ($/hr)	Total Materials ($)	Total Labor ($/hr)	Total Equip ($/hr)	Total Cost ($)
Contracted Inspections	1	90		**$100.00**	**$0.00**	$0.00	$9,000.00	$0.00	$9,000.00
Manager	1	455		**$76.00**		$0.00	$34,580.00	$0.00	$34,580.00
Tailings Facility Technologist	1	1000		**$49.00**		$0.00	$49,000.00	$0.00	$49,000.00
Site Access, Operator wages/equip.	1		**$9,000.00**			$9,000.00	$0.00	$0.00	$9,000.00
						$0.00	$0.00	$0.00	$0.00
Totals						**$9,000**	**$92,580**	**$0**	**$101,580**

NOTES:
Costs estimated by RDCK

RDCK Staffing/Reporting - Operational Phase

Task	Crew/Unit	Hours	Materials ($)	Labor Cost ($/hr)	Equipment cost ($/hr)	Total Materials ($)	Total Labor ($/hr)	Total Equip ($/hr)	Total Cost ($)
Contracted Inspections	1	90		**$100.00**	**$0.00**	$0.00	$9,000.00	$0.00	$9,000.00
Manager	1	227.5		**$76.00**		$0.00	$17,290.00	$0.00	$17,290.00
Tailings Facility Technologist	1	500		**$49.00**		$0.00	$24,500.00	$0.00	$24,500.00
Site Access-Operator wages/equipment	1		**$9,000.00**			$9,000.00	$0.00	$0.00	$9,000.00
						$0.00	$0.00	$0.00	$0.00
Totals						**$9,000**	**$50,790**	**$0**	**$59,790**

NOTES:
Costs estimated by RDCK

RDCK Staffing/Reporting - Passive Closure Phase

Task	Crew/Unit	Hours	Materials ($)	Labor Cost ($/hr)	Equipment cost ($/hr)	Total Materials ($)	Total Labor ($/hr)	Total Equip ($/hr)	Total Cost ($)
Contracted Inspections	1	40		**$100.00**	**$0.00**	$0.00	$4,000.00	$0.00	$4,000.00
Manager	1	113.75		**$76.00**		$0.00	$8,645.00	$0.00	$8,645.00
Tailings Facility Technologist	1	250		**$49.00**		$0.00	$12,250.00	$0.00	$12,250.00
Site Access-Operator wages/equipment	1		**$3,000.00**			$3,000.00	$0.00	$0.00	$3,000.00
						$0.00	$0.00	$0.00	$0.00
Totals						**$3,000**	**$24,895**	**$0**	**$27,895**

NOTES:
Costs Estimated by RDCK

Closure Management Manual/Reclamation Plan Updates

Task	Crew/Unit	Hours	Materials ($)	Labor Cost ($/hr)	Equipment cost ($/hr)	Total Materials ($)	Total Labor ($/hr)	Total Equip ($/hr)	Total Cost ($)
Report Update	1	40	**$10,000.00**			$10,000.00	$0.00	$0.00	$10,000.00
						$0.00	$0.00	$0.00	$0.00
						$0.00	$0.00	$0.00	$0.00
						$0.00	$0.00	$0.00	$0.00
						$0.00	$0.00	$0.00	$0.00
Totals						**$10,000**	**$0**	**$0**	**$10,000**

NOTES:
Budget estimate for Reclamation plan update provided by RDCK - assumed to be required every 10 years.

Post Closure Net Present Cost Calculations

Project: HB Mine Tailings Facility - Remediation Plan Cost Estimate - Jan 2020
Project No.: 1CM012.006
Client: RDCK
Date of Submission: January 2020
File Location: J:\01_SITES\HB_Mine\1CR012.006_TSF 2019 Design Support\999_CostEstimate

NPV CALCULATION INPUTS

Input Parameters

Scenario:	Remediation plan	
Current Year:	2019	Year that the estimate is costed
Closure Year 1:	2020	
Closure Period:	1	yrs
Post-Closure Year 1:	2021	

NPV Discount Rates

##	Discount Rate	Years in effect	Start Year	End Year
1	1.5%	2	2019	2021
2	2.0%	3	2022	2025
3	3.0%	-	2026	

SCHEDULE

NOTE: Some years may be hidden for printing purposes

Monitoring & Maintenance Schedule

		Set Monitoring/C&M Stage:	1 - Interim	2 - Active	3 - PC 1	3 - PC 1	3 - PC 1	3 - PC 1	3 - PC 1	4 - PC 2	4 - PC 2	4 - PC 2	4 - PC 2	4 - PC 2						5 - Perpetual		5 - Perpetual				
		Post-Closure Year:	**Year -2**	**Year -1**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 96**	**Year 97**	**Year 98**	**Year 99**	**Year 100**
		Sum																								
Monitoring	Water Quality Monitoring (surface and groundwater)	Events Per Year:	2	8	4	4	4	4	4	2	2	2	2	2	2	2	2	2	2	2	2	2				
	Geotechnical Monitoring	Events Per Year:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Dam Safety Reviews	Events Per Year:			1					1					1					1		1				
	Closure Management Manual and/or Reclamation Plan Updates (every 10 years)	Events Per Year:			1										1											
	Revegetation Monitoring	Events Per Year:			1	1	1																			
RDCK Staffin	Staffing/Reporting - Prior to implementation	Events Per Year:	1																							
	Staffing/Reporting - Operation Phase	Events Per Year:		1																						
	Staffing/Report - Post-Closure Phase	Events Per Year:					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Site Maintenance (brush clearing etc.		Events Per Year:													1											

UNDISCOUNTED CASH FLOW

Monitoring Costs

		Cost Per Event	Total	% of Total	Check Sum	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2116	2117	2118	2119	2120
Monitoring	Water Quality Monitoring (surface and groundwater	$7,105	$653,660	10%	$653,660	$14,210	$56,840	$28,420	$28,420	$28,420	$28,420	$28,420	$14,210	$14,210	$14,210	$14,210	$14,210	$14,210	$14,210	$14,210	$14,210	$14,210	$14,210	$14,210	$14,210	$0	$0	$0	$0
	Geotechnical Monitoring	$10,690	$1,090,380	17%	$1,090,380	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690	$10,690
	Dam Safety Reviews	$73,400	$1,468,000	23%	$1,468,000	$0	$0	$73,400	$0	$0	$0	$0	$73,400	$0	$0	$0	$0	$73,400	$0	$0	$0	$0	$73,400	$0	$73,400	$0	$0	$0	$0
	Closure Management Manual and/or Reclamation Plan Update	$10,000	$100,000	2%	$100,000	$0	$0	$10,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$10,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Revegetation Monitoring	$27,670	$83,010	1%	$83,010	$0	$0	$27,670	$27,670	$27,670	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
RDCK Staffin	Staffing/Reporting - Prior to implementation	$101,580	$101,580	2%	$101,580	$101,580	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Staffing/Reporting - Operation Phase	$59,790	$59,790	1%	$59,790	$0	$59,790	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Staffing/Report - Post-Closure Phase	$27,895	$2,733,710	43%	$2,733,710	$0	$0	$0	$0	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895	$27,895
Site Maintenance (brush clearing)		$8,600	$77,400	1%	$77,400	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$8,600	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Post Closure Costs Subtotal			**$6,367,530**		$6,367,530	**$126,480**	**$127,320**	**$150,180**	**$66,780**	**$94,675**	**$67,005**	**$67,005**	**$126,195**	**$52,795**	**$52,795**	**$52,795**	**$52,795**	**$144,795**	**$52,795**	**$52,795**	**$52,795**	**$52,795**	**$126,195**	**$52,795**	**$126,195**	**$38,585**	**$38,585**	**$38,585**	**$38,585**

Other Add-on Costs

			Total	% of Total	Check Sum	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2116	2117	2118	2119	2120
1	Contingency	12.5 % of above costs	$795,941		$795,941	$15,810.00	$15,915	$18,773	$8,348	$11,834	$8,376	$8,376	$15,774	$6,599	$6,599	$6,599	$6,599	$18,099	$6,599	$6,599	$6,599	$6,599	$15,774	$6,599	$15,774	$4,823	$4,823	$4,823	$4,823
2	Contractor Profit	0 % of above costs	$0		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3	Contract Administration	0 % of above costs	$0.00		$0	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Add-On Costs Subtotal			**$795,941**		$795,941	**$15,810**	**$15,915**	**$18,773**	**$8,348**	**$11,834**	**$8,376**	**$8,376**	**$15,774**	**$6,599**	**$6,599**	**$6,599**	**$6,599**	**$18,099**	**$6,599**	**$6,599**	**$6,599**	**$6,599**	**$15,774**	**$6,599**	**$15,774**	**$4,823**	**$4,823**	**$4,823**	**$4,823**
TOTAL			**$7,163,471**		$7,163,471	**$142,290**	**$143,235**	**$168,953**	**$75,128**	**$106,509**	**$75,381**	**$75,381**	**$141,969**	**$59,394**	**$59,394**	**$59,394**	**$59,394**	**$162,894**	**$59,394**	**$59,394**	**$59,394**	**$59,394**	**$141,969**	**$59,394**	**$141,969**	**$43,408**	**$43,408**	**$43,408**	**$43,408**

NET PRESENT VALUE

Monitoring Costs

		Cost Per Event	Total	% of Total	NPV - 2019	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2116	2117	2118	2119	2120
Monitoring	Water Quality Monitoring (surface and groundwater	$7,105	$653,660	10%	$411,923	$14,210	$56,000	$27,586	$27,045	$26,515	$25,995	$25,995	$12,619	$12,251	$11,895	$11,548	$11,212	$10,885	$10,568	$10,260	$9,962	$9,671	$9,390	$9,116	$882	$0	$0	$0	$0
	Geotechnical Monitoring	$10,690	$1,090,380	17%	$377,570	$10,690	$10,532	$10,376	$10,173	$9,973	$9,778	$9,778	$9,493	$9,217	$8,948	$8,688	$8,434	$8,189	$7,950	$7,719	$7,494	$7,276	$7,064	$6,858	$664	$644	$626	$607	$590
	Dam Safety Reviews	$73,400	$1,468,000	23%	$517,054	$0	$0	$71,247	$0	$0	$0	$0	$65,182	$0	$0	$0	$0	$56,226	$0	$0	$0	$0	$48,501	$0	$4,558	$0	$0	$0	$0
	Closure Management Manual and/or Reclamation Plan Update	$10,000	$100,000	2%	$37,547	$0	$0	$9,707	$0	$0	$0	$0	$0	$0	$0	$0	$0	$7,660	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Revegetation Monitoring	$27,670	$83,010	1%	$79,005	$0	$0	$26,858	$26,332	$25,815	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
RDCK Staffin	Staffing/Reporting - Prior to implementation	$101,580	$101,580	2%	$101,580	$101,580	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Staffing/Reporting - Operation Phase	$59,790	$59,790	1%	$58,906	$0	$58,906	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Staffing/Report - Post-Closure Phase	$27,895	$2,733,710	43%	$851,477	$0	$0	$0	$0	$26,025	$25,515	$25,515	$0	$24,050	$23,350	$22,670	$22,009	$21,368	$20,746	$20,142	$19,555	$18,985	$18,433	$17,896	$1,732	$1,682	$1,633	$1,585	$1,539
Site Maintenance (brush clearing)		$8,600	$77,400	1%	$23,943	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$6,588	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Post Closure Costs Subtotal			**$6,367,530**		**$2,459,007**	**$126,480**	**$125,438**	**$145,774**	**$63,550**	**$88,329**	**$61,288**	**$61,288**	**$87,294**	**$45,518**	**$44,192**	**$42,905**	**$41,656**	**$110,917**	**$39,264**	**$38,121**	**$37,011**	**$35,933**	**$83,387**	**$33,870**	**$7,836**	**$2,326**	**$2,259**	**$2,193**	**$2,129**

Other Add-on Costs

			Total	% of Total	NPV - 2019	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2116	2117	2118	2119	2120
1	Contingency	13 % of above costs	$795,941		$310,472	$15,810	$15,680	$18,222	$7,944	$11,041	$7,661	$7,661	$14,008	$5,690	$5,524	$5,363	$5,207	$13,865	$4,908	$4,765	$4,626	$4,492	$10,423	$4,234	$980	$291	$282	$274	$266
2	Contractor Profit	0 % of above costs	$0		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3	Contract Administration	0 % of above costs	$0		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Other Add-On Costs Subtotal			**$795,941**		$310,472	**$15,810**	**$15,680**	**$18,222**	**$7,944**	**$11,041**	**$7,661**	**$7,661**	**$14,008**	**$5,690**	**$5,524**	**$5,363**	**$5,207**	**$13,865**	**$4,908**	**$4,765**	**$4,626**	**$4,492**	**$10,423**	**$4,234**	**$980**	**$291**	**$282**	**$274**	**$266**
TOTAL			**$7,163,471**		$2,769,479	**$142,290**	**$141,118**	**$163,996**	**$71,494**	**$99,370**	**$68,949**	**$68,949**	**$101,302**	**$51,208**	**$49,717**	**$48,269**	**$46,863**	**$124,781**	**$44,173**	**$42,886**	**$41,637**	**$40,424**	**$93,811**	**$38,104**	**$8,816**	**$2,617**	**$2,541**	**$2,467**	**$2,395**