Closure and Reclamation Plan for the Tulsequah Chief Mine Site, Near Atlin, British Columbia

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Executive Summary

BC Ministry of Energy, Mines and Petroleum Resources (MEMPR) retained SNC-Lavalin Inc. (SNC-Lavalin) and SRK Consulting (Canada) Ltd. (SRK) to develop a closure and reclamation plan for the Tulsequah Chief Mine, located adjacent to the Tulsequah River in northwestern BC. The scope of work, carried out from February 2019 through March 2020, included review of existing information for the Site, preliminary site investigations, preliminary risk assessment, development and evaluation of remediation options for the Site, and definition of a closure and reclamation plan that would address risks that are currently present at the Site. While conducting work in the region, MEMPR requested that SNC-Lavalin conduct a preliminary investigation of the Big Bull Mine and consider this other site in the closure plan. The development and evaluation of remediation options was completed in conjunction with representatives of the Taku River Tlingit First Nation (TRTFN), MEMPR, Teck Resources Ltd. (Teck), and Ministry of Environment & Climate Change Strategy (ENV) during two workshops and additional meetings.

The Tulsequah Chief and Big Bull mines are polymetallic mines which were developed and operated by Cominco between 1947 and 1958 producing an average of 482 tonnes of ore per day. No tailings management occurred at the Site. Ore was transferred to the mill at Cominco's former Polaris-Taku mine, located upstream across the Tulsequah River, where it was stored over winter until it could be barged to tide-water each spring. Cominco closed the mines in 1957 and they lay dormant until 1987 when Cominco entered a joint venture with Redfern Resources Ltd. (Redfern), who eventually became the sole owner of the Tulsequah and Big Bull mines in 1992. Between 1987 and 2004, underground tunnels were advanced and surface drilling occurred. From 2007 to 2009, Redfern constructed two camps, 25 km of site roads, air strip, waste rock storage areas and construction laydown areas, and completed mill site surface stripping, drilling and underground development. Chieftain Metals Ltd. (Chieftain) purchased the property and claims at the Tulsequah Chief Mine in 2010 and completed exploration drilling and feasibility studies for the mine, constructed and operated a water treatment plant for nine months (with limited success), conducted some underground and above ground water diversion measures to minimize the amount of water to treat at the plant, constructed an exfiltration pond, installed bioreactors in the 5200 level, and started to construct some of the surface infrastructure (e.g., Potentially Acid Generation (PAG) and Non-Acid Generating (NAG) Waste Rock storage area) for the proposed mine. However, they did not bring the mine into production and the company went into care and maintenance by June 2015. Although the Site remains in receivership under the custody of a trustee at this time, MEMPR initiated closure planning in 2018 in order to expedite closure once the receivership has been resolved.

Access to the Site is by light aircraft via the Shazah airstrip constructed at the north end of the Site, or river barge/boat via the barge landing at the south end of the Site near the confluence of the Tulsequah and Taku rivers. On average the barging season spans about 10 to 20 days each freshet and shipments must clear U.S. customs. There is no road access; however, there is a road connecting the barge landing along the east side of the Tulsequah River, approximately 13 km to the airstrip. The road includes numerous bridge and culvert crossings of tributary watercourses to the Tulsequah River. Mine features and associated hazards identified at the Site are summarized below.

Underground workings include unsecured adits at the Lower Workings (5200 and 5400 levels) and Upper Workings (5900, 6400 and 6500 levels), as well as at least two unsecured or partially unsecured shafts above the 6500 level. Preliminary investigations indicate that ground stability issues identified above the 6400 level are low risk, pending further investigation. Exposed PAG waste rock is present in the Upper and Lower Workings including within the Tulsequah River along the bank below the 5200 portal. Acidic metal contaminated drainage from portals and seepage from exposed waste rock discharges to the Tulsequah River adjacent to the Lower Workings either directly or via Portal and Camp Creeks.

Bedrock cuts present at the Lower Workings, along sections of road and at quarries represent potential safely concerns. The north end of the airstrip is currently eroded and requires immediate repair to support mine closure activities. The mine access road connecting Shazah airstrip to the barge landing requires some regrading and filling to support mine closure work. Of the 17 bridges constructed along the mine access road, two of the bridges (including the Roger's Creek crossing) were determined to be unsafe and will require repairs to support mine closure work. Several other bridges and crossings also require less significant repair or maintenance.

Hazardous wastes including drums of chemical reagents, asbestos and other hazardous building materials are present in abandoned buildings, supplies and equipment at various areas of the site including the Shazah airstrip and camp, Lower Workings, historical PAG (HPAG) storage area and barge landing and camp. Former fuel storage tanks located at the Shazah airstrip, Lower Workings, HPAG area, south of Paddy's Flats, and barge camp represent potential for subsurface hydrocarbon contamination in these areas.

Lime sludge from operations at the Acid Treatment Plant (ATP) is stored in a pit immediately adjacent to the Shazah airstrip. Stored lime sludge is considered non-leachable; however, erosion of the airstrip could result in physical entrainment of the sludge into the Tulsequah River if left in place.

A preliminary assessment of the Big Bull Mine identified two open pits, five vertical openings, waste rock piles, three slightly acidic to neutral mine discharges to the Taku River, above ground fuel tanks and core shacks.

The Tulsequah River is the main receiving water flowing adjacent to the mine. The Tulsequah River is fish bearing and it is understood that all fish species have the potential to use tributaries, side-channels and other off channel sloughs as spawning, rearing and overwintering habitat. Tulsequah River mainstem flows are generally turbid and continually split into braided channels of varying depth and velocity. Seasonal flooding due to Jockalups results in significant migration of stream channels across the flood plain. Contaminants of potential concern (COPCs) identified in Tulsequah River surface water included cadmium, copper, lead and zinc. Potential unacceptable risks to aquatic life were predicted in previous studies immediately adjacent to the Tulsequah mine discharge point (i.e., from the Lower Workings) to approximately 1 km downstream (SLR Consulting (Canada) Limited [SLR], 2017).

Portal Creek is a non-fish bearing ephemeral stream (i.e., a dry gully with intermittent flow) that is likely only wetted during spring freshest or prolonged rain events. During these periods, water flowing through the 5900 level waste rock or naturally mineralized soil may affect water quality.

Camp Creek flows from the upper slopes of Mount Eaton past the Upper Workings connects with an unnamed creek and cascades down a steep slope with many small waterfalls, past the 5900 level and Lower Workings into the Tulsequah River. The majority of Camp Creek is assumed to be non-fish bearing except potentially in the lowest reach (approximately 30) where it discharges to the Tulsequah River.

Historically the 5900 level discharged water overland into Camp Creek; however, it was not flowing at the time of the 2019 inspections.

The Site is complex from a closure planning perspective given its remoteness, fluctuating conditions in the aquatic receiving environment due to frequent migration of braided channels across the floodplain, and uncertain regulatory requirements. This closure plan was developed to implement risk-based remediation and closure strategies that focus on what is achievable in the near-term to address as many of the closure objectives as possible, while at the same time gathering information that supports decision making regarding options for discharge of mine water to the receiving environment.

The primary objectives considered in the development of the closure plan were reduction of chemical and physical risk at the Site through source control measures and removal of physical hazards. Some of the source control measures include sealing openings, excavation of leachable waste rock from the Tulsequah River, consolidation and covering of waste rock to reduce exposure to contaminated soils, and flooding of the underground mine to reduce concentrations and loadings associated with the mine water. Measures to reduce physical hazards include demolition and on-site landfilling of buildings and derelict equipment/materials, off-site disposal of hazardous materials, installation of access controls at mine openings, implementation of shoreline and slope protection measures at critical erosion faces, along roadways and at quarries. These core risk reduction measures are relatively straight forward to implement from a construction standpoint but will be complicated by logistics challenges associated with this remote site. Some remedial work such as road, bridge and airstrip repairs are critical to any closure plan and should be implemented as soon as possible.

A key challenge for closure of this Site is determining what is required to meet a site-specific risk-based performance objective in the Tulsequah River and how - or if this discharge will be authorized (i.e., permitted). Further work is needed with regulatory agencies and TRTFN to determine what a site-specific risk-based performance objective would look like and whether this would apply to the end of pipe discharge or at the boundary of a dilution zone within the river. This process is complicated by the constantly changing river morphology and dilution ratios resulting in unstable chemical conditions that typically complicate risk assessments. In addition to uncertainties regarding risk-based performance objectives, there are a number of data gaps identified during the supplemental site investigation and remediation planning workshops that need to be resolved before sound engineering decisions can be made regarding the appropriate remedial alternatives. Additional data collection is required to support decision-making and design of mine discharge solutions.

For the purposes of this closure plan, it is acknowledged that the extent of mitigation that will be required to reduce metal concentrations in mine discharge to levels that will satisfy risk-based performance objectives cannot be explicitly defined at this time and may be constrained by the technical feasibility of the available options – most notably the understanding that long-term active water treatment is not a viable solution for this site given the logistical challenges, safety concerns and costs associated with maintaining permanent year-round operations at the Site. This plan considers three options for long-term mine discharge management: Option 1: discharge to Camp Creek; Option 2: flow augmentation and discharge to Tulsequah River; and Option 3: deep injection to the alluvial groundwater aquifer beneath the Tulsequah River. Additional investigation is required to further evaluate each of these options.

A phased approach over a notional period of five years was considered for this closure plan. The first phase includes implementation of the achievable core risk reduction measures based on the current knowledge of the Site. The performance of the risk reduction measures will be evaluated as additional data is collected at the Site. Both the performance data and the additional information will be used in the second phase to make sound engineering decisions for eventual management of mine discharge.

Regardless of the permanent mine discharge strategy that is selected, it is acknowledged that temporary water management measures will be required during the detailed investigation stage and the remediation construction phase of the project to ensure that metal loadings from the Mine Site do not increase as a result of these activities. Further work will be required to develop this and other management plans to support detailed design and implementation plans and regulatory approvals.

Preliminary cost estimates for key elements of the proposed closure strategy are outlined in this plan, including costs for capital projects, as well as monitoring and maintenance activities. Costs associated with additional investigation necessary to address key remaining data gaps and uncertainties are not included.

The estimated capital costs for core closure activities at the Site are $48,700,000, including a contingency allowance of $6,650,000 based on 25% of the estimated direct capital cost. The estimated annual monitoring and maintenance costs to implement the program are $1,075,000. The 100-year long-term monitoring and maintenance costs were discounted to a present value of $26,980,000.

Estimated costs for the mine water discharge options are estimated at Option 1: $295,000; Option 2: $885,000; and Option 3: $1,180,000 (including total contingency). Estimated annual costs for long-term operations, monitoring and maintenance costs for the three options considered are Option 1: $500,000; Option 2: $750,000; and Option 3: $1,000,000. The 100-year long-term operations and maintenance costs for the three options considered were discounted to the present values (Option 1: $11,500,000; Option 2: $17,270,000; and Option 3: $23,030,000).

Present values were estimated assuming an interim 3.5% discount rate and 1.7% Consumer Price Index (CPI) – EMPR to select the final discount rate. Cost estimates are subject to assumptions as outlined in this plan and are considered accurate within a range of (+100% / -50%) except where noted below. All costs are expressed in first quarter 2020 Canadian dollars.

A Notice to Reader is provided in Section 11 of this document.

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Glossary of Abbreviations

ACMs - Asbestos-containing Materials

AEMP - Aquatic Effects Monitoring Program

AERA - Aquatic Ecological Risk Assessment

AKDNR - Alaska Department of Natural Resources

AMP - Adaptive Management Plan

APECs - Areas of Potential Environmental Concern

ASL - above sea level

ASTs - Above Ground Storage Tanks

ATP - Acid Treatment Plant

BAT - Best Available Technology

BC ENV Technical Guidance 11 - Technical Guidance Document 11: *Checklist for Reviewing a Detailed Site Investigation,* BC MoE, August 2016

BCWQG - *British Columbia Approved Water Quality Guidelines, includes Working Water Quality Guidelines for BC* (BCWQG). British Columbia Ministry of Environment & Climate Change Strategy, updated September 2019

CABIN - Canadian Aquatic Biomonitoring Network

Chieftain - Chieftain Metals Ltd.

CMS - Cavity Measurement Scan

COPCs - Contaminants of Potential Concern

CPI - Consumer Price Index

CSR - *Contaminated Sites Regulation* (CSR), B.C. Reg. 375/96, includes amendments up to B.C. Reg. 13/2019, January 24, 2019

EC - Environment Canada

ECCC - Environment and Climate Change Canada

EEM - Environmental Effects Monitoring

EMA - *Environmental Management Act* (EMA), B.C. Reg. 13/2019 / effective January 24, 2019

ENV - Ministry of Environment & Climate Change Strategy

HDPE - High Density Polyethylene

HDS - High Density Sludge

HPAG - Historical PAG Storage Area

HQs - Hazard Quotients

Glossary of Abbreviations (Cont'd)

HWR - *Hazardous Waste Regulation* (HWR), B.C. Reg. 63/88, includes amendments up to B.C. Reg. 243/2016, November 1, 2017

IDZ - Initial Dilution Zone

LCP - Lead-containing Paint

LDS - Low Density Sludge

LiDAR - Light Detection and Ranging

MDMER - Metal and Diamond Mining Effluent Regulations

MEMPR - BC Ministry of Energy, Mines and Petroleum Resources

Milestone - Milestone Environmental Contracting Inc.

MWs - Monitoring Wells

NAG - Non-acid generating

ODSs - Ozone-depleting Substances

OHSR - *Workers Compensation Act, Occupational Health and Safety Regulation* (OHSR), B.C. Reg. 296/97, includes amendments up to B.C. Reg. 14/2019, June 3, 2019

PAG - Potentially Acid Generating

PCBs - Polychlorinated Biphenyls

PPE - Personal Protective Equipment

Redfern - Redfern Resources Ltd.

SLR - SLR Consulting (Canada) Limited

SNC-Lavalin - SNC-Lavalin Inc.

SRK - SRK Consulting (Canada) Ltd.

TCLP - Toxicity Characteristic Leaching Procedure

Teck - Teck Resources Ltd.

The Act - Mines Act, RSBC 1996, Chapter 293, including amendments up to October 30, 2019

The Code - Ministry of Energy and Mines (2017), Health, Safety and Reclamation Code for Mines in British Columbia, Revised June 2017

TRTFN - Taku River Tlingit First Nation

VMS - Volcanogenic Massive Sulphide

WDR - *Waste Discharge Regulation* (WDR), B.C. Reg. 320/2004, includes amendments up to B.C. Reg. 154/2019, September 15, 2019

WTP - Water Treatment Plant

1 Introduction

BC Ministry of Energy, Mines and Petroleum Resources (MEMPR) retained SNC Lavalin Inc. (SNC-Lavalin) and SRK Consulting (Canada) Ltd. (SRK) (i.e., the Project Team) to develop a closure and reclamation plan for the Tulsequah Chief Mine, located adjacent to the Tulsequah River in northwestern BC.

The scope of work included review of existing information for the Site, preliminary site investigations, preliminary risk assessment, development and evaluation of remediation options for the Site, and definition of a closure and reclamation plan that would address risks that are currently present at the Site. While conducting work in the region, MEMPR requested that SNC-Lavalin conduct a preliminary investigation of the Big Bull Mine and consider this other site in the closure plan.

The development and evaluation of remediation options was completed in conjunction with representatives of the Taku River Tlingit First Nation (TRTFN), MEMPR, Teck Resources Ltd. (Teck), and Ministry of Environment & Climate Change Strategy (ENV). An initial remediation options workshop was held in June 2019 to identify and evaluate possible remediation methods that could be considered at the Site, develop a range of site wide remediation options, and identify of critical information gaps that would need to be addressed before selection of a preferred option could be completed. A summary of the June workshop is provided in SRK 2019a. Where possible, field and desktop studies to address these information gaps were completed between June and September 2019, with preliminary results available in time for a second workshop held in early October 2019. The second workshop focused on further development of options and evaluation of those options using a set of evaluation criteria developed by the workshop participants. A summary of the October workshop is provided in SRK 2019b. The findings of the workshop were used to develop a preliminary closure and reclamation plan for the Site.

At the outset of the project, the Project Team recognized that there would be some critical data gaps and uncertainties that would need to be addressed through further investigations before all aspects of the plan could be defined. Although there was sufficient information to support the selection of many aspects of the plan, there are still a number of mine water discharge options that will require further evaluation before that aspect of the plan can be developed. Additionally, further information is still required to support detailed design, regulatory approval and implementation plans.

This report provides a description of the preliminary closure and reclamation plan and options for specific remediation measures – notably mine water discharge options, which cannot be defined at this time. The report is organized as follows:

- Section 2 presents a summary of relevant background information on the Site, including key issues that need to be addressed in the plan and a summary of the workshop findings.
- Section 3 presents the objectives and approach of the closure plan based on input provided by EMPR, TRT and ENV.
- Section 4 presents a description of the closure and reclamation plan – with the exception of mine water discharge options.
- Section 5 provides a discussion of mine water discharge options.
- Section 6 provides an evaluation of the expected performance of the plan in terms of addressing issues.
- Section 7 outlines monitoring and maintenance considerations of the closure plan.
- Section 8 outlines remaining data gaps and uncertainties, and a preliminary workplan and schedule for addressing those gaps.
- Section 9 provides the conceptual schedule for closure plan implementation.

Supporting information for this Closure Plan is provided in a series of companion documents issued separately by SNC-Lavalin and SRK including:

- SNC-Lavalin 2020a. *Preliminary Human Health and Ecological Risk Evaluation for Soil Contamination Associated with Upper and Lower Workings at the Historical Tulsequah Mine Site*. Memorandum prepared for MEMPR. April 2, 2020.
- SNC-Lavalin 2020b. *Supplemental Site Investigation, Site Hazard Assessment and Risk Analysis, Tulsequah Chief Mine, Tulsequah BC*, prepared for MEMPR. January 20, 2020.
- SRK 2019a. Tulsequah Mine Closure Project – *Preliminary Remedial Options Analysis Workshop Report*. Memorandum prepared for MEMPR. August 13, 2019.
- SRK 2019b. *Tulsequah Mine Closure Project – Remedial Planning Workshop*. Memo prepared for MEMPR. November 22, 2019.
- SRK 2020a. *Review of the pilot and full-scale bioreactor operations at the Tulsequah Chief Mine Site*. Prepared for MEMPR, January 10, 2020.
- SRK 2020b. *Summary of the Tulsequah Chief Mine Site Water and Load Balance*. Memo prepared for SNC-Lavalin Inc. January 14, 2020.

Additional references are provided in Section 10 of this report. The Notice to Reader provided in Section 11 outlines general limitations for use of this document.

2 Background

2.1 Site History

Below is the site history as adapted from the BC ARIS Report# 35093B (JDS Energy and Mining Inc. report titled, *Feasibility Study Technical Report, Tulsequah Chief Project, Northern British Columbia, Canada*, dated November 27, 2014), or where otherwise referenced in text.

Mineral exploration first occurred in the Tulsequah River in the early 1800's. However, the Tulsequah Chief claim (MINFILE 104K 002) was not staked until 1923 when a high-grade mineral outcropping consisting of barite, pyrite, sphalerite, galena and chalcopyrite was discovered in a bedrock gully on the east facing slope of Mt Eaton at approximately 500 m (1,640 ft) above sea level (asl). By the spring of that year, the Alaskan Juneau Mining Company optioned the property and conducted exploration drilling and development of the 'A level' (6500) and 'B level' (6400). The 1923 BC Annual Report to the Minister of Mines (AR) describes these workings as 30 ft of tunnelling at the "B level" at 1,500 ft asl and some trenching at the A level at 1,690 ft asl.

The United Eastern Mining Company owned the Tulsequah Chief Mine in 1929 (AR 1929). A warehouse and log cabin were constructed at the river and the mine camp was located on the bench below the workings at an elevation of 1,050 ft. That same year, the nearby Big Bull deposit was discovered by V Manville on the Taku River near the confluence with the Tulsequah.

In 1947, Cominco acquired the mineral claims to the Tulsequah Chief and nearby Big Bull deposits (MINFILE 104K 008) and a mine access road was completed connecting the landing near the confluence with the Taku and Tulsequah Rivers (near the present day "Barge Camp") to within 2 miles of Tulsequah Chief Mine. Supplies were hauled by tractor up the river and or carried by foot path to the mine (AR 1948).

Cominco leased the Polaris-Taku 200-tons per day mill and camp after its mine closed. Ore from the Big Bull and Tulsequah Chief mines were milled at this site. Concentrates were barged down the Taku River in the summer and shipped to Hamburg, Germany. Large amounts of concentrates were stored over the winter as the barging window was confined to the spring and summer months (AR 1951). In later years, Cominco shipped concentrates to their Trail, BC smelter and to a smelter in Tacoma, Washington, USA (AR's 1953, 1954, 1956). Ore from the mines was trucked by road and trestle bridge over the Tulsequah River to the mill and every year the bridge required repair due to the flood events linked to the Jökulhaups. Cominco operated the mines with an average production rate of 482 tonnes per day. By 1951, the total production from the Tulsequah Chief Mine was approximately 570,000 tonnes and the Big Bull produced 360,000 tonnes, a combined 930,000 tonnes. In 1957, Cominco ceased mining activities due to low metal prices and by the late 1970s the milling equipment was dismantled and sold. Between 1957 and 1980 very little work occurred at these mines.

In 1971, the deposit type was re-classified as a volcanogenic massive sulphide (VMS) deposit rather than a hydrothermal replacement type. The reclassification of the deposit type suggested that there were likely additional mineral reserves and in 1987 Cominco entered a joint venture with Redfern Resources Ltd. (Redfern), who eventually became the sole owner of the Tulsequah and Big Bull mines in 1992. Between 1987 and 2004, underground tunnels were advanced and surface drilling occurred.

In 2007, under Mines Act permit and Environmental Assessment Certificate, Redfern (owned by Redcorp Ventures Ltd.) constructed two camps, 25 km of site roads, air strip, mill site surface striping, drilling and underground development, waste rock storage areas and construction laydown areas. This work was suspended in 2008 and the mine development activities were shut down in February 2009, followed by Redcorp's filing for creditor protection in March 2009.

In 2010, Chieftain Metals Ltd. (Chieftain) purchased the property and claims at the Tulsequah Chief Mine plus some equipment assets including a water treatment plant. In October 2012, Chieftain obtained an amendment to the Environmental Assessment Certificate (M02-01) and a Mines Act Permit (M-232) to conduct some construction activities. Part of this approval process was to address historical acid rock drainage. Chieftain completed exploration drilling and feasibility studies for the Tulsequah Chief Mine which was projected to have a nine-year mine life. Chieftain also proposed construction of a 128 km road connecting the mine to Atlin, BC. Chieftain constructed and operated a water treatment plant for nine months (with limited success), conducted some underground and above ground water diversion measures to minimize the amount of water to treat at the plant, installed bioreactors for water treatment in the 5200 level, and started to construct some of the surface infrastructure (e.g., Potentially Acid Generating [PAG] storage area) for the proposed mine. However, they did not bring the mine into production. No further permitting was completed by Chieftain and the company went into care and maintenance by June 2015.

In 2015 and 2016, the ENV and EMPR jointly inspected the Mine Site and noted Chieftain was not meeting its obligations to ensure protection of the environment and public health. Chieftain was placed into receivership in 2016 and the following year, orders were issued against Chieftain to address the deficiencies described in the inspection reports and to comply with the Mines Act as described on the BC Environment Protection and Sustainability webpage on the Tulsequah Chief Mine[1]. Although the Site remains in receivership under the custody of a trustee at this time, MEMPR initiated closure planning in 2018 in order to expedite closure once the receivership has been resolved.

2.2 Site Description

This site is located approximately 100 kilometres (km) southwest of Atlin, BC on the east bank of the Tulsequah River as shown on Drawing 633249-001. The Site extends approximately 13 km north to south from the Shazah Airstrip to the Barge Camp located at the confluence with the Taku River. The Site is in a remote region of northwestern BC and is only accessible by river barge from Juneau, Alaska or by air.

Identified mine features at the Tulsequah Chief Mine were grouped into Areas of Potential Environmental Concern (APECs) as shown on Drawings 663249-002. Mine features were identified based on a review of the available documents, mine history and site observations as described in SNC-Lavalin, 2020b. A summary of APECs and a description of the associated mine features are presented in Table A. An annotated BING image of the Upper and Lower Workings and adjacent water features is provided in Figure 1.

[1] Web Accessed December 19, 2019 (https://www2.gov.bc.ca/gov/content/environment/air-land-water/site-permitting-compliance/Tulsequah-mine).

Table A: Summary of APEC and Mine Features

ID	APEC	Description of Mine Features
A	Underground Workings	Development at the mine occurred from nine levels: 6500, 6400, 6200, 6100, 5900, 5700, 5500, 5400 and 5200. The 6500, 6400, 5900, 5400 and 5200 levels extend to surface and are not secured. A two-compartment 1,017 ft vertical shaft connects the 5400 to 6400 levels. Two vertical openings to surface were reported above the 6500 level and one was capped. Ground stability was identified as a potential concern in the upper levels of the mine.
B	Lower Workings	Includes the area outside of the 5200 and 5400 level portals, including associated acidic and non-acid waste rock piles and ore storage area. The non-acidic waste rock is a thin veneer over acidic waste rock resultant from tunnel advancement by Redfern. This area also includes the former Acid Treatment Plant (ATP) infrastructure and the exfiltration pond, as well as acidic portal, seep, and surface water discharges and diversions to the Tulsequah River (aquatic receiving environment). High metal concentrations and acidity were observed here. Discharge from the 5400 portal was consistent between the May and July 2019 sampling event at 6 L/sec whereas the discharge rate from the 5200 portal was reduced by 50% between the two events (6.4 L/sec to 3.2 L/sec). The exfiltration rate (loss to shallow groundwater) in the pond was consistent at approximately 2 L/sec between the two events. PAG and non-PAG bedrock cuts are also present in this area and present potential safely concerns from loose rock and falling hazards. Drums of chemical reagents from the ATP (liquid hazardous wastes) were noted in this area. The mine features and water features with estimated flow rate from the May 2019 site visit are shown in Figure 1, Figure 2 and Figure 3 below.
C	Upper Workings	Includes the 6500, 6400, and 5900 level portals and waste rock piles (see Figure 1). Also includes portal and seepage water discharges to Camp Creek and ultimately the Tulsequah River (aquatic receiving environment). High metal concentrations and acidity were observed here. Camp Creek is discussed below.
D	Historical PAG Waste Rock Storage Area	Includes historical PAG and NAG waste rock storage areas as well as the temporary storage garage. Mine waste was never stored in this area. The area is used to store old equipment. The area is mostly overgrown with no significant environmental concerns.
E	Shazah Airstrip and Camp	Includes the Shazah Airstrip, temporary garages/ workshops, stored equipment and camp buildings. Drums of chemical reagents from the ATP (liquid hazardous wastes) were noted in this area. Subsurface hydrocarbon contamination and hazardous waste building materials may be present. The area is actively used by local pilots for fuel drum storage and as an airstrip to access the valley. The north end of the airstrip is currently eroded and requires immediate repair to support mine closure activities.
F	Fuel Storage Facilities	Includes former fuel storage tanks (ASTs) located at the Shazah Airstrip, Lower Workings, HPAG area, south of Paddy's Flats, and Barge Camp. Subsurface hydrocarbon contamination may be present.
G	Mine Access Road	Includes the mine access road connecting Shazah Airstrip to the Barge Camp. Some regrading and filling will be required to support mine closure work. No significant environmental concerns.
H	Temporary Bridges	Includes 17 bridges constructed along the Mine Access Road. Two of the bridges (including the Roger's Creek crossing) were determined to be unsafe and will require repairs to support mine closure work.

Table A (Cont'd): Summary of APEC and Mine Features

ID	APEC	Description of Mine Features
I	Rock Quarries	Includes road cuts in limestone cliffs, quarried bedrock outcrops and stockpiled materials along the Mine Access Road located south of the HPAG area and north of Paddy's Flats. No significant environmental concerns.
J	Proposed Tailings Storage Facility	Comprises the area located northeast of the Shazah Airstrip, defined by a generally flat elevated portion of terrain adjacent to Shazah Creek and Shazah Creek wetland areas. The area is mostly overgrown with no significant environmental concerns. Several groundwater monitoring wells are present which require sealing as part of mine closure.
K	Paddy's Flats	Includes the cleared area and associated stockpiled materials located 6.5 km south of the HPAG area. Some metal debris and core shacks were observed here. No significant environmental concerns were observed.
L	Borrow Pit	Located adjacent to the Shazah Airstrip (120 m east). Includes the former pit currently filled with water. Surface water inflow points were not observed. Some metal debris and core shacks were observed here. No significant environmental concerns.
M	Barge Camp	Includes the Barge Camp area and associated infrastructure located at the southern most point of the Site adjacent to the Taku River. No significant environmental concerns observed other than the old septic field and sewage treatment plant and hazardous waste building materials. Anecdotal information indicates that petroleum hydrocarbon contamination of soil may have occurred here.
N	Exploration Drilling Holes	Includes exploration drilling areas located on the steep slopes south of the Lower Workings. No significant environmental concerns were observed.
O	Lime Sludge Pit	Includes lime sludge from operations at the ATP and is located immediately adjacent to the Shazah Airstrip. Stored lime sludge is considered non-leachable; however, erosion of the airstrip could result in physical entrainment of the sludge into the Tulsequah River if left in place.
P	Tulsequah River	Main receiving water flowing adjacent to the mine. The Tulsequah River is fish bearing and exhibits mainstem, side channels, tributaries, sloughs and wetlands. It is understood at this time that all fish species have the potential to use tributaries and side-channels and other off channel sloughs as spawning, rearing and overwintering habitat. Potential unacceptable risks to aquatic life were predicted in a 2017 aquatic ecological risk assessment for the area immediately adjacent to the Tulsequah mine discharge point (i.e., from the Lower Workings) to approximately 1 km downstream (SLR Consulting (Canada) Limited [SLR], 2017). Tulsequah River mainstem flows are generally turbid and continually split into braided channels of varying depth and velocity. Throughout the mid and lower reaches, clear water segments and/or large deep pools occur in the mainstem and are likely a result of parafluvial springs (clear water) or mixing with flow from tributaries. Mainstem channel morphology is typified by glide and riffle habitat and bed material consisting of gravels and sands with cobbles and boulders. During the 2019 inspections there were no side channels immediately adjacent to the mine.

Table A (Cont'd): Summary of APEC and Mine Features

ID	APEC	Description of Mine Features
Q	Portal and Camp Creek	Portal Creek is a non-fish bearing ephemeral stream (i.e., a dry gully with intermittent flow) that is likely only wetted during spring freshest or prolonged rain events (See Figure 1). During these periods, water flowing through the 5900 level waste rock or naturally mineralized soil may affect water quality. Historically, discharges from the 5900 level were directed to this feature. A water diversion pipe was installed near the 5400 level to direct the non-acidic water from the underground mine and Portal Creek to the Tulsequah River; however, it was not functioning at the time of the 2019 inspections. Camp Creek flows from the upper slopes of Mount Eaton onto a benched area in the Upper Workings where it joins with mine discharge associated with the 6400 level waste rock. From the benched area it connects with an unnamed creek and cascades down a steep slope with many small waterfalls, past the 5900 level and Lower Workings into the Tulsequah River (see Figure 1). Based on the observed shallow waters in the upper reaches not being able to support over-wintering habitat and on the presence of multiple fish barriers in the lower reaches, the majority of Camp Creek is assumed to be non-fish bearing. There may be some aquatic use of the lowest reach (approximately 30) in Camp Creek where it discharges to the Tulsequah River. Historically the 5900 level discharged water overland into Camp Creek; however, it was not flowing at the time of the 2019 inspections. There is also a dry gully / ephemeral stream ("Gully Creek") potentially connecting the 5900 level discharge flow path with the lower reach of Portal Creek.
BB	Big Bull Mine	Includes two open pits, five vertical openings, waste rock piles, three slightly acidic to neutral mine discharges to the Taku River, ASTs and core shacks. The mine and water features with estimated flow rate from the July 2019 site visit are shown in Figure 4 below.

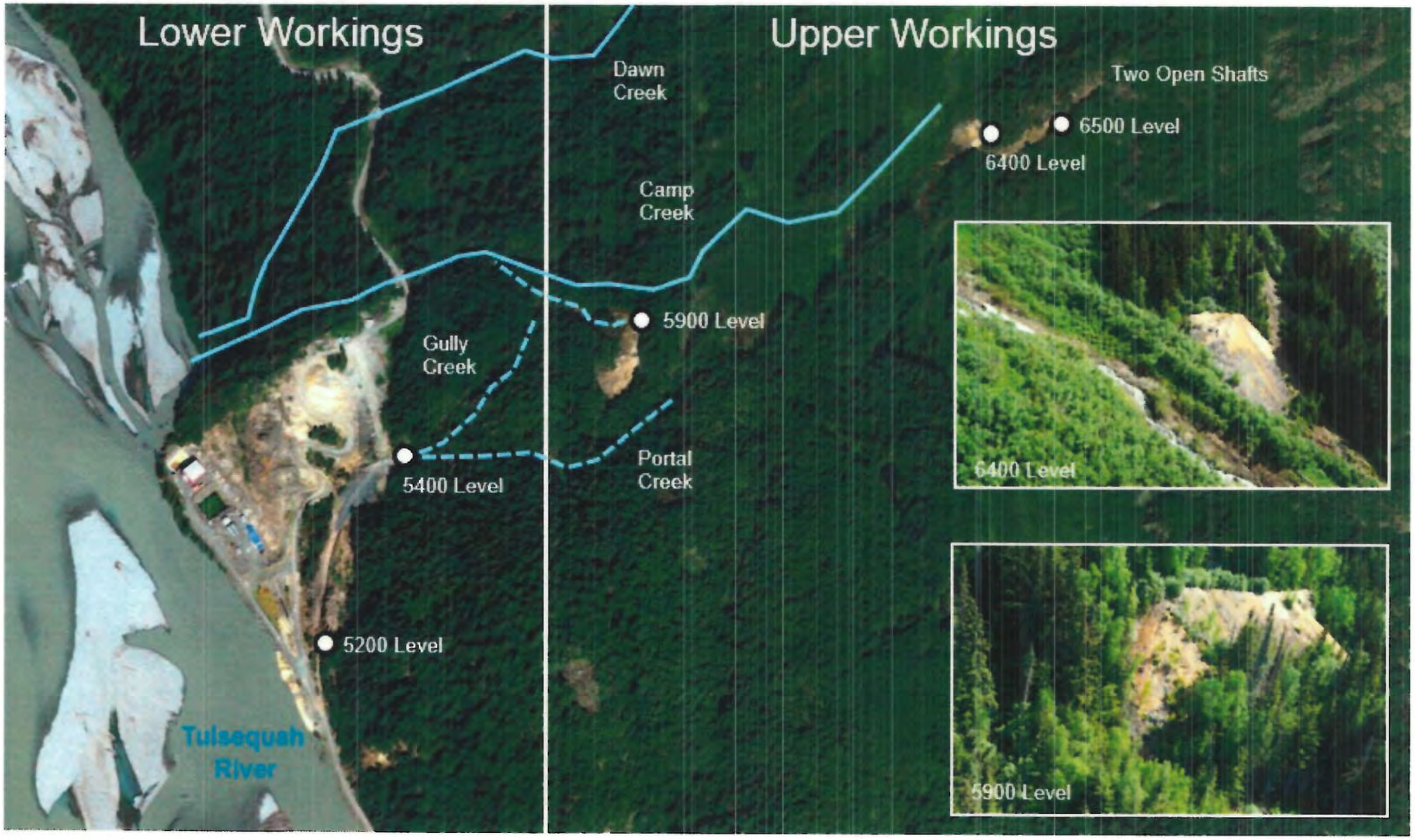

Figure 1: Annotated Image of the Lower and Upper Working Area of the Tulsequah Chief Mine (APECs B and C)

(source https://www.bing.com/maps)

Figure 2: Mine Features at the Lower Workings Area of the Tulsequah Chief Mine

Figure 3: Water Features and Estimated Discharge and Infiltration Rates at the Lower Workings of the Tulsequah Chief Mine on May 30, 2019

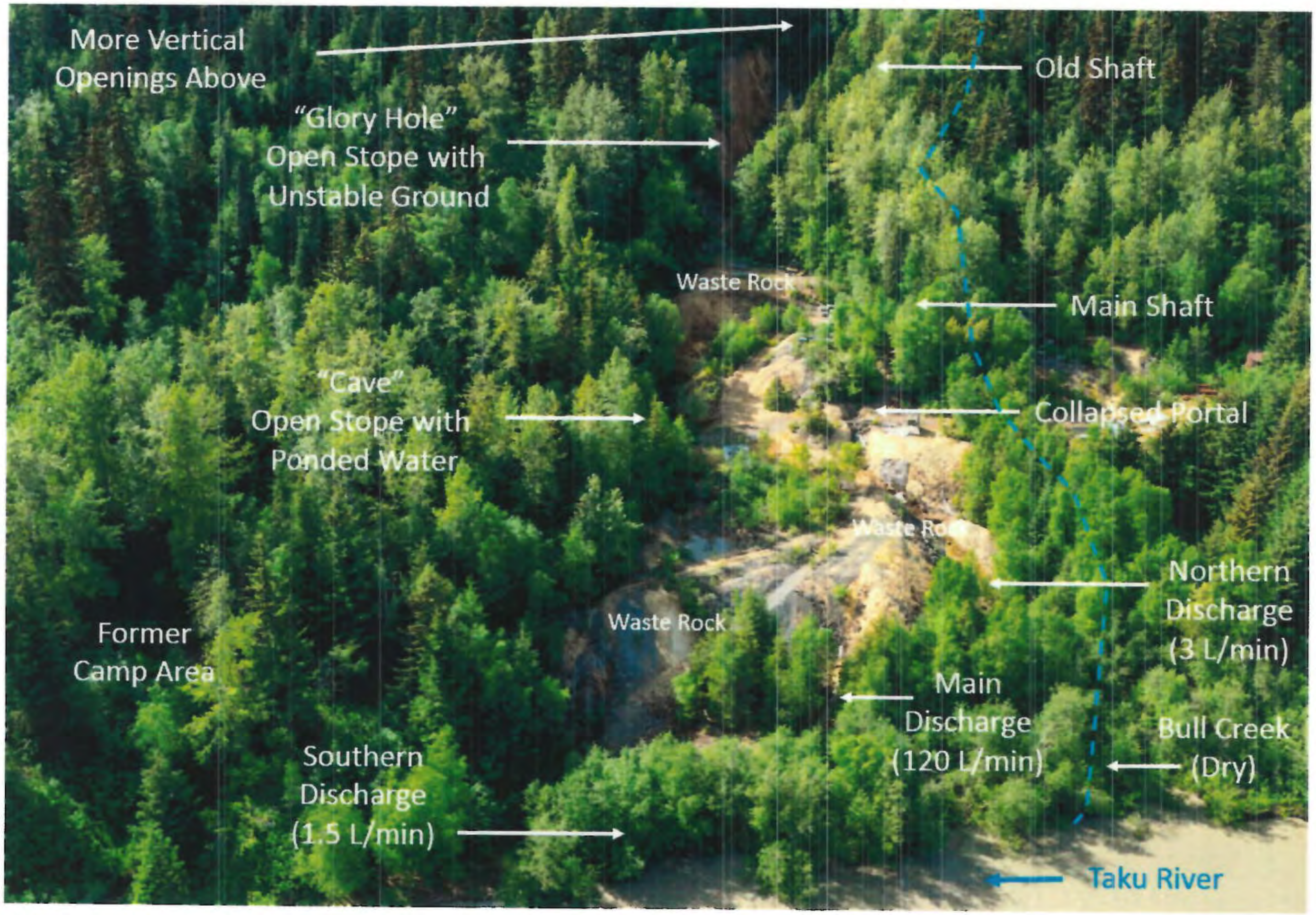

Figure 4: Mine and Water Features at the Big Bull Mine on July 27, 2019

2.3 Site Access

Access to the Site is by light aircraft or river barge/boat; there is no road access. The Site can be accessed by air to the Shazah Airstrip at the north end or by barge/boat to a barge landing on the Taku River near the Tulsequah River confluence at the south end. There is a road connecting the barge landing along the east side of the Tulsequah River, approximately 13 km to the airstrip. The road includes numerous bridge and culvert crossings of tributary watercourses to the Tulsequah River.

The bridges were assessed in summer 2019 by a civil engineer who concluded that some of the log bridges were in poor condition and two were incapable of supporting large vehicles without prior rehabilitation. The culverts were generally in good condition, along with the road prism and its adjacent excavation slopes in both bedrock and soils. There were minimal instances of erosion observed on the running surface and adjacent road slopes.

The Shazah Airstrip was generally in good condition; however, at the north end, the Tulsequah River is actively eroding and damaging its left bank. Chieftain Metals appears to have constructed a setback deposit of rip rap at the north end, intended to resist river erosion once the river would eventually migrate through its floodplain to the airstrip. The setback rip rap was observed to be damaged by the river in spring 2019, with much of the rip rap already eroded away. It is certain that the river will continue eroding its left bank at the airstrip in the near future and begin to shorten the useable length of the airstrip in the absence of additional future reinforcing of the north end with robust rip rap armoring.

The airstrip is located adjacent to the main camp. It is 950 m in length and is in a reasonable condition to accommodate light aircraft such as Dornier and Caravans to provide passenger and freight service to the Site.

Barging is expected to be the lowest cost option for mobilizing heavy equipment and bulk supplies to site. However, the barging program is complex. Supplies are transported via an ocean faring barge to the mouth of the Taku River, and then transferred to river barges that travel up the Taku River to a landing site near the mouth of the Tulsequah River. From there, they are transported via a gravel access road that extends from the barge landing to the Site. Flow in the Taku River must be high enough to allow for conventional low-draft river barges to travel on the Taku River, which is generally limited to freshet. In addition to high flows, a high tide is required to pass over the sand flats at the mouth of the Taku River. On average the barging season is about 10 to 20 days each freshet. Only one barging contractor, Wainwright Marine, was willing to complete the 2011 mobilization to site for Chieftain. Wainright Marine also completed one previous barging program for Redfern. All goods sent to site must clear United States customs and require the use of a broker to facilitate the border crossings during the barging program.

2.4 Summary of Site Hazard Assessment and Risk Analysis

The Project Team developed the Hazard Assessment based on our understanding of the mine features and APECs identified as part of a desktop review of the existing data and confirmed based on 2019 site observations. The Project Team reviewed the existing reports, identified data gaps, and where possible, closed them as part of the 2019 field program, to develop a comprehensive Site Hazard Assessment. This included an assessment of potential physical and chemical hazards at the Site to enable informed decisions regarding a risk-based approach to remediation and closure planning for the mine (SNC-Lavalin, 2020a).

The review evaluated the regulatory, hydrogeology, hydrology, geochemical, biological and geotechnical aspects of the Site with respect to the remediation and closure planning.

The Risk Analysis included a review of the identified hazards and the refined water and load balance to assess the likelihood of potential adverse effects to human or ecological health based on the end land use and development and implementation of a risk-based remediation and closure plan. The Project Team assigned a level of risk, likelihood and uncertainty to each hazard. High risk areas of the Site primarily were related to erosion concerns from the Tulsequah River, unstable bridges and to a lesser extent (to be confirmed) ground collapse potential at the Tulsequah Chief Mine. Based on historical reports and underground mapping, ground collapse is likely a concern at the Big Bull Mine. Moderate risk classification was assigned to all media where exposure to contaminants were suspected. The closure plan was developed to reduce the risks where appropriate or where insufficient data was available, data gaps were identified.

The key issues, risks and considerations factored into the closure plan development are summarized in the sections below.

2.4.1 Required Access

As described in Section 2.3, the Site accessed by air at the Shazah Airstrip at the north end or by boat at a barge landing on the Taku River near the Tulsequah River confluence at the south end. The airstrip is being actively eroded by the Tulsequah River and immediate repairs are required to maintain its use. The closure plan for the Tulsequah Chief and Big Bull mines will require upgrades to the roads and bridges before any heavy machinery can be transported between the various APECs at the Site or before any machinery can be mobilized from the barge camp.

2.4.2 Geochemistry and Water Quality

The Tulsequah Chief deposit is a VMS deposit of Kuroko affinity, similar to that of the Britannia Mine. Large portions of the exposed rock on the walls of the underground workings and waste rock dumps is PAG or already acidic. The distribution of the non-PAG materials within the waste rock dumps is variable, and it would be challenging (and costly) to segregate these without cross-contamination with the other units. Most of the waste rock and underground workings have been exposed for more than 70 years.

The main discharges from the mine are from the 5200 and 5400 portals. Drainage from the 5900 portal is currently forced back into the mine via a temporary dam. Drainage from other portals in the upper mine workings are thought to have smaller and more ephemeral flows that discharge to either Camp Creek or Portal Creek.

Water quality from the underground workings and waste rock dumps is acidic, with high concentrations of aluminum (Al), cadmium (Cd), copper (Cu), iron (Fe) and zinc (Zn) (i.e., generally in excess of Metal and Diamond Mining Effluent Regulations (MDMER) discharge criteria or more than 100x BC Water Quality Guidelines (BCWQG) for receiving water quality protective of aquatic life), and elevated concentrations of arsenic (As), lead (Pb), and sulphate (generally more than 10x higher than BCWQG guidelines for receiving water quality). Other contaminants of potential concern (COPCs) identified in the ecological risk assessments include beryllium (Be) and cobalt (Co). The water quality has remained relatively consistent over the past 27 years of monitoring, and, based on the acidic conditions and the prolonged weathering history, water quality is not expected to worsen over time.

A small quantity of treatment plant sludges is stored in a temporary storage pit located adjacent to the airstrip. This material is geochemically stable in its current storage location and has not had a measurable effect on underlying groundwater quality, indicating that porewater quality likely has neutral pH and low soluble metal concentrations (Chieftain Metals Inc., 2014 and Chieftain Metals Inc, 2016). The sludges are on the floodplain of the Tulsequah river and may be at risk from physical erosion processes.

Groundwater conditions are unknown; however, it is assumed that there is a small acidity and metal load leaving these sites during the wet seasons and spring freshet. Waste rock at the Tulsequah Chief and Big Bull mines extends into the adjacent aquatic receiving habitats of the Tulsequah and Taku Rivers, respectively.

2.4.3 Contaminated Soil

Samples of waste rock collected at the Upper and Lower Workings contained concentrations of antimony, arsenic, cadmium, copper, lead, selenium and zinc more than ten times greater than the *Environmental Management Act's*[2] (EMA's) soil standards for protection of human health and the environment. Samples of inferred native soil collected from the areas around the waste rock exhibit similar metal exceedances but at much lower concentrations. The source of the elevated metals is the sulphide minerals associated with the ore deposit. The waste rock samples collected at the Big Bull Mine contained similar metal concentrations as the Tulsequah Chief Mine. Generally, the concentrations of metals in other sampled APECs were less than or slightly greater than the soil standards and likely reflect background conditions. Waste rock at the Tulsequah Chief and Big Bull mines was mostly already acidic and were a source of soluble metals. The key issues associated with geochemistry and water quality are discussed in Section 2.4.3.

Samples collected for petroleum hydrocarbons contained concentrations less than the soil standards; however, due to equipment and access limitations subsurface samples were not collected. Anecdotally, hydrocarbon contamination was present at the Barge Camp and fuel storage facilities.

SNC-Lavalin conducted a preliminary human health and ecological risk evaluation for contaminated soils associated with mine wastes at the Lower Workings and Upper Workings of the Site (SNC-Lavalin 2020a). The risk evaluation included screening for COPCs, the identification of human and ecological receptors of concern and determination of associated potentially operable exposure pathways between receptors and COPCs. Scenarios for two types of receptors, workers and visitors, were considered as outlined below.

The first scenario considered conditions that would occur during active remediation of the Site or ongoing care and maintenance in which workers would live and work at the Site on a year-round basis. Potentially unacceptable risks were identified for Site workers exposed to mine waste at the Lower Workings of the Site in this scenario. An additional scenario considered exposure to workers conducting ongoing but periodic and infrequent monitoring and/or maintenance at the Site (if required in the future). Potentially unacceptable risks were identified for occasional Site workers exposed to mine waste at the Lower Workings of the Site, at the assumed exposure frequency of one day per week.

Given the remote nature of the Site, it was assumed that site access by visitors (general public) would be relatively infrequent. However, TRTFN has both commercial and scientific fisheries work that takes place downstream on the Taku and has the potential to expand into the Tulsequah valley and, therefore, consideration has been given to this potential site use by campers which could be up to several weeks each summer. While no unacceptable risks were identified for occasional Site visitors, potentially unacceptable

[2] *Environmental Management Act* (EMA), B.C. Reg. 13/2019 / effective January 24, 2019.

risks were identified for campers assumed to have the potential to be exposed to mine waste at the Lower Workings of the Site seven days per week for up to 12 weeks each year. The exposure frequencies should be confirmed by the TRTFN and stakeholder groups to ensure the risk evaluation results are adequately protective of potential Site visitors and campers.

Due to the extent of the area of the contamination at the Lower Workings and its relative accessibility, the implementation of administrative controls to manage camper and Site worker exposure may be challenging. Consequently, consolidation and covering of mine waste at the Lower Workings to render the direct contact pathway inoperable is considered the best approach to manage this risk. Covering would also provide benefits in terms of reducing infiltration and therefore metal loading from the waste rock.

Due to the inaccessibility of the Upper Workings, it is unlikely that Site visitors and campers would be exposed to contaminated soils associated with mine waste in this area, and thus direct contact exposure pathways were not considered to be operable for Site visitors/campers to COPCs at the Upper Workings of the Site. Under assumptions of infrequent exposure, unacceptable risks were identified for Site workers associated with these soil COPCs under relatively conservative exposure terms (e.g., assuming no personal protective equipment [PPE] was worn). If workers are likely to require access to the Upper Workings area (e.g., to maintain remedial systems and carry out reclamation activities), risks to workers could likely be controlled administratively, through the application of signage and requirement to wear appropriate PPE (as per the Code) when in the Upper Workings area.

Due to the relatively high concentrations of COPCs associated with mine wastes at both the Lower and Upper Workings areas of the Site, it is likely that there is some level of potentially unacceptable risk to populations or communities of terrestrial ecological receptors under regulatory methods of risk assessment, specifically including vegetation, soil invertebrates, wildlife with associated small home ranges, and/or small burrowing mammals (if present). It is unlikely that contaminated soils at the Site would result in significant risks to larger wildlife with associated larger home ranges.

Risks to terrestrial ecological receptors at the Lower Workings will be addressed through the consolidation and covering of contaminated soils that are proposed to address the human health risks in that area which render direct contact pathways inoperable.

Habitat quality that is currently and/or could be provided in the future by the Upper Workings area is unclear. Habitat associated with the impacted area of the Upper Workings may be of relatively low ecological value due to the steep, rocky sloped terrain, relatively small area impacted (relative to the remainder of the Site and available habitat that surrounds the Site) and lack of notable or desirable habitat attributes that would preferentially draw ecological receptors to this area relative to adjacent areas. As a result, it is currently uncertain whether or not potentially unacceptable risks to terrestrial ecological receptors would be predicted at the individual level, or if population or community level effects are possible at the Upper Workings area of the Site. To support further evaluation of terrestrial ecological risk in this area, a biological survey/habitat assessment by a Registered Professional Biologist will be conducted at the Site. Results of this assessment will be incorporated into an updated version of a more detailed ecological risk evaluation, to confirm that risk management is a viable remedial plan for contaminated soils at the Upper Workings of the Site.

2.4.4 Buildings and Debris

SNC-Lavalin conducted a destructive assessment of the structures and debris at the Site in July 2019 to identify potential materials of concern during handling and to generate a volume estimate for on-site or off-site disposal options.

The structures and debris were observed for the potential existence of hazardous materials including: asbestos-containing materials (ACMs), lead-containing paint (LCP), polychlorinated biphenyls (PCBs), ozone-depleting substances (ODSs), liquid and vapour-phase mercury, radiological sources and/or substances, silica, biohazardous materials, visible mould and/or moisture, and miscellaneous hazardous materials. Based on the results of the assessments, most of these regulated building materials were confirmed through analysis, observations or assumed present based on corporate experience and requiring specific handling and abatement procedures prior to demolition and disposal.

Based on correspondence with Milestone Environmental Contracting Inc. (Milestone) the volume of inert non-liquid hazard waste (i.e., ACM and silica) encountered at the Tulsequah Chief Mine is small enough that it can be managed in an on-site industrial landfill. Off-site disposal or reuse is recommended for the more than 100 drums of liquid hazardous waste (mostly ferric chloride) as well as small quantities of hazardous materials such as lead-acid batteries.

2.4.5 Receiving Water Environment

2.4.5.1 Tulsequah River

The Tulsequah River is the primary receiving environment of concern adjacent to the historical Mine Site. The river is fish-bearing, and exhibits mainstem, side channels, sloughs and associated wetlands. Tributaries flow into the Tulsequah upgradient, downgradient and at the Mine Site itself (e.g., Portal and Camp Creeks, discussed in Section 2.4.5.2, below). The Tulsequah River provides habitat for a diverse array of aquatic biota, including primary producers, and benthic and pelagic invertebrates. Additionally, though the Tulsequah mainstem is likely primarily used for migration, side channels, sloughs, wetlands and tributaries are known and/or assumed to be used as spawning, rearing and overwintering habitat for a variety of migratory and resident fish species.

Two previous ecological risk assessments have been performed for the Site. The first was prepared in 2013 by representatives of Core6, Palmer and Triton Environmental (Core6, Palmer and Triton Environmental 2013) for Chieftain, and incorporated historical and contemporary water quality data to evaluate potential risks to salmonids, specifically. Contaminants of potential concern identified in Tulsequah River surface water included cadmium, copper, lead and zinc. Potential risks to salmonids were predicted to result from exposure to all COPCs to and beyond the further downstream sampling location (approximately 2.7 km downstream of the Site) at some times of the year, peaking in late April/early May. The defined 'zone of influence', where risks to salmonids were predicted, was assumed to extend beyond 2.7 km downstream, but was not expected to extend into the Taku River.

The most recent aquatic ecological risk assessment (AERA) was completed for the BC ENV in April of 2017 by SLR. The 2017 AERA included an evaluation of four exposure units referred to as 'zones', including the following: a reference zone (Zone 1); a zone of discharge (Zone 2), located adjacent to the main mill site area; an impacted near zone (Zone 3), located approximately 1 km south of the mill site; and an impacted far zone (Zone 4), located approximately 2.5 km south of the Site, which includes Rogers Slough. Three media types (surface water, sediment and porewater) were incorporated into the assessment to represent exposure, and four receptor groups (benthic invertebrates, pelagic invertebrates, fish and fish eggs) were considered. Hazard quotients (HQs) were calculated by zone and receptor group. HQs were highest in Zone 2, with concentrations of aluminum, cadmium, cobalt, copper, iron, lead, sulphate and zinc predicted to result in unacceptable risks to all receptor groups; however, SLR indicated that the results of the habitat assessment indicated that it was unlikely that fish and aquatic invertebrates would spend a significant amount of time within Zone 2, due to high turbidity and low surface water pH documented during their field program. HQs in Zone 3 were lower than in Zone 2; however, potential exposures to concentrations of aluminum, cadmium, copper, iron, lead and zinc were predicted to result in potentially unacceptable risks to all four receptor groups. Zone 3 was also identified as having the potential for the largest number of receptors / highest quality habitat of the impacted zones, particularly as valuable habitat for spawning, rearing and overwintering of numerous fish species. Within Zone 4, all calculated HQs for receptor groups indicated an acceptable level of risk.

2.4.5.2 Portal and Camp Creeks

Portal Creek is not considered to be a receiving environment that supports significant aquatic life, due to its ephemeral nature and primary function as a rain or snow melt run-off channel. Portal Creek is a non-fish bearing intermittent ephemeral stream (i.e., a dry gully with sections of defined stream channel) that is likely only wetted during spring freshest or prolonged rain events. During these periods, water flowing through the 5900 level waste rock or naturally mineralized soil may affect water quality. A water diversion pipe was installed near the 5400 level to direct the non-acidic water from the mine and Portal Creek to the Tulsequah River; however, it was not functioning at the time of the 2019 inspections.

Camp Creek likely supports primary producers and invertebrates, but it is unlikely to be fish-bearing. There may be some fish use of the lowest reach (approximately 30 m) in Camp Creek, where it discharges to the Tulsequah River.

Further field investigation will be conducted to evaluate the benthic habitat value provided by Camp Creek, and to fully understand the potential source(s) of contaminant loading into the lower reach of the Creek and to clarify habitat protection goals for this receiving environment.

2.5 Development of Site-specific Risk-based Performance Objective for Receiving Water

As remedial plans for the Site develop, it is anticipated that site-specific risk-based performance objectives will be developed for aquatic receiving environments, including the Tulsequah River and Camp Creek. At present, it is unknown whether these objectives will be required to support regulatory approvals; however, they will be required to assess the performance of the closure measures.

It is likely that an initial dilution zone (IDZ) would be a component of future remedial options implemented at the Site for some period of time, and it is currently unclear whether site-specific risk-based performance objectives would apply to the end of pipe discharge, the end of an IDZ within the receiving environment, or potentially in groundwater before it daylights into the surface water receiving environment. Additional consultation with regulatory agencies and the TRTFN is required to determine the protection goals of site-specific risk-based performance objectives and how they would be developed and implemented at the Site. These protective goals would be revisited as the plan is implemented and adjusted as the Site impact changes. The protection goals will carry into the adaptive management plan.

An Aquatic Effects Monitoring Program (AEMP) will be developed and implemented to enable ongoing monitoring of potential risks to aquatic receptors, and the reduction of risks achieved over time as remedial measures are carried out at the Site. Further details of a proposed future AEMP are provided in Section 7.

2.6 Closure Planning Workshops

2.6.1 First Workshop

The Preliminary Remedial Options Analysis Workshop for the Tulsequah Mine Closure Project was held on June 13, 2019. A detailed memo documenting the workshop and its findings is provided in SRK, 2019a. The main objective of the workshop was to identify critical information gaps that would need to be addressed during the 2019 summer field investigation to support development, evaluation and eventual selection of potential closure options for the Site. A secondary objective was to identify APECs that have either

1. An "obvious choice" for the best remedial option, and/or have limited data gaps meaning a plan to address them could be developed in 2019 (Stream A); or
2. APECs with more than one feasible approach and/or significant data gaps that would need to be addressed before proceeding to a decision (Stream B).

There were 15 workshop participants, including representatives from MEMPR, TRTFN, (Teck, SNC-Lavalin, and SRK (including an SRK facilitator).

The workshop agenda included a series of common understanding presentations, a discussion of remedial objectives for the Site, a review of remedial methods to establish which ones might be feasible at this site, and development and evaluation of example closure plans. The example closure plans were intended to illustrate a broad range of options for the Site, including two plans with active water treatment and two plans that would not rely on active water treatment. The groups were asked to identify pivotal decisions, key assumptions, advantages and disadvantages of their plan, and data gaps that would need to be addressed prior to selection of a preferred closure option. Lastly, there was a brief polling exercise to understand the participants preferences for remediation plans and methods.

Key findings from the workshop included a list of study gaps and Stream A and Stream B activities (Section 3.1 of SRK 2019a). The list of study gaps formed the basis for the summer field investigations and other desktop studies completed in the latter half of 2019 and as presented in SNC-Lavalin, 2020a.

2.6.2 Second Workshop

The second workshop was held on October 31 and November 1, 2019. A detailed memo documenting the workshop and its findings is provided in SRK 2019b. The main objectives of the second workshop were to confirm participant buy-in on remedial objectives and evaluation criteria, and to understand preferences and/or different perspectives for certain remediation methods or closure plans that could be considered for the Site. There were 28 workshop participants, including representatives from MEMPR, TRTFN, ENV, Alaska Department of Natural Resources (AKDNR), Teck, SNC-Lavalin, SRK (including an SRK facilitator), and two associate consultants with historical knowledge of the Site (Ampex Mining Ltd. and Marsland Environmental Associates).

The workshop agenda included a series of presentations to ensure participants would appreciate the most important considerations for closure, an overview of findings from the first workshop, and review of remedial objectives and evaluation criteria. Closure plan outlines were developed by four multidisciplinary groups comprised of participants from different organizations. The closure plans were then evaluated by groups representing specific organizations and/or discipline groups.

The four closure plan options derived by the groups were broadly similar in terms of the physical works that would need to be completed for closure. Notably, all four plans included installation of bulkheads to flood the mine to the 5900 level. The main differences between the plans were related to the handling of discharges from the underground mine, including 1) variations on where the mine water would be released from the mine (5900 vs 5400), 2) whether the mine water would be actively treated for a period of time, passively treated or not treated, and 3) the location where the water would be released into the receiving environment (i.e., to Camp Creek, to the Tulsequah River channel or via deep injection to the groundwater aquifer beneath the Tulsequah River).

Based on the evaluation and discussion during the workshop, the facilitator identified the following areas of consensus among most or all the participants.

- TRTFN leadership will need to have an opportunity to provide input before a final closure plan is developed.
- Participants from TRTFN and Teck who attended the workshop were not supportive of reliance on barging due to potential risks to worker safety. Other participants in the workshop were also concerned about safety considerations with extensive barging programs.
- The four plans developed during the workshop all included plugging the 5200 and 5400 portals and flooding the mine to the 5900 level.
- The four plans included consolidating and covering the lower workings waste rock (without a base liner) but leaving at least some of the upper workings waste rock unconsolidated and uncovered, pending the results of additional risk assessment work.
- Almost all participants were not supportive of reliance on permanent, year-round active water treatment. There was a preference for temporary, seasonal, and/or adaptable water treatment instead.
- Most of the workshop participants were supportive of reducing water inflows into the underground workings.
- The four plans developed during the workshop included repairing the airstrip, roads, and bridges for temporary use during active construction.
- Most of the workshop participants agreed that additional work needed to be done to understand the environmental impacts of loading from discharge to Camp Creek.

Based on the evaluation and discussion during the workshop, the facilitator identified varying perspectives among the workshop participants for the following:

- Acceptability and expected environmental performance of untreated surface discharges to the Tulsequah River;
- Feasibility of passive treatment, especially over the long-term;
- Acceptability and feasibility of deep injection; and
- Community preference for a long-term functional airstrip.

The findings were considered in developing the preliminary closure and reclamation plan presented herein.

3 Closure Objectives

As noted above, the development and evaluation of remediation options was completed in conjunction with representatives of the TRTFN, MEMPR, Teck and ENV during two workshops held in June and October 2019. One of the important outcomes of the workshops was an agreed set of closure objectives and associated evaluation criteria against which various remedial options could be evaluated, as summarized in the table below.

Table B: Closure Objectives and Evaluation Criteria from the Tulsequah Chief Mine Workshop, November 1, 2019

Closure Objectives	Evaluation Criteria
This option protects people from chemical risks	Degree to which the option meets human health risk-based standards.
This option protects people from physical risks	Degree to which the option meets the closure requirements under the Mines Act.
This option protects the terrestrial environment from chemical risk	Degree to which the option meets ecological risk-based endpoints.
This option protects the aquatic environment from chemical risk	Degree to which the option meets ecological risk-based endpoints.
This option maximizes load reduction	Degree to which the option maximizes the reduction of load originating from the Site.
This option protects aquatic habitat from physical risk	The perceived or modelled long-term ability of the remedial option to protect aquatic habitat and allows ecosystem recovery.
This option has support from the TRTFN leadership	Input from TRTFN representatives at workshop will be used for insight, but is not used for decision making.
This option has support from stakeholders	Qualitative evaluation of stakeholder support for the remedial option, based on engagement to date and or inferred.
This option is technically feasible and scientifically supported	Feasible and applicable to the site conditions with reasonable maintenance requirements.
This option is a proven strategy/technology with a high likelihood of success	Has been used at similar sites with success. Innovative techniques may have a higher level of uncertainty.
This option minimizes cost	Comparison of the cost estimate for each option.
This option minimizes risks to workers involved in completing the remediation work	Evaluates risks to the workers during the remedial work including from physical hazards, as well as acute and chronic affects from exposure to toxic substances.
This option minimizes secondary environmental effects	Related to Sustainable Remediation. Reduces the potential for carbon dioxide emissions and damage to habitat while meeting risk reduction objectives. Considers reduce, reuse, recycling of materials, where possible (qualitative evaluation only).
This option maximizes permanence and resiliency in the future	Considers the long-term human health and ecological risk from residual contamination, longevity and stability of physical structures / features, and resilience to environmental change.

Table B (Cont'd): Closure Objectives and Evaluation Criteria from the Tulsequah Chief Mine Workshop, November 1, 2019

Closure Objectives	Evaluation Criteria
This option minimizes reliance on long-term management and monitoring	Minimizes the number and complexity of engineered controls that require long-term management and monitoring.
This option achieves Provincial and Federal regulator approval	Is accepted by the regulators. Supports site being reclassified by ENV from "high risk site" to "risk managed high risk site."
This option reduces contaminant loading	Degree to which the option reduces contaminant load originating from the Site.

Although these objectives were helpful in understanding the preferences and sensitivities of the workshop contributors, all parties have recognized that some tempering of expectations has been necessary in the development of a final closure plan as outlined below.

The Site is complex from a closure planning perspective given its remoteness, fluctuating conditions in the aquatic receiving environment and uncertain regulatory requirements. This closure plan was developed to implement risk-based remediation and closure strategies that focus on what is achievable in the near-term to address as many of the closure objectives as possible, while at the same time gathering information that supports decision making regarding options for discharge of mine water to the receiving environment.

The primary objectives considered in the development of the closure plan were reduction of chemical and physical risk at the Site through source control measures and removal of physical hazards. Some of the source control measures include sealing openings, excavation of leachable waste rock from the Tulsequah River, consolidation and covering of waste rock to reduce exposure to contaminated soils, and flooding of the underground mine to reduce concentrations and loadings associated with the mine water. Measures to reduce physical hazards include demolition and on-site landfilling of buildings and derelict equipment/materials, off-site disposal of hazardous materials, installation of access controls at mine openings, implementation of shoreline and slope protection measures at critical erosion faces, along roadways and at quarries. These risk reduction measures are relatively straight forward to implement from a construction standpoint but will be complicated by logistics challenges associated with this remote site. Some remedial work such as road, bridge and airstrip repairs are critical to any closure plan and should be implemented as soon as possible.

Mine discharge from the Site to the Tulsequah River is contaminated and was shown to cause isolated risks to aquatic receptors. A key challenge for closure of this Site is determining what is required to meet a site-specific risk-based performance objective in the Tulsequah River and how - or if this discharge will be authorized (i.e., permitted). Further work is needed with regulatory agencies and TRTFN to determine what a site-specific risk-based performance objective would look like and whether this would apply to the end of pipe discharge or at the boundary of a dilution zone within the river. This process is complicated by the constantly changing river morphology and dilution ratios resulting in unstable chemical conditions that typically complicate risk assessments. In addition to uncertainties regarding risk-based performance objectives, there are a number of data gaps identified during the supplemental site investigation and remediation planning workshops need to be resolved before sound engineering decisions can be made regarding the appropriate remedial alternatives. Additional data collection is required to support decision-making and design of mine discharge solutions.

A phased approach was considered for this closure plan. The first phase includes implementation of the achievable risk reduction measures based on the current knowledge of the Site. The performance of the risk reduction measures will be evaluated as additional data is collected at the Site. Both the performance data and the additional information will be used to make sound engineering decisions for eventual management of mine discharge.

Regardless of the permanent mine water discharge strategy that is selected, it is acknowledged that temporary water management measures will be required during the detailed investigation stage and the remediation construction phase of the project to ensure that metal loadings from the Mine Site do not increase as a result of these activities. Further work will be required to develop this and other management plans to support detailed design and implementation plans and regulatory approvals.

4 Preliminary Closure and Reclamation Plan

The Tulsequah Chief and Big Bull are considered closed or possible abandoned mines as defined in the Mines Act[3] (the Act) and therefore subject to the Act and the Health, Safety and Reclamation Code for Mines[4] (the Code). The purpose of the Act and the Code are to protect workers and the public through provisions for minimizing the health, safety and environmental risks related to mining activities. The Act applies to all mines from exploration, production, reclamation to abandonment. Part 10 of the Code outlines the requirements for mine closure which includes (but is not limited to): securing of openings; addressing long-term stability concerns with major dumps/impoundments; and, closure of tailings storage facilities or dams (including regular updates); Operations, Maintenance and Surveillance Manuals; decommissioning water retaining structures; and, development of a closure management manual. The Code also stipulates chemicals and reagents are to be properly disposed in compliance with municipal, regional, provincial and federal statutes.

The EMA regulates waste discharges, pollution, hazardous waste and contaminated site remediation in BC. Relevant regulations under EMA include the *Contaminated Sites Regulation*[5] (CSR), *Waste Discharge Regulation*[6] (WDR) and *Hazardous Waste Regulation*[7] (HWR). As defined in EMA Part 5, the Site is a past producing mine containing both "core areas" and "non-core areas". Non-core areas are regulated under EMA; however, the Director EMA may not issue a remediation order under section 48 in relation to the remediation of a core area of a producing or past producing mine unless:

(a) requested to do so by the Chief Inspector of Mines under the Mines Act;
(b) this was agreed to in the resolution of a dispute under the dispute resolution process; or
(c) the land and water use at the producing or past producing mine site is formally changed from those approved in the applicable Mines Act permit.

We infer the core areas of the Site include the mine access roads, waste rock piles, underground workings and openings. The non-core areas include the fuel storage areas, former acid treatment plant, machine shops and camps.

Mine closure includes protecting the environment and conducting reclamation based on the end land use approved by the Chief Inspector who considers previous and potential uses. Factors considered in reclamation include capability, long-term stability and erosion control, re-vegetation requirements, and removal or management of structures and equipment. Closure may, at the direction of the Chief Inspector, also include ecological risk assessments. If significant risks are considered present, reclamation work should be conducted in a manner to address the risks or other measures. If the aquatic receiving environment is contaminated from any mine feature, as determined by exceedances of the applicable provincial water quality, the Chief Inspector may require remediation strategies to be implemented for as long as necessary to mitigate the problem. Likewise, the Director under EMA may issue a non-compliance notice and require mitigation actions with respect to permitted discharges or off-site contamination issues that present unacceptable risks to human health or ecological receptors.

[3] Mines Act, RSBC 1996, chapter 293, including amendments up to October 30, 2019.
[4] Ministry of Energy and Mines (2017), Health, Safety and Reclamation Code for Mines in British Columbia, Revised June 2017.
[5] *Contaminated Sites Regulation* (CSR), B.C. Reg. 375/96, includes amendments up to B.C. Reg. 13/2019, January 24, 2019.
[6] *Waste Discharge Regulation* (WDR), B.C. Reg. 320/2004, includes amendments up to B.C. Reg. 154/2019, September 15, 2019.
[7] *Hazardous Waste Regulation* (HWR), B.C. Reg. 63/88, includes amendments up to B.C. Reg. 243/2016, November 1, 2017.

SNC-Lavalin and SRK developed the following risk-based closure and reclamation plan to meet (where possible) the requirements of the Act, the Code and EMA. The development and evaluation of remediation options was completed in conjunction with representatives of the TRTFN, MEMPR, Teck and ENV. This section of the report provides a description of the preliminary closure and reclamation plan as described for the Mine Area, Infrastructure Areas, Exploration and Development Sites, Receiving Water Environment and the Big Bull Mine. The plan described herein addresses each of the risks identified in Section 2.4 with the notable exception of the mine water discharges to the Tulsequah River. Mine water control measures described in Sections 4.1.1.2 and 4.1.1.3 are expected to reduce both flows and concentrations in the mine water, and will therefore reduce the total metal loading to the Tulsequah River. However, metal concentrations may still be at levels that are not acceptable for direct discharge. The Project Team have identified a limited number of options for mine water discharge. However, each of the options is subject to a number of uncertainties that will require further investigation before a preferred option can be selected for the project. A detailed discussion of the options for mine water discharge and the advantages and disadvantages associated with each of these is provided in Section 5.

4.1 Mine Area

The mine area includes the Underground Workings (APEC A) and the Lower and Upper Workings (APECs B and C). Key issues for closure include: ground stability issues (i.e., potential for collapse of the crown pillar or adits that currently act as water conveyances within the mine, mine safety issues associated with the openings, elevated sulphate and metal concentrations in discharges from the underground mine and waste rock piles to the Tulsequah River, elevated solid phase metal concentrations in waste rock, hazardous waste and demolition debris. These issues and the closure measures that are proposed for the mine area are described in the following.

4.1.1 Underground Workings (APEC A)

4.1.1.1 Ground Stability

Preliminary findings indicate that reinforcement is not required to prevent collapse of the crown pillar near to Camp Creek. Initial concerns were that the crown pillar could collapse, and Camp Creek could enter into the mine. This will require further confirmation, including an initial precision survey and laser cavity measurement scan (CMS) of the near surface upper workings to determine the current size of the excavations and the thickness of the crown pillar, as well as, geotechnical mapping of rock outcrop and underground workings that are considered safe to access.

Assuming the results of additional investigation confirm the preliminary findings, potential ground stability issues in the crown pillar area will be addressed through ongoing monitoring. Due to hazards posed by the steep terrain, ongoing monitoring will be comprised of an aerial survey of the crown pillar area. This will be supplemented by periodic CMS scans to determine if there have been any changes related to crown pillar degradation. Inspections will initially occur every two years and the frequency would decrease to a maximum of once every five-years once ongoing stability is confirmed.

Some areas of instability were identified on the 5200 and 5400 level adits during the site inspection. These were relatively minor and will be rehabilitated using standard mining ground control practices. It is anticipated that some sections of ground support will need to be upgraded to ensure safe access for bulkhead construction and initial monitoring. Consideration should be given to using composite ground support; e.g., composite rockbolts to mitigate potential corrosion effects. Additionally, the upgrades should consider the need to maintain access to the bulkheads for the initial bulkhead monitoring period – which will likely continue for a period of 20 to 50 years.

Approximately 250,000 tonnes of broken ore is reportedly present in the historical stopes that were mined between the 5200 and 5900 levels. There is potential for mass flow of this material to occur resulting in temporary blockage and then rapid release of mine water from the 5200 and/or 5400 levels. Any potential impact of such an event on the surface environment will be addressed by to the installation of the bulkheads described in Section 4.1.1.3.

The 5900 level adit will require remediation to remove a zone of fallen ground located near the adit entrance. Rehabilitation will include installation of timber sets and resin anchored rockbolts as required. Because of the blockage, an inspection of the 5900 level was not possible during the 2019 site visit. The need for additional rehabilitation in the 5900 level will be determined by an inspection of the level once safe access has been restored.

A drainage pathway is required for all the mitigation strategies in which bulkheads are installed on the 5200 and 5400 levels. As the 5900 level has been impacted by ground stability issues leading to blockage of the adit, any water conveyance pipes along the 5900 level will require protection to ensure serviceability. The simplest approach would be to bury the pipe/s in suitably sized material to protect them from any falls of ground. The protected conveyance will be designed to ensure maximum discharge rates can be safely discharged from the mine if collapse and subsequent blockage of the adit occurs.

4.1.1.2 Openings

The reclamation standards for closure of openings of underground workings to surface are provided in Part 10 of Code. The relevant section of the code, Securing Openings, states that:

> *10.7.21 All shafts, raises, stope openings, adits, or drifts opening to the surface shall be either capped with a stopping of reinforced concrete or filled with material so that subsidence of the material will not pose a future hazard.*
>
> *10.7.22 In the case of shafts or raises, the stopping shall be secured to solid rock or to a concrete collar secured to solid rock and capable of supporting a uniformly distributed load of 12 KPa or a concentrated load of 24 kN, whichever is greater.*
>
> *10.7.23 Where there is evidence or a potential for use by wildlife, mine openings may be fitted with a barrier that allows wildlife passage but prevents human entry.*
>
> *10.7.24 When mine openings are permanently closed and where it may be possible for mine water to build dangerous pressures and cause a blow-out of the fill or concrete with sudden and dangerous force, a permanent and effective drain shall be installed.*

4.1.1.2.1 Shafts and Raises

Two vertical openings are known to exist at Tulsequah. One of these was closed with a concrete cap during the Redfern/Chieftain ownership period, and the other remains open. The concrete cap was not designed by or constructed under the supervision of a Professional Engineer and, therefore, the load bearing capacity of the existing cap is not known. However, it has been effective in limiting surface water inflows. To meet the requirements of the Code, the existing concrete cap will likely need to be upgraded to ensure it meets the required load capacity. The second opening will need to be capped and sealed around the edges to minimize inflows to the extent possible. It is anticipated that installation of these caps could reduce inflows to the mine workings by 2 L/sec during spring freshet, potentially reducing overall discharges from the mine workings from 16.5 L/sec to 14.5 L/sec.

Although the Code requires concrete closures or backfilling, construction of concrete caps is challenging in areas with steep terrain and difficult access conditions. An alternate approach was developed to address similar constraints at several abandoned uranium mines in northern Saskatchewan. Figure 5 shows an example of a cap installed over a vertical opening, and Figure 6 shows closure of a larger vertical open stope. The exact geometry of the openings was surveyed using laser scanning and detailed mapping, and then the caps were prefabricated off site. The caps were constructed using stainless steel with an estimated design life span ranging from 150 years to 1200 years depending on climate, water and rock chemistry. Assuming an exemption to the Code requirements can be obtained, pre-fabricated caps are the preferred type of closure for the vertical openings at Tulsequah.

Figure 5: Stainless Steel Cap Installed Over Vertical Opening at the Cinch/Cenex Mine Site in Northern Saskatchewan

Figure 6: Pre-fabricated Stainless-steel Stope Closure at Rix-Athabasca, Leonard Mine, Saskatchewan

4.1.1.2.2 Adits

The 5200, 5400, 5900 and 6400 level adits will be closed with airtight/restricting closures to prevent formation of ice dams. These closures will include locked gates to prevent inadvertent access while allowing for periodic inspection as this will be important in the early stages of project implementation. The closures can be constructed of steel or aluminium, but consideration should be given to using composite materials to reduce maintenance resulting from interaction with residual acid mine water. Gates will be secured to rock at the adit portals. As the Code requires that the closures be constructed of concrete or backfilled, a variance or exemption will likely be required to install gates as permanent closures.

To date, none of the site inspections have indicated that bats are present in the mine workings. If bats are present, access to the mine workings for wildlife habitat (Section 10.7.24 of the Code) will need to be considered.

4.1.1.3 Mine Water Controls

Water retaining bulkheads will be installed at the 5200 and 5400 levels to control discharges from the underground mine and to allow the mine to flood. Assuming groundwater losses from the flooded mine are less than inflows to the mine, it is anticipated that the workings could be flooded to the 5900 level. Flooding of the workings below the 5900 level is anticipated to reduce sulphate and metal loading by reducing the amount of reactive mine rock that is exposed within the workings and the amount of groundwater inflows to the mine. This in combination with reduced inflows from openings in the upper mine area (Section 4.1.1.2) are expected to reduce discharges from 16.5 L/sec to 12.0 L/sec.

Discharges would either be conveyed from the 5900 level via a protected water conveyance pipe or via valves that control water release through the 5400 or 5200 bulkheads. The current plan is to install a protected water conveyance at the 5900 level and control valves through the 5200 and 5400 level bulkheads. This will provide the flexibility needed to support the range of discharge options that may be considered for the Site. It will also provide redundancy in the event that one or more of the conveyances is compromised at some point in the future. Options for managing discharges from the underground mine are described in Section 5.

Groundwater seepage losses from the mine workings will be minimized by grouting open boreholes and localised rock mass grouting at the bulkhead construction locations.

There is still the potential for some groundwater to enter the 5200 and 5400 level adits between the bulkhead and the portal. This flow would be conveyed away from the bulkhead in a channel and discharge out of the respective portal. Depending on the mine water discharge option selected in Section 5, it is possible that this water will not be collected and instead would discharge directly into the Tulsequah River via surface channels. In the water and load balance it was assumed that the bulkheads would contain 100% of the flooded mine water. This assumption was made as any open boreholes will be grouted and localised rock mass grouting near the bulkheads are planned as part of the remedial works. Therefore, if water was to enter the adit outside the bulkhead it is likely of a quality similar to the natural groundwater recharge and not comparable to the flooded mine water quality and not a significant source of loading to the environment.

Further investigation of the rock mass properties, including targeted geotechnical drilling and mapping of the underground workings will be required to support design of the bulkheads and water conveyance pipe. Figure 7 shows some typical configurations for water retaining bulkheads.

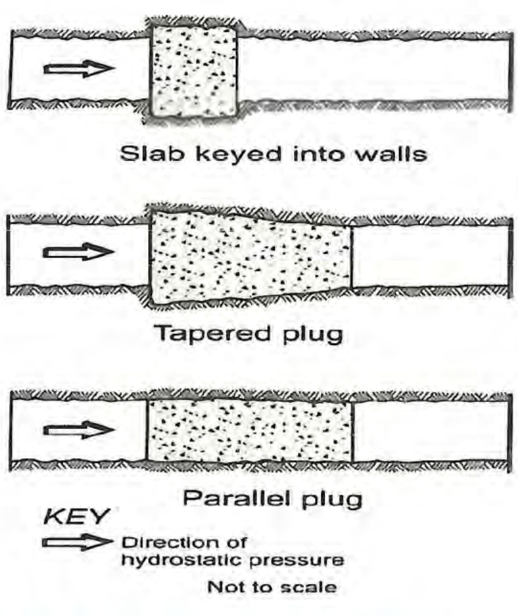

Figure 7: Typical Bulkhead Geometries

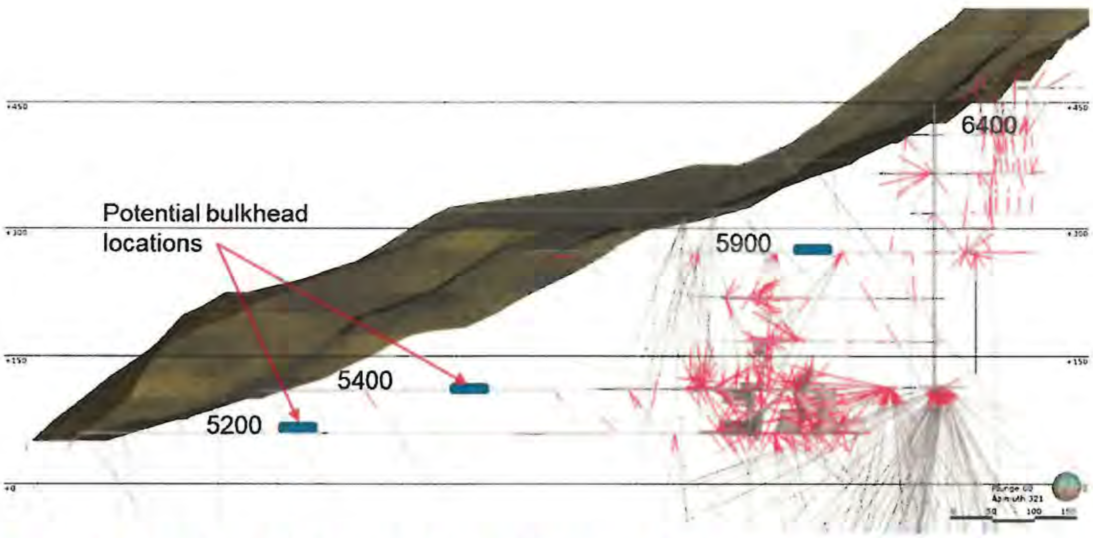

Figure 8: Mine Section Showing Potential Theoretical Bulkhead Locations on the 5200 and 5400 Levels

The bulkheads are typically installed some distance from the adit portal to ensure that there is sufficient confinement in the rock mass to prevent hydraulic jacking, and to ensure there is an adequate thickness of rock between the bulkheads and surface to prevent excessive seepage and pressure related blow-outs. Conceptual locations for the 5200 and 5400 level bulkheads are shown in Figure 8. Pressure grouting will be required to limit groundwater seepage around the bulkhead itself and the immediately surrounding rock mass.

4.1.2 Lower Workings (APEC B)

4.1.2.1 5200 Level Waste Rock

The 5200 level waste rock and soil contaminated by the exfiltration pond will be excavated and consolidated with the 5400 level waste rock. The excavation will be backfilled with non-PAG rip-rap and clean fill sourced from stockpile areas along the mine access road and/or from Paddy's Flats. The backfilled area will be protected with an erosion barrier capable of withstanding a 1:200-year or more severe flood event and Jökulhlaups. The backfill is required to maintain road access and to complete inspections of the bulkheads within the 5200 level. During excavation of the waste rock from 5200 level a temporary erosion / river isolation berm will need to be constructed to facilitate instream excavation work. The rip-rap used for the temporary works will then be pulled out and used as backfill of the excavated area and construction of the permeant erosion barrier. This area will include room for a water treatment plan, if needed.

4.1.2.2 5400 Level Waste Rock

The 5200 and 5400 level waste rock will be consolidated at the 5400 level in waste rock storage facility capable of holding 90,000 m^3. The waste rock storage facility will be prepared by clearing and grubbing the proposed footprint. The access road to the 5400 level will be realigned to create a buttress along the southwestern boundary of the facility. The waste rock storage facility will be sloped with 3H:1V slopes and capped with a low permeability engineered cover to block contaminant exposure pathways and minimize water and oxygen ingress into the PAG waste rock. The final design may factor in a mid-slope bench to reduce erosion and provide drainage. Conceptual drawings of the facility are shown in plan view in Figure 9 and on an oblique view in Figure 10. The waste rock storage facility will be covered using a barrier type final cover system including a high-density polyethylene geomembrane overlain by a seeded vegetative layer. A conceptual cover profile for the facility is shown on Figure 11.

The waste rock storage facility is located within a natural gully, where under current conditions, shallow groundwater daylights from the toe of the waste rock pile. The proposed bulkhead at the 5400 level and engineered cover should greatly reduce the amount of water flowing through the consolidated materials; however, to further minimize this potential contaminant transport pathway the facility will be shaped to promote shedding of upgradient water to a constructed perimeter ditch to divert it away from the stored waste rock. The design also includes a leachate collection system installed along the perimeter of the proposed facility to intercept shallow groundwater in the natural gully. The leachate collection system will be constructed to intercept dewatering from the relocated waste rock (if any) or shallow groundwater flowing from the steep slopes above the waste rock storage facility which may flow under the interception trench. To limit this lateral migration of shallow groundwater into the facility the engineered cover and interception trench will be tied into bedrock where it is shallower than 1.5 m. The leachate collection system will direct water to the temporary water treatment facility and will eventually be incorporated into the final water management option for the Site.

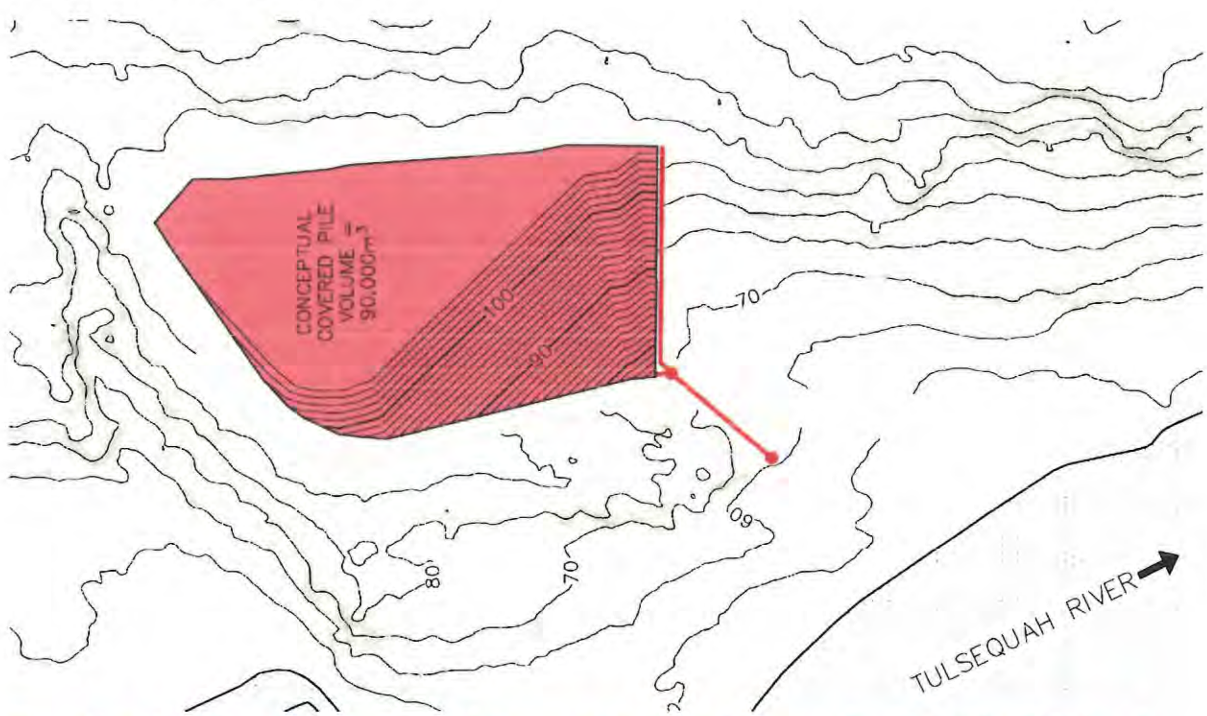

Figure 9: Plan View of the Conceptual Covered Waste Rock Storage Facility at the 5400 Level

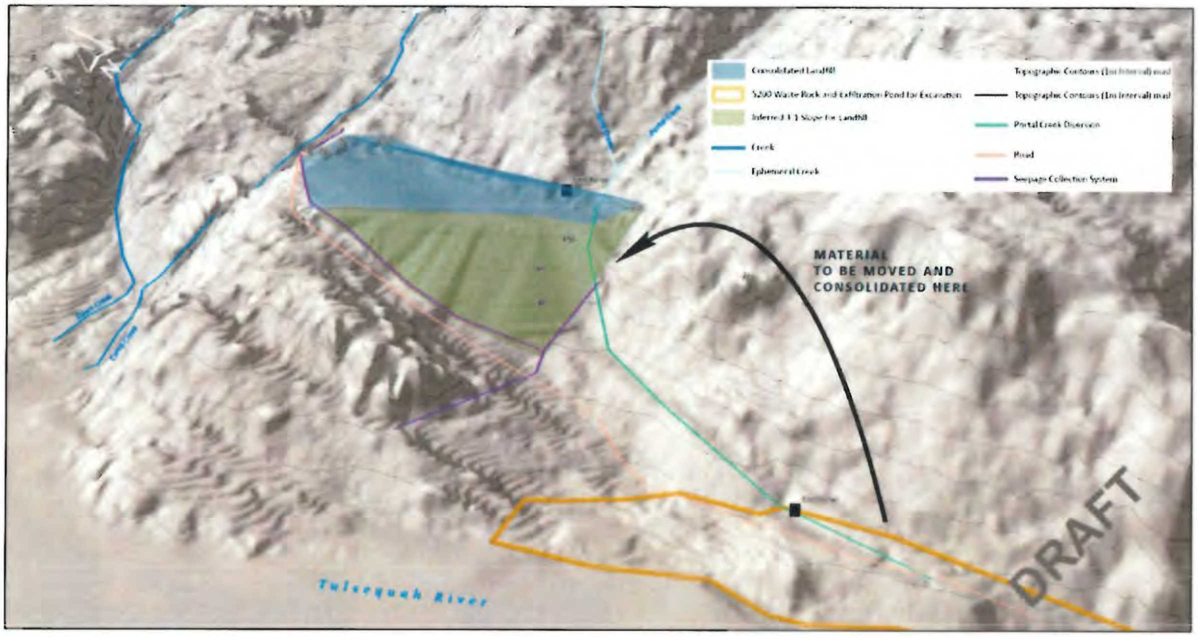

Figure 10: Oblique View of the Conceptual Waste Rock Storage Facility at the 5400 Level

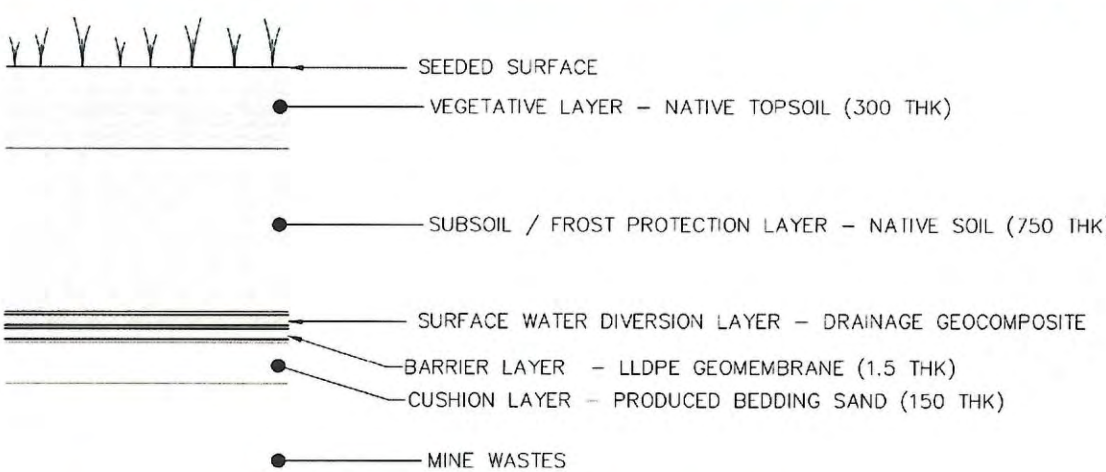

Figure 11: Conceptual Waste Rock Storage Facility Cover Profile

Flows from Portal and Gully Creek that occur seasonally or during heavy rain events will be directed away from the waste rock storage facility through either a water diversion pipe or perimeter ditch on the south end of the facility for direct discharge to the Tulsequah River.

4.1.3 Upper Workings (APEC C)

Because of the relative inaccessibility of contaminated soils in the Upper Workings to human receptors at the Site, as well as the relatively small area impacted and potentially low value habitat for terrestrial ecological receptors associated with mine wastes, a risk management approach will be adopted for this area. The risk management approach will likely consist of administrative controls to protect human health. This will likely include signage, to alert workers or the public of the potential risks associated with exposure to contaminated soils in the area and incorporation of notice of potential risks and the requirement to wear appropriate PPE to reduce potential exposure when accessing the Upper Workings area of the Site.

The current assumption is that risks to ecological receptors from contaminated soils are within limits that would be acceptable for a risk management approach. A biological survey / habitat assessment of the waste rock piles and surrounding areas will be conducted by a professional biologist. Results of this assessment will be incorporated into an updated version of an ecological risk evaluation, to confirm that this approach is a viable remedial plan for this area.

4.2 Infrastructure Areas

4.2.1 General Considerations

A variety of structures and infrastructure are present at various non-core areas of the Site. Structures are all single storey and are constructed of metal, wood or are prefabricated and consist of mixed materials. A variety of mobile and stationary equipment, materials and debris are also present at various areas of the Site. Certain structures, equipment and materials will be further inspected to determine if refurbishment and reuse to support implementation of the closure activities is practical (e.g., camp facilities, mobile equipment and materials such as culverts, steel girders, rolls of geosynthetic liner/cover material, etc.). All non-serviceable structures and equipment, and non-reusable materials and debris will be demolished and consolidated into an engineered landfill to be constructed at Paddy's Flats to meet minimum requirements of the Waste Discharge Regulation (refer to Section 4.2.6).

As required by the WorkSafeBC *Occupational Health and Safety Regulation*[8] (OHSR), hazardous materials identified in the structures will be removed or safely contained by a qualified contractor prior to demolition in order to protect the health of workers. Hazardous liquids that are in good condition (e.g., fuel, reagents), will be used to support closure activities where possible to reduce costs. Similarly, hazardous materials such as batteries will also be re-used at the Site where possible. All other hazardous material and liquids will be re-packaged, consolidating compatible materials where possible, including draining liquids from non-serviceable equipment, and transported off site for disposal (or recycling) at authorized facilities. We infer that hazardous wastes can be transported off site by air (i.e., backhaul flights) to avoid barging.

An exception will be made for inert hazardous materials such as asbestos and silica containing materials which will be packaged as necessary under applicable regulations and consolidated at the Paddy's Flats landfill.

[8] *Workers Compensation Act, Occupational Health and Safety Regulation* (OHSR), B.C. Reg. 296/97, includes amendments up to B.C. Reg. 14/2019, June 3, 2019.

Other elements of the closure of various non-core areas will include erosion protection, slope stabilization and grading to address hazardous conditions, reclamation and, if applicable, remediation of petroleum hydrocarbon contamination as outlined in the sections below.

4.2.2 Shazah Airstrip and Camp (APEC E)

The Project Team considered the Shazah Airstrip and Camp from a short-term and long-term perspective. For the short-term, these facilities are logistically critical to complete remediation and closure at the Site. The airstrip is currently used to bring supplies into the Site. Considering the challenges and uncertainties associated barging, air transport may be the only means to mobilize equipment and supplies for construction.

The north end of the airstrip is being actively eroded by the Tulsequah River and the current deflection berm (erosion barrier) needs to be upgraded to support construction activities. The upstream (north) end of the airstrip once had a setback trench infilled with rip rap; however, the river eroded half of this away by Spring 2019.

The closure plan for the airstrip includes grading the north end of the runway slope to 2H:1V, placing geosynthetic textile and covering with large, angular rip rap transported to the Site from rip rap stockpiles along the access road. A typical section showing the bank erosion protection at the north end of the runway is shown on Figure 12 below.

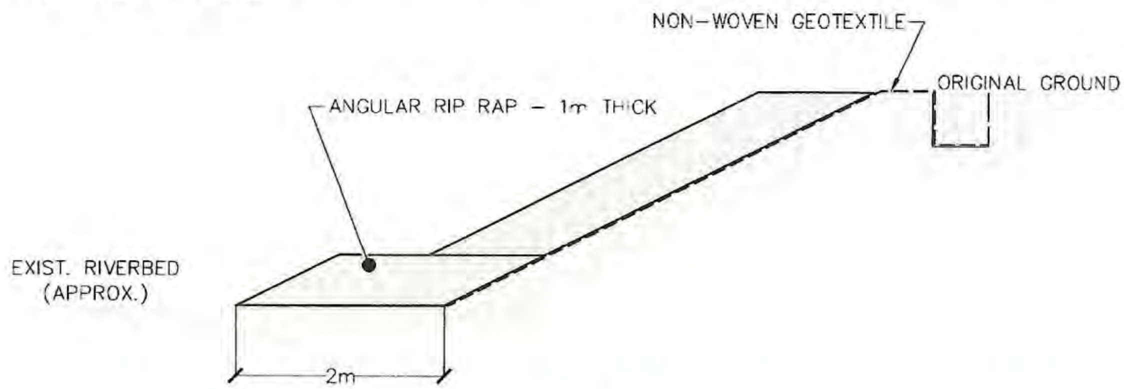

Figure 12: Conceptual Cross-Section of Bank Erosion Protection Feature at Shazah Creek Airstrip

The west side of the airstrip will remain unprotected for the short-term. Repairs and re-grading of the runway will be made on an as-needed basis. The camp buildings will need to be upgraded or replaced to support the construction activities.

For the long-term options the EMPR will need to consult with the local community and TRTFN on future use. If long-term protection of the airstrip is preferred by all communities of interest and approved by EMPR, the short-term option could be upgraded and an interception trench protecting the west side of the airstrip from lateral migration of the river may need to be constructed. Given this uncertainty, this activity has not been included in cost estimates provided in Appendix II.

4.2.3 Lime Sludge Pit (APEC O)

As indicated in Section 2.4.2, the lime sludge is geochemically stable and has not had a measurable effect on underlying groundwater quality. However, the lime sludge is located within the Tulsequah River floodplain. To prevent erosion and physical remobilization of the sludges during flooding from Shazah Creek or the Tulesquah River over the long-term, the sludges will be excavated and consolidated. The wastes in the lime sludge pit will be consolidated at the waste rock storage facility being constructed at the 5400 level of the Lower Workings. It may be necessary to stage the excavated material adjacent to the pit to allow free water to drain prior to transporting it to the waste rock storage facility. The minor volume of free water is expected to have neutral pH and low metal concentrations and will therefore be allowed to drain into the underlying soils. The excavation area will be backfilled with local borrow soil.

4.2.4 Fuel Storage Areas (APEC F)

Bulk storage of petroleum fuels and lubricants were observed at the Shazah Airstrip (e.g., vehicle maintenance facilities and generator shed), Lower Workings ATP area (generator building), the NAG/PAG storage area and the Barge Landing. Petroleum hydrocarbon staining was observed on surficial soils in some areas. Anecdotal information provided by TRTFN members with experience at the Site has indicated the potential presence of petroleum hydrocarbon contamination in soil at some areas. Because excavators could not access these areas, SNC-Lavalin could not conduct intrusive soil investigations to verify the presence or extent of petroleum hydrocarbon contamination in soil, if any. Intrusive soil investigation will be completed in future after road access is re-established. If impacts to soil are identified, shallow groundwater investigation (i.e., drilling) in impacted areas would be necessary to characterize and delineate areas of hydrocarbon contamination.

Given the uncertainty noted above, the project team has not considered management of petroleum hydrocarbon contaminated soil or groundwater within the closure plan at this time. If contamination is determined to be present, it may be feasible to address it through risk assessment and implementation of risk controls. Otherwise the most appropriate remediation option is expected to included excavation of impacted soil and consolidation into a separate containment cell at Paddy's Flats (i.e., separate from the proposed industrial landfill) with monitored natural attenuation of groundwater contamination, if present.

4.2.5 Mine Access Road, Bridges and Quarries (APECs G, H and I)

The roads are in generally good condition. However, some of the bridges assessed by a qualified civil engineer (SNT Engineering Ltd.) were found to be unsafe To support additional closure planning investigations and closure plan implementation, mine access roads will need to be regraded and bridges and crossings will need to be repaired or replaced to temporary or permanent standard depending on other elements of the closure plan. Where possible the bridges will be replaced with culverts to minimize costs and increase safety. Road upgrades will use the steel girders and culverts stored at the Barge Camp and along the mine access road near Shazah Creek. Seasonal maintenance of the roads will be required for as long as the roads are necessary. The southern and northern causeways between the Lower Workings and Rogers Slough will remain in place and maintained as required.

Depending on the selected long-term closure plan, sections of the road may be allowed to undergo monitored natural recovery (i.e., allow vegetation to continue to re-establish). Closure could consider re-contouring and active reclamation/revegetation of some or all disturbed areas; however, further consultation from local community and TRTFN on future use would be required.

The preferred closure plan for the rock quarries is to re-slope or backfill as required to stabilize slopes and faces. Rock scaling may be needed in some areas using existing on-site equipment or qualified professional rock scales. Where equipment is unlikely to be able to scale higher rock faces, berms can be created block potential rock fall from entering onto road or work areas to maintain safety. Where possible roads will be aligned away from the base of high rock faces containing loose rock. Stockpiled soil and rip-rap will be re-used on site for construction activities with disturbed areas or residue materials being regraded to address for safety concerns and seeded to prevent erosion.

4.2.6 Paddy's Flats (APEC K)

Paddy's Flats is primarily viewed as an appropriate location to construct an industrial landfill for consolidation and encapsulation of demolition debris and scrap generated from various areas of the Site, as well as development of borrow sources to support landfill construction and closure activities elsewhere at the Site, as described below. The small quantities of debris identified at Paddy's flats will be consolidated into the landfill. The landfill footprint and borrow areas will be reclaimed in accordance with requirements of the Code. For other areas, monitored natural recovery is inferred to be the most appropriate reclamation strategy.

Based on a survey of building materials, derelict equipment and materials identified at the Site in Summer 2019 (SNC-Lavalin 2020b), wastes to be consolidated into the landfill are primarily inert materials (ferrous and non-ferrous metals, wood, plastics, concrete, etc.) with minor quantities of grease or fluids that cannot be drained from equipment prior to disposal. No free liquids, or hazardous chemicals/wastes will be placed in the landfill (except asbestos and silica containing materials as noted above). Based on available information, the depth to groundwater at Paddy's Flats is expected to be on the order of several to tens of meters and the distance to the nearest aquatic receiving environment (Tulsequah River) is greater than 300 m. Consequently, it is inferred that materials to be disposed have limited potential to generate contaminated leachate and any leachate generated would be naturally attenuated to acceptable levels before migrating with groundwater to the receiving environment. For permitting purposes, it will be necessary to verify this conceptual source-pathway-receptor model through detailed investigation of hydrogeological conditions at the Site and the downgradient receiving environment.

Based on the above, the proposed unlined landfill will include a water balance (store-and-release) cover system. This approach avoids the need for importing geosynthetic liner materials and mobilizing a specialty contractor to the Site and presents fewer maintenance challenges over the long-term. A conceptual profile for the cover system is presented in Figure 13. Granular materials required to construct the covers would be sourced from borrow sites at Paddy's Flats and processed as required.

The landfill will consist of an excavation surrounded by a perimeter berm. Asbestos, silica, and large or irregular demolition debris will be disposed in dedicated cells on the base of the landfill. Asbestos will be double bagged before being transferred to the landfill and will be covered immediately following placement with a 150 mm thick layer of native soil. The cover system will be sloped, and an interceptor ditch will be installed on the cover to convey surface water runoff towards the perimeter of the landfill. A conceptual detail for the interceptor ditch is shown on Figure 14. Runoff from the cover will be discharged to ground via a rock pit.

The proposed water balance cover includes a thick layer of native soil which will be capable of storing soil water until it can be transpired through vegetation or evaporated from the cover surface. The proposed cover profile will comprise the following (from bottom to top):

- A granular filter layer intended to prevent the native soil layer from migrating into the waste and to act as a capillary break to enhance the moisture retention capabilities of the native soil layer;
- A native soil layer of sufficient thickness to limit percolation through the cover to an acceptable rate; and
- A vegetative layer consisting of a topsoil layer with a seeded surface.

Borrow material from Paddy's flats will be used as engineered fill, and to produce granular filter material, drain rock, and rip rap for use in construction of the cover system. The landfill will receive non-hazardous solid waste generated by various closure activities as well as inert hazardous materials (e.g., asbestos and silica containing materials) pending permit approval.

There is a low risk that a water balance cover may not be feasible due to a lack of suitable materials on site. In that case, a barrier type cover system will be employed including a double liner comprised of a linear low- density polyethylene geomembrane in intimate contact with a geosynthetic clay liner. The additional cost to add the barrier type cover to the landfill is estimated to be approximately $1.1M. However, this additional cost has been excluded from the capital cost estimate, as this risk is considered to be low.

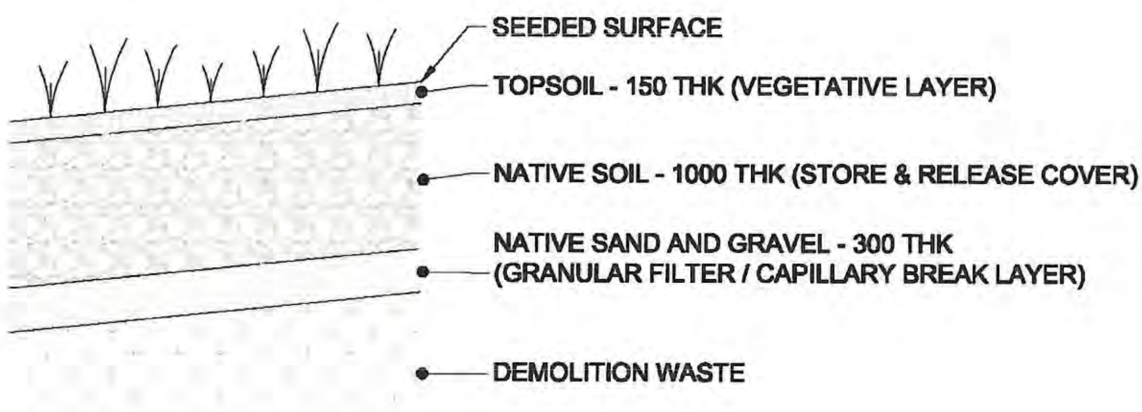

Figure 13: Conceptual Landfill Cover Profile

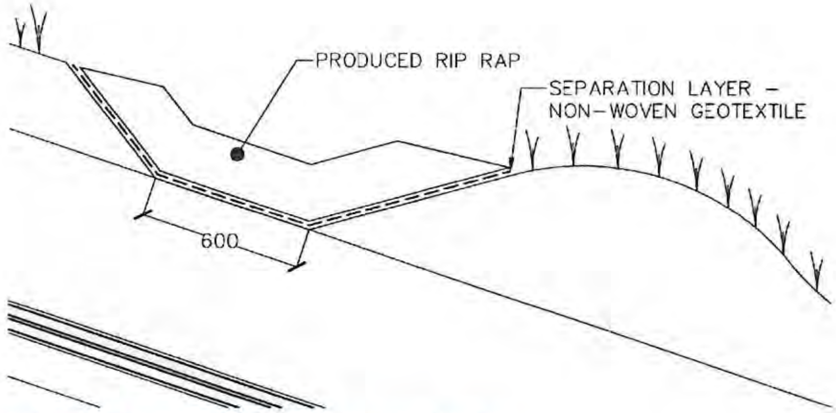

Figure 14: Conceptual Surface Water Interceptor Ditch

4.2.7 Barge Camp (APEC M)

Assuming that some of the supplies and equipment required for closure can be transported via river barge, the Barge Camp will be maintained for temporary use during construction activities. Temporary upgrades and maintenance will be required on an as-needed basis until construction is complete. Before a final closure plan can be developed for this area there will need to be further consultation from local community and TRTFN on future use as there are several cabins at this location. The non-mine wastes, building materials and miscellaneous debris will be relocated to a constructed landfill at Paddy's Flats. Where possible the stored materials (culverts and girders) will be used in road upgrades.

Workshop participants are not supportive of a closure plan that relies on barging, although evaluation of barging compared to other means of transporting supplies and equipment (e.g., by air) will need to be studied to select an optimal approach.

4.3 Exploration and Development Sites

4.3.1 Clearing for Proposed Shazah Creek TSF (APEC J)

Closure of the proposed Tailings Storage Facility in the Shazah Creek watershed will require decommissioning of the groundwater monitoring wells and natural recovery of the disturbed areas which are already mostly overgrown. The groundwater wells will be decommissioned by hand using hydrated bentonite pellets to seal the opening and meet closure requirements. Well casings and PVC will be landfilled with the building materials at Paddy's Flats.

4.3.2 NAG and PAG Storage Areas at Rogers Flats (APEC D)

Demolition debris from the NAG and PAG storage area will be landfilled at Paddy's Flats with other non-mine wastes and building materials from across the Site. The in-situ liner, sumps and associated structures in the PAG storage cell will be removed and landfilled. The area will be re-graded as required for safety purposes and natural recovery of vegetation will be allowed to occur. The 26 rolls (1,087 m^2 per roll) of GSF 60 mm GM1 Ultraflex textured liner stored in this area will be inspected and re-used to support mine closure works where possible (e.g., landfill liners, covers, etc.).

4.3.3 Exploration Drilling Sites (APEC N)

Natural recovery of disturbed areas associated with the exploration drill pads which are already mostly overgrown will be allowed to continue.

4.4 Receiving Environment

Primary concerns for the receiving environment will ultimately be addressed through the application of remedial/reclamation actions to reduce contaminant loading to the receiving environment, primarily by reducing inflows to the underground mine, flooding the lower portion of the mine workings, managing mine water discharge and consolidating and covering the waste rock as described in Sections 4.1.1 and 4.1.2, above.

Despite reductions in flows and loadings that will occur as a result of these closure measures, concentrations in the mine discharges are unlikely to improve to levels that are below thresholds that are acceptable for direct discharge to the receiving environment without some additional measures to reduce magnitude and spatial extent where unacceptable effects could occur. For the purposes of this closure plan, it is acknowledged that the extent of mitigation that will be required to reduce concentrations to levels that are "acceptable for direct discharge" cannot be explicitly defined at this time and may be constrained by the technical feasibility of the available options – most notably the understanding that long-term active water treatment is not a viable solution for this Site. Mine water discharge options that are currently under consideration are presented in Section 5. Most of those options are also likely to require application of an IDZ within the Tulsequah River.

As defined in BC ENV Technical Guidance 11 (2016)[9] an IDZ is a three-dimensional zone around a point of discharge where mixing of effluent and the receiving water environment occurs. An IDZ does not encompass the entire extent where all mixing occurs (as the plume may extend beyond the edge of an IDZ before the plume is fully mixed with the receiving environment). This enables elevated concentrations of COPCs to be present within a receiving environment for a short period of time, without significantly affecting the integrity of the water body as a whole (BC ENV 2019).

The size, shape and position of the IDZ within the Tulsequah River will depend on the concentration, location and the mode of discharge of mine water into the river, which will depend in part on the method of mine water management implemented (refer to Section 5). As well, the IDZ is expected to vary over time depending on seasonal flows within the river and the changing geomorphology of the river. It is anticipated that the IDZ in surface water will be managed by developing and implementing site-specific risk-based performance objectives; however, as described in Section 2.5, additional consultation with regulatory agencies and the TRTFN is required to determine the protection goals of site-specific risk-based performance objectives and how they would be developed and implemented at the Site.

Following implementation of measures to manage mine water discharge to the Tulsequah River, it is anticipated that contaminant impacts to Tulsequah River sediments adjacent to the mine will recover naturally over time due to flushing associated with freshet flows and Jökulhaups events.

[9] Technical Guidance Document 11: *Checklist for Reviewing a Detailed Site Investigation,* BC MoE, August 2016.

4.5 Big Bull Mine (APEC BB)

The preferred closure plan for the building materials and debris at the Big Bull Mine is demolition and management/landfilling at Paddy's Flats with building materials from across the Tulsequah Chief site. The five vertical openings (Main Shaft, Old Shaft and No. 1 Shafts, two vent raises) and two adit portals should be closed to meet the requirements of the Code, as described for the Upper Workings at the Tulsequah Chief Mine. Although Bull Creek was dry during the July site visit, previous reports recommended diverting the creek channel away from the Glory Hole to limit water infiltration into the workings and this option will be explored.

Currently there is not enough data available to select a preferred closure plan for the waste rock and mine discharges at the Big Bull Mine. However, at a conceptual level there are three closure options being considered: 1) In-situ landfilling with targeted pullback of waste rock from the Taku River; 2) Consolidation of the waste rock into the Glory Hole; and 3) Excavation and consolidation of waste rock to a constructed landfill at Paddy's Flats. Additional data is required before additional closure planning can occur. Where practical and appropriate, closure activities for Tulsequah Chief and Big Bull mines should be coordinated to reduce costs.

Road upgrades to access within the last kilometre the Big Bull Mine should consider the potential disturbance of PAG bedrock (testing to confirm and fill to be brought in for road construction if necessary). Note that these road upgrades have not been factored into costs presented in Appendix II.

5 Options for Mine Water Discharge

There are a number of unique challenges associated with this site that limit the options for mine water discharges from the underground mine, including:

- Metal concentrations in the mine water that are currently well above levels that are considered acceptable for direct discharge (refer to Section 4.4), and are likely to remain above those thresholds despite reductions in flows and loadings that will occur as a result of the closure measures described in Section 4.
- Remote location and access considerations that effectively mean it will not be possible to sustain active water treatment options over the long-term.
- Limited options to further reduce loading from the upper mine workings.
- High iron concentrations leading to the formation of iron hydroxide sludges in water conveyances.
- Braided channel conditions in the Tulsequah River leading to highly variable flow conditions – and, therefore, variable amounts of dilution adjacent to and immediately downstream of the mine.

The discharge options currently under consideration include:

- Option 1 – Discharge of mine water from the 5900 level adit to Camp Creek which may provide sufficient dilution to reduce contaminant concentrations to levels that are acceptable for discharge before the mixed water is released to the Tulsequah River.
- Option 2 – Flow augmentation – to reduce contaminant concentrations to levels that are acceptable for discharge before the mixed water is released to the Tulsequah River.
- Option 3 – Deep injection of mine water to the alluvial groundwater aquifer beneath the Tulsequah River which will provide both dilution and dispersion of the mine water before potentially it reaches surface water within the Tulsequah River.

It is possible that some of these options could be used in combination with each other. It is also possible that other options may arise as a result of further investigations. For example, ENV and TRT have inquired about the potential to discharge mine water to the shallow aquifer at the Roger's Creek fan. While this option has not been explored further in this plan due to our perception that this would impact high value habitat at that location, this and other options may need to be further evaluated if none of the options below is found to be feasible.

The only discharge option that has been excluded from further consideration on the basis of existing information is active long-term treatment. Additionally, although passive treatment could be considered, a review of historic field test results showed it may not be viable at this site (SRK 2020a). A preliminary scoping discussion regarding the active-long-term treatment option is provided in Appendix I for information purposes; however, as noted this option is not being considered further at this time.

The closure measures described in Section 4 are expected to result in an appreciable reduction in the total loading to the Tulsequah River, which is one of the primary objectives of the closure plan. However, the reality is that source control measures are unlikely to reduce concentrations to levels that would normally be considered acceptable for direct discharge. As described in Section 4.4, concentration thresholds that are "acceptable for direct discharge" cannot be explicitly defined at this time and are likely to be constrained by the technical feasibility of the available options. As remedial plans for the Site advance, it is anticipated that site-specific risk-based performance objectives will be developed for aquatic receiving environments, including the Tulsequah River and Camp Creek, to manage the implementation of an IDZ, as described in

Section 2.4.5. Additional consultation with regulatory agencies and the TRTFN is required to determine the protection goals of site-specific risk-based performance objectives and how they would be developed and implemented at the Site. These protection goals would be revisited as the plan is implemented and adjusted as the Site impact changes and will be carried forward into the adaptive management plan for the Site.

Most of the discharge options listed above are expected to provide some mitigation of effluent water quality but are still expected to result in the potential for localized effects on the aquatic ecosystem within an IDZ, including potential for acutely toxic effects in the immediate vicinity of the discharge location. Option 3, deep injection of mine water, may reduce or eliminate the magnitude and spatial extent of potential effects, but will require much more extensive investigation and monitoring to demonstrate that there wouldn't be localized effects at some currently unknown location in the downstream environment. Selection of a preferred option will require further information on the technical feasibility, expected performance, and, regulatory and community expectations for the mine water discharges. Additionally, selection of a preferred option will likely require monitoring data from the period immediately following implementation of the source control measures described in Section 4.1.1.2 and 4.1.1.3. The plan would be to implement the source control measures and address critical information gaps so monitoring data that reflects implementation of the source control measures is available before a decision is made regarding discharge options.

The following sections describe each of these options, including the conditions that would need to be met for them to be selected, and the advantages and disadvantages of each. Additionally, critical information gaps associated with each option are discussed.

Regardless of the permanent mine water discharge strategy that is selected, it is acknowledged that temporary water management measures will be required during the detailed investigation and remediation construction phases of the project to ensure that metal loadings from the Mine Site do not increase as a result of activities such as draining the mine to allow access for inspection and survey, removal of waste rock from the river at 5200 portal area, and construction of bulkheads. Additionally, temporary water management measures would need to continue until metal concentrations in the flooded mine water stabilize to the point where they are suitable for discharge. The temporary water management measures may include total suspended solids removal, sludge management, diversion upgrades, silt fencing protection for construction runoff, and if required, temporary water treatment. The temporary water treatment technology has yet to be selected and would likely depend on the source and amount of flow to be collected as well as the logistics requirements for transporting reagents, fuel and, equipment to site. It is expected that an Interim Water Management Plan will be developed as part of remedial activity planning once more details of project execution are developed.

There is the potential to use the ATP already installed on site as a temporary treatment system; however, the condition of the plant is uncertain, and it may require substantial refurbishment. The ATP is a low-density sludge (LDS) lime neutralization system, where lime is added to increase pH and precipitate metals based on the respective solubility limits. The ATP was shut down in 2012 due to performance challenges and high operating costs. It is uncertain if the ATP is appropriately sized for treatment of all contact water flows generated during remedial works. Operation of the ATP would include reagent delivery to site and residuals management either at the Lime Sludge Pit or an alternate location.

5.1 Option 1 – Discharge to Camp Creek

5.1.1 Option 1 Description

Option 1 assumes that water would be discharged from the 5900 level adit to Camp Creek. It assumes water quality in discharges from the 5900 level would be below acutely toxic concentrations before entering the lower reaches of Camp Creek where benthic aquatic habitat is inferred to be present. Water from Camp Creek would then enter the Tulsequah River within an IDZ, which would be managed through the development and implementation of site-specific risk-based performance objectives. Uncertainties regarding discharge water quality, discharge flows, flows in Camp Creek, the amount of dilution required to bring concentrations to levels that are acceptable for direct discharge to the upper reaches of Camp Creek (where habitat value is inferred to be low) will all need to be resolved before the technical feasibility and performance of this option can be fully assessed and compared to other options.

The physical configuration of this option would be relatively straightforward. Discharges would be allowed to flow by gravity into Camp Creek. There would be minor works to create an erosion resistant channel from the mine workings to the creek and limit interaction of the mine discharge with waste rock at that location.

Depending on habitat characteristics at the mouth of the creek, it may be advisable to construct a fish barrier to prevent fish passage from the Tulsequah River into the mouth of Camp Creek.

The mixing zone within the Tulsequah River would extend from the mouth of Camp Creek to an unknown and possibly variable distance downstream of the creek (depending on the configuration of the braided river channels).

5.1.2 Option 1 Advantages and Disadvantages

This option is the simplest configuration and most robust in terms of minimal requirements for active control of discharges, conveyances and other structures. Notably, it would not require operation of a mine water discharge valve or any surface pipes.

This option provides some dilution to mine water flows in the event that no braided channels from the Tulsequah River are close to the Mine Site. Since dilution is provided by Camp Creek, no surface infrastructure is at risk of being lost during freshet flows or Jökulhlaups.

The main disadvantage is that the water quality in the 5900 discharge is unlikely to be below concentrations that are acceptable for direct discharge prior to mixing within Camp Creek, and so it is likely to rely on dilution within Camp Creek to meet those limits before discharging to the Tulsequah River.

Given the likelihood of impacts to aquatic resources in lower Camp Creek, ENV has commented that it may be difficult to justify and subsequently obtain an EMA discharge permit (if required) for this location but that it may be possible to obtain "habitat compensation" under the Fisheries Act which would alleviate the concern about impacts to the aquatic resources in lower Camp Creek.

Depending on both the discharge flows and the flows in Camp Creek – particularly during the winter low flow (or no flow) months, Camp Creek may or may not provide sufficient dilution before the mixed water reaches the Tulsequah River. Once in the Tulsequah River, there would still be a requirement for mixing with Tulsequah River flows for water quality to reach site-specific risk-based performance objective. Due to the braided nature of the river, this mixing zone may extend for variable distances downriver. Furthermore, this option does not address the iron staining and the negative optics that this brings to the Site.

Nonetheless, in comparison to the current situation, both the extent of the mixing zone and the concentrations within the mixing zone are expected to be mitigated due to the reduction in loading achieved by the closure measures described in Section 4 and the dilution provided by Camp Creek.

5.2 Option 2 – Flow Augmentation and Discharge to Tulsequah River

5.2.1 Option 2 Description

Option 2 assumes that water from either the 5900 or 5400 level adits would be discharged directly to the Tulsequah River with flow augmentation to reduce contaminant concentrations to levels that are acceptable for discharge. This option assumes extraction of water from the Tulsequah River or an uncontaminated groundwater source (well) to dilute the mine water prior to discharging into the river. It further assumes that flow augmentation (also referred to as dilution/blending) would be accepted by the regulators and TRTFN as a reasonable solution given the unique challenges presented at this site as outlined above. Flow augmentation is typically not considered a preferred approach since it does not reduce loading to the environment; however, is not prohibited under EMA in circumstances where risk management approaches are being employed. It can be appropriate if the assimilative capacity of the receiving environment is considered

As with Option 1 there would be a mixing zone or IDZ within the Tulsequah River which would likely be managed through the development and implementation of site-specific risk-based performance objectives. The mixing zone within the Tulsequah River would extend from the point of discharge to an unknown and possibly variable distance downstream of the creek (depending on the configuration of the braided river channels and the diluted discharge concentrations).

Key elements required to implement flow augmentation include:

1. Providing a reliable source of clean dilution water – this could include surface water diverted from the Tulsequah River upstream of the mine or groundwater drawn from a suitable location/depth to avoid drawing potentially contaminated mine water. Either approach would likely require a pumping system and a pipeline to convey clean water to the mixing system.
2. Development of a secure mixing environment to ensure that insufficiently amended mine water does not short circuit and discharge directly to the river – options include an open pond/channel or closed chamber configured to promote mixing or a piped system (e.g., incorporating a venturi device).
3. A means of discharge to the river – this could include a direct outfall pipe, release to an exfiltration pond hydraulically connected to the river or release to a subsurface gallery installed adjacent to the river at or below the river level.

The optimal configuration of the flow augmentation system requires further study to gain a better understanding of seasonal flows from the mine (i.e., post-flooding) and within the river, the amount of dilution required to bring concentrations to levels that are acceptable for direct discharge to the Tulsequah River potential complications due to water quality (e.g., potential for iron staining to occur within an open mixing pond or within the river, or for iron precipitate to cause fouling of the water conveyance and discharge systems.

Other components of the system would include the mine water conveyance from the 5900 or 5400 level adit to the flow augmentation system as further described in Option 3 below.

5.2.2 Option 2 Advantages and Disadvantages

Flow augmentation is a relatively simple solution that is not expected to require full time presence at the Site. Limited automated controls (e.g., flow adjustment) and telemetry would likely be sufficient to monitor the system remotely. The system would require periodic inspection and maintenance (e.g., to address potential iron fouling). Additionally, monitoring would be required to ensure that discharge quality consistently meets expectations as well as monitoring within the Tulsequah River IDZ to verify that site-specific risk-based performance objectives are met.

In comparison to both the current situation and Option 1 described in Section 5.1, isolating the mixing zone from aquatic life has many advantages that will need to be weighed against any residual uncertainties related to potential for iron staining/fouling and the technical challenge of providing a reliable clean water source. This option is like Option 3 described in Section 5.3 in this respect but is expected to be a much simpler and lower cost approach compared to deep injection.

At this time, the primary disadvantage of this approach is the large quantity of water that may be required to dilute contaminants (e.g., dissolved copper) in mine water to levels that are acceptable for discharge. Based on the current water quality of the 5900 adit discharge (up to 6,540 µg/L copper) and the modeled flow from the 5900 adit after the 5200 and 5400 portals are plugged (up to 12 L/s), 260 L/s of flow augmentation water would be required to reduce copper concentrations to 0.3 mg/L which is the current MDMER discharge limit. As noted above, post-flooding water quality at the 5900 adit may be found to be of better quality and lower flow than is currently seen. As well, determination of appropriate flow augmentation will depend on establishment of site-specific risk-based performance objectives as described in Section 2.5, above. As such, the feasibility of this option is uncertain.

5.3 Option 3 – Deep Injection to the Alluvial Groundwater Aquifer Beneath the Tulsequah River (Conceptual)

5.3.1 Option 3 Description

Option 3 assumes that water would be conveyed from either the 5900 level or the 5400 level to a deep injection system that would discharge the water into the alluvial aquifer beneath the Tulsequah River. This option assumes that the alluvial aquifer would allow for dispersion and dilution of the injected water such that any groundwater discharging from the alluvial aquifer to the overlying river would meet site-specific risk-based performance objectives. This assumption is particularly important given the information shared by the TRTFN regarding the importance of groundwater discharge zones for fish spawning in the clear channel areas of river.

Some uncertainties that could affect design or feasibility will need to be resolved before this option can be assessed in detail. These include aquifer geometry, hydraulic properties and the expected amount of dispersion (i.e., mixing with natural groundwater) within the aquifer, interactions with surface water and groundwater discharge areas, natural groundwater chemistry, and the potential for fouling of the injection well(s) (and potentially the surrounding aquifer formation) by iron hydroxide precipitates or other inorganic/organic constituents. Assuming moderate head loss due to water conveyance, no additional pumping pressure is expected to be needed for injection; however, this would need to be confirmed based on the transmissivity of the aquifer, design constraints of the conveyance system and the proximity of the injection point to the 5900 or 5400 portal.

The injection system could be configured in a number of different ways, which would be compared in a trade-off study. For example, the system could be configured as a large diameter groundwater injection well extending from the shore of the river out beneath the river channel (Figure 15), or as a vertical well in the river channel with a horizontal distribution pipe buried in the river gravels and extending across the river channel (Figure 16). Variants include either a low angle inclined well or horizontal well for the first concept; and either a vertical well in the valley center, or a relatively shallow buried horizontal screen for the second concept. Options will need to be considered further.

Under either configuration, mine water would ideally be conveyed in a pipeline by gravity to the injection pipe. The mine water would flow at the injected depth within the alluvial aquifer, mix with surrounding groundwater and disperse with distance from the injection location. The mixed groundwater would be assumed to discharge (i.e., "daylight") into surface water in the river, although where or even if that discharge would occur needs to be investigated.

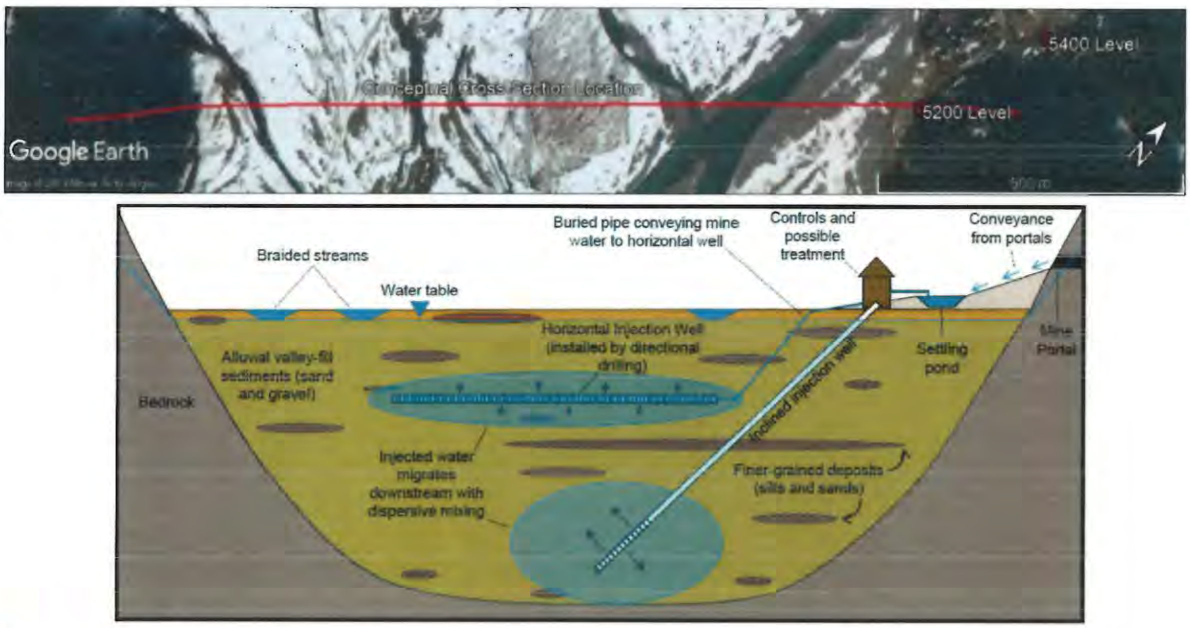

Figure 15: Conceptual Cross-Section Showing Inclined Injection Well Configuration

Preliminary estimates indicate that flows in the alluvial aquifer are at least three orders of magnitude greater than the flows from the Mine Site, indicating there is significantly greater flow in the aquifer than will be injected. Also, preliminary modelling suggests that significant dispersion could be achieved within the aquifer downgradient of the injection point. Dilution and dispersion of the mine water is expected to substantially reduce concentrations in groundwater before it daylights into the Tulsequah River. However, the extent of dilution cannot be quantified at this time due to limited data on the aquifer, with some of it conflicting (e.g., estimates of depth to bedrock differing by an order of magnitude). Also, the preliminary modelling does not account for dilution from surface water recharge to the aquifer (which would provide additional dilution) or the presence of low permeability confining units (which would isolate surface water from the effluent plume). It is possible that water treatment would be required for a period of time until the concept is proven through a targeted field monitoring program.

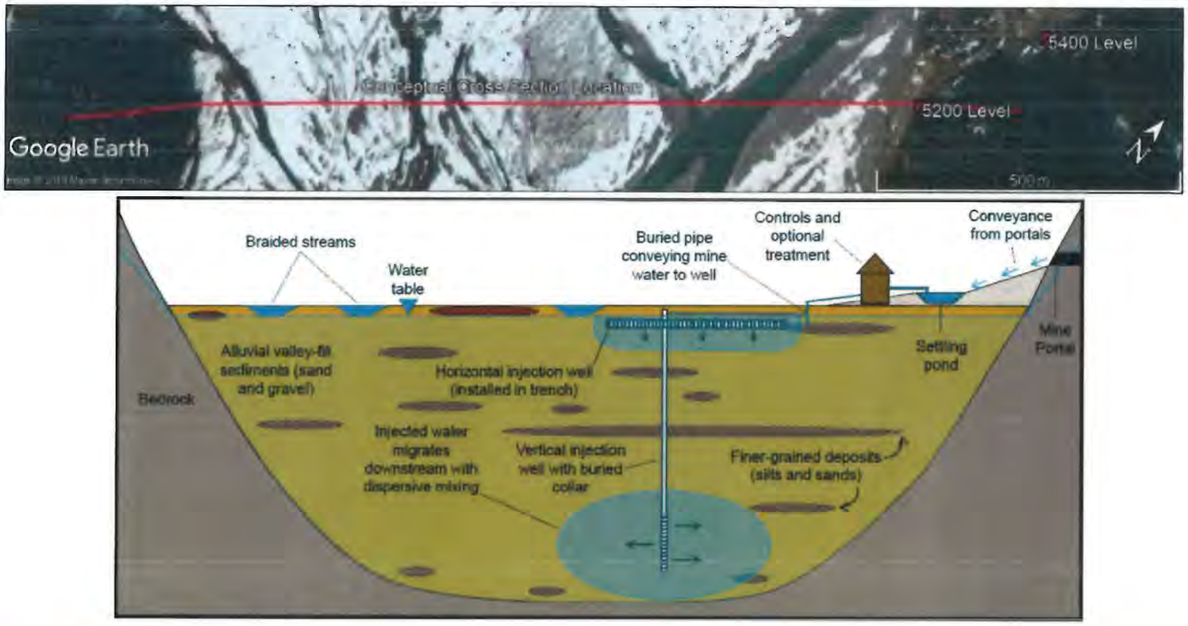

Figure 16: Conceptual Cross-Section Showing Vertical and Shallow Horizontal Well Configurations

Other components of the system would include the water conveyance from the 5900 or 5400 level adit to the deep injection system. Conceptually, discharge from the 5400 level would be preferred because it would eliminate the need to maintain a surface pipeline from the 5900 to the 5400 level. However, this would require operation of a water control valve through the 5400 level bulkhead that is activated when water levels within the mine approach the 5900 level (measured by pressure head at the 5400 level). Such a system would require additional instrumentation that would require periodic maintenance and access to the 5400 level bulkhead.

Additionally, ongoing flow of water through the mine may result in a more prolonged period of time when stored oxidation products within the mine are released into the mine water, which may result in somewhat higher loadings to the downgradient environment. An alternative approach would be to install a pipeline from the 5900 level down to the Lower Workings Area. The pipeline would also require periodic inspection and maintenance, but would be accessible without entering the underground workings, and would not require maintenance of a water control valve.

5.3.2 Option 3 Advantages and Disadvantages

The main advantage of the deep injection option is that the mixing zone or IDZ could potentially be entirely within the alluvial aquifer, effectively eliminating exposure of aquatic life to water that would not be acceptable for direct discharge. At a minimum, it would greatly reduce concentrations within an IDZ. The need for, and spatial extent of, a mixing zone will depend on the actual amount of mixing achieved within the aquifer downgradient of the injection point(s) and the location where this water discharges to surface water. The degree of certainty with which these factors can be estimated depends on the quantity and quality of data obtained regarding mine discharge quality, receiving water quality and aquifer conditions at and downgradient of the injection location. This option also assumes that it is acceptable to release acutely toxic mine discharge from a point source to the groundwater environment (i.e., the aquifer), noting that although there would be no receptors at the release point, this is not a conventional practice.

Installation of injection wells would require mobilization of suitable conventional or directional drilling equipment and supplies to the Site, presumably by barge although potentially by helicopter. Either mobilization approach would be costly and would come with schedule risks (e.g., short barging season, weather conditions affecting helicopter access, etc.).

The system would require periodic inspection and maintenance. Maintenance issues that may arise include leaks (e.g., at the injection well packer, casing or well head), well screen corrosion, and fouling of the well screen, surrounding formation materials and/or conveyance piping. In particular, fouling due to formation of iron hydroxide precipitates (or other organic/inorganic constituents) is an important factor which could be detrimental to successful implementation of this option. Additional data regarding aquifer chemistry at potential injection sites is needed to better understand this risk and its implications with respect to injection well maintenance and replacement timeframe. For purposes of estimating maintenance costs (Appendix II), we have assumed biennial maintenance is required to address fouling/leaks and that this can be accomplished using equipment and materials that can be transported to site by small aircraft (i.e., service drill rig not required). This could limit the size (diameter and screen length) of well that can installed and maintained at the Site. Resolution of these factors is necessary to fully evaluate the feasibility of this option and compare it to other options.

Due to the importance of groundwater discharge areas to fish in the Tulsequah River, it would require a targeted and potentially extensive monitoring program within the Tulsequah River to demonstrate that groundwater quality in these discharge areas is not affected.

In comparison to both the current situation and Option 1 described in Section 4.1, isolating the mixing zone from aquatic life has many advantages that will need to be weighted against any residual uncertainties related the potential for localized groundwater discharge zones.

6 Expected Performance

6.1 Water Quality and Contaminant Loads

The Project Team developed a water and load balance to estimate the current loadings to the environment and predict changes in concentration and loading that would occur for potential closure options (SRK 2020b). For the purposes of this evaluation, the model was used to assess the potential concentration and load reductions that could be expected following implementation of the closure plan described in Section 4, and the discharge options presented in Section 5. The model is a conservative mass balance and does not account for geochemical sinks (e.g., the precipitation of solids along a flow path or the precipitation of low pH mine water when introduced to atmospheric conditions). The evaluation of water quality and contaminant loading reflects medium to long-term performance following implementation of the proposed closure measures. It does not consider the potential for increased loading that could occur during and immediately following flooding of the underground mine.

The primary closure measures described in Section 4 reduce the loadings that will be discharged from mine workings and waste rock dumps. Load reductions are expected to occur as a result of covering of the lower waste rock dumps with a multi-layer low permeability cover (reducing seepage flows from the waste rock dump), the flooding of the lower workings up to the 5900 level (both by reducing the amount of mineralized rock exposed to oxidation and by reducing groundwater inflows to the mine), and capping of all shafts and vents in the upper workings (reducing mine inflows from runoff and precipitation). The model simulates the changes in sulphate and metal concentrations resulting from flooding of the workings using results from historical monitoring of the 5900 discharges during a brief period when the majority of the mine inflows to the 5900 level were prevented from flowing to the lower workings and were instead allowed to discharge from the 5900 portal. The assumed changes in groundwater and surface water inflows are documented in SRK 2020b.

The different mine water discharge options described in Section 5 reflect differences in the way that the water is introduced to the receiving environment. None of the options result in any further reductions in loading, although arguably deep injection (Option 3) is expected to reduce the amount of load that mixes with surface flows in the Tulsequah River.

Concentration estimates from the water and load balance are presented in Table C and loading estimates are presented in Figures 17, 18 and 19 for sulphate, dissolved copper and dissolved zinc respectively. A completed set of parameters is presented in the water and load balance memo (SRK 2020b).

The model results show a significant reduction in concentrations and loadings following implementation of the mine discharge approaches described in Section 5 (shown as Options 1 to 3) when compared to the modelled current conditions.

Table C: Estimated Concentrations of the Combined Discharges from the Tulsequah Mine Site for Remediation Options

Flow Condition	Estimated Concentrations					
	Dissolved Sulphate (mg/L)		Dissolved Copper (mg/L)		Dissolved Zinc (mg/L)	
	Model: Current Conditions	Model: Options 1-3	Model: Current Conditions	Model: Options 1-3	Model: Current Conditions	Model: Options 1-3
Very Low Flow	540	260	16	4.9	77	35
Low Flow	540	260	16	4.9	77	35
Medium Flow	460	250	13	4.8	64	34
High Flow	430	260	12	4.9	60	34

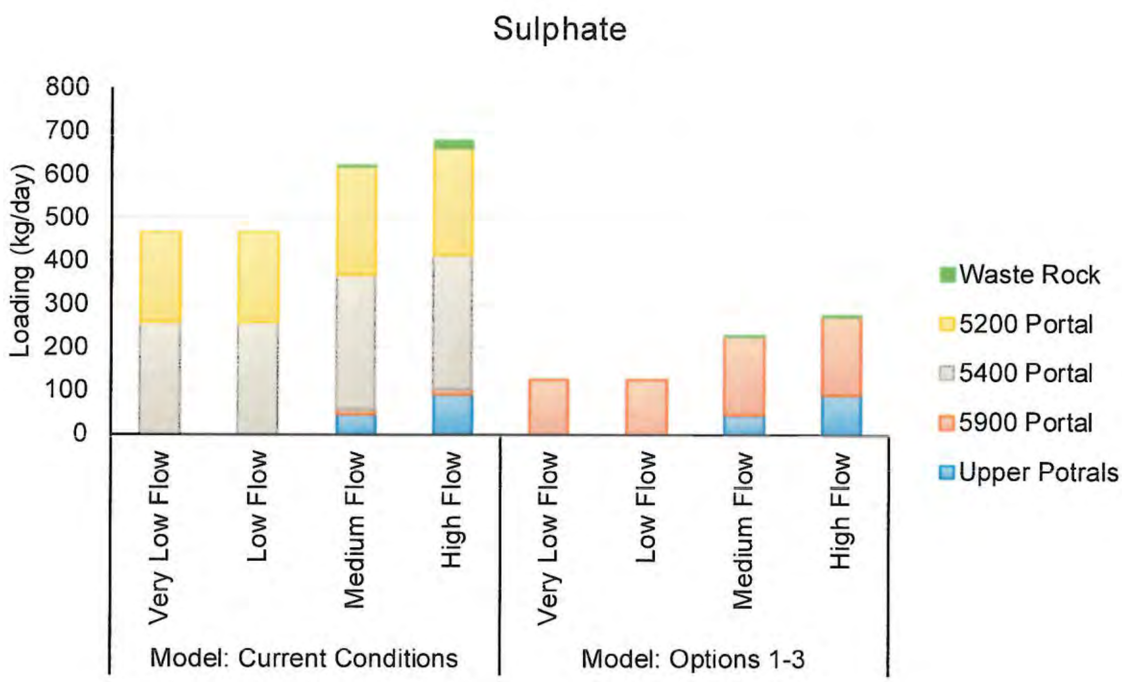

Figure 17: Comparison of Sulphate Loading from the Tulsequah Mine Site for the Proposed Remediation Plan and Discharge Options

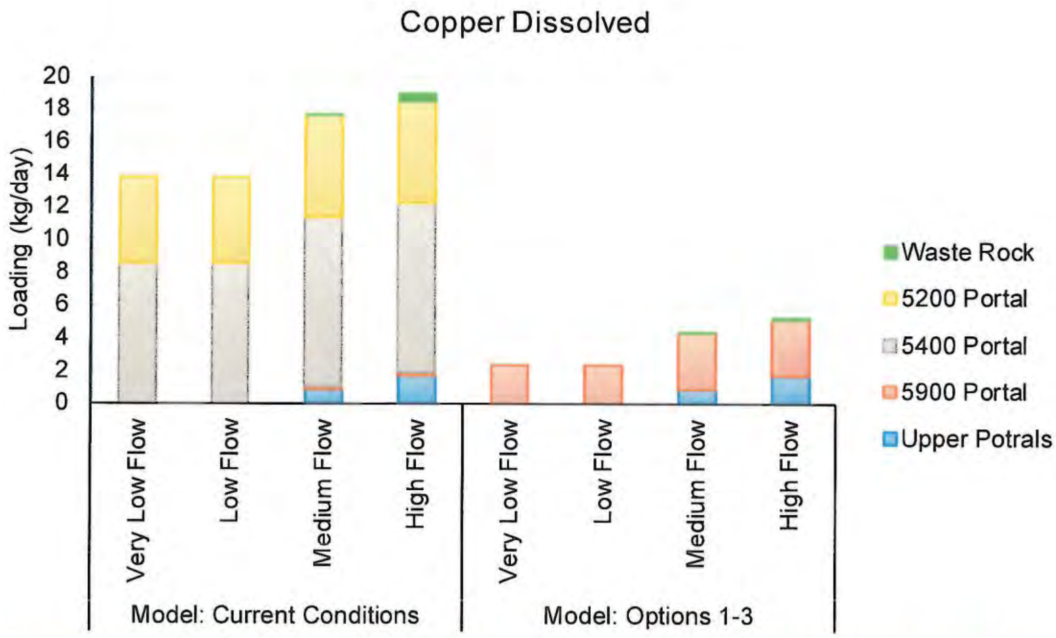

Figure 18: Comparison of Dissolved Copper Loadings from the Tulsequah Mine Site for the Proposed Remediation Plan and Discharge Options

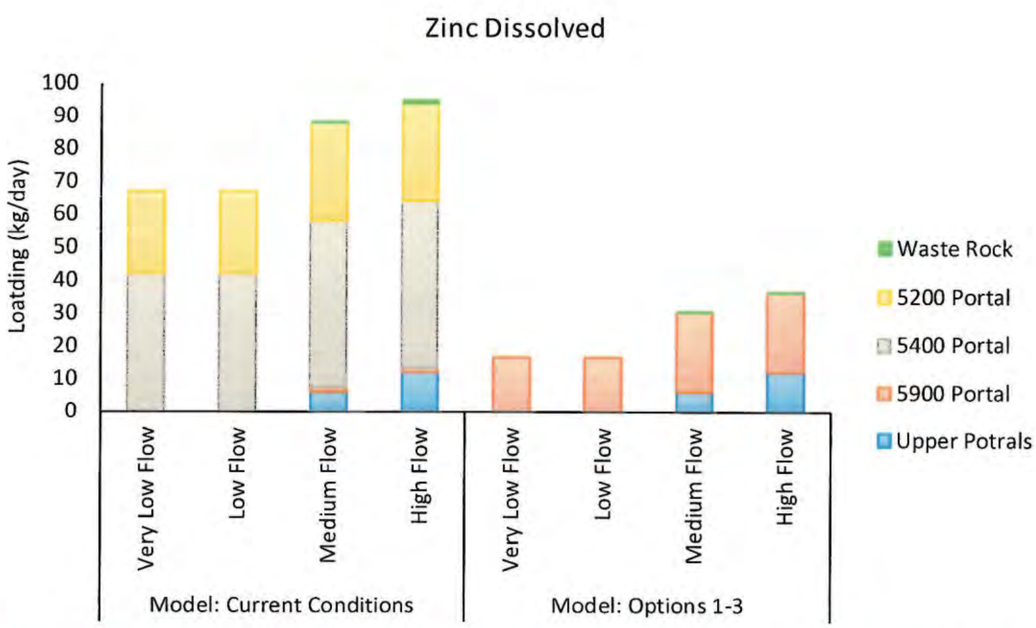

Figure 19: Comparison of Dissolved Zinc Loadings from the Tulsequah Mine Site for the Proposed Remediation Plan and Discharge Options

6.2 Human Health and Ecological Risk

6.2.1 Human and Ecological Risks

A risk evaluation of current (baseline) human health and terrestrial ecological risks associated with the presence of mine waste in the Upper and Lower workings is provided in SNC-Lavalin 2020a. Aquatic risks in the Tulsequah River associated with mine water discharge have been evaluated in previous risk assessments, as summarized in Section 2.4.5. Brief overviews of anticipated reductions to potential risks identified for humans and ecological receptors are provided in the sections below.

6.2.2 Human Health Risks

The recommended remedial measures for mine wastes associated with the Lower Workings, including consolidation and covering of mine waste associated with the 5200 and 5400 levels will ensure the exposure pathway between human receptors and soil COPCs will no longer be operable, thus removing the potential for unacceptable incremental risks to campers and workers frequently accessing this area.

No remediation measures are proposed for the Upper Workings. Due to inaccessibility, it is unlikely that Site visitors or campers would be exposed to soils contaminated with mine waste in the Upper Workings area. If conditions at the Site were to change and the mine wastes at the Upper Workings were to become more accessible (i.e., if a roadway is constructed to the upper workings) human health risks associated with Site visitor and camper potential direct contact with mine waste should be re-evaluated.

Under the assumption that Site workers might require frequent access to the Upper workings area, risk estimates indicated potentially unacceptable incremental risks associated with exposure to these soils. Therefore, if workers are likely to require access to the Upper Workings area (e.g., to maintain remedial systems, etc.), risks would need to be controlled administratively, through the application of signage and requirement to wear appropriate PPE to reduce potential exposure to contaminated soils.

Further consultation with TRTFN and stakeholders should be conducted to confirm anticipated and/or desired future land use at the Site, to ensure that the exposure frequency and duration assumptions applied in the risk evaluation are accurate and adequately conservative. Additional consideration to the indirect exposure pathway of ingestion of edible vegetation should also be considered at that time.

6.2.3 Terrestrial Ecological Risks

As outlined in Section 2.4.3, results of the preliminary risk evaluation indicate that there are potential risks to terrestrial ecological receptors associated with current conditions at the Site for plants, soil invertebrates and wildlife with small home ranges at the Lower Workings area. The recommended remedial measures for mine wastes associated with the Lower Workings include consolidation and covering of mine waste associated with the 5200 and 5400 levels; following consolidation and covering of mine waste, the direct contact exposure pathways between most terrestrial ecological receptors and soil COPCs will no longer be operable, thus removing the potential for unacceptable incremental exposure and risks to terrestrial ecological receptors in this area.

The risk evaluation also indicated the potential for risks to select terrestrial ecological receptors (primarily vegetation, soil invertebrates, wildlife with associated small home ranges, and/or small burrowing mammals [if present]) associated with exposure to mine waste in the Upper Workings area. It is unlikely that contaminated soils at the Upper Workings would result in significant risks to larger wildlife with associated larger home ranges. However, habitat quality that is currently and/or could be provided in the future by the Upper Workings area is unclear. As the above strategy for managing risk to human receptors (i.e., administrative controls) would not be effective for managing risks to ecological receptors, further study (e.g., biological/habitat survey) will be carried out to support the completion of a more detailed terrestrial ecological risk evaluation for this area of the Site, which will be used to confirm the absence of unacceptable risks to ecological receptors such that active risk management approaches are not required to address contaminated soils at the Upper Workings of the Site.

6.2.4 Aquatic Ecological Risks

Potentially unacceptable risks to aquatic receptors in relevant receiving environments, primarily the Tulsequah River, have been identified in previous risk assessments related to the Site. As acidic mine discharge water currently flows directly from the Site into the Tulsequah River, COPCs in this receiving environment are present at concentrations that could result in adverse effects to aquatic life, including primary producers, invertebrates and fish. Current mine discharge entering the Tulsequah River is highly acidic and exhibits elevated metal concentrations well above BCWQG, and is almost certainly acutely toxic to aquatic life at the point of entry into the River. The extent of potentially acutely toxic concentrations in the River likely varies with changes in flow in the River over time and has not been specifically defined; however, results of previous risk assessments have predicted potential chronic effects to aquatic life at distances of up to and beyond 2.7 km downstream of the Mine Site (as described in Section 2.4.5).

All three options proposed herein for the management of mine water discharge presented in Section 5 have been developed with the objective of reducing concentrations of COPCs prior to discharge into the Tulsequah River. The feasibility of these options in reducing the magnitude and spatial extent of water that is potentially acutely toxic to aquatic life will be further investigated as additional information is gathered and methods analyzed in detail. All four options are expected to rely, to some extent, on the implementation of an IDZ in Camp Creek and/or the Tulsequah River, in which levels of COPCs dilute from the point of discharge to the edge of the IDZ plume to concentrations that are not likely to result in unacceptable effects to aquatic life. IDZs in Camp Creek and /or the Tulsequah River will likely be managed through the development and implementation of site-specific risk-based performance objectives.

Option 1 proposes to discharge mine effluent water into Camp Creek; in effect, water from Camp Creek would be used to naturally augment flow. This Option would ultimately likely result in potentially unacceptable risks to aquatic life in Camp Creek. However, habitat value of the Creek is likely relatively low, as it is not known to be fish-bearing (with the exception of the lowest reach of the Creek, before it enters the Tulsequah River). A habitat assessment of Camp Creek to further evaluate the quality of aquatic habitat provided by this watercourse will be completed.

Options 2 and 3 both propose to augment flows outside of receiving environments to decrease COPC concentrations prior to discharge of mine water into the Tulsequah River surface water. Option 2 proposes to achieve concentration reduction through a land-based system, while Option 3 proposes to achieve this by injecting discharge water into the aquifer to allow dilution to occur in the aquifer below the river. Since aquatic life receptors are not present in either of these environments where dilution is occurring, reduced effects to aquatic life would be anticipated. For Option 2, potential risks to aquatic life would be managed through the implementation of an IDZ within the Tulsequah River. The aquifer dilution afforded by Option 3 may be sufficient to lower COPCs to concentrations less than chronic toxicity thresholds before water enters the Tulsequah River receiving environment and may disperse the loading to the extent that an IDZ would not be required, although further investigation is required to determine the feasibility and dilution that would be achieved if this Option is implemented. Consideration will also be given to the uncertainties associated with this option and the lack of certainty with respect to the re-entry into the surface water location.

While the extents of the IDZs associated with each of the options described above are not well-understood at this time, all options are intended to result in a reduction in concentrations of COPCs and anticipated reduction in the size of the present mixing zone that is currently occurring within the Tulsquah River. As a result, the impacted area of the river would be reduced, and risks to aquatic biota would not occur as far downstream as they are currently predicted to be present. Further information regarding the feasibility and performance of water management options will inform further evaluations of potential risks to aquatic life which will in-turn inform decision making regarding mine water discharge management.

7 Monitoring and Maintenance

Expected monitoring and maintenance requirements for key aspects of the closure plan are outlined in the sections below. For certain closure elements, there is substantial information available and/or the closure actions are sufficiently well defined to support development of monitoring and maintenance requirements in some detail. For other elements, the closure activities are defined in less detail pending further site investigation and so there is only a high level understanding of the monitoring and maintenance requirements as reflected in the sections below.

An Adaptive Management Plan (AMP) will be developed for the monitoring and maintenance of the environmental effects monitoring post closure. The purpose of an adaptive management strategy is to identify/mitigate potential impacts to the receptors identified to be potentially at risk after the closure plan has been completed. The AMP includes the details of the environmental endpoints to be monitored and has specific measurable target which can be compared to the risk-based benchmarks that would correlate to stakeholder and First Nations notification to address uncertainties in the Closure Plan as outlined in Section 8. The mitigation outlined in the AMP may include the following aspects that would be developed as part of the monitoring and maintenance program.

- Change in monitoring frequency, assessment and/or water treatment performance;
- Change in maintenance of closure aspects for APECs; landfill and cover monitoring and maintenance, etc.;
- Risk assessment, communication, and/or agreements with affected stakeholders and First Nations; and
- Additional remedial measures due to contaminant load reduction measurements.

The monitoring and maintenance plan, risk management plan and adaptive management plan become part of the comprehensive closure plan.

7.1 Receiving Environment

An AEMP will be developed for the Tulsequah River and Camp Creek: to monitor potential risks and effects to aquatic life associated with site inputs over time, to validate modeled predictions of discharge concentrations and rates of dilution and to verify the adequacy of protection of aquatic life afforded through the development and implementation of site-specific risk-based performance objectives. The monitoring program will be developed in accordance with BC ENV (2016 and 2019), and thus will be based on a conceptual site model for the effluent discharge to assess changes of physical, chemical and biological characteristics of the receiving environment within and at the edge of the IDZ relative to both baseline (i.e., conditions prior to remedial efforts) and natural background conditions. The methods and data evaluation protocols of the AEMP will also align with EC (2012) guidance on metal mining Environmental Effects Monitoring (EEM), where practicable, as many of the monitoring endpoints outlined in the AEMP will relate to those employed for EEM programs. Furthermore, the AEMP will also be supported by the Canadian Aquatic Biomonitoring Network (CABIN) site characterization and sampling protocol methods prescribed by ECCC, to ensure consistency of information collection at site sampling locations, and to enable comparisons of biomonitoring results to a shared database monitoring results for aquatic biological communities across BC.

The monitoring program will be designed and initiated prior to the initiation of remedial efforts at the Mine Site to collect relevant data to establish baseline conditions and to establish natural variability at the discharge and upstream reference locations. The AEMP will be developed in consultation with regulators and TRTFN.

Components of an AEMP will include the following:

- Effluent monitoring – effluent characterization sampling and potential toxicity testing for acute and chronic endpoints;
- Effluent characterization will include collection and evaluation of effluent samples for general chemistry parameters, inorganic parameters (e.g., nitrate, sulfate, etc.) and metals. Field collected data, such as water temperature, pH and dissolved oxygen concentrations will be recorded for all samples.
- Toxicity testing may be used to evaluate effluent toxicity to relevant receptors, if deemed appropriate. Lethal and/or sub-lethal toxicity testing for freshwater organisms could be performed, and would typically be done for a relevant invertebrate, algal and fish species.
- Receiving environment monitoring – will be performed in exposure and reference areas and will include characterization of the following components:
- Site characteristics / physical conditions – substrate characteristics, water depth and flow rate will be recorded at sampling locations. At the outset of the AEMP, in the establishment of baseline conditions, habitat mapping should be included as part of the site characterization; aquatic habitats will be classified and mapped at selected reference locations and within the anticipated exposure zone. Adequate characterization of physical conditions at the sampling locations is integral to the effective interpretation of collected data, particularly for the biological monitoring results. Reference sampling locations will be selected to closely match the site characteristics of sampling locations selected within the exposure zone.
- Water quality – surface water samples will be collected and analyzed for general chemistry parameters, nutrients and metals. Field collected data, such as water temperature, pH and dissolved oxygen concentrations will be recorded at all sampling locations. If the point of effluent discharge is located below the riverbed, monitoring locations, specifically for water quality, may occur at one or more depths within the water column to ensure that maximum concentrations and subsequent dilution are captured in the IDZ samples.
- Sediment quality – sediment samples will be collected from select surface water sampling locations, and analyzed for grain size, general chemistry parameters and metals.
- Biological monitoring – benthic invertebrate community and fish population surveys, along with tissue sampling will occur at select locations. Community indices will be evaluated for exposure sites and reference sites, and statistically significant differences in population and/or community composition between these sites will be identified.
    - Benthic invertebrate community surveys will be performed to evaluate the potential for effluent effects on fish habitat (i.e., as invertebrates serve as fish food). Effect endpoints to be evaluated for benthic invertebrate communities include total benthic invertebrate density, evenness index, taxa richness and similarity index (e.g., Bray-Curtis index).
    - Metal concentrations in benthic invertebrate tissue samples will be measured to assess potential effects to consumers of benthic invertebrates, namely fish and wildlife. Potential risks

to fish and wildlife will be evaluated using ecological risk assessment methods, in accordance with guidance prescribed by ECCC.

- Fish population surveys will be performed as measured indicators of fish population health in exposure and reference areas. Fish population survey effect indicators include growth (size), reproduction (relative gonad size), condition (body weight compared to length, relative liver size) and survival (age). Two species of relatively sedentary finfish will be selected as "sentinel species" for inclusion in the program, in consideration of potential exposure (e.g., mobility and residence time), abundance and relevance to the study area; at least one of these species should be a benthivore. A likely candidate species for inclusion in this program is slimy sculpin, which are non-migratory, easy to capture and tend to be relatively abundant. The second species could be Dolly Varden, which could be sampled using non-lethal methods. Appropriate field sampling methods will be selected once sentinel species have been identified.
- Metal concentrations in fish tissue will be measured to assess potential effects to consumers of fish, including humans and wildlife. Potential risks to humans and wildlife will be evaluated using human health and ecological risk assessment methods, in accordance with guidance prescribed by Health Canada and ECCC. As stated above, at least one of the species to be selected for tissue analysis should have limited mobility/a relatively small home range; if this is not possible, evaluation of an indicator of exposure to the effluent (e.g., liver enzyme induction, stable isotope evaluation, or temporal evaluation of concentrations measured in tissues over time) will be incorporated into the monitoring program. Non-lethal methods for sampling and analyzing fish tissue metals concentrations are preferred, when possible.

Monitoring locations within the receiving environment will be located well upstream of all historical mine operations, as well as select locations included in previous sampling programs located adjacent to and downstream of the Mine Site. In selecting appropriate reference sampling locations, consideration will be given to the location of confounding influences, the habitat type, site access and other potential characteristics that may affect the mobility of relevant fish species. Additionally, as ENV and TRTFN have identified Zone 2 as a preferred IDZ monitoring locations will be set along the downstream edge of Zone 2 and at a distance across the width of the river, where the plume is predicted to cross the Zone 2 boundary. To the extent possible, sampling locations for all receiving environment AEMP components (i.e., water quality, sediment quality, biological monitoring) will be co-located.

Monitoring to inspect the condition of the outfall/diffuser structure is also recommended. Details regarding sampling design, methods, frequency, sample handling, analytical methods, data reporting and quality assurance/quality control practices will be included in the monitoring plan. Rationale for the selection of appropriate fish species, sampling areas, sample size, sampling periods and field and laboratory methodologies will also be provided in the AEMP.

The frequency of monitoring events may evolve as conditions start to stabilize following the completion of remedial efforts but are recommended at a relatively high frequency during the initial baseline data gathering phase and subsequent remedial phase, to capture natural variability over time, as well as shifts associated with changing conditions initiated by remedial efforts at the Mine Site. The frequency of monitoring will vary by AEMP component; effluent and water quality sampling is projected to occur quarterly, while sediment quality sampling and biological monitoring will occur annually with the exception of fish population/tissue metals concentration sampling and analyses, which will occur biennially (every other year). Interpretative reporting of collected data and information will be produced annually.

7.2 Mine Water Discharge

7.2.1 Interim Water Management

As described in Section 5, interim water management will be required during field investigations and implementation of remedial activities to ensure that metal loadings do not increase as a result of these activities. The interim water management plan will need to include ongoing performance monitoring. A detailed interim water management plan will be developed once more details around potential field investigations and the remedial activities are defined. Monitoring of any water management measures in place will be required and included in the interim water management plan.

7.2.2 Monitoring Requirements for Mine Water Discharge

For a period of time following implementation of the closure plan, mine water discharges will need to be sampled on a regular basis for total and dissolved metals, general parameters and anions. Toxicity samples will need to be collected prior to discharge and once a month during discharge. The frequency of these sampling events can be lowered once performance is proven. These samples will be flown off site for testing by a regulated laboratory. Mine water discharge flows should be logged continuously with a flow meter.

The water level in the flooded mine should be recorded either through pressure or level readings. The system should be able to transmit this reading to a receiver/data logger at the Portal entrance to minimize the number of trips underground required by site personnel.

The various mine water discharge options would have more specific monitoring requirements such as:

- Any pipeline conveying contact water from either the 5400 or 5900 Portals shall be equipped with a leak detection system to alarm if there is any loss of flow from the pipeline.
- Pressure monitoring will be required on any deep well injection system to asses if clogging of the injection wells or surrounding gravels are becoming clogged.
- If active water treatment is required, the plant will require ongoing monitoring for a number of internal factors, for example neutralization pH. Monitoring requirements would be included in the operational manual and specific to the treatment option.
- Install and monitor groundwater wells around the permanent sludge repository.

Groundwater monitoring for any remedial works will be required to understand water quality improvements. Baseline groundwater quality monitoring data will be useful, but not essential, in understanding these improvements resulting from the remedial works.

Monitoring of the slopes surrounding the flooded mine workings for daylighting seepage and potential flowing exploration boreholes will also be required. The monitoring would be conducted on a regular basis at elevations lower than the flooded mine level. Monitoring would consist of visual reconnaissance for seepage areas and flowing boreholes, and if possible collection of samples for field and laboratory analysis to evaluate whether the water is representative of mine water. The need for monitoring the slopes should be reviewed on an annual basis as it is expected that the frequency can be reduced after the flooded mine reaches steady state.

If the deep well injection system (Option 3) is selected, an extensive monitoring program will need to be established. Conceptually, this would consist of monitoring of injection rates and concentrations at or before the injection well but also monitoring of surface water and pore water at: groundwater discharge areas downgradient of the injection point (if known); transects where groundwater discharge may be expected based on modelling; any identified downstream sensitive habitat (e.g., Rogers slough, clearwater side channels, etc.) and, upstream reference locations (surface water only). It is very likely that any groundwater monitoring wells will be destroyed during the Jökulhaups events; however, if it is possible to establish downgradient groundwater monitoring wells that would not be destroyed monitoring should also be conducted at those points. Monitoring would consist of collection of samples for field and laboratory analysis, and if possible, flow measurements in surface water for loading calculations.

7.2.3 Maintenance Requirements for Mine Water Discharge

Routine maintenance would be required on all conveyance networks to prevent erosion of the pipeline corridor and to maintain a flat graded surface. The pipeline would be constructed with flanged connections at every 4 to 5 pipeline lengths or at critical or easy to access points, so that sections of pipeline can be changed out easily.

The airstrip, camp and barge landing facilities may all need to be maintained depending on the closure plan selected.

7.3 Monitoring Maintenance Requirements for Ground Stability, Closure of Mine Openings and Bulkheads

Assuming the results of additional investigation confirm the preliminary findings, potential ground stability issues in the crown pillar area will be addressed through ongoing monitoring. Due to hazards posed by the steep terrain, ongoing monitoring would be comprised of an aerial survey of the crown pillar area. This would be supplemented by periodic CMS scans to determine if there have been any changes related to crown pillar degradation. Inspections would initially occur every two years and would increase to a maximum of once every five-years once ongoing stability is confirmed.

For bulkheads and caps/closures installed at mine openings, monitoring would consist of periodic geotechnical inspection and monitoring for leakage around caps and bulkheads to confirm these built features are stable and continue to function as intended. Inspections will be carried out annually until stable conditions are confirmed, after which time the frequency can be reduced.

Ongoing monitoring of pressure inside the mine will also be conducted to verify the depth to which the mine is flooded and to identify potential pressure build-up that could result in additional leakage of mine water or compromise the integrity of the bulkheads.

7.4 Maintenance Requirements for Storage Facilities and Landfills

Post-closure monitoring and maintenance activities for the landfill at Paddy's Flats and the covered waste rock storage facility at the Lower Workings will include the following:

- Annual leachate management including disposal (i.e., through the mine discharge works);
- Annual maintenance and cleanout of surface water conveyance infrastructure including drainage ditches;
- Annual inspection and maintenance of vegetation on the covers as required to establish and sustain vegetation (e.g., irrigation and reseeding as needed) and prevent erosion of the covers;
- Biennial removal of trees from the covers;
- Biannual leachate sampling, analysis, and reporting;
- Biannual leachate quantity monitoring and reporting; and
- Biannual groundwater sampling, analysis, and reporting.

The frequency of monitoring should be reviewed annually and can be reduced once expected performance and stable conditions are confirmed.

7.5 Maintenance Requirements for Erosion Protection

Where rip rap armoring is utilized to resist erosion from river flows, the subject segments of the riverbank, and nearby segments, should be visually monitored on an annual basis in summer, complete with photographic documentation of the conditions. Oblique aerial (from aircraft) and ground-based photographs should be collected and compared to prior year images for an analysis of river geomorphics and the performance of armored and unreinforced riverbanks related to infrastructure like roads, the lower workings area, and the airstrip. Repairs, if required in the short-term or long-term, should be specified based on the actual conditions and future use requirements at that time.

7.6 Maintenance Requirements for Roads and Bridges

Depending on the closure options implemented, some or all sections of the access road and bridges between the barge landing and airstrip may need to be maintained in a relatively accessible condition to allow for emergency and maintenance access for the longer-term. The road running surface will likely become overgrown by vegetation such as alders and grasses during periods of disuse. Annual visual inspections of the road should be conducted and documented with photographs and a summary report, comparing to previous years' observations. Specific attention should be applied to surface and river erosion, fill slope and cut slope stability, and bridge abutments. Site specific repairs should be prescribed based on actual conditions and future use requirement.

8 Data Gaps and Uncertainties

Table D summarizes the key remaining data gaps and uncertainties and outlines further investigation work required to address these. Information obtained through completion of future work may result in changes (additions or deletions) to this list as closure planning proceeds and options are further refined and evaluated. Costs associated with completion of these detailed data collection activities are not included in the estimated closure costs presented in Appendix II.

Table D: Summary of Data Gaps and Future Studies

Topic/Subject Matter	Data Gap	Description	Relevance / Dependencies
Site Readiness and Logistics	› Feasibility of suppling materials and equipment to site for closure plan implementation; › Requirements for maintaining crews on site for closure plan implementation; › Consider immediate and long-term needs to facilitate all options.	› Logistics study to supply site by barging, smaller craft, air (fixed wing and helicopter); › Includes methods for transport of hazardous waste materials (primarily liquids) for off site disposal; › Assess camp services needs to support workforce.	› Clarify site constraints relevant to closure planning.
Interim Water Management	› Prepare interim water management plan.	› Consultation with EMPR, ENV, TRTFN to establish objectives for interim water management (e.g., no worse than current conditions, or other); › Address timing, duration, location, water quality and quantity associated with detailed investigation and remediation activities.	› Temporary water management needed during removal of 5200 waste rock from river, during mine rehabilitation and during bulkhead construction to prevent metal loadings from increasing during these activities.
	› Active water treatment.	› Water treatment plant (WTP) trade off study – existing LDS vs HDS.	› Active treatment may be needed during closure implementation phase depending on objectives.
Crown Pillar Stability Assessment	› Detailed evaluation required.	› Review recently obtained historic mine plans and documents to determine stope geometry; › Collect rock mass data for upper mine; › Conduct cavity survey of upper stopes where possible.	› Validate preliminary findings that crown pillar remediation is not required.

Table D (Cont'd): Summary of Data Gaps and Future Studies

Topic/Subject Matter	Data Gap	Description	Relevance / Dependencies
Upper Workings (access and infiltration control)	› Uncertainty regarding the total number of vertical excavations that breach the surface in the upper workings; › Cap constructed during the Chieftain/Redfern era is considered unlikely to have met the BC regulatory requirements.	› Review recently obtained mine plans to identify potential shafts and raises; › Review of existing cap; › Field assessment of vertical excavation locations; › Determine rock mass properties; › Detailed 3D laser survey of openings using LiDAR.	› Eliminate physical hazard and reduce potential water ingress to mine; › Support design of prefabricated caps/closures to meet BC closure regulations.
Mine Water Control / Bulkhead Design	› Data needed for detailed design of bulkheads at 5200/5400 and water control infrastructure at 5900.	› Mine rehabilitation to clear blockage at 5900 level (water treatment will be required); › Targeted geotechnical drilling and mapping of underground workings (assume heli-portable equipment); › Detailed 3D laser survey of openings using LiDAR.	› Allow an inspection and collection of geotechnical and hydrogeologic data during the 2020 field program; › Required to determine rock mass properties to support bulkhead design; › Required to support bulkhead design.
Mine Water Discharge	› 5900 water quality (post-flooding).	› Ongoing seasonal monitoring of 5900 and 5400 water quality and flows.	› Establish changes in 5900 water quality and flows as/after mine is flooded; › Determine treatment/dilution requirements (flow and concentration), and fouling potential for conveyance, treatment or injection systems.
	› Potential for leakage from flooded mine.	› Monitor for seepage from exploration boreholes and other sources during flooding of mine so that these can be opportunistically plugged.	› Maximize control of mine water.
	› Camp Creek seasonal flow.	› Ongoing monitoring of Camp Creek quality and flows; › Confirm of refute if the creek is frozen in the winter.	› Dilution capacity within Camp Creek.

Table D (Cont'd): Summary of Data Gaps and Future Studies

Topic/Subject Matter	Data Gap	Description	Relevance / Dependencies
Mine Water Discharge (Cont'd)	› Water conveyance from 5900 to Mill area.	› LiDAR of pipeline route.	› Required to support design of pipeline.
	› Shallow hydrogeology adjacent to mine.	› Hydrogeological investigation (shallow drilling) of shallow aquifer adjacent to mine.	› Verify current and future loading to river via shallow groundwater pathway; › Assess capacity of shallow infiltration gallery / exfiltration pond.
	› Deep injection feasibility.	› Hydrogeological investigation (deep/angled drilling) and geophysical investigation of aquifer; › Field pilot testing and monitoring (proof of concept) – e.g., tracer study; › Reconnaissance for downgradient groundwater discharge zones on floodplain to develop monitoring program; › Numerical modelling of effluent migration to develop monitoring program; › Evaluate potential for fouling within injection well and aquifer to evaluate system maintenance requirements.	› Evaluate aquifer geometry and dispersivity; › Evaluate groundwater-surface water interactions; › Model/monitor effluent migration from injection well(s).
	› Semi-passive water treatment.	› Best available technology (BAT) assessment of passive treatment methods.	› Determine feasibility of semi-passive treatment given site constraints.

Table D (Cont'd): Summary of Data Gaps and Future Studies

Topic/Subject Matter	Data Gap	Description	Relevance / Dependencies
Waste Rock	› Upper Workings - validate risk assessment at waste rock piles.	› A biological survey/habitat assessment by a Registered Professional Biologist should be conducted to support the completion of a more detailed terrestrial ecological risk evaluation.	› Required to finalize detailed terrestrial risk assessment.
	› Lower Workings – detailed design for waste rock storage facility.	› LiDAR of Lower Workings area; › Assess condition/suitability of HDPE cover material stored at site for constructing storage facility.	› Required to confirm waste rock volume estimates and support design of storage facility system, reconstructed access road and drainage network; › MWs installed for shallow hydrogeological investigation (see above) can perform as monitoring network for storage facility.
Erosion Protection (Lower mine area and Shazah airstrip)	› Design basis.	› LiDAR at 5200 waste rock (included above) and at Shazah Airstrip outer banks (north and west); › Source rip rap and aggregate materials on site for constructing erosion protection barriers.	› Required support detailed design of erosion protection measures.
	› Long-term requirements.	› Uncertainty about long-term need for airstrip beyond closure plan implementation (i.e., for local community use); › Updated hydrological/hydrotechnical assessment of river; › Source substantial additional rip rap and aggregate materials.	› Erosion protections will likely need to be improved along western (long) bank if airport will be maintained over long-term; › Required to support detailed design of expanded erosion controls for long-term protection of air strip.

Table D (Cont'd): Summary of Data Gaps and Future Studies

Topic/Subject Matter	Data Gap	Description	Relevance / Dependencies
Infrastructure	› Quantities of recoverable infrastructure, equipment and materials.	› Follow up on 2019 building materials assessment to determine what (if any materials) are suitable for re-use during closure implementation; › Assess condition/suitability of HDPE cover material stored at site for constructing landfill at Paddy's flats.	› Potential to limit logistics costs by re-using some or all camp facilities at the airstrip, mobile equipment (light trucks, rock trucks, excavators, bulldozer, etc.).
	› Landfill design basis.	› LiDAR at Paddy's flats; › Evaluate demolition debris to predict leachate generation potential; › Identify on-site sources of aggregate liner/cover materials for landfill construction at Paddy's flats; › Hydrogeological assessment at Paddy's flats. Wells to monitor baseline conditions.	› Support landfill design, including drainage network and leachate collection requirements; › Support landfill permitting and potentially refine/reduce landfill design requirements.
	› Presence/absence of petroleum hydrocarbon (PHC) contamination at fuel storage areas.	› Subsurface soil assessment at fuel storage areas. Potential for risk assessment or targeted remediation.	› If identified, fuel contamination in soil, remedial and/or risk management assessment may be implemented; › Options would include targeted source removal (landfarming/landfilling).
	› Quantities of liquid hazardous wastes.	› Refine quantity estimates for liquid hazard wastes in sealed containers, drums, tanks; › Identify opportunities to re-use water treatment reagents.	› Refine costs for consolidation and disposal of hazardous wastes.

Table D (Cont'd): Summary of Data Gaps and Future Studies

Topic/Subject Matter	Data Gap	Description	Relevance / Dependencies
Reclamation	› Feasibility of monitored natural recovery (MNR) approach.	› Invasive species survey of all areas where MNR is considered.	› Most minimally to moderately disturbed areas appear to be recovering naturally such that active reclamation may not be required.
Roads and Bridges	› Design basis.	› LiDAR along roads and at stream crossings; › Evaluate on site supplies (culverts, bridge components) for re-use; › Source rip rap for erosion protection at culverts and bridge abutments.	› Required to support detailed design for bridge replacement work and for road maintenance planning. Preliminary engineering can proceed with existing data.
Rock Quarries	› Design basis.	› LiDAR and photo documentation.	› Required to support detailed design of stabilization works (grading, rock scaling, backfilling).
	› Quarry potential.	› Rock suitability testing if substantial additional material needed for various engineering designs (erosion protection, bridges, etc.).	› Required to support detailed design and construction of several closure elements.
Lime Sludge Pit	› Sludge leachability.	› TCLP testing of sludge.	› Determine if sludge can be disposed at 5400 Waste Rock storage facility.

Table D (Cont'd): Summary of Data Gaps and Future Studies

Topic/Subject Matter	Data Gap	Description	Relevance / Dependencies
Receiving Environment	› Tulsequah River – Environmental effects from closure.	› Future implementation of an initial dilution zone (IDZ); › Additional work needed to review/update regional background water quality concentrations for the COPCs; › Design for an AEMP and initiation of sampling prior to remedial efforts, to establish seasonal baseline conditions and natural variability at the discharge and upstream reference locations.	› Dependent on water quality in river, variability of mine water discharge quality, and dilution effect on the receiving waters; › Acute and/or chronic toxicological indicators may be required to be developed based on laboratory testing with dilutions and selected representative aquatic markers for the receiving waters environmental health; › Discrete targets may not be suitable. A range based on water chemistry variability may be more appropriate; › Selected critical preliminary COPCs may evolve with time and additional monitoring data.
	› Camp Creek – Environmental Effects from closure.	› Further study needed to evaluate benthic habitat effects/value; › Additional investigations to understand potential source of contaminant loading to the lower reach of the creek.	› Identify what/where habitat protection goals are relevant and applicable within Camp Creek; › Understand the contaminant migration pathway and loading areas to the Tulsequah River (upstream of the Lower Workings).

9 Schedule

A conceptual schedule for closure implementation is provided in Appendix III. The schedule allows for a five year implementation phase with Year 1 and 2 (2020 and 2021), primarily focussed on completion of additional studies, design work, preparation of management plans (e.g., interim water management, construction environmental management), permitting (e.g., water discharge, work in streams, landfill authorization), and completion of upgrades to access infrastructure as outlined in Section 4.2.

Additionally, as discussed above in Sections 3.5, 5.0 and 6.2.4, throughout the implementation phase there will be ongoing discussion with EMPR, ENV and TRTFN regarding the most appropriate approach for authorization of mine discharge to the receiving environment and development of associated site-specific risk-based objectives.

Appendix III also includes a conceptual flow diagram for the overall closure plan. Several critical path activities are identified in both figures. Delays in completing these tasks will result in delays to later tasks. Overall, the conceptual schedule presented is considered to be optimistic considering the number of outstanding data gaps that need to be investigated, permitting requirements (including temporary permits for mine water discharges), seasonal constraints, site access constraints, and the availability of funding.

As significant planning and preparation activities are necessary before summer 2020 field campaigns, achievement of this schedule will depend on approval from MEMPR to proceed as early as practical in 2020.

10 References

Bowell, R. (2003). The influence of speciation in the removal of arsenic from mine waters. Land Contam. & Reclam. 11(2), 231-238.

British Columbia Ministry of Environment and Climate Change Strategy (BC ENV). 2016. Technical Guidance 8. Environmental Management Act. A Framework for the Development and Use of Freshwater Science-Based Environmental Benchmarks for Aquatic Life in *Environmental Management Act* Permitting for Mines. Version 1.0. March 2016.

British Columbia Ministry of Environment and Climate Change Strategy (BC ENV). 2019. Technical Guidance 11. Environmental Management Act. Development and Use of Initial Dilution Zones in Effluent Discharge Authorizations. Version 1.0. April 2019.

Chieftain Metals Inc. 2014. Tulsequah Chief Project – 2014 Annual Environmental Monitoring Report. March 2015.

Chieftain Metals Inc. 2016. Annual Reclamation Report for 2015, Mines Act Permit No. M-232, Tulsequah Chief Mine. Report prepared for Ministry of Energy and Mines. March 2016.

Core6, Palmer and Triton Environmental (Core6 Environmental, Palmer Environmental Consulting Group Inc and Triton Environmental Consulting Ltd.). 2013. Aquatic Ecological Risk Assessment, Tulsequah Chief Mine. Report prepared for Chieftain Metals Inc. December 2013.

Environment Canada (EC). 2012. Metal Mining Technical Guidance for Environmental Effects Monitoring. 2012.

SLR Consulting (Canada) Ltd. 2017. 2016 Aquatic Ecological Risk Assessment, Tulsequah Chief Mine, Skeena Region. Report prepared for BC Ministry of Environment. April 2017.

SNC-Lavalin Inc. 2020a. Preliminary Human Health and Ecological Risk Evaluation for Soil Contamination Associated with Upper and Lower Workings at the Historical Tulsequah Mine Site. Memorandum prepared for MEMPR.

SNC-Lavalin Inc. 2020b. Data Gap Analysis and Site Investigation, Tulsequah Chief Mine, Tulsequah BC, prepared for MEMPR. January 17, 2020.

SRK Consulting (Canada) Ltd., 2019a. Tulsequah Mine Closure Project – Preliminary Remedial Options Analysis Workshop Report. Memorandum prepared for MEMPR. August 13, 2019.

SRK Consulting (Canada) Ltd., 2019b. Tulsequah Mine Closure Project – Remedial Planning Workshop. Memo prepared for MEMPR. November 22, 2019.

SRK Consulting (Canada) Inc., 2020a. Review of the pilot and full-scale bioreactor operations at the Tulsequah Chief Mine Site. Prepared for MEMPR, January 10, 2020.

SRK Consulting (Canada) Ltd., 2020b. Summary of the Tulsequah Chief Mine Site Water and Load Balance. Memo prepared for SNC-Lavalin Inc. January 14,2020.

Watzlaf, George R. and Robert S. Hedin. 1993. A Method for Predicting the Alkalinity Generated by Anoxic Limestone Drains. U.S. Bureau of Mines. Pittsburgh, PA.

11 Notice to Reader

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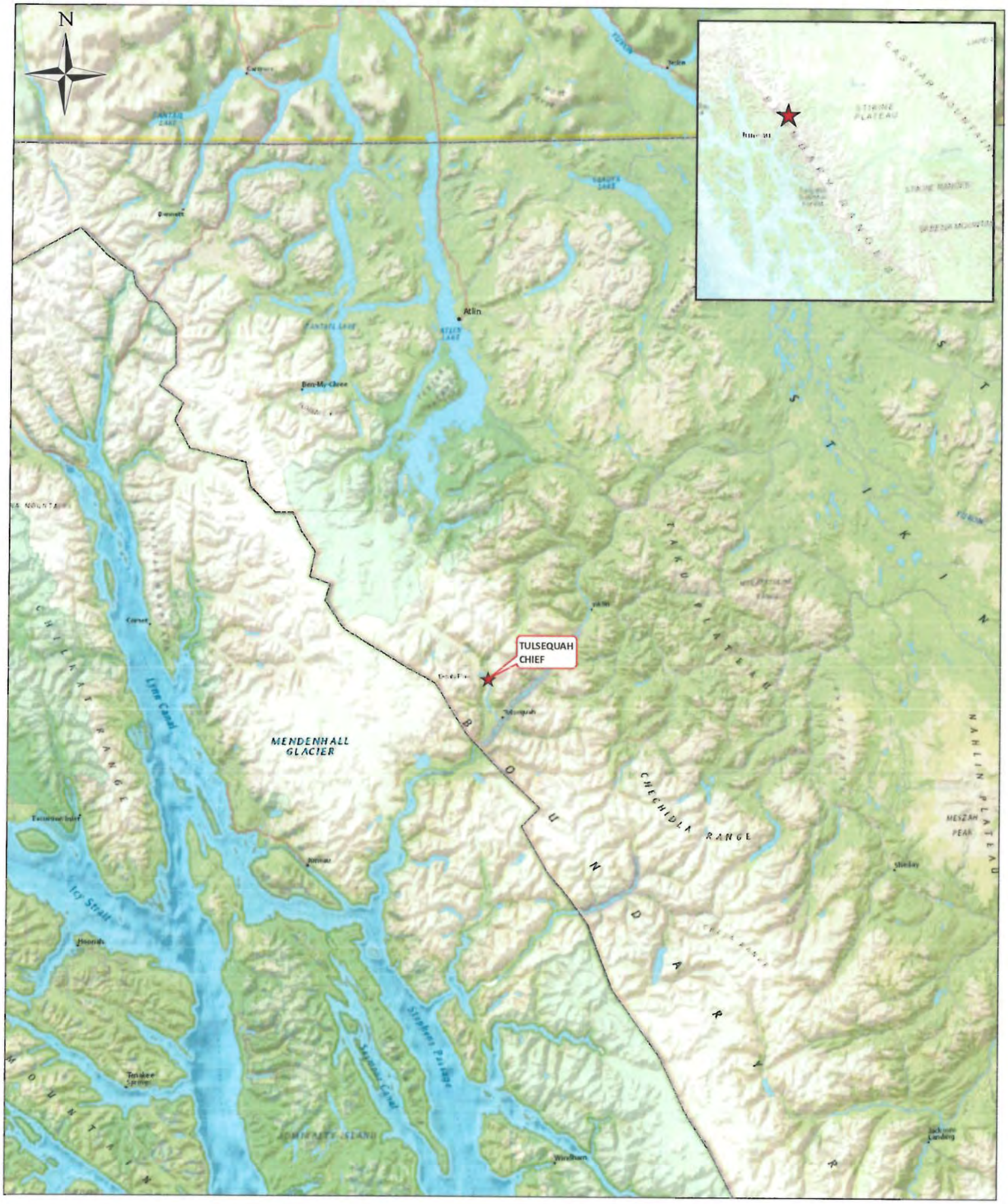
Drawings

- 663249-001 – Site Location Plan
- 663249-002 – Site Overview



Legend

★ Site Location

---- Canada/USA Border

Notes:

1. Intended for illustration purposes only.
2. Original in colour.
3. Site location is approximate.

References:

Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS,

0 12.5 25 50 75 100 km

PROJECT LOCATION: Tulsequah Chief Mine

CLIENT NAME: Ministry of Energy Mines and Petroleum Resources

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Site Location Plan

CHK'D: JC	DATE: 2020/01/10	SCALE: 1:1,500,000	Ref Num:	REV: 0
BY: AO	COORD SYS: NAD 1983 UTM Zone 8N		663249-001	

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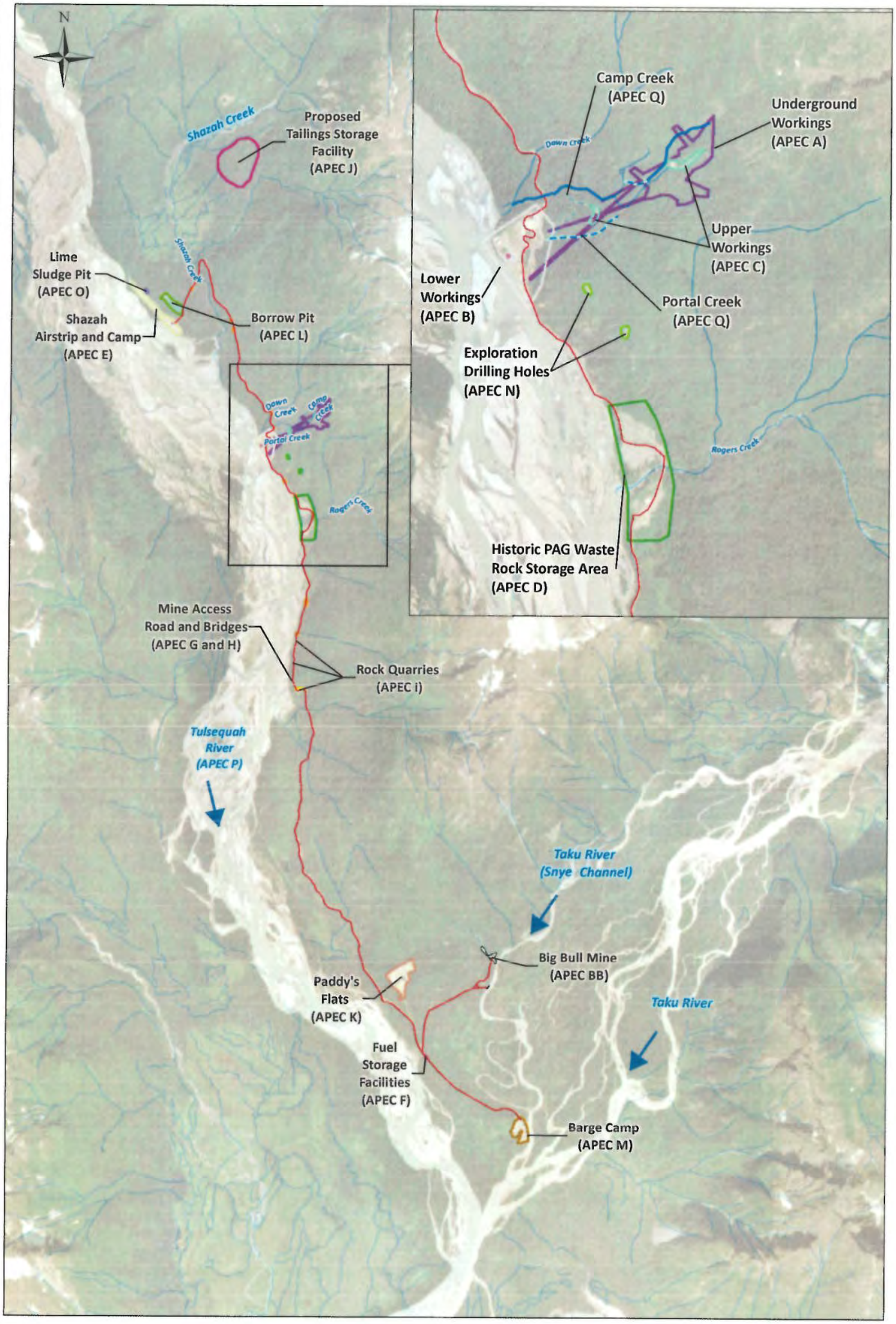

Legend

- APEC A: Underground Workings
- APEC B: Lower Workings
- APEC C: Upper Workings
- APEC D: Historic PAG Waste Rock Storage Area
- APEC E: Shazah Airstrip and Camp
- APEC F: Fuel Storage Facilities
- APEC G: Mine Access Road and Causeways
- APEC H: Temporary Bridges
- APEC I: Rock Quarries
- APEC J: Proposed Tailings Storage Facility
- APEC K: Paddy's Flats
- APEC L: Borrow Pit
- APEC M: Barge Camp
- APEC N: Exploration Drilling Holes
- APEC O: Lime Sludge Pit
- APEC P: Tulsequah River
- APEC Q: Portal and Camp Creek
- APEC BB: Big Bull Mine
- Roads
- Creek
- Ephemeral Creek

Notes:
1 Intended for illustration purposes only
2 Original in colour
3 Site location is approximate.
4 Extenet of underground workings is approximate

References:
1 Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Revisons:
0 - AO - 2019-04-30 - DRAFT

0 245 490 980 1 470 1 960 2 450 Meters

PROJECT LOCATION: Tulsequah Chief Mine

CLIENT NAME: Ministry of Energy Mines and Petroleum Resources

SNC·LAVALIN

Site Overview

CHK'D JC	DATE 2020/01/10	SCALE 1:55,000	Ref Num REV 0
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Appendix I

Closure and Reclamation Plan for the Tulsequah Chief Mine Site - Mine Water Discharge Option 4

Memo

To:	File	**Client:**	MEMPR
From:	Kelly Sexsmith	**Project No:**	1CS035.013
Cc:		**Date:**	March 24, 2020
Subject:	Closure and Reclamation Plan for the Tulsequah Chief Mine Site - Mine Water Discharge Option 4		

1 Introduction

In the draft Closure and Reclamation Plan for the Tulsequah Chief Mine Site, Near Atlin, British Columbia, SRK and SNC included four options for mine water discharges at the site. One of the discharge options was direct discharge to the Tulsequah River following active or semi-passive treatment.

The Project Team and MEMPR have determined that active treatment is not a viable option for this site. Additionally, based on the review of a pilot scale passive treatment system, semi-passive water treatment is not viewed as a reliable option. For these reasons, the section of the report describing Option 4 - direct discharge to the Tulsequah River following active or semi-passive treatment has been removed from the plan. However, to retain the information developed in the draft plan, it has been copied to this memo. The memo includes the description and advantages/disadvantages from Section 5 of the report, and cost estimates from Section 8 of the report. Additional information presented in Section 6.1 on load reductions were not preserved but are presented in the original draft report.

2 Option 4 –Discharge to the Tulsequah River

2.1 Option 4 - Description

Option 4 assumes that water from either the 5900 or 5400 levels would be discharged directly to the Tulsequah River following passive or active treatment.. Despite reductions in flows and loadings that will occur because of the closure measures described in Section 3, mine water concentrations are unlikely to improve to levels that would normally be acceptable for direct discharge. Therefore, the mine water would need to be treated prior to discharge. This option assumes that a seasonal or year-round semi-passive or active treatment system would be constructed to reduce concentrations to levels that are acceptable for discharge. As with Options 1 and 2, there would be a mixing zone or IDZ within the Tulsequah River which would be managed through the development and implementation of site specific risk based performance objectives. The mixing zone within the Tulsequah River would extend from the point of discharge to an unknown and possibly variable distance downstream of the creek (depending on the configuration of the braided river channels and the end-of-pipe concentrations from the treatment system).

As described previously, the remote location and access considerations are significant constraints on the ability to supply and operate an active water treatment plant. Semi-passive treatment or seasonal treatment may help to alleviate these issues to some extent. However, there are significant uncertainties associated with the feasibility and performance of these alternative systems in meeting the discharge requirements and further assessment of treatment alternatives is required before the technical feasibility and performance of this option can be assessed.

There are several possible configurations that could be considered for the semi-passive treatment system. However, the applicability of these systems depends on inlet water chemistry (temperature, pH, reductive state), flowrate, topography and site characteristics. Generally semi-passive treatment systems are applied when flows are at or below 5 L/s due in part to the size required to meet the target residence time. Two potential types of semi-passive treatment systems are described below:

1. Anoxic limestone drains treat chemically reduced ML/ARD through a cell filled with limestone to add alkalinity to the water through the dissolution of limestone (Watzalf and Hedin 1993). Typical effluents are around pH 6.3 and after exiting the cell, reduced iron will oxidize and precipitate from solution when exposed to atmospheric conditions. The drain only works for chemically reduced influent containing iron. The drains can hydraulically fail if oxygen ingress causes iron precipitation to occur or if dissolved aluminum is present as it will precipitate above pH 5. The drain can also chemically fail if the limestone becomes armoured with precipitates. This type of system could also be coupled with an upstream bioreactor to create reducing conditions. At Tulsequah, it is possible that the mine workings could be used for this initial stage of treatment. This would require the addition of a carbon source.

2. Bioreactors rely on sulphate reducing bacteria to precipitate metal sulphides. Biological activity is limited when the pH is below 4, so a neutralization step using limestone is typically required to increase the pH (EPA 2006). The pH adjustment may generate precipitates. Sulphate reducing bacteria require a metabolizable carbon source to reduce sulphate. Sulphate reducing bacteria can grow at moderately low temperatures (4 to 8°C) but at lower rates. Maintaining these temperatures or at least non-freezing temperatures during the winter will need to be evaluated when selecting a bioreactor location. It is noted that pilot scale and full-scale bioreactor trials were completed in the 5200 level adit at Tulsequah in 2005-2007. A review of the system and its limitations is presented in SRK 2020a.

Both anoxic limestone drains and bioreactors rely on ongoing maintenance of the bioreactor cells or drains. Periodic replenishment of limestone, an organic carbon source and sludge management with transportation to a repository would be required. These systems would likely require an ongoing seasonal site presence. Both would require the use of heavy equipment therefore maintenance of an airstrip is required and there may be the potential need to maintain barge landing facilities and access from site.

An active water treatment system would consist of a more conventional lime treatment system, with lime addition to elevate the pH of the influent water resulting in the precipitation of mixed metal hydroxides based on the respective solubility limits of each metal. Arsenic is known to co-precipitate with iron when the ratio of iron III to arsenic v is three or greater (Bowell 2003). The treatment plant reagents would be lime (hydrated or pebble) and flocculant. A repository for sludge generated by the plant would be required onsite and access to this repository would need to be maintained year-round. Two operators would be required to be site-based to run the plant and additional operators may be required to maintain camp and other surface facilities throughout the year (e.g. road repairs, snow removal for sludge transportation). Operation of the plant would require ongoing maintenance using heavy equipment and therefore the airstrip and barge landing including the access from site would need to be maintained.

The water conveyance system from the mine to the treatment system would be similar to the one described for Options 2 and 3. However, there may be advantages in using storage within the mine to limit flows at certain times of the year, or to use the underground mine "pool" as a pre-treatment step to the passive treatment system. Therefore, it is more likely that discharges would be from the 5400 level.

2.2 Option 4 - Advantages and Disadvantages

The main advantage of this option is that it would result in further reduction of loadings to the downgradient environment as compared to the other options. Although there would still be a mixing zone, it would originate in a known location that is more easily monitored, and concentrations within the mixing zone would be reduced in comparison to current conditions.

A disadvantage to both semi-passive and active treatment is that a sludge repository would be required for long term storage of treatment residuals. Access to this repository would need to be maintained throughout the open water season for a semi-passive treatment system and throughout the entire treatment season for active treatment. The repository location would need to be above the flood plain of the Tulsequah River and large enough to store volumes for the expected treatment duration.

Key disadvantages are that the feasibility of a semi-passive treatment system in terms of reducing metal concentrations to levels that are acceptable for discharge is unknown and may not be possible. Even if it is capable of reaching discharge limits, it would continue to require ongoing and regular care and maintenance, and it would still require management and disposal of treatment residuals. If the passive treatment system does not prove feasible, active treatment options would need to be implemented to meet the end-of-pipe requirements of not-acutely toxic water quality and would need to be implemented despite the significant investments made in installing bulkheads and other water controls measures in the mine.

Water treatment, whether active or passive, presents considerable logistical challenges at this site due to its remoteness and difficult access. Barging of equipment and supplies (e.g., fuel, reagents) to the site to construct and maintain the system, air transport of crews to and from the site either routinely to operate an active treatment system or periodically for maintenance of passive treatment system (e.g., sludge management), carries considerable risk of accident and mishap over the long timeframes in question with potentially grave consequence for the environment (barge sinking) and human life (plane crash).

2.3 Option 4 Costs

Capital costs associated with Option 4 are provided in Table E:

Table A: Estimated Capital Costs for Mine Water Discharge Options

Water Treatment Options		Total Direct Costs	Indirect Costs	Owner's Costs	Total Estimated Cost
Option 4	Discharge to the Tulsequah River*	$7,600,000	$1,140,000	$228,000	$8,968,000

Monitoring and maintenance costs are provided in Table F:

Table B: Operations, Monitoring and Maintenance Costs – Long Term Mine Water Discharge Management Options

Monitoring and Maintenance Requirement		Annual Costs (Year 4+)
Option 4	Discharge to the Tulsequah River*	$3,600,000

Option 4 costs assume quarterly monitoring and sampling of the Tulsequah River, seepages and groundwater at the mine and Camp Creek with helicopter access to and from the mine. It is assumed the workers would stay at the camp for the duration of the sampling event.

Appendix II

Cost Estimate Details

Preliminary Cost Estimate

Preliminary cost estimates for key elements of the proposed closure strategy are outlined below, including costs for capital projects as well as monitoring and maintenance activities. Costs associated with additional investigation necessary to address key remaining data gaps and uncertainties, as summarized in Section 8 of the Closure and Remediation Plan Report, are not included herein.

Capital Costs

The scope of core closure activities, for the three mine water discharge management options being considered, and for monitoring and maintenance activities are outlined in Sections 4, 5 and 7 of the Closure and Remediation Plan Report.

Basis of Estimate

This capital cost estimate is preliminary in nature and is not considered suitable for the appropriation of funds. The estimates are accurate within a range of (+100% / -50%) except where noted below. A real rate of return of 1.8% was used for the calculation of present values. All present values are expressed in first quarter 2020 Canadian dollars.

For each area, conceptual designs and quantity take-offs were prepared by experienced engineers and scientists. Based on the conceptual designs and quantities, Milestone Environmental Contracting Inc. (Milestone) prepared preliminary budget quotations for key construction materials and activities. A contingency allowance of 25% has been included in the total direct costs for each area.

Indirect costs include engagement with communities of interest, geotechnical investigations, detailed design, project management, project services, construction management, quality assurance, and engineering field support. The indirect costs have been estimated at 15% of the total direct costs for each area, based on SNC-Lavalin experience from projects of similar size and complexity.

Owner's costs include Owner's project management team, permitting, commissioning, and provincial sales tax (PST) on materials. Owner's costs have been estimated at 3% of the total direct costs for each area, based on SNC-Lavalin experience from projects or similar size and complexity.

Exclusions

The following items have been excluded from the cost estimates:

- Management of mines wastes from Big Bull Mine;
- Force Majeure;
- Escalation;
- Fluctuations in foreign currency exchange rates;
- Additional investigation costs; and
- Land acquisition.

Cost for operations, maintenance and monitoring are not included in capital costs estimates. These costs are summarized in section below.

Capital Cost Estimate Summary

[redacted]

[redacted]

Table II-A: Estimated Capital Costs – Core Closure Activities

Closure Activity	Total Direct Costs	Indirect Costs	Owner's Costs	Total Estimated Cost
Mobilization / Demobilization, Freight, Barging, and Construction Support	[redacted]	[redacted]	[redacted]	[redacted]
Borrow Pit and Landfill Development at Paddy's Flats	[redacted]	[redacted]	[redacted]	[redacted]
Upgrades to Access Roads and Bridges	[redacted]	[redacted]	[redacted]	[redacted]
Demolition of Existing Structures	[redacted]	[redacted]	[redacted]	[redacted]
Closure of Openings in the Upper Workings	[redacted]	[redacted]	[redacted]	[redacted]
Interim Water Treatment (three-year program)	[redacted]	[redacted]	[redacted]	[redacted]
Mine Discharge Control (Bulkheads) and Water diversion at 5900 Level	[redacted]	[redacted]	[redacted]	[redacted]
Disposal of Non-Hazardous Waste at Paddy's Flats	[redacted]	[redacted]	[redacted]	[redacted]
Off-Site Disposal of Hazardous and Liquid Wastes	[redacted]	[redacted]	[redacted]	[redacted]
Consolidated Storage Facility at Lower Workings	[redacted]	[redacted]	[redacted]	[redacted]
Bank Erosion Protection at Shazah Airstrip	[redacted]	[redacted]	[redacted]	[redacted]
			Total (Rounded)	[redacted]

Assumptions:

- Costs are based on quantity estimates derived from information provided to SNC-Lavalin with limited validation based on 2019 Site observations, actual quantities may vary.
- A sufficient volume of angular rip rap is available in existing on-site stockpiles.
- Waste rock embankments as conceptually designed will achieve the required slope stability safety factors.
- The construction window for the Site is approximately 4 months long running from June to September.
- Productivity assumptions are based on having appropriate equipment on site to complete the work.

[redacted]

[redacted]

[redacted]

Table II-B: Estimated Capital Costs for Mine Water Discharge Options

Water Treatment Options		Total Direct Costs	Indirect Costs	Owner's Costs	Total Estimated Cost
Option 1	Discharge to Camp Creek	[redacted]	[redacted]	[redacted]	[redacted]
Option 2	Flow Augmentation and Discharge to Tulsequah River	[redacted]	[redacted]	[redacted]	[redacted]
Option 3	Deep injection to the alluvial groundwater aquifer beneath the Tulsequah River	[redacted]	[redacted]	[redacted]	[redacted]

Monitoring and Maintenance Costs

The estimated monitoring and maintenance costs to implement the program described in Section 7 of the Closure and Remediation Plan Report are [redacted] as summarized in Table II-C. Detailed cost estimate tables are provided in Tables II-E through II-R.

Table II-C: Estimated Monitoring and Maintenance Costs

Monitoring and Maintenance Requirement	Cost Per Year
Receiving Water Environment (AEMP)	[redacted]
Geotechnical Inspection (Above Ground)	[redacted]
Geotechnical Inspection (Underground)	[redacted]
Annual Reporting	[redacted]
Maintenance Costs	[redacted]
Project Management Services	[redacted]
Total Estimated Costs	[redacted]

Assumptions:

- Annual costs include a 25% contingency mark up to account for uncertainties in closure requirements.
- Assumes one annual geotechnical inspection of the landfill and waste rock storage facility, erosion barriers and one inspection of the bulkheads. Reporting of results of the environmental sampling and geotechnical inspections are covered in the annual reporting costs.
- Assumes post-closure aquatic effects monitoring based on the scope outlined in Section 7.1 of the Closure and Remediation Plan Report with water quality monitoring occurring semi-annually for the first four years post-closure, then annually for the next eight years and then at five year intervals going forward. Biological monitoring would occur biennially for four years, then every four years for the next eight years, and then every ten years going forward. Assumes helicopter access to and from the mine and staying at the camp for the duration of the sampling event.
- Maintenance costs were based the average long-term costs incurred at mine sites as presented in USEPA 2016. The 100-year long-term monitoring and maintenance costs were discounted to a present value of [redacted] assuming an interim 3.5% discount rate and 1.7% Consumer Price Index (CPI) – EMPR to select the final discount rate. Long-term monitoring and maintenance costs were reduced by 50% at year 30 to account for a reduction of water sampling requirements based on an assumption that the treatment plant would performing as expected and no risk to aquatic receptors was present. Maintenance costs include upgrades and repairs to the mine access roads, erosion barriers, landfill and waste rock storage facility covers and bulkheads.

Table II-D: Operations, Monitoring and Maintenance Costs – Long Term Mine Water Discharge Management Options

Monitoring and Maintenance Requirement		Annual Costs (Year 6+)
Option 1	Discharge to Camp Creek	[redacted]
Option 2	Flow Augmentation and Discharge to Tulsequah River	[redacted]
Option 3	Deep injection to the alluvial groundwater aquifer beneath the Tulsequah River	[redacted]

Assumptions:

- All options assume that long-term water management costs will apply after the initial five year implementation phase during which interim water management will be undertaken.
- Option 1 assumes quarterly monitoring and sampling of the discharge and system inspection/routine maintenance.
- Option 2 costs are the same as Option 1 costs with increased budget for power and maintenance of the pipes and diffusion areas of the flow augmentation system.
- Option 3 costs are the same as Option 1 costs with increased budget for power and maintenance of the pipes and diffusion areas and antiscaling of the deep water injection system.
- The estimated costs for Options 2 and 3 are placeholder amounts. The actual costs cannot be known until the preferred configuration is selected and detailed engineering has been completed.

The 100-year long-term monitoring and maintenance costs were discounted to the present values assuming an interim 3.5% discount rate and 1.7% CPI – EMPR to select the final discount rate [redacted] Options 1 to 3 assume a reduction in monitoring and maintenance costs of 50% at year 30 to account for a reduction of receiving water sampling requirements based on an assumption that the treatment plant would performing as expected and no risk to aquatic receptors was present.

Table II-E: Summary of Full Time Water Treatment CapEx and OpEx Costs

Cost Item	Year 1	Year 2	Year 3
Capex Breakdown			
- Plant Mechanical Equipment and Install	[redacted]	-	-
- Earthworks + Add. Civil Direct Costs	[redacted]	-	-
Opex Breakdown			
- Regents	[redacted]	-	-
- Power	[redacted]	-	-
- Operating Labour (contractor)	[redacted]	-	-
- Annual Barging Program	[redacted]	-	-
- Maintenance Parts and Equipment	[redacted]	[redacted]	[redacted]
Total	[redacted]	[redacted]	[redacted]

direct costs	[redacted]
risk allowance @ 25%	[redacted]
total directs	[redacted]

Table II-F: Summary of Interim Water Treatment CapEx and OpEx Costs

Cost Item	Year 1	Year 2	Year 3
Fuel - Treatment Operations	[redacted]	[redacted]	[redacted]
Reagents	[redacted]	[redacted]	[redacted]
Barging	[redacted]	[redacted]	[redacted]
Personnel - Contract Employee	[redacted]	[redacted]	[redacted]
Ongoing Capex Replacement	[redacted]	[redacted]	[redacted]
Total	[redacted]	[redacted]	[redacted]

direct costs (3 yrs)	[redacted]
risk allowance @ 25%	[redacted]
total directs	[redacted]

Table II-G: Deep Injection Estimated Costs

Cost Items	Total Estimated
Geophysics	[redacted]
Drilling Program	
Injection Pilot Testing	
Data Analysis	

direct costs	[redacted]
risk allowance @ 25%	[redacted]
total directs	[redacted]

Table II-H: Summary of Mine Opening Closure and Water Diversion CapEx Costs

ACTIVITY/MATERIAL	Unit	Qty	Code	Unit Cost	Cost
Bulkhead at 5400	LS	1	SRK	[redacted]	[redacted]
Bulkhead at 5200	LS	1	SRK	[redacted]	[redacted]
Water Diversion at 5900	LS	1	SNC	[redacted]	[redacted]
				Total	[redacted]
				% of Total	

direct costs	[redacted]
risk allowance @ 25%	[redacted]
total directs	[redacted]

Table II-I: Estimated Cost for Closure of Mine Openings

ACTIVITY/MATERIAL	Unit	Qty	Code	Unit Cost	Cost
Close portal #1 (stainless steel prefab w door)	m2	31	SRC*	[redacted]	[redacted]
Close portal #2 (stainless steel prefab w door)	m2	31	SRC*	[redacted]	[redacted]
Close portal #3 (stainless steel prefab w door)	m2	11	SRC*	[redacted]	[redacted]
Cap raise # 1 (Stainless Steel prefab.)	m2	31	SRC*	[redacted]	[redacted]
Cap raise # 1 (Stainless Steel prefab.)	m2	31	SRC*	[redacted]	[redacted]
Extra Mob to Site	LS	1		[redacted]	[redacted]
Helicopter	day	30	-	[redacted]	[redacted]
				Total	[redacted]

* Normalized installation costs based on Sanscartier et al. and estimated areas include 25% contingency

direct costs	[redacted]
risk allowance @ 15%	[redacted]
total directs	[redacted]

Table II-J: Estimated Mobilization, Freight, and Barging, Demobilization for Closure Work

Item No.	Description	Unit Rate	Quantity	Units	Sub total
1	mobilize and establish temporary site facilities (excluding barging)	[redacted]	2	lump sum	[redacted]
2	barging	[redacted]	2	allowance per season	[redacted]
3	construction support including fuel and food delivered by air and camp costs	[redacted]	3,240	man/day	[redacted]
4	demobilize prime contractor	[redacted]	2	lump sum	[redacted]
				direct costs	[redacted]
				contingency & risk allowance @ 25%	[redacted]
				total directs	[redacted]

Table II-K: Borrow Pit and 11,000m3 Demolition Landfill @ Paddy's Flats Cost Estimate

Item No.	*Description*	*Unit Rate*	*Sunro Unit Rate*	*Quantity*	*Units*	*Sub total*
1	borrow pit - bulk excavation to on-site stockpile	[redacted]	[redacted]	20,280	m^3	[redacted]
2	landfill cell - bulk excavation to on-site stockpile	[redacted]	[redacted]	3,100	m^3	[redacted]
3	landfill cell - bulk excavation to embankment	[redacted]	[redacted]	1,550	m^3	[redacted]
4	process native soil to produce bedding drain rock and rip rap	[redacted]	[redacted]	3,500	m^3	[redacted]

direct costs	[redacted]
contingency / risk allowance @ 25%	[redacted]
total directs	[redacted]

Table II-L: Demolition Landfill Final Cover System

Item No.	*Description*	*Unit Rate*	*Sunro Unit Rates*	*Quantity*	*Units*	*Sub total*
1	granular filter layer	[redacted]		1,200	m^3	[redacted]
2	native soil	[redacted]		4,000	m^2	[redacted]
3	topsoil	[redacted]		600	m^2	[redacted]
4	seeding	[redacted]		1,200	m^3	[redacted]
5	interceptor trench - excavation to sidecast	[redacted]		80	m^3	[redacted]
6	interceptor trench - rip rap	[redacted]	[redacted]	70	m^3	[redacted]
7	interceptor trench - geotextile	[redacted]		450	m^2	[redacted]
8	perimeter trench - excavation to on-site stockpile	[redacted]		240	m^3	[redacted]
9	perimeter trench - rip rap	[redacted]	[redacted]	135	m^3	[redacted]
10	rock pit - excavation to on-site stockpile	[redacted]		300	m^3	[redacted]
11	rock pit - geotextile	[redacted]		750	m^2	[redacted]
12	rock pit - rip rap	[redacted]		300	m^3	[redacted]
13	supply and install groundwater monitoring well - 12 m depth	[redacted]	[redacted]	6	each	[redacted]

direct costs	[redacted]
contingency / risk allowance @ 25%	[redacted]
total directs	[redacted]

Table II-M: Estimated Costs for Roads and Bridges

Item No.	*Description*	*Including*	*Unit Rate*	*Quantity*	*Units*	*Sub total*
1	upgrade access roads and bridges - Option 3 as per cost estimate from SNT Engineering		[redacted]	1	lump sum	[redacted]
					direct costs	[redacted]
					contingency / risk allowance at 25%	[redacted]
					total directs	[redacted]

Table II-N: Estimated Cost for Facilities Demolition

Item No.	*Description*	*Unit Rate*	*Quantity*	*Units*	*Sub total*
1	demolition as per budget quotation from Pacific Blasting and Demolition	[redacted]	1	lump sum	[redacted]

direct costs	[redacted]
contingency / risk allowance at 25%	[redacted]
total directs	[redacted]

Table II-O: Relocate Non-Hazardous Solid Waste to Landfill at Paddy's Flats

Item No.	*Description*	*Unit Rate*	*Quantity*	*Units*	*Sub total*
1	transport waste from Barge Landing - Lower	[redacted]	610	m^3	[redacted]
2	transport waste from Barge Landing - Upper	[redacted]	2,350	m^3	[redacted]
3	transport waste from Air Strip	[redacted]	4,810	m^3	[redacted]
4	transport waste from Borrow Pond	[redacted]	690	m^3	[redacted]
5	transport waste from various areas	[redacted]	270	m^3	[redacted]
6	transport waste from ATP Area	[redacted]	1,280	m^3	[redacted]
7	transport waste from HPAG	[redacted]	970	m^3	[redacted]

direct costs	[redacted]
contingency / risk allowance @ 25%	[redacted]
total directs	[redacted]

Table II-P: Hazardous Waste and Liquid Waste to Off-Site Disposal

Item No.	*Description*	*Unit Rate*	*Quantity*	*Units*	*Sub total*
1	off-site disposal of hazardous wastes as per budget quotations from Nucur Environmental Service	[redacted]	1	lump sum	[redacted]
				direct costs	[redacted]
				contingency / risk allowance @ 25%	
				total directs	

Table II-Q: Estimated Costs for the 5400 Waste Rock Storage Facility

Miscellaneous					
Item No.	*Description*	*Cost*	*Unit Rate*	*Quantity*	*Units*
1	tree removal to on-site stockpile	[redacted]	[redacted]	1	allowance
2	management of Portal Creek	[redacted]	[redacted]	1	allowance
3	backfill at 5200 level using material from Paddy's Flats	[redacted]	[redacted]	15,000	m^3
4	erosion protection at 5200 level - geotextile	[redacted]	[redacted]	750	m^3
5	erosion protection at 5200 level - install processed sand in anchor trench	[redacted]	[redacted]	100	m^3
6	erosion protection at 5200 level - install angular rip rap from existing stockpiles	[redacted]	[redacted]	575	m^3
7	Cable reinforment of rip-rap	[redacted]	[redacted]	1	LS
8	fill exfiltration pond	[redacted]	[redacted]	1,500	m^3
9	access road - rock excavation to embankment	[redacted]	[redacted]	600	m^3
10	access road - import fill to embankment	[redacted]	[redacted]	6,400	m^3
11	east perimeter berm - import fill to embankment	[redacted]	[redacted]	900	m^3

Leachate Seep Collection System					
Item No.	*Description*	*Cost*	*Unit Rate*	*Quantity*	*Units*
1	leachate seep collector - perforated DN300 mm DR11 PE	[redacted]	[redacted]	215	lineal m
2	leachate seep collector - drain rock	[redacted]	[redacted]	200	m^3
3	leachate seep collector - non-woven geotextile	[redacted]	[redacted]	860	m^2
4	solid DN300 mm DR11 PE4710 HDPE pipe	[redacted]	[redacted]	100	lineal m
5	compacted sand bedding	[redacted]	[redacted]	35	m^3
6	1200 mm ID RSC250 HDPE manhole - 2 m deep c/w CI fra	[redacted]	[redacted]	2	each

On-Site Waste Relocation					
Item No.	*Description*	*Cost*	*Unit Rate*	*Quantity*	*Units*
1	Temporary erosion/river isoloation barrier	[redacted]	[redacted]	9,000	m^3
2	relocate on-site waste rock into covered pile	[redacted]	[redacted]	30,000	m^3

Final Cover System					
Item No.	*Description*	*Cost*	*Unit Rate*	*Quantity*	*Units*
1	granular filter layer	[redacted]	[redacted]	4,680	m^3
2	native soil	[redacted]	[redacted]	15,600	m^3
3	topsoil	[redacted]	[redacted]	2,340	m^3
4	seeding	[redacted]	[redacted]	15,600	m^2
5	interceptor trench - excavation to sidecast	[redacted]	[redacted]	90	m^3
6	interceptor trench - rip rap	[redacted]	[redacted]	90	m^3
7	interceptor trench - geotextile	[redacted]	[redacted]	260	m^2
8	perimeter trench - excavation to sidecast	[redacted]	[redacted]	210	m^3
9	perimeter trench - rip rap	[redacted]	[redacted]	210	m^3
10	supply and install groundwater monitoring well - 4 m de	[redacted]	[redacted]	4	each

direct costs	[redacted]
contingency / risk allowance @ 25 %	
total directs	

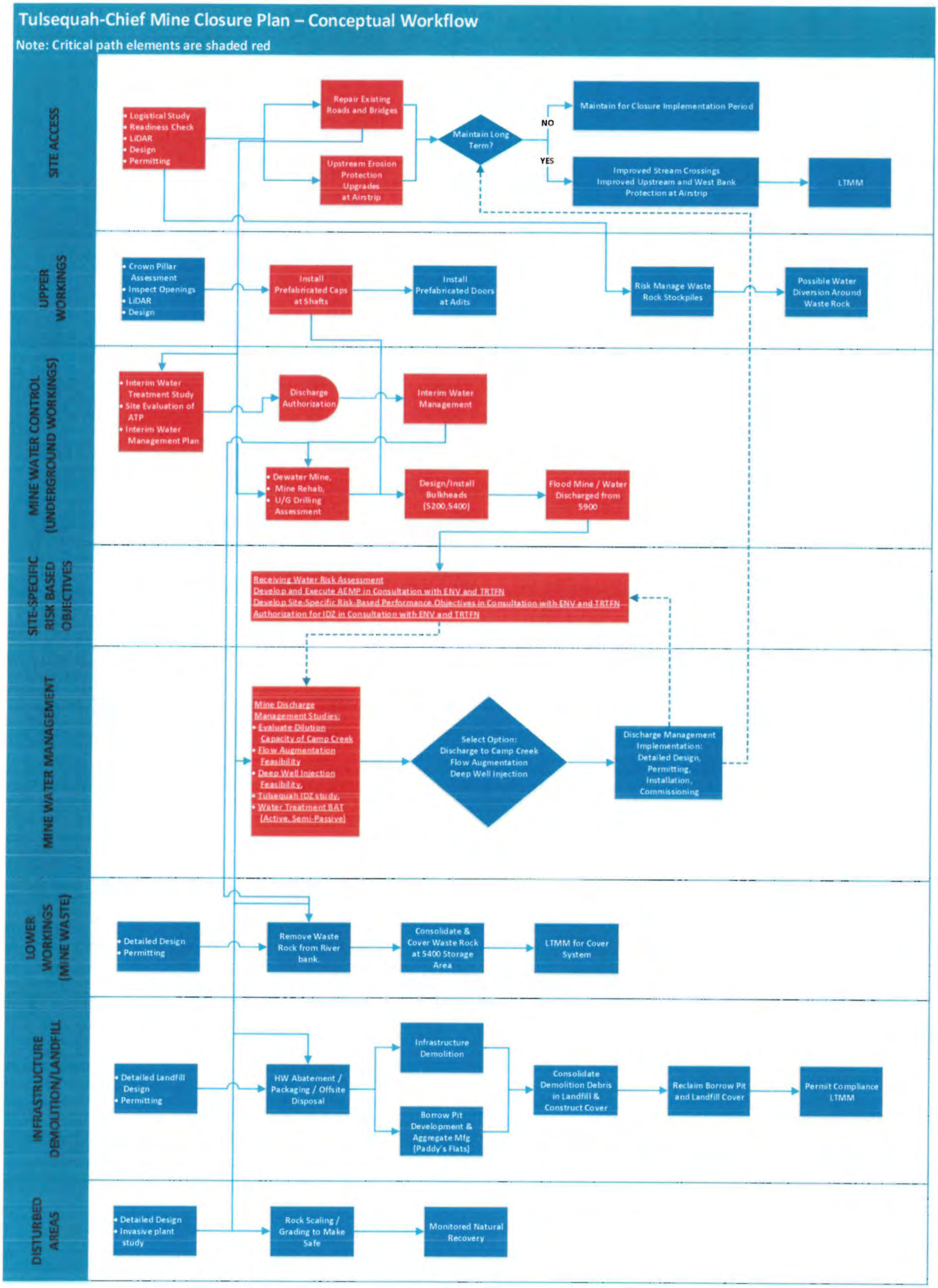
Table II-R: Estimated Cost for Erosion Protection along upstream bank at Shazah Airstrip

Item No.	Description	Cost	Unit Rate	Quantity	Units
	excavation to embankment	[redacted]	[redacted]	260	m^3
	Cable reinforment of rip-rap	[redacted]	[redacted]	1	LS
	geotextile	[redacted]	[redacted]	975	m^2
	install bedding sand in anchor trench	[redacted]	[redacted]	130	m^3
	install angular rip rap from existing stockpiles	[redacted]	[redacted]	750	m^3

direct costs	[redacted]
contingency / risk allowance @ 25 %	[redacted]
total directs	[redacted]

Appendix III

Conceptual Closure Plan Schedule and Workflow Diagram



Tulsequah-Chief Mine Closure Plan – Conceptual Workflow
Note: Critical path elements are shaded red
SITE ACCESS
• Logistical Study
• Readiness Check
• LiDAR
• Design
• Permitting
Repair Existing Roads and Bridges
Upstream Erosion Protection Upgrades at Airstrip
Maintain Long Term?
NO
YES
Maintain for Closure Implementation Period
Improved Stream Crossings
Improved Upstream and West Bank Protection at Airstrip
LTMM
UPPER WORKINGS
• Crown Pillar Assessment
• Inspect Openings
• LiDAR
• Design
Install Prefabricated Caps at Shafts
Install Prefabricated Doors at Adits
Risk Manage Waste Rock Stockpiles
Possible Water Diversion Around Waste Rock
MINE WATER CONTROL (UNDERGROUND WORKINGS)
• Interim Water Treatment Study
• Site Evaluation of ATP
• Interim Water Management Plan
Discharge Authorization
Interim Water Management
• Dewater Mine,
• Mine Rehab,
• U/G Drilling Assessment
Design/Install Bulkheads (5200,5400)
Flood Mine / Water Discharged from 5900
SITE-SPECIFIC RISK BASED OBJECTIVES
Receiving Water Risk Assessment
Develop and Execute AEMP in Consultation with ENV and TRTFN
Develop Site-Specific Risk-Based Performance Objectives in Consultation with ENV and TRTFN
Authorization for IDZ in Consultation with ENV and TRTFN
MINE WATER MANAGEMENT
Mine Discharge Management Studies:
• Evaluate Dilution Capacity of Camp Creek
• Flow Augmentation Feasibility
• Deep Well Injection Feasibility,
• Tulsequah IDZ study,
• Water Treatment BAT (Active, Semi-Passive)
Select Option:
Discharge to Camp Creek
Flow Augmentation
Deep Well Injection
Discharge Management Implementation:
Detailed Design,
Permitting,
Installation,
Commissioning
LOWER WORKINGS (MINE WASTE)
• Detailed Design
• Permitting
Remove Waste Rock from River bank.
Consolidate & Cover Waste Rock at 5400 Storage Area
LTMM for Cover System
INFRASTRUCTURE DEMOLITION/LANDFILL
• Detailed Landfill Design
• Permitting
HW Abatement / Packaging / Offsite Disposal
Infrastructure Demolition
Borrow Pit Development & Aggregate Mfg (Paddy's Flats)
Consolidate Demolition Debris in Landfill & Construct Cover
Reclaim Borrow Pit and Landfill Cover
Permit Compliance LTMM
DISTURBED AREAS
• Detailed Design
• Invasive plant study
Rock Scaling / Grading to Make Safe
Monitored Natural Recovery

TULSEQUAH CHIEF MINE - CONCEPTUAL CLOSURE SCHEDULE
Updated: March 31, 2020

Priority #	Closure Option and Key Action Items
1	Preliminary Eng. and Permitting
	Logistical Study
	LiDAR
	Site Trip - Readiness Check (Camp, Fuel, Generators)
2	Maintain Airstrip and Roads for Access and construction
	Source Rip-Rap
	Detailed Road/Airstrip Engineering and Tendering
	Permitting (work in stream)
	Road and Bridge Upgrades
	Damaged Runway Repair
	Erosion Barrier Construction
3	Interim Water Treatment
	Interim Water Management Study and Plan
	Site Evaluation of Acid Treatment Plant (ATP)
	Interim Water Management - detailed engineering and procurement
	Interim Water Management
4	Closure of Openings in Upper Workings
	Detailed Engineering
	Prefabrication of Caps and doors
	Installation of Caps and Doors
5	Mine Water Control (Bulkheads @ 5200 and 5400 Levels and Water Diversion at 5900
	Dewater the mine
	Mine Rehab. (includes remove bioreactor)
	Geological and Geotechnical Mapping
	Bulkhead Drilling
	Detailed Eng.
	Water Diversion Pipe Construction
	Bulkhead Construction
	Flood Mine
6	Develop AEMP Detailed Plan
	Implement AEMP Baseline Monitoring (Mine Discharge, Camp Cr., Tulsequah R.)
	Develop Site-Specific Risk Based Performance Objectives
7	Mine Water Management (Selection of Preferred Option)
	BAT assessment of Passive Treatment Technologies
	Evaluation of Passive Treatment (as warranted based on BAT assessment)
	Evaluation of Deep Injection & Flow Augmentation (A,B,C)*
	Selection of Preferred Long-term Management Option (subject to authorization of site-specific risk-based objectives)
	Engineering/implementation of Long-term Option
8	Off-Site Disposal of Haz Wastes
	Abatement contractor selection
	Consolidate/Package HW for transport
	Backhaul HW on Empty Planes
9	Consolidation of Infrastructure, Equipment & Debris, PHC at Paddy's Flats
	Detailed Engineering
	Demolition, Waste Consolidation at Paddy's Flats
	Borrow Development, Aggregate Mfr, Landfill Cover Construction
9	Consolidation of Mine Wastes
	Detailed Engineering
	Consolidation and Landfilling at the 5400 Level
11	Monitored Natural Recovery
	Document Current Conditions & Decommission Wells
	Monitor Site Reclamation and Infrastructure as required
	Additional Studies to Support Closure
A	Hydrogeo: seismic refraction survey of Tulsequah valley
B	Hydrogeo: intrusive investigation for injection of mine drainage
C	Hydrogeo: hydraulic and injection testing of injection well(s)
D	PHC Soil/Groundwater Investigation
F	Hydrogeo Drilling at Paddy's Flats and Lower Workings
G	Crown Pillar/Rock Stability and Mine Opening Assessment
	Detailed Risk Assessment for Upper Workings Waste Rock
J	Feasibility/Constructability Assessment for cover options

Schedule columns: 2020, 2021, 2022, 2023, 2024 — each Q1 Q2 Q3 Q4 — months J F M A M J J A S O N D.

Notes:
X = Go/No Go
Duration of tasks is dependent on site conditions, production rates and other factors to be verified

Study
Procurement/Fabrication
[illegible]
Detailed Engineering
Tendering / Procurement
Permitting / Authorisation
Critical Path

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